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Distal pancreatectomy with resection of the celiac trunk, right or left hepatic artery without arterial reconstruction (extended DP-CAR)

V.I. EGOROV[1], R.V. PETROV[1], E.L. AMOSOVA[1], A.F. KHARAZOV[2], K.S. PETROV[3], YU.A. ZHURINA[4], E.V. KONDRATYEV[1,2], P.M. ZELTER[5], S.O. DZIGASOV[1], M.V. GRIGORIEVSKY[6]

[1]Ilyinskaya Hospital, Krasnogorsk, Russia;
[2]Vishnevsky National Medical Research Center of Surgery, Moscow, Russia;
[3]Medskan LLC, Moscow, Russia;
[4]Brothers Bakhrushiny Hospital, Moscow, Russia;
[5]Samara State Medical University, Samara, Russia;
[6]Evdokimov Moscow State University of Medicine and Dentistry, Moscow, Russia

ABSTRACT

Objective. To evaluate safety and postoperative outcomes of DP-CAR with resection of one of the lobar hepatic arteries without arterial reconstruction (extended DP-CAR).

Material and methods. Perioperative data and survival after 7 extended DP-CARs R0 were retrospectively analyzed. Arterial blood flow in the liver was assessed using intraoperative ultrasound and postoperative CT angiography.

Results. Among 40 DP-CARs, resection of left or right hepatic artery was performed in 7 cases of aberrant anatomy including 1 case of portal vein resection. Mortality and ischemic complications were not observed. The main source of blood supply to the «devascularized» liver lobe was interlobar communicating artery or the arcade of the lesser curvature of the stomach. Incidence of pancreatic fistula was 44%, mean blood loss — 230 (100—650) ml, surgery time — 259 (195—310) min, mean hospital-stay — 14 (9—26) days. Median survival of patients with pancreatic ductal adenocarcinoma was 25 months after combined treatment. Three patients died after 26, 28 and 77 months. Other patients are alive without progression for 109, 24, 23 and 12 months after therapy onset.

Conclusion. Extended DP-CAR is advisable and safe procedure if reliable intraoperative control of liver and stomach blood supply is ensured.

Keywords: *DP-CAR, modified Appleby procedure, celiac trunk resection, hepatic artery resection, collateral hepatic arteries, mAppleby.*

INFORMATION ABOUT THE AUTHORS:
Egorov V.I. — e-mail: egorov12333@gmail.com; https://orcid.org/0000-0002-8805-7604
Petrov R.V. — e-mail: petrov-r-v@yandex.ru; https://orcid.org/0000-0003-3872-7363
Kharazov A.F. — e-mail: kharazov@ixv.ru; https://orcid.org/0000-0002-6252-2459
Petrov K.S. — e-mail kirillpetrov1@gmail.com; https://orcid.org/0000-0002-0997-7825
Amosova E.L. — e-mail: e.amosova@ihospital.ru; https://orcid.org/0000-0002-4841-4259
Zhurina Yu.A. — e-mail: gupigup@yandex.ru; https://orcid.org/0000-0002-2309-7330
Kondratyev E.V. — e-mail: evgenykondratiev@gmail.com; https://orcid.org/0000-0001-7070-3391
Zelter P.M. — e-mail: pzelter@mail.ru; https://orcid.org/0000-0003-1346-5942
Dzigasov S.O. — e-mail: s.dzigasov@ihospital.ru; https://orcid.org/0000-0003-0443-6162
Grigorievsky M.V. — e-mail: dr.grmv@gmail.com; https://orcid.org/0000-0002-9596-8107
Corresponding author: Egorov V.I. — e-mail: egorov12333@gmail.com

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Introduction

Locally advanced and borderline resectable pancreatic ductal adenocarcinoma (PDAC) has a median survival of 6 to 38.6 — 43.4 months, and better results are achieved for patients who undergo combined modern systemic and R0 surgical treatment [1—6]. Although arterial tumor encasement is generally considered a sign of unresectability, it was not definitely shown that arterial involvement means advanced systemic process. The collected experience of pancreatic resections combined with vascular resections shows that arterial resections can be beneficial with acceptable morbidity and mortality in select patients, taking into consideration that arterial reconstructions are risky in partial pancreatectomy [7—11]. In selected cases of borderline or locally advanced pancreatic body cancer, distal pancreatectomy with en bloc splenectomy and celiac axis resection (DP-CAR) may lead to curative resection and prolonged survival even without neoadjuvant therapy [12]. With improved neoadjuvant regimens, this aggressive surgical approach is becoming more justified due to the preoperative impact on tumor and patient selection [4, 6, 8—10, 12—30].

Distal pancreatectomy with en bloc celiac axis resection in combination with total gastrectomy was invented by Appleby in 1952 as "de principle" gastric cancer treatment [31]. This surgery was used for the first time for the treatment of pancreatic cancer in 1976 [32], and it was later developed into the modified Appleby procedure with stomach preservation [33]. These surgical interventions are based on the anatomical findings of the feeding of the pancreatic head, liver and stomach by the flow from the superior mesenteric artery through the pancreatoduodenal arcades and hepatic and right gastroepiploic arteries after celiac artery resection [34].

In some cases of arterial aberrations originating from celiac artery (CA), such as replaced left hepatic artery (LHA) (Michels II, IV, VIIIb) or right hepatic artery (RHA), the accomplishment of R0-resection may require resection or excision of one of the main hepatic arteries in addition to CA resection. In these circumstances, the risk of ipsilateral liver lobe ischemia after DP-CAR is theoretically increased [35, 36]. Arterial reconstruction during partial pancreatic resection is a possible and desirable, but risky, procedure and should be avoided when possible [10, 11]. The present study investigated the feasibility and efficacy of extended DP-CARs with an emphasis on the anatomical, radiological and surgical bases for the use of the constant interlobar hepatic arterial collaterals instead of arterial reconstructions.

Patients and methods

Study design

The case reports, demographic, radiological and short- and long-term perioperative data of 7 patients treated by our pancreatic group using DP-CAR with resection of the left or right hepatic artery without arterial reconstructions between May 2010 and January 2021 were retrospectively analyzed for safety, efficacy, assessment of arterial blood supply adequacy and oncological outcomes.

All patients were discussed at multidisciplinary meetings, and all of the procedures were undertaken with the intention of performing DP-CAR. The indications for DP-CAR were locally advanced pancreatic ductal adenocarcinoma (5), unidentified tumor (1) of the pancreas body and T4 gastric cancer spreading to the pancreas (1), plus involvement of the common hepatic artery (CHA) and/or the CA on CT scans. Abdominal MRI and chest CT excluded distant metastases. The gastroduodenal artery (GDA), superior mesenteric artery (SMA) and aorta must be tumor-free on CT and endoUS. Stomach or IVth duodenal portion involvement, and portal-superior mesenteric vein (PV-SMV) involvement, were not considered contraindications for surgery after neoadjuvant therapy. The arterial anatomy delineated on 3D CTA [37] was classified according to Michels [38]. Tumor size delineated on CT was measured in mm before surgery. The severity of complications was classified using the Clavien–Dindo system [39]. Postoperative pancreatic fistula (POPF) was defined according to the International Study Group on Pancreatic Fistula classification [40], and postpancreatectomy hemorrhage (PPH) was defined in accordance with guidelines given by the International Study Group of Pancreatic Surgery [41]. Resection margins, including transection and circumferential margins, were categorized according to the Royal College of Pathologists definition and classified as R0 (no residual tumor, distance margin to tumor ⩾ 1 mm), R1 (residual tumor, distance margin to tumor <1 mm), and R2 (residual tumor, macroscopically positive margin) [42]. The grade of tumor regression on postoperative pathology was categorized according to the College of American Pathologists [43]. Ischemic morbidity was defined as an abdominal organ complication caused by surgery-related ischemia. Complications, readmissions, and mortality were collated up to 90 days postoperatively. Overall survival and progression-free survival (OS and PFS) data were collected based on the last CT or MRI results, last visit to the hospital or follow-up phone calls.

Surgery

Staging laparoscopy was performed during the same procedure, followed by bilateral subcostal or midline laparotomy, if no metastases were found. Intraoperative ultrasound (IOUS) and frozen-section biopsy were used in cases of doubtful structures in the liver or peritoneum. The CHA and LGA were visualized and temporary clamped using vascular instruments. The adequacy of the collateral flow to the liver was assessed using pulse and IO Doppler US measurements from the arteries in the hepatoduodenal ligament and liver parenchyma. The adequacy of the collateral flow to the stomach was assessed visually and via pulsation over the right gastroepiploic artery (RGEA) and ICG-based near-infrared fluorescence imaging (the last 11 cases). In cases of acceptable collateral arterial flow and positive decision on resectability, CHA (and its branches, if involved in cases of aberrant arterial anatomy) was excised with the lymph nodes of groups 8 a, p, and left 12 a1, a2, and 12p2, 1 cm proximally to the GDA. The pancreas in all the cases was transected to the right of the right border of the portal vein, generally using a stapler. The stapling line was excised and examined on frozen-section biopsy. With a positive transection line, total pancreatectomy with arterial reconstruction was considered. The Cattell-Braasch maneuver, including extended Kocher maneuver, was performed when PV-SMV resection was planned. The spleen and left pancreas were mobilized from the left to the right, or vice versa, in the frames of the posterior RAMPS procedure with emphasis on removal of the left paraaortic lymph nodes, which are generally located between the left renal vein and artery. Both diaphragmatic cruses were transected cranially to the CA to open the left lateral and front surfaces of the aorta and the origins of the CA and SMA, both of which were encircled with vessel loops. At this stage, the CA was clamped, and collateral flow to the liver and stomach was reassessed using the abovementioned methods. Preservation of the pulse on the hepatoduodenal ligament and/or arterial (main or collateral) blood flow velocity ⩾ 20 cm/sec in the liver parenchyma and the absence of signs of gastric ischemia characterized the adequacy of the collateral arterial blood supply to both critical organs. The celiac artery was ligated or closed using a double clip. The left gastric vein and artery were excised. Transection of the LGA before its division to the ascendant and descendent branches and preservation of right gastric artery are important, but preservation of the RGEA is absolutely mandatory to prevent or reduce gastric ischemia. Transection of the splenic vein was performed safely with the possible narrowing of the PV-SMV to half of its diameter. It is possible and desirable to do this after CA clipping, but before its transection, to avoid cancer cell migration due to excessive manipulation of the tumor. In this context, clipping of the splenic artery is helpful to prevent spleen swelling. Tension-free PV-SMV anastomosis may be used in cases of circular resection of a vein fragment no longer than 1.5 cm. Otherwise, autovenous (generally, left renal or superficial femoral) graft is used. The superior mesenteric artery was freed of all nervous and lymphatic tissue on both sides, which is specifically important in cases of venous resection. The peripancreatic tissues were meticulously detached from the front and left surfaces of the uncinate process, and a complex of organs, which included the pancreatic neck, body and tail, spleen, left adrenal gland, pararenal fat with anterior renal fascia and lymph nodes of the 8 -11, left 12 a1,a2, 12p2 and 18 groups, was removed. The CA, CHA and LGA in all the cases were excised without reconstructions **(Fig. 1)**.

If it was necessary to remove the left or right hepatic artery in addition to the abovementioned organs and vessels, then the liver lobe ipsilateral to the sacrificed artery was thoroughly examined using IO Doppler US after the temporary clamping of this artery, CHA and LGA. Transection of the lobar artery was performed only after IOUS confirmed the presence of intramural arterial blood flow within the entire liver. All operations were performed under 3.5 — 4.5 magnification.

Transabdominal US examination including Doppler US was performed for the first three postoperative days. Liver function tests were taken on postoperative days 1, 2, 7 and 14. All patients were discharged with a drain at the pancreas transection site, which was removed between postoperative days 12 and 26. All patients received somatostatin inhibitors percutaneously 200 mkg 3 times daily for 10 days postoperatively and proton pump inhibitors for 3 months. All patients continued or began and finished an adjuvant chemotherapy course. Follow-up consisted of physical examination, laboratory studies and CT imaging at 3- month intervals for the first 2 years, at 6-month intervals for years 3 through 5, then at yearly intervals. At the time of the final assessment (May 2021), no patient had been lost to follow-up evaluation.

Statistics

The Kolmogorov-Smirnov test confirmed the abnormality of the data distribution. Therefore, the data are presented as the median and range (the minimum and maximum values), and due to the small number of cases, as absolute numbers.

Results

Tables 1 and 2 demonstrate patients' demographics, radiological, short- and long-term perioperative data. Two of the seven patients (#4) were males. The mean (range) BMI was 22.2 (20—26) kg/m^2, and the mean (range) age was 62.5 (57—70) years. All seven patients had a history of back pain and weight loss at the beginning of the disease. Patient #4 was an active smoker. Diagnosis was confirmed preoperatively in 6 cases (except #3) using endoUS-guided fine-needle aspiration or gastric biopsy (#2), and all six patients received perioperative chemotherapy with 6—12 neoadjuvant courses and exhibited decreases in CA-19—9 of 12, 4.5, 24, 5, and 3.5 times.

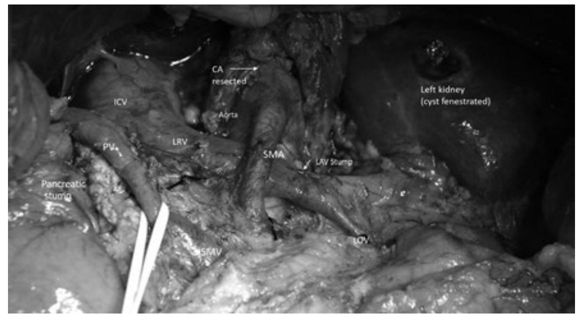

Fig. 1. **Surgical field after R0 distal pancreatectomy (posterior RAMPS) with resection of the celiac trunk (CA) and no arterial reconstruction.**

Intraoperative image. Explanations in the text. SMA — superior mesenteric artery, PV — portal vein, SMV — superior mesenteric vein, LRV — left renal vein, LAV stump — left adrenal vein stump (clipped), LOV — left ovarian vein, ICV — inferior vena cava.

Five of the seven patients underwent surgery for PDAC. One patient received surgery for advanced gastric body adenocarcinoma G2 with spread to the pancreas, and one patient (#3) underwent surgery for large B-cell lymphoma due to bleeding after repeated core-needle biopsy. There were no arterial reconstructions, aortal stenting, preoperative angiography and/or embolization of CHA, CA and/or left gastric artery (LGA).

All patients had aberrant arterial anatomy, because the right hepatic artery originating from the CA is also an important aberration in circumstances of the CA tumor involvement, but formally belongs to Michels I (classical) type. None of the patients had major comorbidities, including pre-existing liver disease, and the physical statuses of all patients were categorized as ECOG 0 and American Society of Anesthesiologists (ASA) class II.

Six patients underwent modified Appleby procedures with left or right hepatic artery resection. The patient with gastric cancer underwent total gastrectomy in combination with total pancreatectomy, GDA and replaced left hepatic artery resection as a completion of the Appleby procedure due to tumor spread to the pancreatic head (positive pancreatic margin at frozen-section biopsy). In one case (#5), the confluence of the SMV and PV was circularly resected with direct PV-SMV anastomosis. The mean (range) tumor size was 55 (37—86) mm. All procedures were R0 with a median lymph node harvest of 31.8 (IQR 19—78).

The mean (range) operative time was 246 (195—310) min, and the mean (range) blood loss was 327.5 (105—650) ml with no need for blood transfusion. No patient died, had a major complication (Dindo-Clavien > 3), or required reoperation or readmission within 90 days after surgery. Three patients had minor complications (Clavien—Dindo grade II) postoperatively due to grade B postoperative pancreatic fistula (POPF) with the drain staying in place for more than 21 days. One patient (#4) developed intense abdominal pain caused by herpes zoster postoperatively, which prolonged the hospital stay. The mean (range) length of stay was 14.7 (9—26) days **(Table 1)**.

Arterial blood flow in the liver parenchyma after temporary clamping and resection of the CA, CHA, LGA and rRHA or rLHA have never ceased, with flow velocity $\geqslant$ 20 cm/sec. The US spectrum remained unchanged in two cases, but it changed from the main to collateral flow after clamping of the arteries in the other six cases. No ischemic signs, necroses or abscesses in the liver and/or stomach were found during the early or late postoperative periods by transabdominal US, including Doppler US, contrast CT or MRI.

Liver function tests showed slight and transient plasma ALT and AST elevation on POD 1 with spontaneous and quick recuperation. The level of enzymes returned to normal within two weeks after surgery. The most prominent enzyme elevations were registered in patients #4 and #5, one after 12 courses of chemotherapy and the second after PV-SMV resection associated with updated DP-CAR. Total bilirubin (TB) levels in plasma never exceeded normal values **(Table 3)**.

Survival analysis for the PDAC patients demonstrated cure for patient #1 (109 months after surgery she is alive, tumor-free and absolutely functional). Patients #5—7 were operated on relatively recently but are progression-free 12, 23 and 24 months after treatment beginning, functional and symptom-free. One patient died 26 months after the diagnosis due to peritoneal and lung progression.

Patient #2 lived in a remote region of the country and died gastric cancer-free 28 months after commencement of treatment due to pneumonia associated with poorly controlled diabetes mellitus.

Patient #3 underwent surgery for abdominal bleeding after core-needle biopsy of the pancreatic body tumor, distinct from PDAC. After surgery, the tumor was identified as B-cell lym-

***Table 1.* Demographic, radiological and immediate perioperative data after extended DP-CAR**

Patient No.	Age, sex	BMI kg/m^2	Michels	Arteries resected	OP time, min	Blood loss, ml	Morbidity, D-C > 3a	POPF	LOS, days
1	65, f	20	IV	CA, rLHA, GDA, SIV	310	305	—	—	9
2	62, f	22	IV	CA, rLHA, GDA, SIV	305	550	—	—	12
3	57, f	23	II	CA, rLHA	195	105	—	B	14
4	59, m	26	I, RHA from CA	CA, rRHA	205	650	—	B	26
5	62, f	21	II	CA, rLHA/ VR	245	155	—	B	13
6	70, f	21	I, RHA from CA	CA, rRHA	220	200	—		14
7	56, m	22	II	CA, rLHA	300	150	—	—	11

Note. LOS — length of hospital stay, CA — celiac, rRHA — replaced right hepatic, rLHA — replaced left hepatic, GDA — gastroduodenal arteries, SIV — artery to segment IV, Michels — Michels' classification of celiaco-mesenterial arterial anatomy, POPF — postoperative pancreatic fistula, VR — porto-mesenteric vein resection.

***Table 2.* Perioperative data and long-term results after extended DP-CAR**

Patient No.	Age, sex	DS	ChT, N of courses	CA-19-9, first/last	Tumor size, mm/ regression grade	N of lymph nodes harvested/involved	R0	OS, PFS, months
1	65, f*	PDAC, ypT4N0M0	NA Gem, 6	86/17	51/II	29/0	+	109, 109
2	62, f	Gastric Ca, ypT4bN2M0	NA FOLFIRINOX, 4	390/ 136	78/II	78/3	+	28, 28
3	57, f	B-cell lymphoma	CHOP, 9	—	86	28/0	+	77, 64
4	59, m	PDAC, ypT4N2M0	NA FOLFIRINOX, Gem+A,12	1145/144	42/III	34/3	+	26, 23
5	62, f*	PDAC, ypT4N1M0	NA,FOLFIRINOX, 6	350/71	37/III	28/1	+	24, 24
6	70, f*	PDAC, ypT4N1M0	NA,FOLFIRINOX, 6	99/41	39/II	22/1	+	23, 23
7	56, m*	PDAC, ypT4N0M0	NA,FOLFIRINOX, 6	321/28	37/II	30/0	+	12, 12

Note. PDAC — pancreatic ductal adenocarcinoma, OS — overall survival, PFS — progression-free survival, Gem — gemcitabine, A — abraxane (Nab-paclitaxel), * — alive, NA — neoadjuvant, ChT — chemotherapy, type and number of courses.

***Table 3.* Postoperative changes in hepatic parameters after extended DP-CAR**

Patient No.	AST IU/L POD				ALT IU/L POD				ALP IU/L POD				Max TB µmol/l
	1	2	7	14	1	2	7	14	1	2	7	14	
1	137	—	—	52	174	—	—	61	168	—	—	55	14
2	205	101	—	49	198	145	—	59	183	151	—	114	19
3	78	—	—	40	99	—	—	31	134	—	—	83	15
4	664	332	141	69	767	293	102	78	393	214	—	159	23
5*	443	219	122	55	612	222	97	69	377	171	144	77	16
6	119	87	48	44	176	98	73	53	194	—	—	133	12
7	312	196	57	43	431	188	69	47	133	—	78	51	18

Note. POD — postoperative day, AST — aspartate aminotransferase, ALT — alanine transaminase, ALP — alkaline phosphatase, max TB — maximum total bilirubin level during stay, * — porto-mesenteric vein resection phoma, which dramatically progressed 77 months after surgery on the background of adjuvant treatment and have led to the patient's death **(Table 2)**.

Postoperative pathology revealed involvement of the arterial wall of the CA and/or CHA in all cases, except #3. Tumor regression score varied from II (##1, 2, 6 and 7) to III (##4 and 5).

CT and CT angiograms (CTA) of all patients before and after surgery were compared to obtain a detailed explanation of the sources of liver and stomach arterial supplies **(Fig. 2—8)**.

Discussion

Previous studies showed that radical excision of cancer of the pancreatic body with involved CA offered better survival to a highly selected group of patients with borderline or locally advanced pancreatic adenocarcinoma, especially after neoadjuvant chemotherapy [6, 25, 28]. The safety of DP-CAR depends on the experience of pancreatic surgical team and center volume [6, 8, 10, 12, 25—30]. The value of the methods of prevention of specific DP CAR complications, such as gas-

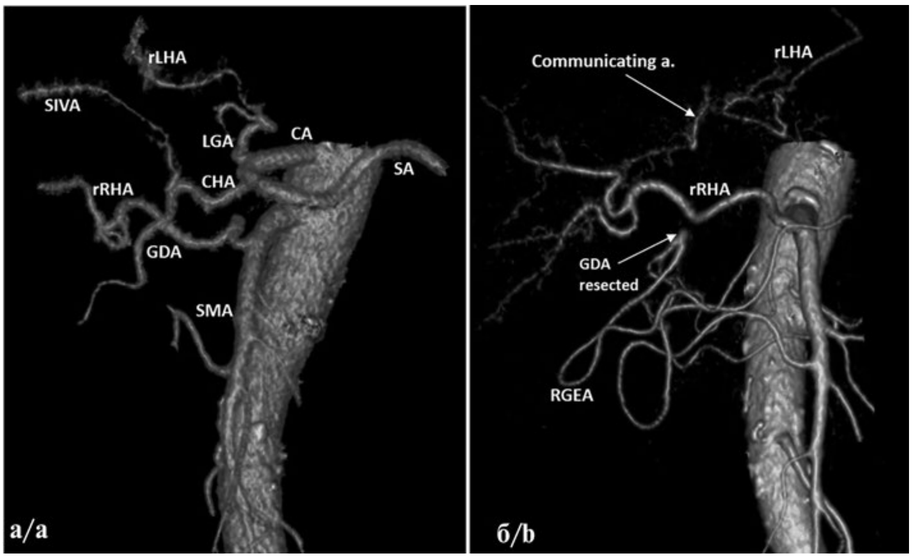

Fig. 2. **Ductal pancreatic adenocarcinoma in a 65-year-old female. 3D CT angiography.**
a — before surgery. Michels IV arterial anatomy: the replaced right hepatic artery (rRHA) arising from superior mesenteric artery (SMA), the replaced left hepatic (rLHA) — from the left gastric (LGA) and segment IV artery (SIVA) originating from the common hepatic (CHA). CA — celiac artery; GDA — gastroduodenal artery, RGEA — right gastroepiploic artery SA — splenic artery; Communicating a. — artery, connecting right and left hepatic arteries; b — 9 years after DP-CAR with excision of the CHA and resection of the LGA, GDA and SIVA. Liver is supplied via SMA through rRHA communicating with the branches of rLHA via interlobar collaterals. Stomach is supplied from SMA via gastroduodenal artery (GDA) and right gastroepiploic artery (RGEA).

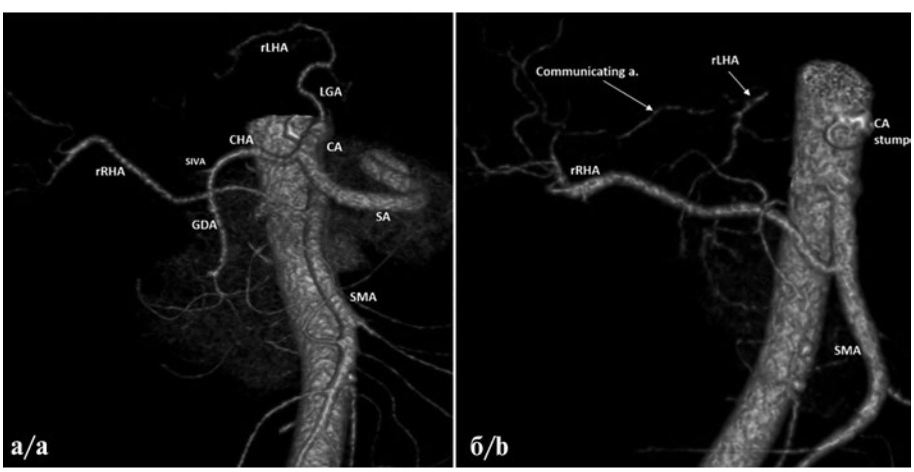

Fig. 3. **Gastric adenocarcinoma G2 with involvement of the pancreatic head and body in a 66-year-old female. 3D CT angiography.**
a — before surgery. Michels IV arterial anatomy: the replaced right hepatic artery (rRHA) arising from superior mesenteric artery (SMA), the replaced left hepatic (rLHA) — from the left gastric (LGA), segment IV artery (SIVA) — from the common hepatic artery (CHA); b — 20 months after total gastrectomy and total pancreatectomy (completion of the Appleby procedure due to positive margins) with resection of the celiac artery (CA), CHA, LGA, S IVA and gastroduodenal (GDA) arteries.

tric and/or liver ischemia and/or postpancreatectomy hemorrhage are controversial [29, 44—52].

Better outcomes may be achieved if the DP-CAR is R0, patients are carefully selected, and the following factors are ensured: perioperative modern chemotherapy, reliable intraoperative tools for the detection of liver and stomach ischemia, mitigation of pancreatic fistula and the absence of arterial reconstructions [6, 8, 10—12, 25—30].

DP-CAR is an invasive and complex procedure due to extensive organ, tissue and vascular removal, but sometimes additional resection of the left or right hepatic artery is necessary to achieve R0 status. This situation leads to decisions that vary from risky arterial reconstructions to a rejection of surgery. This paper considered the systematic use of knowledge of liver interlobar arterial communications for the performing of these DP-CARs (and some other pancreatectomies), which require additional resection of the left or right hepatic artery without arterial reconstruction.

Anatomical and clinical bases for the extension of arterial resections in DP CAR

The capabilities of the collateral arterial supply of the liver and stomach after CA resection were described by N. Michels on cadavers and confirmed by Appleby clinically. After DP-CAR, the liver and stomach are supplied from the SMA to the proper hepatic and right gastroepiploic arteries via the pancreaticoduodenal arcade and gastroduodenal artery. Both of the latter vessels are consistent and exist in 100% of cases, but their origins may vary [38].

For some reasons, less attention was paid to Michels' research for anastomoses between major hepatic arteries, which showed that 10 collateral arterial pathways to the liver may work

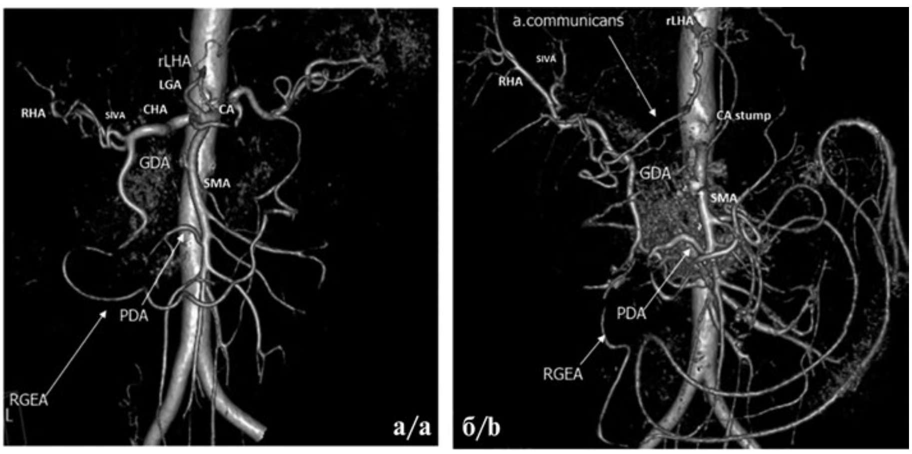

Fig. 4. **B-cell lymphoma of the pancreatic body and tail in a 57-year-old female. 3D CT angiography.**

a — before surgery. Michels II arterial anatomy: the replaced left hepatic artery (rLHA) arising from the left gastric artery (LGA); b — 5 years after DP-CAR with excision of the common hepatic artery (CHA) and LGA resection. Left liver lobe is supplied *via* collateral communicating artery. The last one is presented by the lesser curvature arcade between the proper or right hepatic artery (RHA) and the branches of rLHA. Stomach is supplied from superior mesenteric artery (SMA) *via* pancreaticoduodenal arcade (PDA) and gastroduodenal artery (GDA) and right gastroepiploic artery (RGEA).

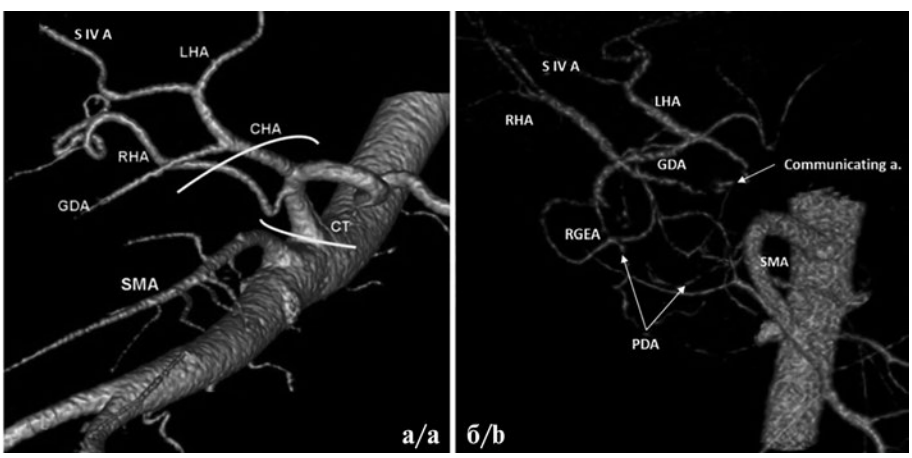

Fig. 5. **Ductal adenocarcinoma of the pancreatic body in a 59-year-old male. 3D CT angiography.**

a — before surgery. Michels I arterial anatomy with the right hepatic (RHA) arising from the celiac artery (CA); b — 12 months after DP-CAR with excision of the common hepatic artery (CHA) and RHA resection. Resection lines are shown in yellow. The left liver is supplied from superior mesenteric artery (SMA) via pancreaticoduodenal arcade (PDA), gastroduodenal (GDA) and left hepatic artery (LHA). The right liver is supplied via interlobar collateral artery (communicating a.) connecting LHA and RHA. The stomach is supplied from SMA via PDA, GDA and right gastroepiploic artery (RGEA).

when the hepatic arteries were occluded, extrahepatic anastomoses between the hepatic arteries existed, and "no major intrahepatic anastomoses exist between the hepatic arteries inside the liver". It was definitely demonstrated that extrahepatic anastomoses could function between the vessels: 1. RHA and LHA or middle hepatic artery (MHA, SIVA), MHA and LHA, and two branches of the RHA; 2. RHA and aberrant RHA from SMA; 3. Terminals of the MHA or LHA and arteries of the caudal lobe; 4. LHA and LGA; 5. CHA or RHA and GDA, supra- or retroduodenal arteries; 6. Cystic artery and RHA or CHA; and 7. RHA or PHA and aLHA or rRHA through the lesser gastric curvature arcade [38, 53]. Tohma T. et al. compared CT and angiography data during temporary balloon occlusion of the right or left hepatic artery and showed that communicating arteries between the RHA and LHA were consistently present as interlobar collateral vessels of the liver [54], and these vessels are generally part of the hilar bile duct arterial net [55]. Kim HC (2005) tried to avoid the complications of transcatheter arterial chemoembolization by recognizing the extrahepatic collaterals to hepatocellular carcinoma and showed that not all of the 10 collaterals described by Michels would be activated and sufficient for liver arterial supply at the moment of acute occlusion of the main artery [56]. Pancreatectomy combined with simultaneous complex artery(ies) resection has traditionally been considered a general contraindication to radical surgery, and these patients were rigorously selected by our team [57, 58]. We considered arterial reconstruction during partial pancreatectomy too risky due to probable fistula formation and possible fatal bleeding, which corresponds to the data of other authors [8, 10—12, 26, 29]. Knowledge about the arterial collaterals provides a chance to avoid arterial reconstructions during partial pancreatectomies during the left-sided and right-sided resections.

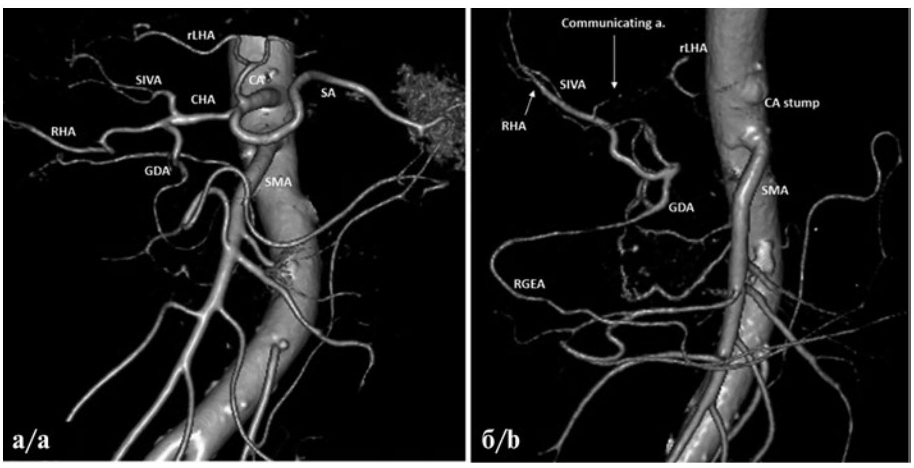

Fig. 6. **Ductal adenocarcinoma of the pancreatic body in a 62-year-old female. 3D CT angiography.**

a — before surgery. Michels II arterial anatomy: the replaced left hepatic artery (rLHA) arising from the left gastric artery (LGA); b — 12 months after DP-CAR with excision of the common hepatic artery (CHA) and resection of LGA, resection and reconstruction of PV-SMV confluence. The left liver lobe is supplied from rLHA via collateral (Communicating a.) anastomosing with branches of segment IV artery and proper hepatic artery. Stomach is supplied from superior mesenteric artery (SMA) via pancreaticoduodenal arcade, gastroduodenal artery (GDA) and right gastroepiploic artery (RGEA).

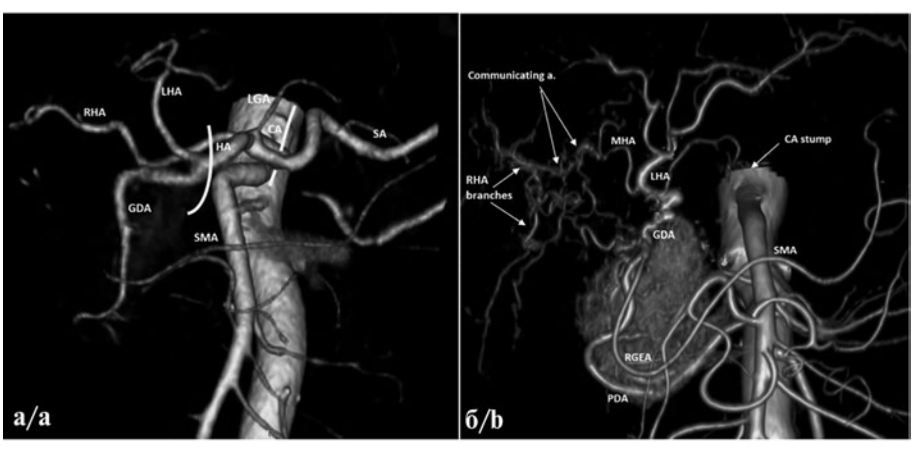

Fig. 7. **Ductal adenocarcinoma of the pancreatic body in a 70-year-old female. 3D CT angiography.**

a — before surgery. Michels I arterial anatomy with the right hepatic artery (RHA) arising from the celiac artery (CA); b — 13 months after DP-CAR with excision of celiac artery (CA) and RHA resection. Resection lines are shown in yellow. The left liver is supplied from superior mesenteric artery (SMA) via pancreaticoduodenal arcade (PDA), gastroduodenal (GDA) and left hepatic arteries (LHA). The right liver lobe is supplied via interlobar collateral (communicating a.) connecting LHA, middle hepatic artery (MHA) and RHA. Stomach is supplied from SMA via PDA, GDA and right gastroepiploic artery (RGEA).

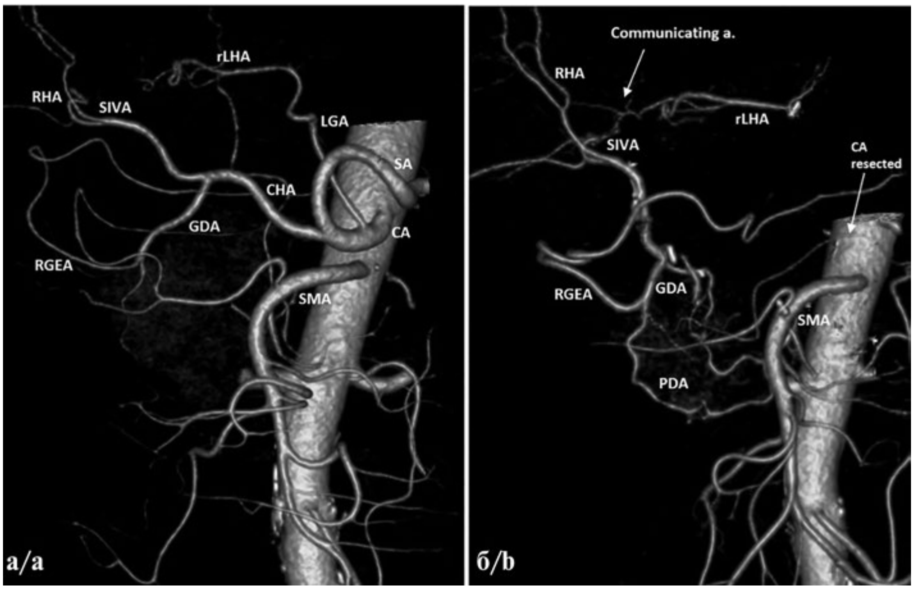

Fig. 8. **Ductal adenocarcinoma of the pancreatic body in a 56-year-old male. 3D CT angiography.**

a — before surgery. Michels II arterial anatomy: the replaced left hepatic artery (rLHA) arising from the left gastric artery (LGA); b — 6 months after DP-CAR with excision of celiac artery (CA), common hepatic artery (CHA) and LGA. The left liver lobe is supplied from rLHA via collateral artery (communicating a.) anastomosing with the branches of segment IV artery and right hepatic artery (RHA). Stomach is supplied from superior mesenteric artery (SMA) via pancreaticoduodenal arcade, gastroduodenal artery (GDA) and right gastroepiploic artery (RGEA).

Possible anatomical and clinical effects of the preoperative common hepatic or celiac artery and its branches embolization

The pancreaticoduodenal and gastroduodenal arteries are 100% present and are easily delineated by CT [59].

1. In the event of a CHA preoperative occlusion (PHAE) [29, 45, 46, 48], the collateral flow always appears in the direction of the proper hepatic artery (PHA) from the SMA. The possibility of adequate arterial hepatopetal flow through the GDA is very high, because the stomach is supplied by the left gastric (LGA) and splenic (SA) arteries, which makes the flow deviation into the right gastroepiploic artery insignificant [31, 49]. Moreover, the constant collaterals (which are disconnected during DP CAR) between the system of the left gastric, hepatic and aa. communicantes between the left and right hepatics are kept in reserve and invisible even in selective angiography after embolization [60]. This condition absolutely differs from conditions that develop after DP CAR, when the SA, LGA dorsal and transverse pancreatic and transpancreatic arteries are excised. All of the abovementioned arguments reduce the value of preoperative common hepatic artery embolization.

2. In case of CA preoperative occlusion [30,52], the collateral flow from the SMA through the PDA and GDA goes into the PHA and the CHA and through it, into the CA, LGA and SA to supply the liver, stomach, spleen and pancreas along the patent paths **(Fig. 9)**. In this situation, a) the pathway from the aorta to the remote consumer organs (e.g., gastric fundus, spleen, pancreatic tail) elongates significantly; and b) the other collaterals from the SMA (which will be sacrificed during DP CAR) could be activated to compensate for the possible arterial insufficiency of the abovementioned organs.

3. With CA and CHA, CA and LGA, or CA, CHA, SA and LGA preoperative occlusion [31], arterial flow redistribution may be achieved via the PDA and GDA, which is similar to the flow pattern resulting after DP CAR. The big difference in this situation is a great reduction in flow supply to the abovementioned power-consuming organs (for example activation of RGEA with liver stealing), which is more significant than just after CA occlusion and which may lead to the appearance of collaterals not related to post DP-CAR anatomy [47].

Theoretically, variants 2 and 3 of preoperative artery occlusions could lead to 1. “appearance” of the interlobar liver communicating arteries on CT and angiography; 2. ischemia of some organs before surgery, which may lead to a refusal of surgery that would otherwise have been feasible without preoperative embolization.

Because of these theoretical and practical issues [28—31, 44—47, 50], the absence of established advantages of preoperative embolization preoperative stenting of the aorta, embolization of CA, CHA, LGA and/or SA[3, 60], we never used these options.

There was no 90-day mortality in our series. Morbidity was represented primarily by grade B POPF in half of the patients, which manifest as the drain staying longer than 21 days. One case (#4) of prolonged hospital stay was a result of a herpes zoster attack. The relatively high incidence of POPF may be explained by the level of transection of the unchanged pancreas, which was always to the right of the pancreatic neck along the head border or through the pancreatic head. Our team did not see any improvements in POPF rate using round ligament, hemostatic patches and glues after distal pancreatectomies, and we only used prolonged draining for abscesses and bleeding prevention.

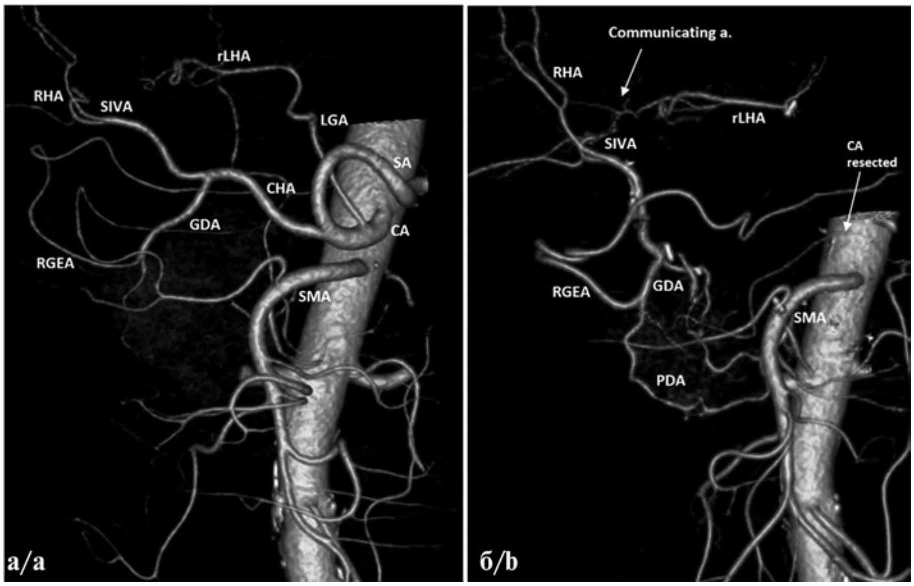

Fig. 9. **Celiac artery (CA) aneurysm and right colon cancer in a 71-year-old male. 3D CT angiography.**
a — before surgery. Michels I arterial anatomy with the saccular CA aneurysm; b — 1 week after right-sided hemicolectomy with CA resection proximal to its bifurcation. Liver, stomach, pancreas and spleen are supplied from superior mesenteric artery (SMA) *via* pancreaticoduodenal arcades, gastroduodenal (GDA), common hepatic (CHA), left gastric (LGA) and splenic arteries (SA). The same diameter of right gastroepiploic artery (RGEA) and LGA indirectly shows their unchanged participation in supplying the stomach.

Prevention of ischemic complications was only intraoperative and comprised of the determination of intraparenchymal arterial liver flow using Doppler ultrasound after temporary clamping of the CHA, LGA and/or CA (see Methods). Previous works [39] and our experience of 54 consecutive distal spleen-preserving pancreatectomies with splenic vessel resection showed that detection of the main or collateral intraparenchymal arterial flow velocity ⩾ 20 cm/sec using US Doppler after clamping of the splenic artery was a reliable sign of adequate arterial supply of the spleen [61]. We used the same principle for the assessment of liver arterial flow after clamping and resection of the CHA and considered this flow sufficient even in cases of undetectable pulse on the hepatoduodenal ligament (case #4). Using this approach, no severe postoperative ischemic complications, such as liver infarctions or abscesses, were recorded. For assessment of the stomach ischemia, we used only visual monitoring and pulse detection at the right gastroepiploic on the level of the gastric body after the CA clamping. In three cases out of seven we used fluorescent angiography in the near-infrared light with intravenous indocyanine green (ICG) in addition to the visual data and RGEA pulse monitoring. Doppler ultrasound and ISG-based fluorescence detection are now mandatory methods for any surgery associated with hepatic and/or celiac artery resections in our institution. In this series of seven patients, there were no cases of ischemic gastropathy.

IOUS was not used for the assessment of vascular involvement because it did not provide any additional data to the CT data after neoadjuvant therapy in our experience.

The seven updated DP-CARs were a part of our series of 53 consecutive pancreatectomies associated with CA and/or CHA resections. In this mixed group of patients with adjuvant and neoadjuvant therapy, arterial reconstructions were performed in 24.5% (13/53) of cases. Twenty tree procedures were added to the first results [57] from 2015, and the current R0-resection rate is 92.5% (4/53), with 7.5% (4/53) 90-day mortality and 46% (24/53) morbidity (primarily POPF B) with a major morbidity rate (Dindo-Clavien > 3a) of 17% (9 of 53). DP CARs were performed in 40 cases, and all of them were planned with no primary arterial reconstructions. For PDAC, the overall survival was 25 months with a progression-free survival of 20 months. Although the last 12 procedures were accomplished from 2018 to November 2020 and long-term survival data will be corrected, the 19.4% actual 5-year survival (6 of 31) in this mixed (adjuvant + neoadjuvant) DP-CAR group is a promising result. The short-and long-term results in this subgroup of seven patients did not differ significantly from the results of the whole DP-CAR group.

Thirty-three retrospective series of DP CARs containing more than two patients collected 528 cases from 1976 to 2020 [6, 8—12, 15—28, 44, 47, 48, 51, 52, 57] and demonstrated postoperative 90-day mortality rates that ranged from 0% in the Baltimore (17 patients), 3% in the Inokawa (1 of 38), 5% in the Sapporo (4 of 80) and 6.5% in the Chiba (2 of 31) cohorts to 14% in the Pittsburgh (4 of 30), 16% in the pan-European (11 of 68) and 18% in the Rochester (6 of 34 patients) cohorts [6, 9, 12, 25, 26, 29, 60]. Major morbidity rates in the largest series ranged from 25% in the pan-European cohort to 59% in the Rochester cohort, although definitions were heterogeneous [6, 9, 12, 25, 26, 29, 60]. The most common complication was POPF (30%), which was as frequent as after standard distal pancreatectomy [61]. The rates of POPF varied from 6% (Baltimore) to 57.5% (Sapporo). The R0 rate varied from 55% in the Pan-European to 92.5% in the Sapporo cohort, and mean lymph node harvest fluctuated from 16 (15—24) in the Baltimore and 23.9±18 in the Pittsburg series to 22 (19—31) in the European series [6, 9, 12, 25, 26, 29].

Overall survival in the mixed (adjuvant plus neoadjuvant therapy) groups varied from 18 months [29] to 30.9 months [12]. Authors from Baltimore (*n*=17), Pittsburgh (*n*=30) and Inokawa (*n*=38) reported 20, 35 and 38.6 month median overall survival after neoadjuvant therapy [6, 9, 25, 26].

The present study demonstrated that DP CAR associated with resection of the left or right hepatic arteries without reconstructions (extended DP CAR), performed under intraoperative blood flow monitoring, was technically feasible and safe and oncologically justified because of the acceptable mortality and morbidity, lack of ischemic complications and acceptable long-term results compared to published data. This technique was mentioned as an extension of DP-CAR only once in the literature [29], but without short- and long-term details.

The key point of this paper was to demonstrate the importance of the interlobar communicating arteries between the main hepatic arteries and the capabilities of intraoperative monitoring of their functioning, for the safe resection of the main hepatic arteries without reconstructions during pancreatectomies and other radical abdominal procedures.

The data presented in this work will help decrease the risk of fatal complications associated with arterial reconstructions and provide an explanation about the rarity of left liver ischemia after excision of the aberrant left hepatic artery during gastrectomy. The data **(Fig. 2—9)** show that in cases of acute occlusion of the aberrant left hepatic artery, the artery(ies) of first response are the communicating interlobar hepatic artery(ies), and sometimes left inferior diaphragmatic artery, as was shown previously using angiography [62—65].

The limitations of this study are the small number of cases and patient selection. Technical limitations involved the low resolution of 3D CT angiography compared to the maximum intensity projection (MIP) regimen. Three-dimensional CTA was used as a method of comprehensive and more demonstrative visualization of the visceral arteries, which is much more difficult with the use of MIP technology.

In conclusion, DP-CAR with resection of the right or the left hepatic artery is feasible and safe for patients with pancreatic body cancer that involves the CA, CHA and/or one of the main hepatic arteries. The combination of modern chemotherapy, reliable monitoring of the liver and stomach blood supply and updated DP-CAR can provide R0 resection and survival benefit for these patients.

The authors declare no conflicts of interest.

REFERENCES

1. Ferrone CR, Marchegiani G, Hong TS, Ryan DP, Deshpande V, McDonnell EI, Sabbatino F, Santos DD, Allen JN, Blaszkowsky LS, Clark JW, Faris JE, Goyal L, Kwak EL, Murphy JE, Ting DT, Wo JY, Zhu AX, Warshaw AL, Lillemoe KD, Fernández-del Castillo C. Radiological and surgical implications of neoadjuvant treatment with FOLFIRINOX for locally advanced and borderline resectable pancreatic cancer. *Ann Surg.* 2015;261(1):12-17. PMID: 25599322. https://doi.org/10.1097/SLA.0000000000000867
2. Sadot E, Doussot A, O'Reilly EM, Lowery MA, Goodman KA, Do RK, Tang LH, Gönen M, D'Angelica MI, DeMatteo RP, Kingham TP, Jarnagin WR, Allen PJ. FOLFIRINOX induction therapy for stage 3 pancreatic adenocarcinoma. *Ann Surg Oncol.* 2015;22(11):3512-3521. PMID: 26065868. https://doi.org/10.1245/s10434-015-4647-4
3. Truty M, Kendrick M, Nagorney D, Smoot R, Cleary S, Graham R, Goenka A, Hallemeier C, Haddock M, Harmsen W, Mahipal A, McWilliams R, Halfdanarson T, Grothey A Factors Predicting Response, Perioperative Outcomes, and Survival Following Total Neoadjuvant Therapy for Borderline. *Locally Advanced Pancreatic Cancer Ann Surg.* 2021;273(2):341-349. PMID: 30946090. https://doi.org/10.1097/SLA.0000000000003284
4. Noda Y, Goshima S, Kawada H, Kawai N, Miyoshi T, Matsuo M, Bae KT. Modified National Comprehensive Cancer Network Criteria for Assessing Resectability of Pancreatic Ductal Adenocarcinoma. *AJR Am J Roentgenol.* 2018;210(6):1252-1258. PMID: 29629801. https://doi.org/10.2214/AJR.17.18595
5. Cloyd JM, Katz MH, Prakash L, Varadhachary GR, Wolff RA, Shroff RT, Javle M, Fogelman D, Overman M, Crane CH, Koay EJ, Das P, Krishnan S, Minsky BD, Lee JH, Bhutani MS, Weston B, Ross W, Bhosale P, Tamm EP, Wang H, Maitra A, Kim MP, Aloia TA, Vauthey JN, Fleming JB, Abbruzzese JL, Pisters PW, Evans DB, Lee JE. Preoperative Therapy and Pancreatoduodenectomy for Pancreatic Ductal Adenocarcinoma: a 25-Year Single-Institution Experience. *J Gastrointest Surg.* 2017;21:164-174. PMID: 27778257. https://doi.org/10.1007/s11605-016-3265-1
6. Yoshitomi H, Sakai N, Kagawa S, Takano S, Ueda A, Kato A, Furukawa K, Takayashiki T, Kuboki S, Miyzaki M, Ohtsuka M. Feasibility and safety of distal pancreatectomy with en bloc celiac axis resection (DP -CAR) combined with neoadjuvant therapy for borderline resectable and unresectable pancreatic body/tail cancer. *Langenbecks Arch Surg.* 2019;404(4):451-458. PMID: 30188399. https://doi.org/10.1097/SLA.0000000000003010
7. Vincente E, Quijano Y, Ielpo B. Arterial Resection for Pancreatic Cancer: A Modern Surgeon Should Change Its Behavior According to the New Therapeutic Options G Chir. 2014;35(1-2):5-14. PMID: 24690335.
8. Bachellier P, Addeo P, Faitot F, Nappo G, Dufour P. Pancreatectomy With Arterial Resection for Pancreatic Adenocarcinoma: How Can It Be Done Safely and With Which Outcomes?: A Single Institution's Experience With 118 Patients. *Ann Surg.* 2020;271(5):932-940. PMID: 30188399. https://doi.org/10.1097/SLA.0000000000003010
9. Tee MC, Krajewski AC, Groeschl RT, Farnell MB, Nagorney DM, Kendrick ML, Cleary SP, Smoot RL, Croome KP, Truty MJ. Indications and Perioperative Outcomes for Pancreatectomy With Arterial Resection. *Am Coll Surg.* 2018;227(2):255-269. PMID: 29752997. https://doi.org/10.1016/j.jamcollsurg.2018.05.001
10. Glebova N, Hicks C, Tosoian J, Piazza K, Abularrage C, Schulick R, Wolfgang C, Black J3rd, Outcomes of Arterial Resection During Pancreatectomy for Tumor. *J Vasc Surg.* 2016;63(3):722-9.e1. PMID: 26610641. https://doi.org/10.1016/j.jvs.2015.09.042
11. Ozer I, Kayaalp C. Regarding «Outcomes of arterial resection during pancreatectomy for tumor». *J Vasc Surg.* 2016;64(4):1192-1193. PMID: 27666458. https://doi.org/10.1016/j.jvs.2016.05.083
12. Nakamura T, Hirano S, Noji T, Asano T, Okamura K, Tsuchikawa T, Murakami S, Kurashima Y, Ebihara Y, Nakanishi Y, Tanaka K, Shichinohe T. Distal pancreatectomy with en bloc celiac axis resection (modified Appleby procedure) for locally advanced pancreatic body

cancer: a single-center review of 80 consecutive patients. *Ann Surg Oncol.* 2016;23(5):969-975. PMID: 27495282.
https://doi.org/10.1245/s10434-016-5493-8

13. Amin MB, Edge S, Greene F, Byrd DR, Brookland RK, Washington MK, Gershenwald JE, Compton CC, Hess KR, Sullivan DC, Jessup JM, Brierley JD, Gaspar LE, Schilsky RL, Balch CM, Winchester DP, Asare EA, Madera M, Gress DM, Meyer LR. *AJCC cancer staging manual.* 8th ed. New York: Springer; 2017.

14. Bockhorn M, Uzunoglu FG, Adham M, Imrie C, Milicevic M, Sandberg AA, Asbun HJ, Bassi C, Büchler M, Charnley RM, Conlon K, Cruz LF, Dervenis C, Fingerhutt A, Friess H, Gouma DJ, Hartwig W, Lillemoe KD, Montorsi M, Neoptolemos JP, Shrikhande SV, Takaori K, Traverso W, Vashist YK, Vollmer C, Yeo CJ, Izbicki JR; International Study Group of Pancreatic Surgery. Borderline resectable pancreatic ancer: a consensus statement by the International Study Group of Pancreatic Surgery (ISGPS). *Surgery.* 2014;155(6):977-988. PMID: 24856119.
https://doi.org/10.1016/j.surg.2014.02.001

15. Sperti C, Berselli M, Pedrazzoli S. Distal pancreatectomy for body-tail pancreatic cancer: is there a role for celiac axis resection? *Pancreatology.* 2010;10:491-498. PMID: 20720451.
https://doi.org/10.1159/000276984

16. Amano R, Kimura K, Nakata B, Yamazoe S, Motomura H, Yamamoto A, Tanaka S6, Hirakawa K2. Pancreatectomy with major arterial resection after neoadjuvant chemoradiotherapy gemcitabine and S-1 and concurrent radiotherapy for locally advanced unresectable pancreatic cancer. *Surgery.* 2015,158(1):191-200. PMID: 25900035.
https://doi.org/10.1016/j.surg.2015.02.016

17. Baumgartner JM, Krasinskas A, Daouadi M, Zureikat A, Marsh W, Lee K, Bartlett D, Moser AJ, Zeh HJ 3rd. Distal pancreatectomy with en bloc celiac axis resection for locally advanced pancreatic adenocarcinoma following neoadjuvant therapy. *J Gastrointest Surg.* 2012;16:1152-1159. PMID: 22399269.
https://doi.org/10.1007/s11605-012-1839-0

18. Christians KK, Pilgrim CH, Tsai S, Ritch P, George B, Erickson B, Tolat P, Evans DB. Arterial resection at the time of pancreatectomy for cancer. *Surgery.* 2014;155(5):919-926. PMID: 24787115.
https://doi.org/10.1016/j.surg.2014.01.003

19. Denecke T, Andreou A, Podrabsky P, Grieser C, Warnick P, Bahra M, Klein F, Hamm B, Neuhaus P, Glanemann M. Distal pancreatectomy with en bloc resection of the celiac trunk for extended pancreatic tumor disease: an interdisciplinary approach. *Cardiovasc Intervent Radiol.* 2011;34:1058-1064. PMID: 20936285.
https://doi.org/10.1007/s00270-010-9997-5

20. Klompmaker S, De Rooij T, Korteweg JJ, van Dieren S, van Lienden KP, van Gulik TM, Busch OR, Besselink MG. Systematic review of outcomes after distal pancreatectomy with coeliac axis resection for locally advanced pancreatic cancer. *Br J Surg.* 2016;103(8):941-949. PMID: 27304847.
https://doi.org/10.1002/bjs.10148

21. Yamaguchi K, Nakano K, Kobayashi K, Ogura Y, Konomi H, Sugitani A, Tanaka M. Appleby operation for pancreatic body-tail carcinoma: report of three cases. *Surg Today.* 2003;33(11):873-878. PMID: 14605963.
https://doi.org/10.1007/s00595-003-2602-7

22. Yamamoto Y, Sakamoto Y, Ban D K Shimada, Esaki M, Nara S, Kosuge T. Is celiac axis resection justified for T4 pancreatic body cancer? *Surgery.* 2012;151:61-69. PMID: 22088810.
https://doi.org/10.1016/j.surg.2011.06.030

23. Yashima Y, Shimamura H, Takeda K. Significance of distal pancreatectomy with en block celiac axis resection (DP-CAR) for pancreatic cancer. Abstracts of the EPC meeting — 2015. *Pancreatology.* 2015;3S(15):116.

24. Zhou YM, Zhang XF, Li XD, Liu XB, Wu LP, Li B. Distal pancreatectomy with en bloc celiac axis resection for pancreatic body-tail cancer: Is it justified? *Med Sci Monit.* 2014;20:1-5. PMID: 24382572.
https://doi.org/10.12659/MSM.889847

25. Ocuin LM, Miller-Ocuin JL, Novak SM, Bartlett DL, Marsh JW, Tsung A, Lee KK, Hogg ME, Zeh HJ, Zureikat AH. Robotic and open distal pancreatectomy with celiac axis resection for locallyadvanced pancreatic body tumors: a single institutional assessment of perioperative outcomes and survival. *HPB.* 2016;18(10):835-842. PMID: 27506992.
https://doi.org/10.1016/j.hpb.2016.05.003

26. Peters NA, Javed AA, Cameron JL, Makary MA, Hirose K, Pawlik TM, He J, Wolfgang CL, Weiss MJ. Modified Appleby procedure for pancreatic adenocarcinoma: does improved neoadjuvant therapy warrant such an aggressive approach? *Ann Surg Oncol.* 2016;23(11):3757-3764. PMID: 27328946.
https://doi.org/10.1245/s10434-016-5303-3

27. Wu X, Tao R, Lei R, Han B, Cheng D, Shen B, Peng C. Distal pancreatectomy combined with celiac axis resection in treatment of carcinoma of the body/tail of the pancreas: a single-center experience. *Ann Surg Oncol.* 2010;17:1359-1366. PMID: 20198445.
https://doi.org/10.1245/s10434-009-0840-7

28. Sugiura T, Okamura Y, Ito T, Yamamoto Y, Uesaka K. Surgical indications of distal pancreatectomy with celiac axis resection for pancreatic body/tail cancer. *World J Surg.* 2016;41(1):258-266. PMID: 27473130.
https://doi.org/10.1007/s00268-016-3670-3

29. Klompmaker S, van Hilst J, Gerritsen S, Adham M, Quer, MTA, Bassi C et al. Pan-European E-AHPBA series of distal pancreatectomy with celiac axis resection (DP-CAR; Appleby) for cancer. 2016. Accessed 3 June 2016.
https://www.emips. org/wp-content/uploads/sites/3/2016/12/Protocol-EAHPBA-Appleby-cohort-2016.6.3.pdf

30. Cesaretti M, Abdel-Rehim M, Barbier L, Dokmak S, Hammel P, Sauvanet A. Modified Appleby procedure for borderline resectable/locally advanced distal pancreatic adenocarcinoma: a major procedure for selected patients. *J Visc Surg.* 2016;153(3):173-181. PMID: 26775202.
https://doi.org/10.1016/j.jviscsurg.2015.11.014

31. Appleby LH. The coeliac axis in the expansion of the operation for gastric carcinoma. *Cancer.* 1953;6:704-707. PMID: 13059764.
https://doi.org/10.1002/1097-0142(195307)6:4<704::aid-cncr2820060410>3.0.co;2-p

32. Nimura Y, Hattori T, Miura K.: A case of advanced carcinoma of the body and tail of the pancreas resected by the Appleby operation (in Japanese). *Shujutu.* 1976;30:885-889.

33. Hishinuma S, Ogata Y, Tomikawa M, Ozawa I. Stomach-preserving distal pancreatectomy with combined resection of the celiac artery: radical procedure for locally advanced cancer of the pancreatic body. *J Gastrointest Surg.* 2007;11:743-749. PMID: 17417712.
https://doi.org/10.1007/s11605-007-0143-x

34. Michels NA. Collateral arterial pathways to the liver after ligation of the hepatic artery and removal of the celiac axis. *Cancer.* 1953;6:708-724. PMID: 13059765.
https://doi.org/10.1002/1097-0142(195307)6:4<708::aid-cncr2820060411>3.0.co;2-a

35. Rokke O, Nesvik I, Sondenaa K. Traumatic and postoperative ischemic liver necrosis: causes, risk factors and treatment. *Dig Surg.* 2000;17:595-601. PMID: 11155005.
https://doi.org/10.1159/000051968

36. Miura F, Asano T, Amano H, Yoshida M, Toyota N, Wada K, Kato K, Hayano K, Kadowaki S, Shibuya M, Maeno S, Takada T, Eguchi T. Eleven Cases of Postoperative Hepatic Infarction Following Pancreato-Biliary Surgery. *J Gastrointest Surg.* 2010;14(2):352-358. PMID: 19937194.
https://doi.org/10.1007/s11605-009-1089-y

37. Egorov VI, Yashina NI, Fedorov AV, Karmazanovsky GG, Vishnevsky VA, Shevchenko TV. Celiaco-mesenterial arterial aberrations in patients undergoing extended pancreatic resections: correlation of CT angiography with findings at surgery. *JOP.* 2010;11(4):348-357. PMID: 20601809.

38. Michels NA. *Blood Supply and Anatomy of the Upper Abdominal Organs with a Descriptive Atlas.* Philadelphia, PA: Lippincott; 1955.

39. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg.* 2004;240(2):205-213. PMID: 15273542.
https://doi.org/10.1097/01.sla.0000133083.54934.ae

40. Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, Allen P, Andersson R, Asbun HJ, Besselink MG, Conlon K, Del Chiaro M, Falconi M, Fernandez-Cruz L, Fernandez-Del Castillo C, Fingerhut A, Friess H, Gouma DJ, Hackert T, Izbicki J, Lillemoe KD,

Neoptolemos JP, Olah A, Schulick R, Shrikhande SV, Takada T, Takaori K, Traverso W, Vollmer CR, Wolfgang CL, Yeo CJ, Salvia R, Buchler M; International Study Group on Pancreatic Surgery (ISGPS). The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. *Surg.* 2017;161(3):584-591. PMID: 28040257.
https://doi.org/10.1016/j.surg.2016.11.014

41. Wente MN, Veit JA, Bassi C, Dervenis C, Fingerhut A, Gouma DJ, Izbicki JR, Neoptolemos JP, Padbury RT, Sarr MG, Yeo CJ, Büchler MW. Postpancreatectomy hemorrhage (PPH)—an International Study Group of Pancreatic Surgery (ISGPS) definition. *Surgery.* 2007;142(1):20-25. PMID: 17629996.
https://doi.org/10.1016/j.surg.2007.02.001

42. Standards and minimum datasets for reporting cancers minimum dataset for the histopathological reporting of pancreatic, ampulla of Vater and bile duct carcinoma. London: The Royal College of Pathologists; 2002;261035.

43. Kakar S, Shi C, Adsay V, Bergsland E, Berlin J, Branton P, Fitzgibbons P, Wendy L. Frankel, Klimstra DS, Krasinskas AM, Mino-Kenudson M, Pawlik T, Vauthey JN, Washington MK. College of American Pathologists, protocol for the examination of specimens from patients with carcinoma of the pancreas. 2017, Version: Pancreas Exocrine 4.0.0.1.

44. Kondo S, Katoh H, Shimizu T, Omi M, Hirano S, Ambo Y, Okushiba S, Morikawa T. Preoperative embolization of the common hepatic artery in preparation for radical pancreatectomy for pancreas body cancer. *Hepatogastroenterology.* 2000;47(35):1447-1449. PMID: 11100373.

45. Abo D, Hasegawa Y, Sakuhara Y, Terae S, Shimizu T, Tha KK, Tanaka E, Hirano S, Kondo S, Shirato H. Feasibility of a dual microcatheter-dual interlocking detachable coil technique in preoperative embolization in preparation for distal pancreatectomy with en bloc celiac axis resection for locally advanced pancreatic body cancer. *J Hepatobiliary Pancreat Sci.* 2012;19:431-437. PMID: 21938409.
https://doi.org/10.1007/s00534-011-0455-9

46. Hirai I, Kimura W, Kamiga M, Mizutani M, Takeshita A, Watanabe T, Fuse A. The significance of intraoperative Doppler ultrasonography in evaluating hepatic arterial flow when assessing the indications for the Appleby procedure for pancreatic body cancer. *J Hepatobiliary Pancreat Surg.* 2005;12(1):55-60. PMID: 15754101.
https://doi.org/10.1007/s00534-004-0939-y

47. Yamagami T, Yoshimatsu R, Kajiwara K, Ishikawa M, Murakami Y, Uemura K, Awai K. Arteriography after embolization before distal pancreatectomy with en bloc celiac axis resection. *Minim Invasive Ther Allied Technol.* 2015;8:1-6. PMID: 25854119.
https://doi.org/10.3109/13645706.2015.1034729

48. Miyakawa S, Horiguchi A, Hanai T, Mizuno K, Ishihara S, Niwamoto N, Iwase Y, Asano Y, Furusawa K, Miura K, Kainuma M. Monitoring hepatic venous hemoglobin oxygen saturtion during Appleby operation for pancreatic cancer. *Hepatogastroenterology.* 2002;49:817-821. PMID: 12063998.

49. Raut V, Takaori K, Kawaguchi Y, Mizumoto M, Kawaguchi M, Koizumi, Kodama S, Kida A, Uemoto S. Laparoscopic common hepatic artery ligation and staging followed by distal pancreatectomy with en blocresection of celiac artery for advanced pancreatic cancer. *Asian J Endosc Surg.* 2011;4(4):199-202. PMID: 22776310.
https://doi.org/10.1111/j.1758-5910.2011.00105.x

50. Trabulsi N, Pelletier JS, Abraham C, Vanounou T. Preoperative Diagnostic Angiogram and Endovascular Aortic Stent Placement for Appleby Resection Candidates: A Novel Surgical Technique in the Management of Locally Advanced Pancreatic Cancer. *HPB Surgery.* 2015;2015:523273. PMID: 26491217.
https://doi.org/10.1155/2015/523273

51. Miura T, Hirano S, Nakamura T, Tanaka E, Shichinohe T, Tsuchikawa T, Kato K, Matsumoto J, Kondo S. A new preoperative prognostic scoring system to predict prognosis in patients with locally advanced pancreatic body cancer who undergo distal pancreatectomy with en bloc celiac axis resection: a retrospective cohort study. *Surgery.* 2014;155:457-467. PMID: 24462074.
https://doi.org/10.1016/j.surg.2013.10.024

52. Shimada K, Sakamoto Y, Sano T, Kosuge. Prognostic factors after distal pancreatectomy with extended lymphadenectomy for invasive pancreatic adenocarcinoma of the body and tail. *Surgery.* 2006;139:288-295. PMID: 16546491.
https://doi.org/10.1016/j.surg.2005.08.004

53. Michels NA. The hepatic, cystic and retroduodenal arteries and their relations to the biliary ducts with samples of the entire celiacal blood supply. *Ann Surg.* 1951;133:503-524. PMID: 14819988.
https://doi.org/10.1097/00000658-195104000-00009

54. Tohma T, Cho A, Okazumi S, Makino H, Shuto K, Mochiduki R, Matsubara K, Gunji H, Ochiai T. Communicating arcade between the right and left hepatic arteries: evaluation with CT and angiography during temporary balloon occlusion of the right or left hepatic artery. *Radiology.* 2005;237:361-365. PMID: 16118153.
https://doi.org/10.1148/radiol.2371040919

55. Gunji H, Cho A, TohmaT, Okazumi S, Makino H, Shuto K, Mochizuki R, Matsubara K, Hayano K, Mori C, Murakami G, Ochiai T. The Blood Supply of the Hilar Bile Duct and Its Relationship to the Communicating Arcade Located Between the Right and Left Hepatic Arteries. *Am J Surg.* 2006;192(3):276-280. PMID: 16920417.
https://doi.org/10.1016/j.amjsurg.2006.01.046

56. Kim HC, Chung JW, Lee W, Jae HJ, Park JH. Recognizing Extrahepatic Collateral Vessels That Supply Hepatocellular Carcinoma to Avoid Complications of Transcatheter Arterial Chemoembolization. *Radiographics.* 2005;25(1):25-39. PMID: 16227494.
https://doi.org/10.1148/rg.25si055508

57. Egorov VI, Petrov RV, Starostina NS, Zhurina YA, Grigorievsky MV. Results of the modified Appleby procedure. *Khirurgiia* (Mosk). 2016;(3):9-17. (In Russ.). PMID: 27070870.
https://doi.org/10.17116/hirurgia201639-17

58. Egorov VI, Kharazov AF, Pavlovskaya AI, Petrov RV, Starostina NS, Kondratiev EV, Filippova EM. Extensive Multiarterial Resection Attending Total Duodenopancreatectomy and Adrenalectomy for MEN-1-associated Neuroendocrine Carcinomas. *World J Gastrointest Surg.* 2012;4(10):238-245. PMID: 23443490.
https://doi.org/10.4240/wjgs.v4.i10.238

59. Jin ZW, Yu HC, Cho BH, Kim HT, Kimura W, Fujimiya M and Murakami G. Fetal Topographical Anatomy of the Pancreatic Head and Duodenum with Special Reference to Courses of the Pancreaticoduodenal Arteries. *Yonsei Med J.* 2010;51(3):398-406. PMID: 20376893.
https://doi.org/10.3349/ymj.2010.51.3.398

60. Ueda A, Sakai N, Yoshitomi H, Furukawa K, Takayashiki T, Kuboki S, Takano S, Suzuki D, Kagawa S, Mishima T, Nakadai E, Miyazaki M, Ohtsuka M. Is hepatic artery coil embolization useful in distal pancreatectomy with en bloc celiac axis resection for locally advanced pancreatic cancer? *World J Surg Oncol.* 2019;17(1):124. PMID: 31315628.
https://doi.org/10.1186/s12957-019-1667-8

61. Egorov VI, Yashina NI, Zhurenkova TV, Petukhova MV, Starostina NS, Zarinskaya SA, Dmitriyeva KA, Shevchenko TV, Petrov RV. Spleen-preserving distal pancreatectomy with resection of the splenic vessels. Should one rely on the short gastric arteries? *JOP.* 2011;12(5):445-457. PMID: 21904069.

62. Kim J, Kim SM, Seo JE, Ha MH, An JY, Choi MG, Lee JH, Bae JM, Kim S, Jeong WK, Sohn TS. Should an Aberrant Left Hepatic Artery Arising from the Left Gastric Artery Be Preserved during Laparoscopic Gastrectomy for Early Gastric Cancer Treatment? *Gastric Cancer.* 2016;16(2):72-77. PMID: 27433391.
https://doi.org/10.5230/jgc.2016.16.2.72

63. Ang RRG, Lee HJ, Bae JS, Zhu CC, Berlth F, Kim TH, Park SH, Suh YS, Kong SH, Kim SH, Yang HK. Safety of Ligation of Aberrant Left Hepatic Artery Originating From Left Gastric Artery in Laparoscopic Gastrectomy for Gastric Cancer. *Sci Rep.* 2020;10(1):5856. PMID: 32246010.
https://doi.org/10.1038/s41598-020-62587-7

64. Koehler RE, Korobkin M, Lewis F. Arteriographic Demonstration of Collateral Arterial Supply to the Liver After Hepatic Artery Ligation. *Radiology.* 1975;117(1):49-54. PMID: 1162072.
https://doi.org/10.1148/117.1.49

65. Reimann B, Lierse W, Schreiber HW. Anastomosen zwisehen Segmentarterien der Leber und phrenico-hepatische arterio-arterielle Anastomosen Langenbecks. *Arch Chir.* 1983;359:81-92.
https://doi.org/10.1007/BF01257255

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