Forty years ago, well within the lifetime of most of us, the practice of hepatopancreatobiliary surgery barely existed. While there was great interest and research in HPB pathophysiology, therapeutic options were limited, and operative interventions, in particular, remained rare. Attempted operations were typically high-risk, resource-intensive procedures associated with high morbidity and mortality, undertaken only by the boldest of surgeons. Over the ensuing several years, however, the work of many pioneering investigators set the stage for the emergence of HPB as a specialty area of surgery in its own right, bringing it out of the dark ages and into the mainstream of practice. Indeed, in the current state of the art, HPB operations are now commonplace for a wide array of disease processes, with the expectation of successful outcomes for most patients.

Many factors have played a role in the remarkable transformation of the field, too many to list here, but the point is that our surgical forebears laid a solid foundation upon which the technical advances that have shaped our field have been built. As the beneficiaries of these advances and hard-won lessons from the past, we now have the ability to offer effective and safe surgical therapies to our patients. But for those to whom much has been given, much is expected, and it is our charge now to continue refining and improving the clinical, technical, and investigative aspects of HPB surgery, to work toward uniform standards of training and practice, and to continually assess and reassess the long-term results of our interventions. It is imperative that we do this, first and foremost, to ensure the best possible outcomes for our patients, and also to honor the legacy of those great surgeons and others who have blazed the trail that we all now have the privilege to hike.

It is also fitting and proper for the AHPBA to be a leader in this process. Formally established in 1994 as the American Chapter of the IHPBA, the society has grown from a small group of surgeon thought leaders to a powerful, well-funded, and dynamic society of over 1500 members. Over the years, this chapter has evolved to become renamed the Americas, proudly claiming members from the northern reaches of Canada to the southernmost regions of South America, and every country in between. The AHPBA is now one of the largest and most active societies dedicated to advancing the field of HPB surgery by disseminating knowledge, fostering research and innovation, advancing education and training, and encouraging multidisciplinary collaboration.

The current textbook was undertaken by the AHPBA leadership in an ongoing effort to fulfill its mission. Written in a novel, dilemma-focused format, with each chapter addressing a specific question, this is a unique textbook addressing all aspects of HPB surgery by society members who are leading experts in the field. The book is well illustrated, with several salient points highlighted at the end of each chapter. The scope of the book is very broad, and its content is thus appropriate for a wide range of readers, from residents and fellows to established general surgeons and expert HPB surgeons. We expect that this text will remain an important resource for many years to come.
FOREWORD

It has been a privilege for us to have played a small part in this project and in the ongoing advancement of the field through the AHPBA. We congratulate the book’s editors, the contributing authors, the AHPBA leadership, and Marjorie Malia and the staff at Association Management for the great effort in bringing this book to completion.

William R. Jarnagin, MD
New York, NY

William C. Chapman, MD
St. Louis, MO
Surgical management of diseases affecting the liver, pancreas, and biliary tract (HPB) is a mature but rapidly evolving discipline. Clinicians with special interest in these 3 organ systems have diligently endeavored through the decades to innovate their specialties to first and foremost optimize patient outcomes. With a steadfast commitment to this principle, these clinicians have created thriving societies such as the Americas Hepato-Pancreato-Biliary Association (AHPBA) and the International Hepato-Pancreato-Biliary Association (IHPBA). The former has over 1,200 active members from over 40 countries throughout North, Central, and South America, while the latter includes over 1,800 members from over 60 different countries.

In 2017, the AHPBA leadership set out to publish a practical textbook, with chapters written by the experts in the field that would encompass a broad range of HPB topics, with the intention of dispersing critical knowledge towards the mission of educating practicing surgeons, physicians, and the wider health care provider community. The goal was to encapsulate the essence of this vibrant and exciting discipline in a more cogent, concise, and practical manner than traditional texts. We editors hope that this textbook, *Hepato-Pancreato-Biliary and Transplant Surgery: Practical Management of Dilemmas*, has achieved its goals.

The editors aimed to develop a format of the HPB textbook that encompasses a broad clinical scope of 5 disciplines: surgical oncology, HPB surgery, transplantation, interventional radiology, and trauma. The content of *Hepato-Pancreato-Biliary and Transplant Surgery: Practical Management of Dilemmas* is further divided into 6 major sections: (1) Hepatic, (2) Biliary, (3) Pancreatic (4) Transplantation, (5) Trauma, and (6) Innovation and Technology.

We believe that one of the unique aspects of *Hepato-Pancreato-Biliary and Transplant Surgery: Practical Management of Dilemmas* is its format. Rather than assigning a chapter a traditional title such as “Gallstone Ileus,” the title is presented in the form of a question, such as “Should a Cholecystectomy Be Done for Gallstone Ileus?” This approach reflects the mindset of a clinician who is facing an actual clinical dilemma and wants to know how to best care for his/her patient. Another distinct feature of this textbook is that each section is structured into 3 major components (preoperative, intraoperative, and postoperative) that highlight dilemmas across the spectrum of care. Furthermore, embedded within each of these components are debates that we believe provide a wonderful opportunity for the readers to have a more in-depth understanding of simmering controversies in HPB diseases.

*Hepato-Pancreato-Biliary and Transplant Surgery: Practical Management of Dilemmas* has been a global undertaking. Over 350 authors from different corners of the globe have contributed to its final product. Each chapter is written by recognized experts and begins with a clinical scenario followed by a concise and in-depth text that is filled with compelling images, detailed illustrations, comprehensive tables, thorough algorithms, and other adjunctive tools that enhance the learning process. Key references are provided for further review. The “Salient Points” at the end of each chapter reinforce key concepts for the readers.

We have strived to address a broad spectrum of clinically relevant scenarios in this large-volume textbook, with the understanding that additional content may have been omitted due to text length and content evolution constraints. Hence, we welcome suggestions from you, the readers, with the prospect that we will
incorporate your valuable suggestions into future editions.

We hope that you will benefit from and enjoy this textbook, and believe that you will find *Hepato-Pancreato-Biliary and Transplant Surgery: Practical Management of Dilemmas* to be not only an invaluable resource, but also a must-have textbook for all interested in this exciting specialty.

Quyen D. Chu, MD, MBA
Charles M. Vollmer, MD
Gazi B. Zibari, MD
Susan Orloff, MD
Mallory Williams, MD
Mariano Gimenez, MD, PhD
Is There a Role for Living Donor Liver Transplant for Hepatocellular Carcinoma?

Khalid Khwaja, MD, and Robert A. Fisher, MD

Case Scenario

A 52-year-old Caucasian man with HCV cirrhosis, genotype 1a, treatment-naïve, presented with a 7.2 cm enhancing lesion in segment 6 of his liver, consistent with hepatocellular carcinoma (Figure 1). He had grade 1 esophageal varices and a history of encephalopathy. His total bilirubin was 2.1 mg/dl, creatinine 1.3 mg/dl and INR 1.6, giving him a calculated MELD score of 16. His platelet count was 63,000/µL, albumin 2.1 g/dl and alpha-fetoprotein 78 ng/ml. Given his advanced liver disease, he was not felt to be a candidate for surgical resection. He did not qualify for exception MELD points for transplant, as his tumor was > 5cm.

On further work-up, there was no evidence of extra-hepatic disease and he had no significant comorbid condition. The primary lesion was targeted with trans-arterial Yttrium90 embolization after appropriate planning studies. Three months after the procedure, the tumor had decreased to 4.8cm with central necrosis and a small rim of peripheral enhancement (Figure 2). His total bilirubin remained stable at 2.2 mg/dl and alpha-fetoprotein decreased to 34 ng/ml.

At 6 months post-embolization, there was no clinical or radiological progression of disease. His brother had been evaluated and approved as a living liver donor. He underwent an uneventful living donor liver transplant, receiving a right lobe graft. Anterior sector venous outflow was established using deceased donor aortic conduit to reconstruct segment 5 and 8 hepatic veins, and a duct to duct biliary anastomosis was performed (Figures 3-6).

At 2 years post-transplant, he received ledipasvir/sofosbuvir treatment for HCV with a sustained viral response at 12 weeks. At 5 years post-transplant, he is alive with no evidence of tumor recurrence.

Background

Liver transplantation for cirrhotics with unresectable hepatocellular carcinoma (HCC) has been an accepted treatment for over two decades. Outcomes are excellent in recipients with Stage 1 (single lesion < 2cm) or Stage 2 (single lesion 2-5cm or up to 3 lesions all ≤ 3cm) disease. Equivalent survival has also been achieved in individuals with more extensive disease applying the so-called ‘expanded-criteria.’ In the US, patients with Stage 2 HCC are prioritized for transplant by awarding ‘exception’ MELD (Model for End Stage Liver Disease) points equivalent to a 15% 3 month mortality risk, and points are increased every 3 months equivalent to a 10% 3 month mortality. However, there is much regional variation in the US as to how long candidates wait to receive a transplant. In our region, wait times can be up to 18 months for candidates with HCC. Candidates who have higher than stage 2 disease, or ‘beyond Milan criteria’, received no exception points for transplantation and as such, living donor liver transplantation (LD LT) is their best hope of receiving a transplant.

Early experience in the US suggested the rates of HCC recurrence were higher after LDLT than after deceased donor transplant. This was likely due to more advanced disease as well as a shorter interval to transplant in the LDLT group, thus selecting patients with biologically more aggressive disease. We believe that carefully selected candidates who are beyond Milan criteria for transplant can be successfully downstaged and receive liver transplants after an appropriate period of observation. There is currently no consensus as to what is appropriate for downstaging in terms of number and size of tumors. A conference in the US proposed a single tumor not greater than 8 cm or up to three tumors, none greater than 5

cm with a total tumor burden of less than or equal to 8 cm. The Kyoto group in Japan considers candidates for transplant with up to 10 tumors, all ≤ 5 cm and others place no restriction on tumor number as long as none are > 5 cm.

There is general consensus that there should be an appropriate waiting period between diagnosis and transplant. However, the optimal duration of this time period is less clear. We prefer to wait at least three months to allow a response to downstaging and to ascertain the true biology of the disease as supported by our past experience. Candidates with extrahepatic disease, single tumors > 8 cm, more than 3 tumors, macrovascular invasion, and alpha-fetoprotein levels > 400 ng/ml are excluded. Less than a three month interval between tumor ablation and transplantation and des-γ-carboxyl prothrombin (DCP) concentration ≥ 300 mAU /ml have also been shown to be independent predictors of worse recurrence free survival.

Many techniques are currently available and in use for tumor downstaging, including local ablation with radio frequency, microwave or percutaneous ethanol injection, or transarterial embolization with drug eluting beads or radiolabeled microspheres. Our preferred approach for larger lesions, as in this case, is using yttrium90 radioembolization (Y90). There is level two evidence that Y90 may be superior to transarterial chemoembolization (TACE) with a higher likelihood of downstaging to within stage two. Cross-sectional imaging is repeated at 1 and 3 months post-embolization and candidates are fully ‘restaged’ prior to being accepted as transplant candidates.

A comprehensive living donor selection evaluation is performed, as has been previously described by us. The recipient operation is always started first, in the event that there may be extrahepatic tumor precluding transplant. This avoids unnecessary donor surgery. After careful inspection for extrahepatic malignancy, recipient hepatectomy is performed in the standard way, minimizing handling of the area of tumor. The retrohepatic vena cava is preserved and the recipient liver dissected off that structure to allow for ‘piggybacking’ of the new liver graft. Venovenous bypass may be used if necessary.

On the donor side, the right lobe is procured. Care is taken not to devascularize the bile duct. We strive to preserve as much length as possible of the portal vein and right hepatic artery. We prefer to stay to the right of the middle hepatic vein, saving that structure for the donor, and reconstructing any significant narrowing of segment five or eight veins of the donated liver on the back table. The right hepatic artery is not dissected behind or to the left of the bile duct to prevent biliary ischemia. The graft is flushed with University of Wisconsin solution via the portal vein and hepatic artery (Figure 3). Our preference is to reconstruct the anterior sector veins using deceased-donor aortic conduit if available (Figure 4). We found that the aortic conduit is easy to sew to and does not compress like the vein. Implantation of the graft begins with anastomosing the donor right hepatic vein directly to the cava or widened orifice of the recipient right hepatic vein followed by portal vein anastomosis and reperfusion of the liver. The conduit draining the anterior sector veins can then be implanted directly into the cava or the orifices of the recipient middle and left hepatic veins as is our practice. An end-to-end right hepatic artery to right hepatic artery anastomosis is then performed followed by a duct to duct biliary anastomosis whenever feasible (Figure 5). We have employed both cryopreserved IVC and aortic conduit for our
**Figure 3: Right Living Donor Graft.** The stumps of the Right Hepatic Vein, Right Portal Vein, Right Hepatic Artery, and Right Common Hepatic Duct are shown. Also depicted are two large anterior sector hepatic veins (segments 5 and 8).

**Figure 4: Backtable reconstruction of anterior sector hepatic veins using deceased donor aortic conduit.**

**Figure 5: Implantation of Liver.** Donor Right Hepatic Vein is drained into the widened orifice of the recipient Right Hepatic Vein. Anterior sector veins are drained via the aortic conduit into the recipient Middle and Left Hepatic Veins.

**Figure 6: Backtable.** Reconstruction of anterior sector veins with deceased donor aortic conduit.
reconstruction and have not seen HCC recurrence over a one year follow-up.

In instances where the suprahepatic vein branches or retrohepatic vena cava of the recipient are compromised either because the HCC is very close to them or a reaction to Y90 is so severe that it makes anastomosing to these venous structures unsafe, we proceed with stapling the suprahepatic vein branches and retrohepatic cava and the diseased liver and involved venous structures are then removed en-bloc. Reconstruction of the venous outflow tracts can be done using either cryopreserved IVC (Figure 7) or ABO compatible cadaveric thoracic aorta that was saved from previous donor procurement procedures (Figure 8). The cryopreserved IVC is obtained from LifeNet Health Transplant Services Division, a federally designated Organ Procurement Organization that coordinates the recovery and transplant of organs in Virginia and part of West Virginia.

We switch to mTOR-based immunosuppression whenever possible at around three months using either everolimus or sirolimus for its theoretical antitumor properties. Careful screening for HCC recurrence with cross-sectional imaging is performed every three months for the first year post transplant and then less frequently subsequently. Screening should be continued for at least five years post-transplant.

Figure 7: This is a depiction of a cryopreserved ABO matched IVC used to sew to the recipient IVC at the level of the right renal vein.

Figure 8: ABO matched cadaveric thoracic aorta conduit was used to reconstruct the middle and right hepatic veins tract as a single outflow conduit, which is then reanastomosed in a triangulated side to side fashion to the recipient’s IVC.
**Selected References**


**Salient Points**

- LDLT is an excellent option for candidates with HCC who do not qualify for exception MELD points or live in regions where wait times for transplant are long.
- Candidates for transplant must be carefully selected based on tumor size, number and other factors such as macrovascular invasion and serum AFP levels.
- Tumors can be downstaged using local ablative or embolic techniques. An observatory period of at least 3 months is recommended prior to transplant.
- In appropriately-selected recipients, outcomes with LDLT for HCC are equivalent to those achieved with deceased donor transplants.
Pancreas
Jordan Cloyd, MD, and Jeffrey E. Lee, MD

A Pancreatic Cancer At The Portal Confluence Requires A Vein Resection. How Do You Reconstruct The Vein – Primary Repair, Venous Conduit, Synthetic Graft?

Case Scenario
A 65-year-old woman was found to have a borderline resectable pancreatic ductal adenocarcinoma (PDAC) with >180° involvement of the superior mesenteric vein (SMV) (Figure 1). She received 4 cycles of FOLFIRINOX followed by 30gy of external beam chemoradiation. After completing preoperative therapy, the CA 19-9 had decreased from 670 to 29 U/L and repeat imaging demonstrated stable disease. At the time of pancreatoduodenectomy (PD), the mass was encasing the portal vein (PV) and SMV at the portosplenic confluence. After an en-bloc resection of the tumor, together with the portosplenic confluence, the PV-SMV was repaired primarily in end-to-end fashion. In addition, given that the inferior mesenteric vein (IMV) entered the SMV rather than the splenic vein (SV), and therefore could not decompress the divided SV, a splenorenal shunt was constructed.

Background
PDAC is one of the leading causes of cancer-related mortality in the United States, largely due to the fact that the majority of patients have metastatic disease at the time of presentation. Survival rates are better in patients with localized disease amenable to surgical resection, especially when combined with multimodality therapy. Historically, vascular involvement, whether diagnosed radiographically prior to surgery or at the time of laparotomy, was considered a contraindication to surgical resection. Therefore, patients with localized cancers and major vessel involvement were treated solely with chemotherapy and radiation. Since surgical resection is considered necessary, though not necessarily sufficient, for curative intent, attempts to extend the criteria of resectability to patients with vascular involvement have long been of interest.

The first large series of vascular resection at the time of pancreatectomy was described by Fortner as he introduced the concept of “regional pancreatectomy” in the 1970s. Although Fortner’s original description demonstrated the technical feasibility of venous and arterial resections with pancreatectomy, the procedure was not associated with improved oncological outcomes and therefore was largely abandoned. Nevertheless, over the past several decades, developments in cross sectional imaging, preoperative staging, vascular techniques, and multimodality therapy have led investigators to again consider the merits of vascular resection at the time of pancreatectomy. In

FIGURE 1: Preoperative computed tomography of borderline resectable pancreatic ductal adenocarcinoma with >180° involvement of the superior mesenteric vein (SMV). In order to perform a meticulous dissection of the superior mesenteric artery (SMA), given its proximity to the tumor (T), the splenic vein (SV) is divided. The SMV-PV is reconstructed primarily and a splenorenal shunt is created to prevent sinistral hypertension.
fact, pancreatectomy with venous resection comprises a substantial proportion of operations for PDAC at high volume centers and large series suggest no worse survival in patients that are able to undergo a margin negative resection.

**Patient Selection**

Since microscopic and macroscopic resections are associated with both locoregional recurrence and reduced overall survival, the likelihood of obtaining a margin negative resection must be critically assessed when evaluating whether to proceed with surgical resection. As the ability to safely perform complex vascular resections at the time of pancreatectomy has evolved, a new radiographic classification system was needed to more accurately characterize the anatomic relationship of the tumor to its nearby vascular structures. Broadly defined as potentially resectable, borderline resectable (BR) and locally advanced (LA) (Table), these designations provide important prognostic information regarding the ability to achieve a margin negative resection, the likely need for vascular resection, and the selection of preoperative therapies prior to surgery.

In addition to anatomic staging, patients must be appropriately selected in terms of their potential for harboring occult metastatic disease as well as their physiologic capacity to safely undergo major surgery. Patients with significantly elevated CA 19-9, indeterminate liver or lung lesions, or subtle signs of peritoneal disease should be considered for preoperative chemotherapy and/or chemoradiation therapy as an opportunity to select for patients with biologically favorable disease. Those

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### TABLE 1: Criteria Defining Resectability Status (Data derived from the National Comprehensive Cancer Network. NCCN Guidelines, version 2.2016, Pancreatic Adenocarcinoma).

<table>
<thead>
<tr>
<th>Vessels</th>
<th>Potentially Resectable</th>
<th>Borderline Resectable</th>
<th>Unresectable*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>No tumor contact</td>
<td><strong>Body and Tail:</strong></td>
<td><strong>Head/Uncinate Process:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ≤180° solid tumor contact</td>
<td>• &gt;180° solid tumor contact</td>
</tr>
<tr>
<td>CHA</td>
<td>No tumor contact</td>
<td><strong>Head/Uncinate:</strong></td>
<td><strong>Head/Uncinate Process:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solid tumor contact without extension to celiac axis or hepatic artery bifurcation allowing for safe and complete resection and reconstruction</td>
<td>• &gt;180° solid tumor contact</td>
</tr>
<tr>
<td>SMA</td>
<td>No tumor contact</td>
<td><strong>Head/Uncinate:</strong></td>
<td><strong>Head/Uncinate Process:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ≤180° solid tumor contact</td>
<td>• &gt;180° solid tumor contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Presence of variant arterial anatomy and the presence and degree of tumor contact should be noted if present as it may affect surgical planning</td>
<td></td>
</tr>
<tr>
<td>SMV/PV</td>
<td>No tumor contact or ≤180° contact without vein contour irregularity</td>
<td>• &gt; 180° solid tumor contact with the SMV or PV</td>
<td><strong>Head/Uncinate Process:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ≤180° contact with contour irregularity of the vein or thrombosis of the vein but with suitable vessel proximal and distal to the site of involvement allowing for safe and complete resection and vein reconstruction</td>
<td></td>
</tr>
<tr>
<td>IVC</td>
<td></td>
<td><strong>Head/Uncinate Process:</strong></td>
<td><strong>Head/Uncinate Process:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solid tumor contact</td>
<td>• Unreconstructible SMV/PV due to tumor involvement or occlusion (can be due to tumor or bland thrombus)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Contact with most proximal draining jejunal branch into SMV</td>
</tr>
</tbody>
</table>
* Distant metastasis is considered unresectable; CA: Celiac Artery; CHA: Common Hepatic Artery; SMA: Superior Mesenteric Artery; SMV: Superior Mesenteric Vein; PV: Portal Vein; IVC: Inferior Vena Cava

who demonstrate normalization of their CA 19-9, as well as stable radiographic findings, could then be considered for surgical resection. Similarly, those patients whose comorbidities or performance status make PD prohibitive should also be considered for preoperative therapy, simultaneously focusing on improving their suitability for surgery through medical optimization and prehabilitation.

SURGICAL ANATOMY

Venous Anatomy
The pancreas is anatomically intimately associated with critical vascular structures including the PV, SMV, celiac artery (CA), hepatic artery (HA) and superior mesenteric artery (SMA). The SMV drains the midgut and courses posterior to the neck of the pancreas, joining the splenic vein (SV) in order to form the PV. The IMV typically drains into the SV but occasionally enters in to the SMV or forms a common confluence with SMV and SV. The gastrocolic trunk is an early anterior tributary of the SMV and often divides into the right gastroepiploic and middle colic vein. The first jejunal vein typically runs posterior to the SMA to join the ileal branch in order to form the SMV. The first jejunal vein carries particular significance as it can be directly invaded by tumors of the uncinate process, preventing separation of the tumor from the SMV. In addition, injuries of the first jejunal vein can lead to excessive hemorrhage since vascular control at the root of the mesentery can be extremely challenging.

Knowledge of the venous anatomy is critical to understanding and applying sound technical principles for venous reconstruction. In general, the limits of venous resection extend proximally from the bifurcation of the left and right PV to the first jejunal/ileo branches in the root of the mesentery. The two most important factors to consider are the location of the tumor relative to the portosplenic confluence and the extent of involvement. Classification systems exist that describe the extent of tumor involvement as a means of guiding the reconstruction (Figure 2).

Arterial Anatomy
The SMA originates from the aorta and courses posterior to
the pancreas as it enters the root of the mesentery. The SMA maintains a fairly constant posteromedial relationship to the SMV and is close in proximity to the SMV throughout its length. Therefore, it is uncommon for pancreatic tumors to directly invade the SMA in the absence of venous involvement. On the other hand, the SMA is surrounded by a rich network of nerve and lymphatic tissues that frequently harbor microscopic tumor cells directly invading from adenocarcinomas of the head or uncinate process. For this reason, a meticulous dissection during PD along the periadventitial plane of the SMA is encouraged to maximize the retroperitoneal margin. Pancreatectomy with concomitant SMA resections have historically been associated with prohibitively high morbidity and mortality and are therefore not routinely performed nor discussed further in this chapter.

**FIGURE 3**: Intraoperative photograph of patch venoplasty using internal jugular autograft for repair of a V1 venous resection. This reconstruction method is preferred when segmental resection is not required but the venous defect is >25% of the diameter of the SMV-PV or located at the portosplenic confluence. PV, portal vein; SV, splenic vein; SMV, superior mesenteric vein

**FIGURE 4**: Intraoperative photograph of SMV-PV reconstruction using internal jugular (IJ) vein as an interposition autograft. The graft is fashioned using interrupted 6-0 Prolene and care is taken to ensure that is not rotated. PV, portal vein; SMV, superior mesenteric vein; LHA, left hepatic artery; RHA, right hepatic artery; SMA, superior mesenteric artery

**TECHNICAL ASPECTS**

**Lateral Venorrhaphy**

While the need for venous resection should be anticipated preoperatively based on a thorough examination of cross-sectional imaging, a formal assessment of the tumor-vein interface may be conducted after transection of the pancreatic neck and obtaining vascular isolation and control. Venous resection is indicated when, in the estimation of the surgeon, tumor adherence prevents separation of the PV-SMV from the pancreatic head or uncinate process. That is, venous resection is not performed routinely, for example, in attempts to achieve a wider margin or enhance the lymphadenectomy.

When tumor involves only the right lateral wall of the SMV, a segment of vein may be excised en bloc with the tumor. If the subsequent defect comprises <25% of the vein diameter, lateral venorrhaphy with primary suture may occasionally be
performed. Transverse closure, as is done during pyloroplasty for example, is the least likely method to result in stenosis. If the venous defect is larger, or is located at the confluence, then patch venoplasty with either autologous vein graft or bovine pericardial patch is preferred (Figure 3).

**Segmental Resection and Reconstruction**

For more extensive venous involvement, segmental resection should be performed. Primary anastomosis is preferred when possible. In fact, defects as long as 4cm can be repaired primarily after removal of the specimen and complete mesenteric mobilization. When a tension free primary anastomosis is not possible, an interposition graft should be used. Autologous grafts are preferred over synthetic grafts due to their reduced risk of infection and thrombosis. Our preference is the internal jugular (IJ) vein because of its favorable size match to the PV-SMV and ease of harvest. Other autologous options include the left renal vein (LRV) or saphenous vein. Alternatively, a customized bovine pericardial tube graft (xenograft) can be fashioned to the appropriate size using an endovascular stapler. The possible need for interposition vein graft should be anticipated prior to the operation and the patient prepped and positioned appropriately. If IJ vein is the preferred conduit, a shoulder bump is placed and the head positioned to the right in order to expose the left neck, which is then prepped and draped at the start of the case. Once the tumor is deemed resectable and the surgeon commits to proceed with PD (i.e., generally following division of the pancreas and dissection of the specimen from the SMA), a longitudinal incision is made along the left sternocleidomastoid muscle and the internal jugular vein is isolated and harvested from the clavicle to the facial vein; it is then kept in heparinized saline until needed.

Once the SMA dissection is completed and the retroperitoneal tissues divided, the tumor remains only attached to the PV-SMV. The right colon is returned to its normal anatomic position in order to de-rotate the mesentery. Low-dose systemic heparinization may be administered but is not required. Vascular clamps are placed 2-3cm proximal and distal to the area of venous involvement. SMA clamping is not routinely performed but may be used as a means of preventing intestinal wall congestion that can interfere with subsequent anastomoses, particularly if the reconstruction is anticipated to be especially complex, or take a longer-than-average amount of time to complete (e.g., oblique segmental interposition; or placement of a graft prior to a difficult SMA dissection due to the presence of a large uncinate process tumor, a close SMA margin or the presence of a replaced right hepatic artery). Either primary anastomosis or insertion of an interposition graft is then performed using 6-0 non-absorbable monofilament suture (Figure 4). In the case of interposition grafting, we recommend performing the more challenging side first. This is generally the distal anastomosis, as inadvertent displacement of the distal vascular clamp can lead to significant hemorrhage, which is difficult to control at the root of the mesentery. Occasionally, however, the proximal anastomosis is more challenging and should be performed first. This could be the case, for example, when the tumor is located cephalad in the pancreatic head and extends to the undersurface of the liver, forcing a portal venous anastomosis high in the hilum.

Postoperatively, patients are routinely administered anti-platelet therapy as well as standard chemical and mechanical prophylaxis for deep vein thrombosis; therapeutic anticoagulation is not necessary. Routine radiographic monitoring (e.g. ultrasound) of the venous reconstruction is not required, but attention to venous patency should be given on any follow-up imaging studies.

**Management of the Splenic Vein**

Venous resection and reconstruction is traditionally deferred as the last step of PD after the retroperitoneal dissection has been completed; this helps ensure an optimal configuration to the final reconstruction. In the absence of venous involvement, the PV-SMV may be separated from the pancreas and reflected to the left in order to maximally expose the SMA. However, when separation of the venous structures is not possible, the tumor and vein must be reflected together to the right. In this scenario, however, exposure of the SMA is limited by the portosplenic confluence. While the SMA dissection may proceed in many cases by intermittently retracting the SV cephalad and caudal, division of the splenic vein at the splenoportal confluence is often the most oncologically appropriate strategy in order to maximize exposure of the SMA. It will also shorten the distance between PV and SMV after removal of the specimen, since the SV is no longer tethering either structure, thereby enabling a primary anastomosis.

However, when the SV has been divided during the course of the operation, the surgeon must ensure the patient has adequate gastroplenic outflow. In most cases, outflow continues retrograde through the IMV as it typically enters the SV. However, when the IMV enters the SMV, gastroplenic outflow may be compromised, especially if the coronary vein has been divided previously during the dissection. In this scenario, in order to prevent postoperative sinistral hypertension, creation of a distal splenorenal shunt is recommended. The surgeon exposes the LRV to the left of the SMA. The left adrenal vein and/or gonadal vein may be divided in order to maximize exposure if necessary. The SV is mobilized and anastomosed to the LRV in an end-to-side fashion using 6-0 non-absorbable monofilament suture (Figure 5).

**Outcomes**

**Short-Term Outcomes**

PD with venous resection and reconstruction is a technically challenging endeavor and one might expect higher rates of
adverse postoperative events. In fact, a study utilizing the National Surgical Quality Improvement Project found higher postoperative morbidity (39.9% vs 33.3%) and mortality (5.7% vs 2.9%) rates in patients undergoing PD with vascular resection compared to those who did not undergo vascular resection. However, this finding, and those of similar studies, are limited by the inability to differentiate planned vascular resection and reconstruction from repair of inadvertent vascular injuries at the time of surgery. Other single-institutional series, multi-institutional studies, and meta-analyses have suggested that elective, planned venous resection can be performed safely without significantly increased morbidity rates compared to standard PD.

**Long-Term Outcomes**

Compared to non-operative therapies, PD with venous resection and reconstruction leads to improved long term outcomes. In fact, it is now universally accepted that venous involvement should not be an absolute contraindication to surgical resection. Lygidakis et al randomized patients with PDAC and limited vascular involvement to either PD with vascular resection or double bypass and found 2 year survival rates of 81.8% vs 0%, respectively. Other comparative studies have suggested similar oncologic outcomes between patients with PDAC who underwent standard PD and those who underwent PD with venous resection, especially when preoperative therapy was utilized.

**Impact of Preoperative Therapy**

Increasingly, patients with PDAC are receiving chemotherapy and/or chemoradiation therapy prior to surgical resection, especially those with BR or LA tumors. Preoperative therapy offers multiple advantages, including the guaranteed delivery of multimodality therapy to all patients, the early treatment of micrometastatic disease presumed present in nearly all patients with PDAC, facilitation of a margin negative resection,
and, most importantly, the selection of patients with favorable tumor biology who are most likely to benefit from major surgery. Furthermore, evidence suggests that the administration of preoperative therapy is not associated with increased adverse events. On the other hand, preoperative radiation has the advantage of being associated with reduced rates of postoperative pancreatic fistula.

**Patency**

In general PV-SMV resection and reconstruction is associated with high patency rates. Venous thrombosis can occur at any time after surgery, but acute thrombotic events are associated with the highest morbidity. Late thrombotic events are often related to cancer recurrence. Little literature exists on risk factors for venous thrombosis after reconstruction, though some studies have suggested that size mismatch, interposition grafting, duration of the operation, and postoperative complications are associated with patency failures. Primary suture repair, either lateral venorraphy or end-to-end anastomosis, is associated with the lowest incidence of thrombosis.

**Selected References**


**Salient Points**

- With meticulous attention to preoperative cross-sectional imaging, careful patient selection, the use of multimodality therapy, and sound technical principles, the benefits of surgical resection can be safely extended to those patients with PDAC and venous involvement.
- The need for vascular resection should be anticipated based on the preoperative imaging but critically assessed intraoperatively after division of the pancreas.
- Attempts at splenic vein preservation should be undertaken but not at the expense of an oncologically inadequate SMA dissection.
- The venous resection and reconstruction is deferred as the last step of the operation and attempts should be made to perform primary repair when possible.
- When the venous defect cannot be repair primarily, an interposition graft using autologous vein, should be fashioned.
- When performed at experienced high volume centers in appropriately selected patients, PD with concomitant venous resection is associated with excellent short and long term outcomes.
Hepato-Pancreato-Biliary and Transplant Surgery: Practical Management of Dilemmas

Quyen D. Chu, MD, MBA, Charles M. Vollmer, MD, Gazi B. Zibari, MD, Susan L. Orloff, MD, Mallory Williams, MD, and Mariano E. Gimenez, MD, PhD

This unique textbook provides a concise and practical approach to clinical dilemmas involving the liver, pancreas, and biliary tree. Six major sections encompass: (1) Hepatic, (2) Biliary, (3) Pancreas, (4) Transplantation, (5) Trauma, and (6) Innovative Technology.

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