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TECHNICAL NOTE

Distal Pancreatectomy With *En Bloc* Resection of the Celiac Trunk for Extended Pancreatic Tumor Disease: An Interdisciplinary Approach

Timm Denecke · Andreas Andreou · Petr Podrabsky · Christian Grieser · Peter Warnick · Marcus Bahra · Fritz Klein · Bernd Hamm · Peter Neuhaus · Matthias Glanemann

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Abstract
Purpose Infiltration of the celiac trunk by adenocarcinoma of the pancreatic body has been considered a contraindication for surgical treatment, thus resulting in a very poor prognosis. The concept of distal pancreatectomy with resection of the celiac trunk offers a curative treatment option but implies the risk of relevant hepatic or gastric ischemia. We describe initial experiences in a small series of patients with left celiacopancreatectomy with or without angiographic preconditioning of arterial blood flow to the stomach and the liver.
Materials and Methods Between January 2007 and October 2009, six patients underwent simultaneous resection of the celiac trunk for adenocarcinoma of the pancreatic body involving the celiac axis. In four of these cases, angiographic occlusion of the celiac trunk before surgery was performed to enhance collateral flow from the gastroduodenal artery. Radiologic and surgical procedures, findings, and outcome were analyzed retrospectively.
Results Complete tumor removal (R0) succeeded in two patients, whereas four patients underwent R1-tumor resection. After surgery, one of the two patients without angiographic preparation experienced an ischemic stomach perforation 1 week after surgery. The other patient died from severe bleeding from an ischemic gastric ulcer. Of the four patients with celiac trunk embolization, none presented ischemic complications after surgery. Mean survival was 371 days.
Conclusion In this small series, ischemic complications after celiacopancreatectomy occurred only in those patients who did not receive preoperative celiac trunk embolization.

Keywords Pancreatic cancer · Distal pancreatectomy · Celiac trunk resection · Angiography · Embolization

Introduction

The long-term prognosis of pancreatic cancer remains poor despite continuous progress in the development of chemotherapeutic regimes [1, 2]. Especially carcinoma of the body of the pancreas is often discovered at an advanced stage and is often unresectable at diagnosis [3]. The most common reasons for unresectability are the presence of hepatic metastases, peritoneal carcinomatosis, or invasion into major vessels, such as the celiac trunk or the common hepatic artery (CHA) [4–8]. The most important predictor for long-term survival of patients with nonmetastatic pancreatic cancer is whether complete resection was possible [9, 10].

Radical distal pancreatectomy with splenectomy and *en bloc* resection of the celiac trunk (distal celiacopancreatectomy), first described by Nimura et al., aims to provide a curative approach for cancer of the pancreatic body with infiltration of the celiac trunk [11–17] and has a 5-year survival rate ≤42% (median overall survival 21 months) [13]. Thereby, the direct arterial blood supply to liver and

Timm Denecke and Andreas Andreou contributed equally to the manuscript.

T. Denecke (✉) · P. Podrabsky · C. Grieser · B. Hamm
Klinik für Strahlenheilkunde, Charité—Universitätsmedizin Berlin, Campus Virchow-Klinikum, Augustenburger Platz 1, 13353 Berlin, Germany
e-mail: timm.denecke@charite.de

A. Andreou · P. Warnick · M. Bahra · F. Klein · P. Neuhaus · M. Glanemann
Klinik für Allgemein-, Viszeral-, und Transplantationschirurgie, Charité—Universitätsmedizin Berlin, Campus Virchow-Klinikum, Augustenburger Platz 1, 13353 Berlin, Germany

stomach from the celiac trunk is interrupted, but it may be maintained by collateral pathways by way of the superior mesenteric artery (SMA), the pancreatoduodenal arcades, and the gastroduodenal artery (GDA) feeding the hepatic, right gastric, and gastroepiploic arteries. A smaller alternative supply exists by way of the esophagogastric arterial network, which is fed by esophageal arteries arising mainly from the thoracic aorta and the left inferior phrenic artery [18–21]. Nevertheless, arterial perfusion of these organs has been in some cases compromised after this procedure, resulting in severe complications, such as acute liver failure and necrosis of the stomach and the gallbladder [22]. Preoperative digital subtraction angiography (DSA) with embolization of the celiac axis helps enhance collateral pathways before the surgical procedure [12].

We herein report on our initial experience with *en bloc* tumor and celiac trunk resection (distal celiacopancreatectomy) and underline the necessity of preoperative celiac trunk embolization.

Patients and Methods

Patients

Patients were eligible for distal celiacopancreatectomy when computed tomography (CT) or magnetic resonance imaging (MRI) showed involvement of the celiac trunk and/or the CHA but no tumor contact to the SMA or the GDA. Other unresectability criteria included curative pancreatic cancer resection [8, 23, 24]. Accordingly, between January 2007 and October 2009, six patients (age 56 to 71 years; four men and two women) underwent distal celiacopancreatectomy at our center (Table 1). Written informed consent was obtained from all patients.

Radiology

In four of the six patients, preoperative embolization of the celiac trunk and the CHA was performed to precondition

Table 1 Angiographic and surgical procedure and histopathologic results[a]

Patient	Age/sex	Angiographic procedure				Surgical procedure	Pathology (TNM)	Category
		Celiac trunk situation	Approach for occlusion	Test balloon	Occlusion material			
A	67/M	Tumor stenosis	Femoral artery	No	PDA coil (5/50 mm)	Distal pancreatectomy, splenectomy, celiac trunk resection, lymphadenectomy, left adrenalectomy, cholecystectomy, portal vein partial resection, reconstruction with alloplastic material	Ductal adenocarcinoma pT3pN1(1/5)G2	R1
B	56/M	Not performed				Distal pancreatectomy, splenectomy, celiac trunk resection, lymphadenectomy, left adrenalectomy, cholecystectomy, portal vein partial resection with anastomosis	Ductal adenocarcinoma pT3pN0(0/6)G2	R1
C	71/M	Not performed				Distal pancreatectomy, splenectomy, celiac trunk resection, lymphadenectomy	Ductal adenocarcinoma pT3pN1(2/19)G2	R1
D	61/F	Minimal tumor stenosis	Femoral artery (?)	Yes (8 × 20 mm)	Amplatzer Plug II (10 mm)	Distal pancreatectomy, splenectomy, celiac trunk resection, lymphadenectomy, cholecystectomy	Ductal adenocarcinoma pT3pN0(0/18)G2	R0
E	64/F	Ligamental stenosis	Axillary artery	No	Amplatzer Plug I (12 mm) plus LGA (2 coils: 4/15 and 5/15)	Distal pancreatectomy, splenectomy, celiac trunk resection, lymphadenectomy	Ductal adenocarcinoma pT3pN1(4/16)G2	R1
F	54/M	Patent	Femoral artery	Yes (8 × 20 mm)	Amplatzer Plug II (8 mm) plus LGA (2 coils: 3/30 and 5/15)	Distal pancreatectomy, splenectomy, celiac trunk resection, lymphadenectomy, left adrenalectomy, cholecystectomy	Ductal adenocarcinoma pT3pN1(5/31)G2	R0

PDA patent ductus arteriosus

[a] Coils are described as coiled diameter [(mm)/length (mm)]

the future arterial blood supply to the liver and stomach by enhancing the collateral pathways from the SMA by way of pancreatoduodenal arcades to the GDA, the proper hepatic artery (PHA), the gastroepiploic artery, and the right gastric artery by the time of surgery. The other two patients refused angiography.

In all four patients who underwent celiac trunk embolization, a regular arterial anatomy of the celiac trunk and SMA was present as displayed on preinterventional CT (n = 3) and MRI (n = 1). The interventions were performed by way of DSA (Integris V5000; Philips, Best, The Netherlands) with local anesthesia at the puncture site. First, aortography (pigtail catheter, 5F), as well as selective celiacography and mesentericography (Cobra catheter, 5F), was performed to visualize the arterial anatomy for further consideration and to obtain measurements. In two patients, spontaneous collateral flow to the GDA and the hepatic arteries was seen on selective mesentericography due to celiac trunk stenosis; therefore, a balloon occlusion test of the celiac trunk was considered unnecessary. In the other two patients without spontaneous collateralization, test occlusion of the celiac axis using a balloon device (8*20 mm, Wanda; Boston Scientific, Natick, MA) was performed before definite embolization. For the balloon catheter, a second arterial access was established. Provoked by occlusion of the celiac axis and the CHA, selective mesentericography confirmed the presence of collateral flow from the SMA to the hepatic and gastroepiploic arteries. Then, depending on the anatomic situation, either a PDA coil (Cook, Bloomington, IN) or vascular plugs (Amplatzer Vascular Plug I or II; AGA Medical, Plymouth, MN) were chosen to occlude the celiac trunk with the origin of the CHA. In two patients, the left gastric artery (LGA) was additionally coil embolized because their origin was not blocked by the trunk embolization. This was performed selectively to leave the proximal part of the celiac trunk free for better surgical handling during resection. Finally, selective mesentericography was repeated to document the final result and revealing strong collaterals in the gastroduodenal region feeding the hepatic and gastroepiploic arteries in all four patients (Table 1 and Figs. 1, 2).

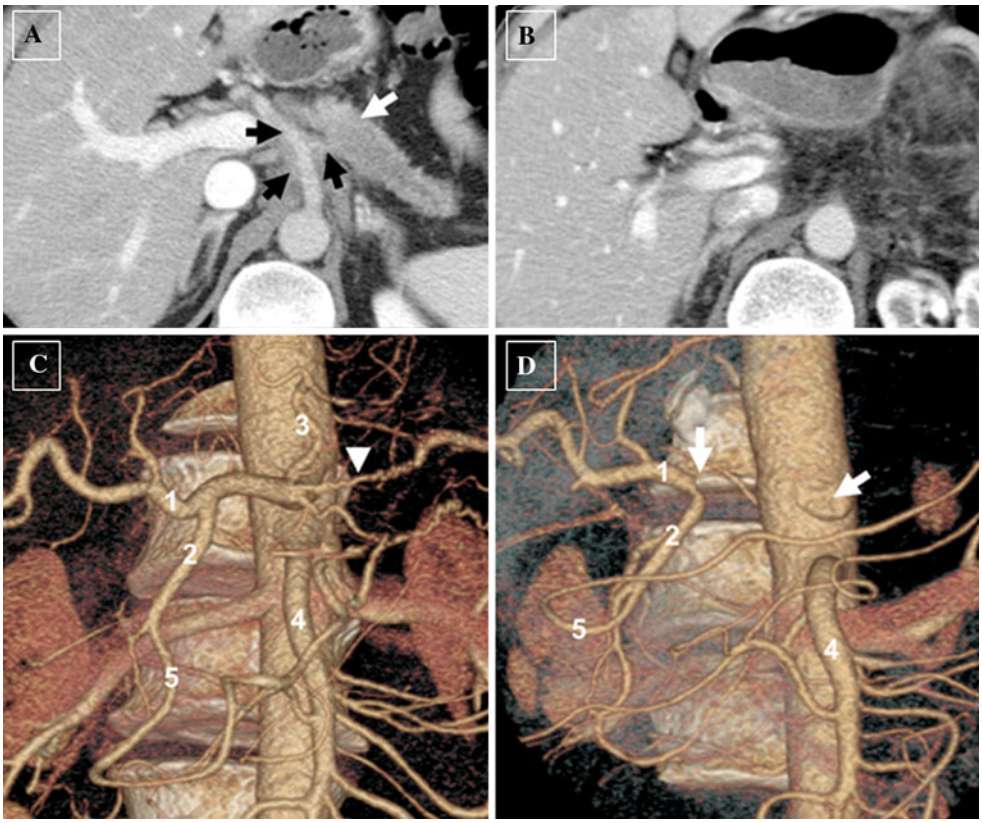

Fig. 1 Preoperative contrast-enhanced (portal venous phase) CT (**A**) showing the pancreatic cancer (*white arrow*) with infiltration along the splenic artery to the celiac trunk and the CHA (*black arrows*). CT after extended distal pancreatectomy (**B**) demonstrates the resection site of the celiac axis. CT angiography before (**C**) and after (**D**) surgery shows the persistently well-perfused GSA (*2*), the gastroepiploic artery (*5*), and the PHA (*1*) over collateral flow from the SMA (*4*) despite resection of the celiac trunk and CHA (*arrows*), including the tumor-encased splenic artery (*arrow head*) and the LGA (3)

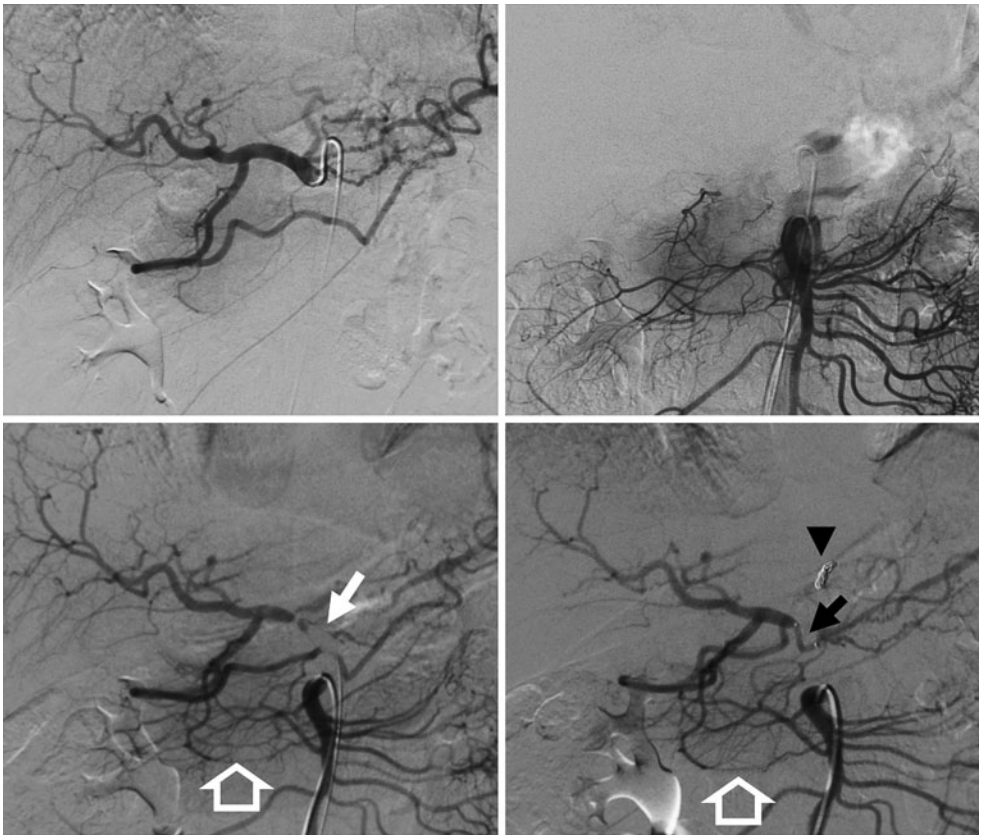

Fig. 2 DSA [selective celiacography (*upper left panel*) and mesentericography (*upper right panel*)]. Selective mesentericography with test balloon (*white arrow*) in the celiac axis (*lower left panel*) and after definite embolization (*lower right panel*) of the celiac trunk with a vascular plug (*black arrow*) and the LGA with coils (*black arrowhead*) showing strong collateral flow from the mesenteric artery over the pancreaticoduodenal arteries (*white block arrows*) to the hepatic and gastroepiploic arteries provoked by the embolization maneuver

Surgery

After laparotomy and exclusion of liver metastasis and peritoneal carcinomatosis, the omental bursa was accessed. In the patients without embolization, flow signal in the GDA and PHA during clamping of the celiac trunk was confirmed by Doppler sonography. The portal vein, the inferior mesenteric vein, and the splenic vein were exposed at the lower margin of the pancreas. The CHA was exposed and divided immediately proximal to the origin of the GDA. The portal vein was additionally prepared at the upper margin of the pancreas while several lymph nodes were removed. The splenic and inferior mesenteric veins were divided without compromising the flow of the portal vein. The pancreas was dissected. The pancreatic body and spleen were mobilized from the retroperitoneum. The SMA was carefully exposed at its full length. The LGA was divided, and thereafter the short gastric vessels along the greater curvature were ligated. Finally, the celiac trunk was divided at its origin by way of transfixing suture. The entire compound, consisting of the pancreatic body and tail, the spleen, and the celiac trunk, was then removed (Fig. 3). The remnant pancreas was sutured (Table 1).

Dependent on clinical presentation, patients started mobilization and enteral feeding at day 1 after surgery. Adjuvant chemotherapy followed depending on the TNM category and clinical situation. All patients were seen routinely for follow-up examinations, which included CT or MRI and CA19-9 level (Table 1).

Results

Four patients underwent embolization of the celiac trunk before surgery. Angiographic control with DSA (n = 1) or CT (n = 2) 1 day before surgery confirmed the compensatory enlargement of collateral pathways from the SMA. This confirmation was considered necessary to assume that a sufficient arterial supply to liver and stomach would be maintained after the resection. Despite this, in one patient with intolerance to iodinated contrast material, angiography was not repeated before surgery. In these four patients,

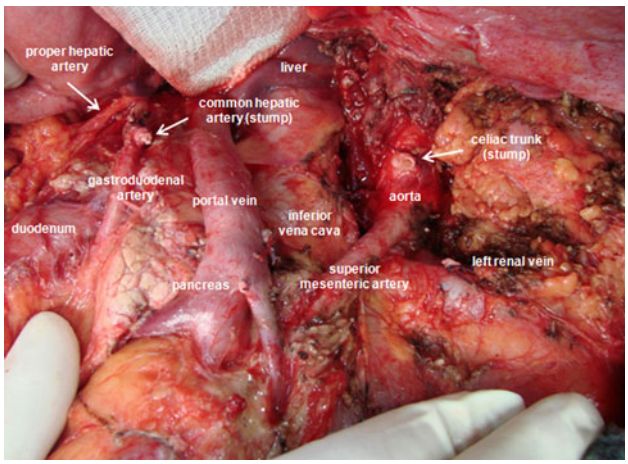

Fig. 3 Operative field after distal pancreatectomy with *en bloc* resection of the celiac trunk and splenectomy

surgery was performed 4 to 29 days (median 10.75) after embolization (Table 1).

The mean duration of surgery was 286 min. None of the patients required blood transfusion. In two patients, portal vein resection was necessary to achieve grossly clear margins (Table 1).

The preoperative mortality rate was 0%. In three of six patients, a pancreatic leakage developed and was graded as B or C according to the Bassi classification [25]. One of these patients also experienced a perforation of the posterior gastric wall on day 38 after surgery, and this was treated surgically; this patient did not receive preoperative celiac trunk embolization (Table 2). Histological examination showed ductal adenocarcinomas (25–60 mm) with vascular and perineural infiltration involving the celiac axis in all patients (Table 1).

After discharge, one of six patients did not receive chemotherapy because of a persisting pancreatic fistula. Five of six patients developed tumor recurrence at various sites (liver, malignant pleural effusion, retroperitoneum), whereas only one patient is currently without any evidence of tumor-disease (follow-up 156 days). Two patients died in the later follow-up period, resulting in a mean survival of 12.4 months. One patient who did not receive angiographic preparation died on postsurgical day 64 due to severe bleeding from ischemic gastric ulceration, and 1 patient died from tumor recurrence on postsurgical day 370 (Table 2).

Discussion

Distal celiacopancreatectomy is a radical procedure, but it offers the only curative option for locally advanced cancer of the pancreatic body if a complete resection can be achieved, thus preserving the entire stomach without the need for gastroenterostomy and providing potential pain relief due to the resection of the celiac plexus [16, 17]. Accurate staging is demanded and was successfully realized by CT or MRI in the present series. CT and MRI also reliably display relevant anatomic variants of the arteries and their relation to the tumor, which is essential for this

Table 2 Perioperative and postoperative data after distal pancreatectomy with *en bloc* resection of the celiac trunk

Patient	Preoperative embolization	Operative time (min)	RBC/FFP	Hospital/ICU length of stay (day)	Perioperative complications	Adjuvant chemotherapy	Tumor recurrence	Diabetes mellitus	Outcome
A	Yes	395	0/4	57/5	Pancreatic fistula (Bassi C), pneumonia	Gemcitabine	Liver	No	Dead (POD 370), tumor recurrence
B	No	261	0/2	17/3	None	Gemcitabine	Malignant pleural effusion	No	Dead (POD 64), bleeding from ischemic gastric ulcera
C	No	268	0/0	165/1	Pancreatic fistula (Bassi C), ischemic stomach perforation	Gemcitabine	Liver	Insulin-dependent	Alive (POD 691)
D	Yes	253	0/0	28/1	None	Gemcitabine, erlotinib	Local/retroperitoneal	No	Alive (POD 545)
E	Yes	265	0/0	61/2	Pancreatic fistula (Bassi B)	No[a]	Local/retroperitoneal	No	Alive (POD 397)
F	Yes	274	0/0	22/1	None	Gemcitabine	No	No	Alive (POD 156)

RBC red blood cells, *FFP* fresh frozen plasma, *ICU* intensive care unit, *POD* postoperative day

[a] No chemotherapy due to persistent pancreatic fistula

interdisciplinary approach [24, 26–29]. Despite these staging procedures, radical surgery, and adjuvant chemotherapy, hepatic and peritoneal tumor recurrence is frequent and significantly affects patient survival [13, 15]. In our patient population, mean survival was 12.4 months (1-year survival 83.3%), which is comparable with the results of Kondo et al. (mean survival 12.2 months) [12].

Although the most frequent complication in our series, pancreatic fistula, can be seen as being related to the pancreatic resection itself, the ischemic events affecting two patients, in the forms of ischemic ulcer with fatal bleeding and stomach perforation, are most probably related to ischemia induced by the celiac trunk resection. This happened despite intraoperative Doppler confirmation of hepatic arterial flow after clamping the celiac trunk as proposed in the literature [10]. Ischemic ulcera of the stomach occurred frequently in other series as well [12]. Development of the collateral pathways from the SMA can be enhanced by preoperative embolization of the celiac trunk, potentially minimizing the danger of ischemic-related complications [12, 20]. Remarkably, in the present study, ischemic complications occurred in both patients who did not undergo preoperative embolization of the celiac trunk. In the four patients who underwent angiographic preparation, no ischemic complications occurred. Along the same line of evidence, we refused surgery for another patient because no relevant collateral flow from the SMA could be provoked during test occlusion of the celiac axis. This emphasizes the value of test occlusion with a balloon catheter at least in cases in which no spontaneous collateral flow from the SMA to the hepatic arteries (e.g., due to a pre-existing celiac trunk stenosis) is present. The new concept of celiac trunk test occlusion was employed in an effort to more accurately select patients in whom embolization and resection of the celiac trunk is possible without ischemic complications occurring. Furthermore, the use of vascular plugs for occlusion of the celiac axis before resection is being introduced herein, which allow well-controlled positioning [30]. Compared with previous studies, we also embolized the LGA if it was not occluded by the embolization material in the celiac trunk to further enhance collateral flow to the stomach.

In conclusion, distal celiacopancreatectomy for pancreatic cancer with infiltration of the celiac trunk and the AHC is feasible and provides the chance for complete tumor resection. The morbidity of this operation is dependent on sufficient arterial blood supply to the liver and stomach after celiac trunk resection. Therefore, the presence of a collateral network between the SMA and the hepatic and gastric arteries should be confirmed angiographically, and, when needed, with balloon test occlusion of the celiac trunk. Furthermore, according to the present data, preoperative preconditioning by occlusion of the celiac trunk, the AHC, and the LGA helps avoid postoperative ischemic complications by enhancing collateral flow from the SMA. The optimal time interval between interventional preconditioning and surgery remains to be determined.

Conflict of interest The authors declare that they have no conflict of interest.

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