

# Portal Vein Arterialization: A Therapeutic Option for Hepatic Artery Interruption in Pancreaticoduodenectomy

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## Abstract

Commonly known as the Whipple's procedure, a pancreaticoduodenectomy is a surgical operation for aggressive pancreatic cancer with a 10% five-year survival rate, which can potentially provide clearance or control of patient symptomatology. In pancreaticoduodenectomy, injury to major vascular structures such as the hepatic artery can occur, with subsequent high morbidity and mortality related to hepatic complications. This paper describes two cases where damage to major vasculature occurred during a pancreaticoduodenectomy, and portal vein arterialization (PVA) was used as a revascularization option. The first case describes a 69-year-old female who sustained an injury to the common hepatic artery during the procedure. Initial revascularization via direct primary end-to-end anastomosis and a saphenous vein graft were unsuccessful, so PVA was established with success. The second case describes a 52-year-old male who had a segment of the right hepatic artery resected en bloc with the tumor. Initial attempts at end-to-end arterial reconstruction proved futile, and intraoperatively ischemic changes were noted by the surgeon who opted to perform PVA to establish arterial flow. Although multiple options for revascularization of the hepatic artery exist, here we describe two cases where portal vein arterialization is used as a straightforward and successful salvage technique, especially when other options have proved futile.

## Keywords

General Surgery; Portal Vein; Pancreaticoduodenectomy

## 1. Introduction

Major hepatopancreatobiliary surgery is associated with significant morbidity and mortality, and the avoidance of vascular structures is at the forefront of the surgeon's operative approach [1,2]. Operative injury to the hepatic artery remains a serious risk in pancreaticoduodenectomy, occurring in up to 3% of patients, which, if not lethal, often results in both short- and long-term consequences [2]. The operative priority remains the immediate restoration of arterial flow to prevent early life-threatening complications; however, guidelines about the appropriate management of this complication remain lacking. Portal vein arterialization (PVA) has been described in liver surgery as a promising technique to prevent liver necrosis and accelerate the regeneration capacity of hepatocytes [3–6]. First suggested in 1992 by Iseki *et al.* [7] to replace a damaged hepatic artery during major hepatobiliary

surgery, PVA has also been used as a salvage procedure to rescue grafts in liver transplant surgery when arterial thrombosis occurs or if there is no alternative way to restore arterial supply [3–5].

Although regarded as a useful technique in liver resection and transplantation, portal vein arterialization has not been recognized as a rescue procedure in pancreatic surgery. Therefore, we describe our recent experiences.

## 2. Patients

### 2.1. Case 1

A 69-year-old female underwent magnetic resonance cholangiopancreatography (MRCP), which revealed an acute significant narrowing of the pancreatic duct in the pancreatic head, with persistent duct dilatation in the body and tail

of the pancreas was worked up for surgical management. There was no vascular involvement of the presumed tumor on preoperative cross-sectional imaging. Following an endoscopic ultrasound-guided biopsy, given the suspicious nature of the findings, the decision was for operative management through pancreaticoduodenectomy. During the resection, no aberrant anatomy was observed, although the porta was fibrotic, leading to a difficult dissection. Unfortunately, the surgery was complicated by an inadvertent injury to the common hepatic artery, which was initially repaired through a direct primary end-to-end anastomosis using interrupted 6-0 Prolene sutures.

The patient was admitted to the intensive care unit postoperatively but experienced deterioration overnight, with markedly deranged liver function: AST 1763 U/L, ALT 2295 U/L, LDH 1053 U/L, low platelet count, elevated ammonia level of 80  $\mu\text{mol/L}$ , and deranged coagulation function. A computed tomography (CT) the next day demonstrated a well-defined occlusion of the common hepatic artery 5mm from its origin, along with multifocal areas of wedge-shaped hypodensity in the liver on the portal venous phase (**Figure 1**). A re-exploratory laparotomy identified the hepatic artery thrombosis, and a saphenous vein graft was used as a conduit for hepatic artery reconstruction. However, intraoperative Doppler USS could not detect any flow in the liver, presumably due to intimal dissection. Consequently, PVA was established via an end-to-side anastomosis between the common hepatic artery and the portal vein, using the saphenous vein graft as a conduit (**Figure 2**).

## 2.2. Case 2

A 52-year-old male was referred with a one-week history of postprandial epigastric pain and jaundice. CT and MRCP revealed subtle soft tissue thickening in the mid and distal aspect of the common bile duct. The patient underwent a standard pancreaticoduodenectomy. Portal dissection during the operation demonstrated an early bifurcation of the proper hepatic artery and tumor involvement in a segment of the right hepatic artery. The affected arterial segment was resected en bloc with the tumor. Initial attempts at end-to-end arterial reconstruction proved futile, with thrombosis of the anastomosis primarily due to the size mismatch of the arterial ends and small size vessels. Although it is accepted that there is usually “arterial crossover” to supply the liver and uninterrupted portal vein flow, it was noted by the surgeon that there were certainly ischemic changes to the right lobe. Hence, given the already high morbidity procedure, the prevention of further potential complications related to liver ischemia was the rationale behind persisting to establish arterial flow to the right lobe of the liver via PVA.

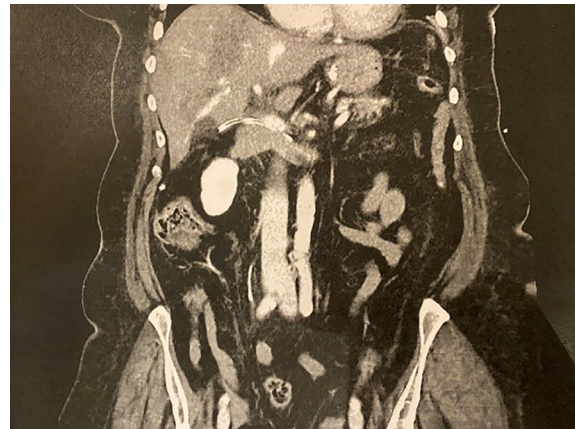
## 3. Results

### 3.1. Case 1

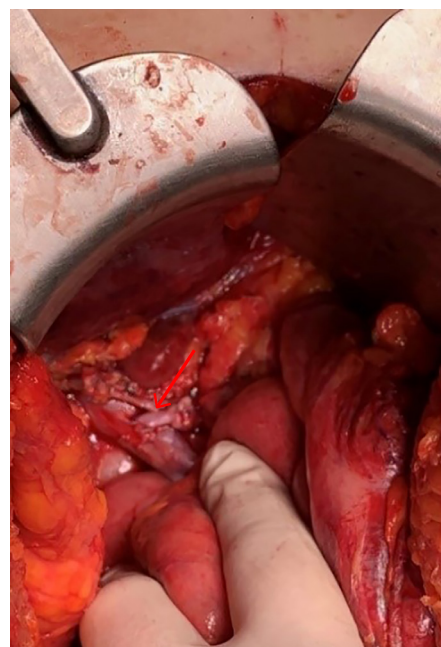
Postoperative liver function tests showed a significant improvement, returning to normal within 7 days. The postoperative recovery period was prolonged with the patient developing *Serratia marcescens* sepsis resistant to cefazolin and amoxicillin and requiring three weeks of intensive care admission with intravenous antibiotics, but she was then

successfully discharged home after a further week on the general ward.

Histopathology confirmed a 30mm moderately differentiated adenocarcinoma of the pancreatic head with perineural invasion and lymphatic involvement, classified as stage T2N1M0. A plan was established for gemcitabine and capecitabine adjuvant chemotherapy for six months. A follow-up at 6 weeks showed satisfactory liver function tests, and a CT scan confirmed the patency of arterioportal anastomosis and a healthy liver. The original plan was to perform an embolization of the saphenous vein conduit after 6 to 12 weeks to avoid potential long-term complications of portal hypertension. However, the patient developed a spinal metastasis, so the decision was to closely monitor the patient. At 12 months, the patient remains asymptomatic from portal hypertension, and a recent CT scan confirmed the patency of the PVA.



**Figure 1:** The CT scan of the abdomen/pelvis on the first postoperative day demonstrated a well-defined occlusion of the common hepatic artery located 5mm from its origin and multifocal areas of wedge-shaped hypodensity observed on the portal venous phase.



**Figure 2:** End-to-side anastomosis (arrow) of the common hepatic artery to the portal vein using the saphenous vein graft.

### 3.2. Case 2

On the first day post-operation, the patient experienced worsening liver function and an ammonia level of 128  $\mu\text{mol/L}$ . Radiological findings revealed a patent PVA, but the left hepatic artery was occluded. The patient was closely monitored, and liver function gradually improved.

Histology confirmed a 15mm moderately differentiated extrahepatic cholangiocarcinoma with perineural invasion and invasion into the adipose tissue surrounding the bile duct, classified as stage T1N0M0. The patient recovered, and recent liver function tests showed normal results. The patient underwent adjuvant chemotherapy for six months. At the last review, the patient had been well, but unfortunately, 12-month imaging showed recurrent disease, although the PVA remained patent. The patient is currently undergoing palliative chemotherapy, and again we have chosen not to embolize the PVA.

### 4. Discussion

In radical hepatopancreatobiliary surgery, the arterial network can be disrupted by skeletonization, with a total interruption of the hepatic arterial flow potentially causing serious postoperative complications [8,9]. Typically, the liver receives dual blood supply via the portal vein and hepatic artery. The hepatic artery contributes 20% of the blood supply and approximately 50% of oxygen to the liver [1,10]. Consequently, interruption to the hepatic artery and its perihepatic, intrahepatic, and peribiliary collaterals exposes the liver and biliary tree to ischemic complications [1,10].

The reported incidence of hepatic artery injury ranges from 0.5% to 2.7% during operative management of the liver and pancreas [2,11]. Portal vein arterialization (PVA) was initially introduced by Iseki *et al.* [7] to improve encephalopathy and prevent massive necrosis due to hepatic artery obstruction. However, this technique remains poorly publicized, and its use is virtually unknown in pancreatic surgery [7]. PVA has been used in liver transplantation as a salvage technique or as a bridge to re-transplantation, but it can also be used in cases of tumor invasion of hepatic arterial vessels or after failed revascularization through grafts [1,2,12]. The concept of PVA is to increase the oxygen saturation of the portal vein, preventing hepatic necrosis and promoting liver regeneration [12,13].

Bhangui *et al.* [12] analyzed the outcomes in patients who underwent PVA for hepatic artery thrombosis after liver transplantation or after hepatic artery interruption during hepato-pancreatobiliary cancer resection [12]. Four out of sixteen experienced early PVA thrombosis, with two undergoing further PVA and two requiring no further management of the conduit due to the development of good collateral inflow [12]. This study, one of the few to document mid- to long-term complications of PVA, found that 44% of patients had some form of portal hypertension-related complication, including significant ascites or bleeding (either intra-abdominal or variceal). Nevertheless, the authors concluded that the survival rates were acceptable, with 63% of patients reporting good liver function at the 12-month follow-up [12]. These findings are congruent with those of Nardo *et al.* [14], who reviewed PVA in the management of acute liver failure and observed improvement in liver function despite established liver necrosis [13,14]. Although the need

for prophylactic closure of shunts after recovery from surgery has previously been recommended, the jury is still out on this matter [6,9]. However, a strict surveillance protocol and management of portal hypertension are necessary [13–16].

Currently, there is still limited evidence regarding the utility of PVA in hepatic surgery. Ideally, further studies should review the long-term complications and duration of surveillance required for this population. Unfortunately, given the rarity of PVA and the poor cancer-specific survival for pancreatic and hepatic malignancy, this could be challenging. Nevertheless, PVA should be considered as a potential salvage technique to restore arterial inflow when no other form of arterial reconstruction is possible. Furthermore, it has been shown that PVA can be used as a rescue even in cases of hepatic arterial thrombosis-related acute liver failure following pancreatic surgery.

### 5. Conclusion

Operative injury to the hepatic artery is an infrequent but serious, potentially life-threatening complication of pancreaticoduodenectomy [1,2,11]. Rapid restoration of arterial flow is clearly required, but if this is not possible, then PVA is a safe alternative [8,9,12,13]. PVA is surgically more straightforward than hepatic artery reconstruction, and it deserves recognition as a sensible salvage option for both inadvertent hepatic artery injury and for curative resection in locally advanced pancreatobiliary malignancies, where arterial resection may be necessary or when acute arterial thrombosis occurs [12,15,16].

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We confirm that all authors have contributed to the generation of the manuscript.

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### Conflicts of Interest

The authors have no conflicts of interest to declare.

### Ethical Approval

All procedures performed in this study involving the human participant were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

### Patients' Consents

Written consents were obtained from the patients through hospital documentation for information to be included in the manuscript. The information has been identified to the best of the author's ability to protect privacy.

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