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Management of Type 9 Hepatic Arterial Anatomy at the time of Pancreaticoduodenectomy: Considerations for Preservation and Reconstruction of a Completely Replaced Common Hepatic Artery

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Abstract

Recognition and management of aberrant hepatic arterial anatomy for patients undergoing pancreaticoduodenectomy (PD) are critical to ensure safe completion of the operation. When the common hepatic artery (CHA) is noted to emanate from the superior mesenteric artery (Michels' type 9 variant), it is vulnerable to injury during the dissection required for PD. While this anatomy does not preclude an operation, care must be taken to avoid injury, often by identifying the CHA throughout its entire course before beginning the dissection of the portal venous structures. The oncologic principle that cautions against resection of a pancreatic cancer when it involves the CHA in its standard position may not universally apply to tumors that focally involve the CHA in the type 9 anatomic variant. In highly selected patients, surgical resection may be entertained as disease biology may be analogous to local involvement of the gastroduodenal artery in a patient with standard anatomy. Here, we review the indications, techniques, and outcomes associated with arterial resection and reconstruction during pancreatotomy among patients with a pancreatic tumor involving a common hepatic artery arising from the superior mesenteric artery.

Keywords

Arterial reconstruction; Type 9 hepatic artery; Pancreaticoduodenectomy; Pancreatic cancer

How I Do It

Recognition of aberrant hepatic arterial anatomy was a cornerstone of surgical training throughout the twentieth century. Surgical pioneers such as Lahey and Cattell gained their fame, in part, based upon a thorough understanding of anatomic vascular variants that enabled them to perform cholecystectomy safely. In 1966, a series of 200 autopsies carried out at Jefferson Medical College by Dr. Nicholas Michels detailed ten anatomic variants of

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hepatic arterial anatomy.¹ Detailed understanding of vascular anatomy first delineated by Dr. Michels and his contemporaries enabled the performance of increasingly complex operations in and around the porta hepatis over the subsequent decades. The prevalence of these variations has been comprehensively reported in both the transplant and hepatobiliary literature.^{2,3} Today, the performance of both extirpative and reconstructive operations involving pancreas, liver, and the biliary tree are routinely completed with limited morbidity.

Pancreaticoduodenectomy (PD) involves the routine transection and excision of the gastroduodenal artery (GDA) caudal to its origin en route to removal of disease in the head of the pancreas or proximal duodenum. Indicated for locally-confined malignancy, the risk and benefit profile for this operation has changed dramatically over the past four decades, due in large part to reduced surgical risk, improved understanding of tumor biology, and improved adjuvant therapeutic options.^{4,5} With improved perioperative outcomes, the traditional limits defining resectable disease are being pushed. As an example, the practice of portal vein resection and reconstruction during PD for malignancy has expanded considerably over the last decade.^{6–8} Despite the increased utility of venous reconstruction for locally advanced pancreatic cancer, the role of concomitant arterial resection remains more controversial.^{9–11}

One particular subset of patients in which arterial reconstruction may be considered is patients in whom the common hepatic artery (CHA) emanates directly from the superior mesenteric artery (SMA) (Michels' type 9 variant; Fig. 1). In this group of patients, disease biology may be more analogous to local involvement of the GDA rather than the SMA. Importantly, the oncologic principles that caution against resection of pancreatic cancer involving the SMA, or even the common hepatic artery (CHA) in its standard location, may not be relevant to patients with type 9 hepatic arterial anatomy. Specifically, while encasement of the SMA or CHA/celiac artery in its standard location is not only technically more challenging, it can also connote invasion of the tumor into the peri-vascular retroperitoneal neuronal plexus.¹² In contrast, tumor involvement of the type 9 CHA variant is more akin to involvement of the GDA, as both structures are not retroperitoneal/posterior in location. As such, when tumor involvement of the CHA as a type 9 hepatic arterial variant is encountered, this should not be considered a contraindication to proceeding with an en bloc PD resection with the CHA to obtain an R0 resection.

There are a number of different options for resection and reconstruction of the type 9 CHA variant in conjunction with PD. The specific repair chosen at our institution is dependent on the extent and location of the arterial involvement. Common options for arterial reconstruction include primary end-to-end anastomosis of the native vessel, interposition grafting in situ, or extra-anatomic bypass grafting. When tumor involvement of the CHA is only for a short segment, reconstruction with a primary end-to-end anastomosis between the replaced common hepatic and proper hepatic arteries is appropriate. The key to successful reconstruction with this technique is the same as for vascular anastomoses performed in other anatomic locations. Most importantly, a tension-free anastomosis must be constructed to prevent risk of disruption. In cases of PD with type 9 CHA anatomy, extirpation of the surgical specimen can often provide the additional proximal and distal arterial vessel length required to span a gap of several centimeters.

When a tension-free primary end-to-end arterial anastomosis is not possible, placement of an interposition graft is appropriate. Autologous grafts with artery or vein are preferred, and several techniques have been previously described.¹³ Successful use of the gastroepiploic artery, GDA, right gastric artery, middle colic artery, splenic artery, radial artery, internal jugular vein, or greater saphenous vein have all been reported.^{10,13–16} Another option that we favor involves the use of a cadaveric iliac artery, which is a technique often used in liver transplantation when standard hepatic artery reconstruction is not possible.¹⁷

In cases where the hepatic artery is encased by tumor for a longer segment, or when the CHA must be transected at its branch point off of the SMA, arterial reconstruction using an extra-anatomic (i.e. “jump”) bypass graft may be necessary. In these situations, retrograde revascularization with inflow from the right renal or right iliac artery is typically employed in our practice (Fig. 2). The aorta can also be used as the inflow vessel depending on the patient’s anatomy and exposure. For example, the use of a cryopreserved cadaveric femoral artery to revascularize the liver by an infrarenal aorta jump graft to the distal end of the type 9 CHA can be employed (Fig. 3). The use of autogenous conduits is much preferred when doing a PD given the risk of contamination of a synthetic graft. When a jump graft is employed, there can sometimes be difficulties with the length of the conduit, as well as the risk of narrowing or kinking of the conduit. When these risks are prohibitive and a synthetic graft is required, the conduit of choice should be ringed PTFE, as it can be tunneled without kinking more easily than vein graft, and length limitations are less of a concern. The infectious risk associated with placing a synthetic graft in a patient undergoing PD should be noted, and care should be taken to prevent exposure of the graft to enteric contents during reconstruction after the pancreatectomy. Often we use an omental pedicle flap to protect and isolate the graft from the reconstruction.

There are currently no prospective randomized trials comparing outcomes among patients with locally advanced pancreatic cancer undergoing surgical resection with arterial reconstruction versus medical treatment alone. In a report of 35 patients undergoing pancreatectomy with arterial reconstruction versus 75 propensity-matched patients undergoing pancreatectomy without arterial reconstruction, the risk of post-operative complications was similar between groups.¹⁴ In contrast, a meta-analysis of 26 retrospective studies demonstrated a higher risk of perioperative mortality (OR 5.04) and worse 1- and 3-year survival (OR 0.49 and 0.39, respectively) among patients undergoing pancreatectomy with arterial reconstruction compared with patients who did not have arterial reconstruction.⁸ It is important to note, however, that in the latter report patients who underwent pancreatectomy with arterial reconstruction did have better survival than patients who did not undergo surgical resection at all (OR 4.28 and 19.7 at 1- and 2-years, respectively).

It must be kept in mind that there are no published guidelines as to which patients with locally advanced pancreatic cancer with arterial involvement are appropriate for attempted surgical resection. Neoadjuvant chemoradiation is generally accepted as the first-line approach, as it can potentially improve the chances of tumor resectability and survival.⁶ Following this, patients can either be offered attempted resection with possible vascular reconstruction in highly-selected cases, continued medical management including systemic

chemotherapy, local-regional disease burden control with radiation therapy, or palliation. A multidisciplinary team of specialists, including surgeons, medical oncologists, and radiation oncologists, should be involved in the decision making process. In general, the decision to resect should be based on demonstration of favorable tumor biology, surgeon experience, patient preferences, and the capacity of the individual patient to tolerate increased perioperative morbidity that accompanies an additional arterial resection with reconstruction.⁸ It should also be cautioned that these complex resections with arterial reconstruction should be performed only in facilities with advanced hepatobiliary and vascular or transplantation support.

Long-term complications associated with arterial resection and reconstruction include delayed infection, embolic complications, and graft patency. Data previously reported from our group has documented a graft patency rate of about 90–95 % at a mean follow up of 1.4 years.¹⁴ For graft patency, we routinely begin antiplatelet therapy with aspirin following arterial reconstruction. Occasionally, antithrombotic therapy using oral Coumadin or low-molecular weight heparin injections can be employed. In the setting of significant luminal narrowing of the graft, a secondary procedure to maintain patency may be necessary (i.e., balloon angioplasty; Fig. 4).

In sum, surgical resection with arterial reconstruction for locally advanced pancreatic cancer may be indicated in select patients. In particular, given that surgical resection is not contraindicated in patients with local tumor extension into and around the GDA, our group believes that surgical resection should be considered in the setting of CHA involvement, especially in the setting of the type 9 hepatic arterial anatomic variant.

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Fig. 1. Type 9 hepatic arterial anatomy

In what is commonly referred to as a type 9 hepatic arterial anatomy, the common hepatic artery arises directly from the superior mesenteric artery. Its course towards the porta hepatis can be variable, but is most commonly located posterolaterally in relation to the head of the pancreas. *GDA* gastroduodenal artery

Fig. 2. Case example #1

Pancreatic tumor circumferentially encased the common hepatic artery in the setting of a pancreatic body tumor requiring en-bloc resection of the common hepatic artery along with distal pancreatectomy and splenectomy. Here, a bifurcated PTFE graft is utilized to reconstruct the hepatic arterial inflow from the right iliac artery to right and left hepatic arteries. A similar approach can be used when arterial involvement is encountered in other hepatic arterial variants. *LHA* left hepatic artery, *RHA* right hepatic artery, *RIA* right iliac artery

Fig. 3. Case example #2

Pancreatic tumor was found to circumferentially encase the common hepatic artery in the setting of type 9 hepatic arterial anatomy. The tumor was resected en bloc with a pancreaticoduodenectomy and partial common hepatic artery resection (panel **a**, *arrow* denotes encased artery). The hepatic artery was then reconstructed using a cadaveric femoral artery jump graft with inflow from the distal infrarenal aorta (panel **b**, *arrow* denotes jump graft reconstruction). *CHA* common hepatic artery

Fig. 4. Hepatic artery graft stenosis

The list of possible complications is increased when arterial resection and reconstruction are added to pancreaticoduodenectomy. One such risk is stenosis of the reconstruction (either at the anastomosis or of the conduit). Here, we demonstrate an early postoperative (2 weeks) graft stenosis in the same patient from Figure 3 who underwent hepatic artery reconstruction using a cadaveric femoral artery jump graft with inflow from the distal infrarenal aorta. Angiography suggests this stenosis occurred at the proximal anastomosis created between a proximal common hepatic artery and a cadaveric vein graft used in a case with type 9 hepatic arterial anatomy (panel **a**, arrow denotes stenosis). This was treated by angioplasty and systemic anticoagulation with good results (panel **b**)