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Original article

Embolize, supercharge, resect: Embolization to enhance hepatic vascularization prior to en-bloc pancreas and arterial resection

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ABSTRACT

Introduction: Embolization could increase the resectability of pancreatic tumors by supercharging visceral arterial perfusion prior to pancreatic surgery with arterial *en-bloc* resection. Its indications, however, are controversial.
Methods: We retrospectively analyzed the results of a single-center database of patients undergoing pancreatic surgery with arterial resection (AR) after preoperative arterial embolization (PAE) to increase hepatic vascular flow and spare arterial reconstruction.
Results: PAE was planned in 15 patients with arterial involvement due to pancreatic tumors. Three patients were excluded due to the finding of irresectable disease during surgery. Twelve cases were resected because of pancreatic cancer (10), distal cholangiocarcinoma (1), and pancreatic neuroendocrine tumor (1). Arterial involvement in these cases required embolization of the substitute right hepatic artery (RHA) (5), left hepatic artery (1), and common hepatic artery (CHA) (6) to enhance liver vascularization. Two patients presented migration of the vascular plug after PAE. Six pancreatoduodenectomies and 6 distal pancreatectomies were performed, the latter associated with *en-bloc* celiac trunk and CHA

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Abbreviations: RHA, right hepatic artery; SMA, superior mesenteric artery; PDAC, pancreatic ductal adenocarcinoma; AR, arterial resection; PNET, pancreatic neuroendocrine tumor; CHC, cholangiocarcinoma; CHA, common hepatic artery; PD, pancreatoduodenectomy; DP, distal pancreatectomy; PAE, preoperative arterial embolization; CT, computed tomography.
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resection. R0 was achieved in 7 out of 12 patients, and pathological vascular involvement was confirmed in 8. Postoperative complications included one patient who developed gastric ischemia and underwent gastrectomy, and one patient who underwent reoperation for acute cholecystitis with liver abscesses.
Conclusion: Preoperative arterial embolization before pancreatic surgery with hepatic arterial resection enables surgeons to precondition hepatic vascularization and prevent hepatic ischemia. In addition, this avoids having to perform arterial anastomosis in the presence of pancreatic suture.
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Embolizar, sobrecargar, resecar: Embolización preoperatoria con el fin de mejorar la vascularización hepática previa a la resección pancreática y arterial en bloque

Palabras clave:
Neoplasias pancreáticas
Procedimientos quirúrgicos
Embolización

RESUMEN

Introducción: La embolización preoperatoria podría aumentar la resecabilidad de los tumores pancreáticos al sobrecargar la perfusión arterial visceral antes de la cirugía pancreática con resección arterial en bloque. Sus indicaciones, sin embargo, son controvertidas.
Métodos: Analizamos retrospectivamente los resultados en nuestro centro de la cirugía pancreática con resección arterial (RA) después de embolización arterial preoperatoria (EAP) para aumentar el flujo vascular hepático y preservar la reconstrucción arterial.
Resultados: Se planificó EAP en 15 pacientes con afectación arterial por tumores pancreáticos. Se excluyeron tres pacientes por hallazgo de enfermedad irresecable durante la cirugía. Se llevaron a cabo doce casos debido a cáncer de páncreas (10p), colangiocarcinoma distal (1p) y tumor neuroendocrino de páncreas (1p). La afectación arterial en estos casos requirió la embolización de la arteria hepática derecha sustituta (RHA, 5p), la arteria hepática izquierda (1p) y la arteria hepática común (CHA, 6p) para mejorar la vascularización del hígado. Dos pacientes presentaron migración del *plug* tras EAP. Las operaciones realizadas fueron seis pancreatoduodenectomías cefálicas y seis pancreatectomías distales, estas últimas asociadas a resección en bloque del tronco celíaco y CHA. R0 se logró en 7/12p. Se confirmó afectación vascular patológica en 8p. Como complicaciones postoperatorias, 1p desarrolló isquemia gástrica y se le realizó gastrectomía, y 1p fue reintervenido por colecistitis aguda con abscesos hepáticos.
Conclusión: La embolización arterial previa a la cirugía pancreática con resección de la arteria hepática permite preacondicionar la vascularización hepática y prevenir la isquemia hepática, evitando realizar anastomosis arteriales en presencia de sutura pancreática.
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Introduction

Several groups have recently published encouraging results on arterial resection (AR) in pancreatic cancer surgery.[1–5] However, international consensus does not currently defend its widespread use for the treatment of pancreatic cancer.[6–8] The combination of pancreatic anastomosis and arterial suturing in the same surgical field is a concern[9]: fistula associated with pancreatic anastomosis may lead to bleeding due to severe arterial erosions in the peripancreatic vasculature, especially in patients undergoing preoperative radiotherapy[10]; on the other hand, suturing the hepatic artery in the setting of pancreatic surgery increases the risk of arterial thrombosis, leading to hepatic infarction and ischemia of the hepaticojejunal anastomosis.[11] For these reasons, most pancreatic surgeons avoid combining pancreatic and arterial sutures in a nearby surgical field. Some authors even advocate performing total pancreatectomy when planning large pancreatectomies with associated arterial resection,[9,12] despite its morbidity. However, preoperative arterial embolization (PAE)[13,14] has 2 benefits: it improves liver and gastric vascularization preoperatively in preparation for subsequent arterial resection,[15,16] and it allows for *en-bloc* resection, thereby avoiding the combination of arterial and pancreatic sutures. Nonetheless, there is still no unanimity regarding the advantages of PAE. Some groups defend its use to avoid arterial reconstructions,[13,15,17] while others have shown that it does not provide benefits and even describe worse results, especially related with the radiological procedure, such as arterial wall dissection or thrombosis.[18,19]

The present study describes our results in patients undergoing oncologic pancreatic surgery with *en bloc* arterial resection and preoperative PAE to protect against postoperative ischemic complications.

Methods

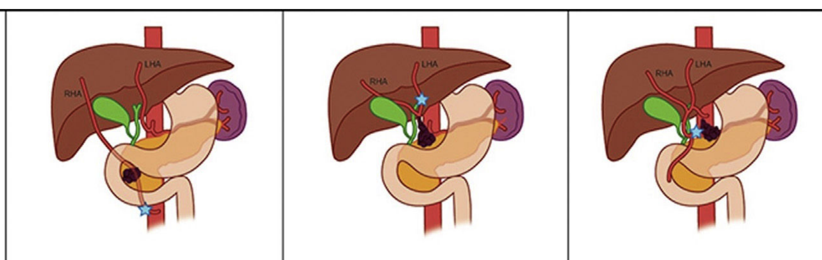
We performed a retrospective observational study about the embolization of an involved hepatic artery before pancreatic surgery between June 2010 and October 2021 at Hospital Universitari de Bellvitge.

Patient selection

We included all patients with any pancreatic tumor involving a short segment of the common hepatic artery (CHA) with the possibility of reconstruction, a replaced right hepatic artery (rRHA) from the superior mesenteric artery (SMA) or CHA before the gastroduodenal artery, or the celiac axis (CA) with a tumor-free aortic plane (Fig. 1). Preoperative workups included thoracoabdominal computed tomography (CT) scan, tumor markers, and endoscopic ultrasound with biopsy. Contrast-enhanced thin slice was performed to assess tumor and vascular anatomy. All cases were discussed by each multidisciplinary oncological committee. Neoadjuvant treatment (NAT) was decided in patients with pancreatic ductal adenocarcinoma (PDAC), while patients with cholangiocarcinoma (CHC) were considered on an individual basis. For pancreatic neuroendocrine tumors (PanNET), we assessed resectability according to current criteria.[20,21] Involvement of the SMA $>180^{\circ}$ was not considered for resection. We excluded patients with PDAC or CHC who were not resected because of metastatic disease at surgical exploration and patients with AR and reconstruction without PAE.

Embolization procedure

Arteriography was performed 1–3 weeks before surgery. Patients remained hospitalized for 24 h to confirm the absence of complications after embolization by blood tests with liver function parameters. After percutaneous access to the right common femoral artery, selective angiographies of the celiac trunk and SMA were performed to visualize the arterial anatomy and obtain measurements. Depending on the anatomical characteristics, vascular plugs (Amplatzer Vascular Plug; AGA Medical, Plymouth, MN), coils (Cook, Bloomington, IN) (one patient), or both (one patient), were used to occlude the rRHA in 5 patients, CHA in 6 patients, and left and middle hepatic arteries in one patient (Fig. 1). For the rRHA and left/middle hepatic arteries, embolization was performed as selectively and segmentally as possible, being neither too close to the hilum to leave enough space for surgical ligation nor too deep in the hilum to maintain distal hepatic artery permeability and preserve the development of collateralization. Finally, angiography was repeated to check the result and, in some cases, to demonstrate immediate intrahepatic collaterals coming from the left hepatic artery to the right lobe. No test occlusion was needed. To embolize CHA for extended distal pancreatectomies, occlusion was performed on the CHA, ensuring the patency of the gastroduodenal artery (GDA). No CT was performed to assess the embolization results before surgery because: (1) the final angiographic series confirmed correct occlusion and revascularization; and (2) subsequent blood tests showed an optimal curve of liver enzymes.



Surgery	Pancreatoduodenectomy plus aberrant right hepatic artery resection	Pancreatoduodenectomy plus common hepatic artery resection	Splenopancreatectomy plus celiac trunk resection
Preoperative embolization	Right hepatic artery embolization	Left hepatic artery embolization	Common hepatic embolization
Arterial reconstruction	No	Hepatic to hepatic arterial anastomosis	No
Neoplasm	5 PDAC	1 CHC	5 PDAC – 1 PanNET

Fig. 1 – Treatment scheme. Hepatic arterial embolization before pancreatic surgery with arterial resection allows pancreatectomy to be carried out without synchronic liver resection. PDAC, pancreatic ductal adenocarcinoma. CHC, cholangiocarcinoma. PNET, pancreatic neuroendocrine tumor. LHA, left hepatic artery. RHA, right hepatic artery. LGA, left gastric artery. RGA, right gastric artery. SA, splenic artery. GEA, gastroepiploic artery.

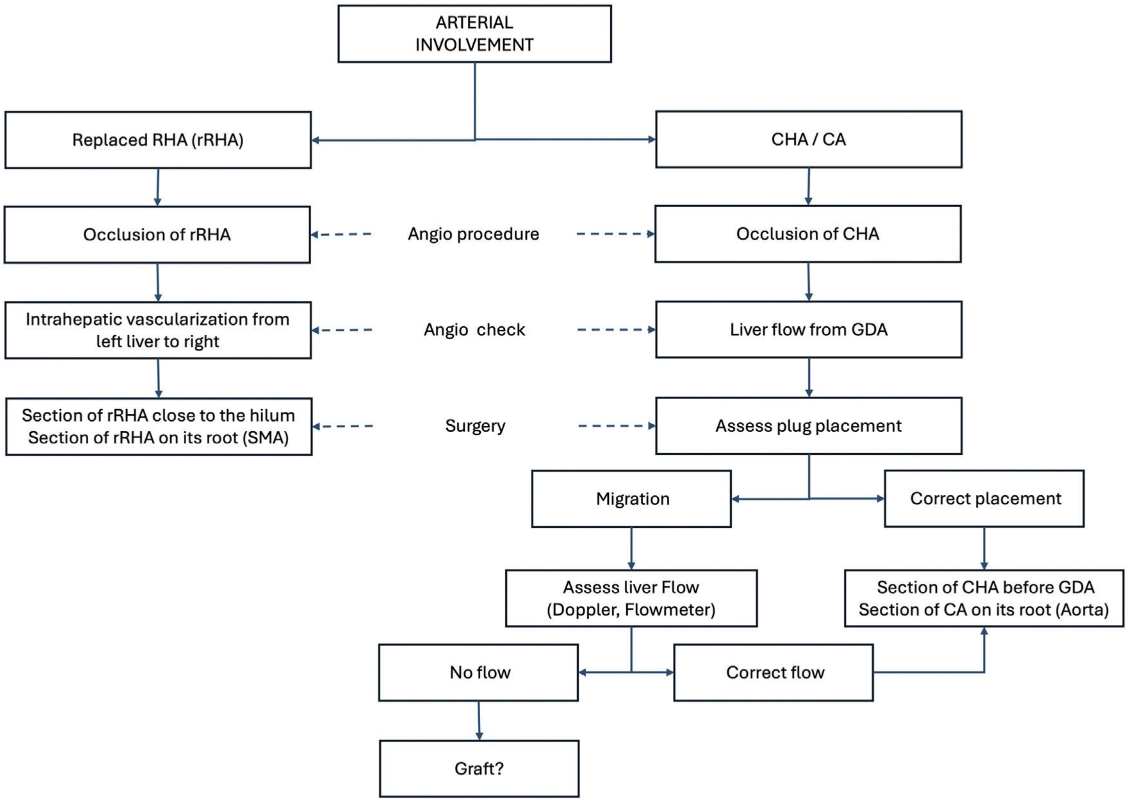


Fig. 2 – Planning for pancreatectomy with arterial resection: Decision-making algorithm.

Surgical procedure

Pancreatic surgery began with exploratory laparoscopy to exclude liver metastasis or carcinomatosis. For PD with rRHA, we initially assessed the absence of SMA disease involvement; then, we ligated the rRHA cranial and caudal to the tumor and proceeded with the usual procedure.[22,23] For DP with CHA, we initially assessed a free-tumor plane above the aorta and correct flow through the gastroduodenal artery; we then resected the CHA and completed the splenopancreatectomy in accordance with oncological criteria.[24] We did not explore liver flows with Doppler ultrasound. In those cases where we could not ensure arterial patency with direct exploration, we used a flowmeter on the artery (Fig. 2).

Statistical analysis

Given the exploratory nature of this study, we did not perform a formal power-based sample size calculation. We obtained a convenience sample from all the patients operated on and followed at our medical center over a 12-year period (with a minimum follow-up of 6 months) who met all the inclusion criteria and none of the exclusion criteria. We defined postoperative mortality as any death within the first 90 days after surgery, and postoperative morbidity was any complication related to the surgical procedure, graded according to the Clavien-Dindo classification.

We performed a standard descriptive analysis of all collected data. Categorical variables were expressed as absolute and relative frequencies. The statistical analyses were performed with Stata© (StataCorp LLC, 4905 Lakeway Drive, College Station, Texas, USA).

Results

We planned 18 pancreatectomies with any AR. Six patients were excluded: 3 patients without PAE (one PanNET with SMA involvement, and 2 patients with an intraoperative finding of CHA involvement); and 3 patients were not resected because of the intraoperative finding of disease progression. Thus, 12 patients (5 women, 41.7%) with a median age of 65 years (range 48–79) were ultimately included in the study group: 6 PD with 5 PAE of the rRHA and one PAE of the LHA; and 6 DP with PAE of the CHA (Fig. 1, Table 1).

Preoperative embolization

PAE was performed on all patients, and no complications were reported. However, we observed that 2 vascular plugs had migrated from the CHA to the proper hepatic artery. We checked liver function tests 24 h after embolization, except in 2 cases (Table 2), with no significant changes. Before surgery, embolization was carried out for 20 days (range 6–32). Delay of

Table 1 – Preoperative and postoperative data.

Patient	Age (years)	Gender	Disease type	Neoadjuvant therapy	Arteries embolized	Time from embolization to operation (days)	Surgical technique	Arterial anastomoses	Morbidity	Mortality	Hospital stay (days)	Follow-up (months)	Recurrence	Alive
1	65	Male	PDAC	GEMOX	rRHA from SMA	27	PD + rRHA	No	No	No	7	42	Yes	No
2	48	Male	PanNET	–	CHA	10	DP + CA	No	Yes	No	24	76	Yes	No
3	68	Female	Cholangio-carcinoma	–	rLHA	22	PD + CHA	Yes	Yes	No	13	57	No	Yes
4	58	Male	PDAC	GEMOX	CHA	14	DP + CA	No	Yes	No	35	23	No	NO
5	65	Male	PDAC	FOLFIRINOX	rRHA from SMA	32	PD + rRHA	No	No	No	7	23	Yes	No
6	75	Male	PDAC	GEMOX	CHA	6	DP + CA	No	Yes	No	7	26	Yes	No
7	63	Male	PDAC	FOLFIRINOX + GEM-A	CHA	20	DP + CA	No	Yes	No	15	18	Yes	Yes
8	60	Female	Carcinosarcoma	NALIRINOX	rRHA from CA	20	PD + rRHA	No	No	No	7	2	Yes	No
9	79	Male	Acinar cell carcinoma	–	rRHA from SMA	27	PD + rRHA	No	Yes	No	13	4	No	Yes
10	75	Female	PDAC	GEM-A	CHA	21	DP + CA	No	Yes	No	31	5	No	Yes
11	66	Female	PDAC	FOLFIRINOX	CHA	20	DP + CA	No	Yes	No	13	2	No	Yes
12	61	Female	PDAC	GEM-A	rRHA from SMA	13	PD + rRHA	No	No	No	8	3	No	Yes

Table 2 – Blood test results prior to and after embolization.

Patient	Preembolization/postembolization													
	Na (mmol/L)	K (mmol/L)	Cr (μmol/L)	AST (μkat/L)	ALT (μkat/L)	Bil (μmol/L)	GGT (μkat/L)	ALP (μkat/L)	Gluc (mmol/L)	Hb (g/L)	Ht (%)	Pl (×10E9/L)	WBC (×10E9/L)	PT (IRP 67/40)
1[a]	140/140	4.42/4.27	91/89	0.47/1.06	0.36/0.76	7/8	0.94/0.90	1.35/0.74	6.6/9.8	145/111	42.7/33.0	210/174	9.2/11.9	0.96/0.99
2	143/137	4.05/4.00	80/79	0.28/0.85	0.39/0.27	5/7	0.51/1.11	1.00/0.80	5.4/6.4	141/144	43.2/45.2	176/115	5.7/6.3	0.93/1.11
3	140/140	4.43/3.59	56/42	0.37/0.72	0.35/0.34	18/9	1.61/2.43	2.57/1.81	5.6/10.7	128/119	38.5/36.0	406/446	8.2/13.1	1.04/1.05
4	143/139	3.90/4.15	65/63	0.34/0.37	0.39/0.41	4/8	4.97/3.77	2.40/1.90	7.6/6.1	148/141	45.3/47.1	156/214	6.4/6.7	0.93/1.02
5[a]	139/143	5.22/5.04	102/95	0.38/0.34	0.30/0.35	4/7	0.50/0.54	1.31/1.25	13.8/7.7	108/109	33.6/33.4	239/190	8.1/6.3	0.92/0.92
6	143/141	4.18/3.70	58/55	0.26/0.48	0.28/0.20	6/7	0.20/0.14	1.10/0.85	9.4/5.7	142/128	42.6/37.0	152/131	7.8/5.1	1.03/1.11
7	138/141	4.27/3.57	69/67	0.32/1.38	0.70/0.50	13/19	0.60/0.28	0.67/0.93	5.7/5.4	95/121	30.2/38.0	153/153	9.6/9.6	0.96/1.13
8	138/135	5.11/3.60	39/34	0.33/0.50	0.35/0.35	3/3	0.72/3.00	2.4/4.15	6.8/5.1	117/105	36.3/32.0	570/467	12.5/10.5	1.04/1.21
9	142/139	4.80/4.35	74/71	0.28	0.28/0.18	11/19	0.67/0.50	1.18/1.03	4.9/5.4	121/110	41.1/35.1	229/149	5.2/4.3	1.08/1.17
10	143/141	4.65/4.61	72/62	0.35/0.28	0.43/0.22	3/5	2.55/1.32	1.92/1.40	7.7/6.2	114/111	37.1/34.8	256/179	9.5/6.9	0.98/1.03
11	145/143	4.04/4.13	61/59	0.38/0.30	0.35/0.30	18/21	0.20/0.18	2.08/1.88	4.9/6.0	131/123	39.6/36	136/90	4.1/3.6	1.05/1.19
12	139/136	4.76/4.28	43/40	0.45/0.57	0.37/0.37	8/11	4.42/4.45	3.22/2.87	7.0/8.9	114/106	32.7/33.2	313/244	5.7/5.2	1.04/1.01

Na: sodium [135–147], K: potassium [3.83–5.10], Cr: creatinine [0–111], AST: aspartate-aminotransferase [0.00–0.50], ALT: alanine aminotransferase [0.00–0.73], Bil: bilirubin [0–18], GGT: gamma-glutamyl transferase [0.00–1.11], ALP: alkaline phosphatase [0.00–2.15], Gluc: glucose [4.1–6.9], Hb: hemoglobin [120–166], Ht: hematocrit [36.00–50.00], Pl: platelets [135–333], WBC: white blood cell count [3.9–10], PT: prothrombin time [0.80–1.20].

[a] Time between emboliztation and blood test greater than 3 days.

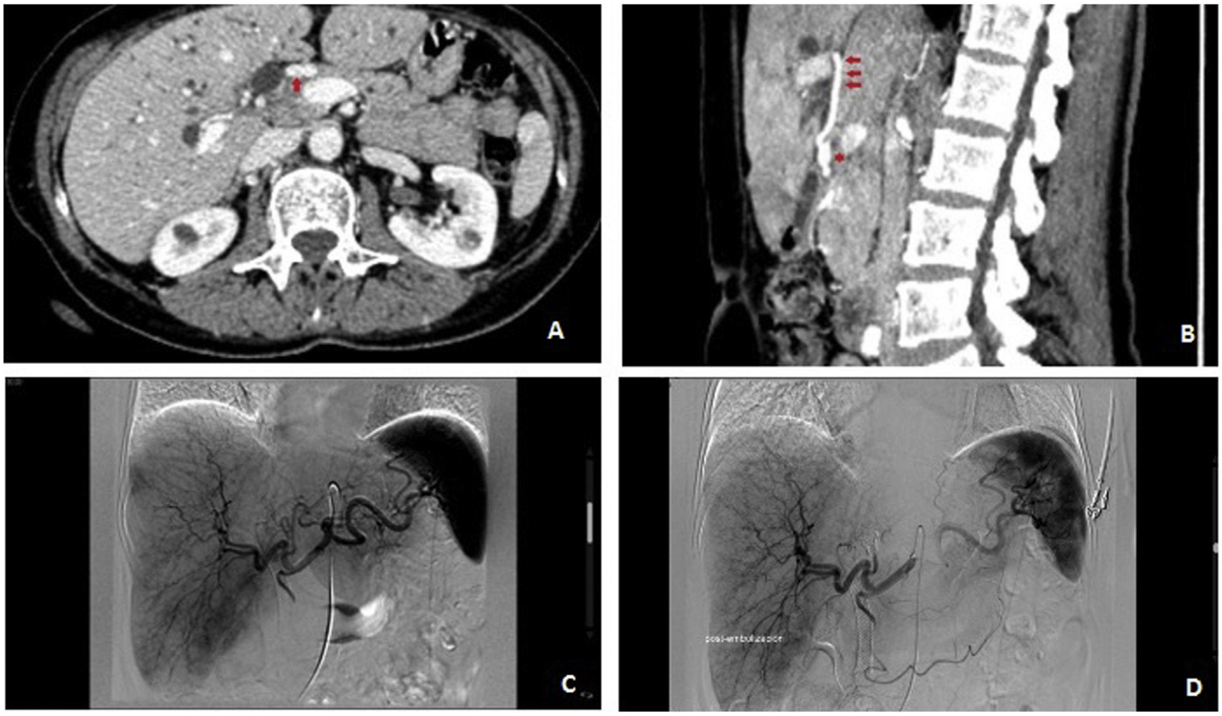


Fig. 3 – 67-year-old woman with distal cholangiocarcinoma: Preoperative coil embolization of the left and middle hepatic artery.
A. Preoperative axial contrast-enhanced CT image (portal phase) showing tumoral contact with the posterior aspect of the proper hepatic artery (arrow).
B. Preoperative sagittal contrast-enhanced CT image (pancreatic phase) demonstrates tumoral contact with the posterior aspect of the proper hepatic artery (*) next to the origin of the left hepatic artery (arrows).
C. Digital subtraction angiography (DSA) of the celiac artery prior to left hepatic artery embolization.
D. DSA of the celiac trunk after selective microcoil embolization of the 2 left hepatic arteries.

Table 3 – Anatomopathological data.

Patient	Histologic type	Tumor size (specimen) (cm)	Residual tumor status	Vascular invasion	Perineural invasion	Lymph node metastasis	TNM
1	Pancreatic ductal adenocarcinoma	2.3	R1	Yes	Yes	5/35	ypT3ypN1
2	Pancreatic endocrine tumor	7.0	R0	Yes	No	0/35	pT3pN0
3	Distal bile duct adenocarcinoma	2.5	R0	Yes	Yes	0/18	pT2pN0
4	Pancreatic ductal adenocarcinoma	3.0	R0	No	No	0/42	ypT3ypN0
5	Pancreatic ductal adenocarcinoma	1.5	R1	No	Yes	2/22	ypT3ypN1
6	Undifferentiated carcinoma	3.0	R1	Yes	No	0/26	ypT2ypN0
7	Pancreatic ductal adenocarcinoma	3.0	R1	Yes	No	3/19	ypT2ypN1
8	Pancreatic carcinosarcoma	4.2	R0	Yes	Yes	5/23	ypT3ypN2
9	Pancreatic acinar cell carcinoma	4.5	R0	No	No	0/22	pT3pN0
10	Pancreatic ductal adenocarcinoma	3.0	R0	Yes	Yes	1/21	ypT2ypN1
11	Pancreatic ductal adenocarcinoma	4.5	R0	Yes	Yes	5/24	ypT3ypN2
12	Pancreatic ductal adenocarcinoma	2.2	R1	No	Yes	0/18	ypT2ypN0

TNM: tumor, node, metastasis classification.

the surgical procedures was caused by several incidences, such as surgical emergencies or liver transplantation.

Embolization morbidity

The 2 patients with plug migration were diagnosed intraoperatively. One had no clinical repercussions; the other developed liver abscesses due to hepatic ischemia, and ischemic cholecystitis (see the ‘‘Postoperative morbidity’’ section).

Arterial reconstruction

For patients with rRHA involvement, embolization enabled us to preserve right liver vascularization by means of intrahepatic shunts, avoiding surgical arterial reconstruction. In patients with involved CHA, PAE allowed us to supercharge the liver flow from the GDA and gastric flow by collateralization, avoiding arterial reconstruction with an aortoiliac graft in all cases.

Despite PAE, we had to perform arterial reconstruction of the CHA due to a CHC with hilar extension (Fig. 3), as follows: division of the biliary confluence to assess the biliary free margins, hilar lymphadenectomy, division of the embolized LHA, division of the RHA and CHA before the tumor, and reconstruction with an end-to-end anastomosis between the CHA and RHA using 6/0 monofilament non-absorbable suture (Prolene). PD was then completed.

Postoperative morbidity

Seven patients (58.3%) developed postoperative complications, 2 of which were greater than Clavien IIIA (16.7%). Following the Appleby procedure, 2 patients were reoperated (33.3%): one for acute cholecystitis in the context of liver abscesses, and one for gastric ischemia requiring total gastrectomy. Four patients presented pancreatic fistula. For PD, one patient underwent angiography due to delayed bleeding (finding no cause), and one patient developed a chylous fistula resolved with conservative management. Thus, if we consider the 2 patients who were reoperated, ischemic complications were 16.7% (2/12). The median postoperative hospital stay was 14.69 days (range 7–35). There was no 90-day postoperative mortality.

The definitive diagnosis at pathological examination were 8 PDAC, one case of pancreatic acinar cell carcinoma, and one case of pancreatic carcinosarcoma, confirming one PanNET and one CHC. The pathological examination confirmed vascular involvement by the tumor in 8 cases (66.7%), and microscopic involvement of the surgical margin (R1) in 5/12 patients (41%). With a median follow-up of 20.5 months, 6 patients presented disease recurrence (50%), and 6 patients died (50%). Mean survival time was 25.2 months (Table 3).

Discussion

This study was conducted to evaluate the short-term outcomes of PAE before pancreatic surgery with *en-bloc* AR. Several prestigious groups have published their experience with AR during pancreatic surgery, all reporting considerable postoperative mortality, mainly due to ischemic or thrombotic complications.[5,18,25–28] In this scenario, different strategies have been proposed [29]: (1) combine AR with pancreatic anastomosis simultaneously (AR with arterial anastomosis,[25–27] PAE with *en-bloc* AR,[14,15,17] and *en-bloc* AR without embolization or reconstruction)[30,31]; (2) AR associated with total pancreatectomy.[9,32] Some of the strategies described advocate overloading the hepatic and gastric vasculature by PAE and anastomosis as tools for improvement, while resection without anastomosis and total pancreatectomy do not defend that position. We agree with the Thomas Jefferson University group, which states: "When the resultant collateral circulation is inadequate to provide sufficient hepatic and gastric arterial inflow, arterial reconstruction is necessary to 'supercharge' the inflow."[33] Pancreatic surgery with lymphadenectomy and AR involves removing much of the lymphatic/fatty tissue and small-caliber vasculature supplying the liver and stomach.[34,35] This could imply worse postoperative vascularization and increased postoperative morbidity. In addition, several authors have reported ischemic problems after pancreatic surgery, with no clear organic explanation.[11,36,37] In this regard, the Beaujon group thoroughly analyzed ischemic complications after more than 500 PD and found that 36% of deaths were caused by hepatic ischemia.[37] Similarly, the Heidelberg group recorded 17 patients with hepatic ischemia over more than 700 pancreatectomies, with a mortality of 29%. They found that 6 patients had hepatic ischemia without vascular occlusion and stated that "liver perfusion failure may represent an important and underestimated risk factor for death after pancreatic resection".[11]

However, the dilemma is how to overload the inflow after pancreatic resection and lymphadenectomy. While some groups advocate overloading the inflow by PAE, others prefer arterial reconstruction in most cases. American medical centers, such as the University of Wisconsin or the Mayo Clinic,[26,27] and European centers like the University of Strasbourg,[25] which have extensive experience in vascular resections, advocate arterial reconstruction and discourage the use of PAE. Moreover, recent studies have reported no benefit from PAE.[19,38] However, in a European multicenter series, there were serious postoperative problems related to the arterial anastomosis, such as hepatic artery hemorrhage repair (n = 2) and re-do anastomosis for a hepatic confluence thrombus (n = 1).[38] On the other hand, a Spanish series reported a high percentage[19] (albeit not statistically significant) of ischemic problems among non-embolized patients, as well as high morbidity among previously embolized patients, without being able to establish a relationship with PAE.

Thus, the use of PAE appears to be controversial and is, in fact, very disparate.[18] The Japanese groups of Sapporo and Wakayama[15,17] advocate its systematic use after encouraging results. Recently, a French bi-center study focusing on the use of PAE in cases of rRHA has suggested a management algorithm that may help in planning the management of some patients. The study described severe ischemic problems, even in embolized patients; however, some patients also underwent additional portal clamping and resection.[14] Thus, while PAE is feasible, we must be cautious about its indication since it is not free of complications. In our series, we reported 30% of ischemic complications after AR with PAE, similar to reports by other groups.[13] In a large review, Klompmaker showed that resection of the celiac trunk can be associated with gastric ischemia in up to 30% of patients, even in patients with PAE.[39] Subsequently, a European multicenter study[40] showed that patients with and without PAE had similar incidences of liver ischemia and postoperative mortality.

Accordingly, the use of PAE alone would not be ideal, either. In our opinion, both enhancement flow strategies could be combined. That is, depending on the arterial involvement and the patient's anatomy, one strategy or the other should be used. Thus, in patients with rRHA involvement due to a tumor, PAE appears to be a useful technique.[41] However, patients with involvement of the CHA should be managed with an associated anastomosis.

Finally, 2 recently published strategies have joined the debate to avoid the added morbidity of synchronous pancreatic and arterial anastomosis.[28,30] On one hand, there is hepatic AR without reconstruction of any kind and, on the other hand, total pancreatectomy, both of which aim to avoid AR near a pancreatic anastomosis. The Sapporo group[30] advocates hepatic AR without reconstruction and recently published their experience in PD with systematic resection of 9 cases of tumor-affected rRHA. Only one patient developed a liver abscess, related to hepatic ischemia; however, none of the patients presented hepaticojejunal anastomotic problems. These authors consider reconstruction if there is evidence of low flow to the right lobe measured by intraoperative Doppler. Nonetheless, a policy of hepatic vascular resection without reconstruction or prior embolization seems risky and needs to be validated. In contrast, the Osaka group recently published their experience in PD with CHA resection and reconstruction, and 100% of the R0 resections had acceptable short-term results (23% Clavien-Dindo III–IV, no postoperative mortality).[42]

Lastly, the Heidelberg[32] and Denver[9] groups have recently proposed performing total pancreatectomy as an option to avoid combining pancreatic sutures and arterial resections. However, it seems clear that this option is not above criticism.[43] The short-term mortality of total pancreatectomy and long-term sequelae seem to advise against using this technique from the outset.

The use of PAE in scenarios other than the involvement of the celiac trunk or rRHA remains to be explored. In our series, we present one case in which the left hepatic artery was embolized. Other authors have performed PAE of the common hepatic artery without apparent consequences.[44,45] PAE presented asymptomatic complications in 2 patients.

The most important limitation of this study is that it is a short retrospective series, and the patients were heterogeneous in terms of their underlying pathology. While we are aware of this problem, this study aimed to highlight how a preoperative tool such as embolization can help pancreatic surgeons plan oncological surgery with AR without associated morbidity. Nonetheless, the long- and short-term outcomes and the indications of PAE still need to be well defined in future studies.

Conclusion

The results of our study suggest that PAE can ensure hepatic and gastric vascularization in the setting of oncological pancreatic surgery with arterial resection, without vascular reconstruction, and with acceptable morbidity and mortality rates.

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