ORIGINAL ARTICLE

Celiaco-Mesenterial Arterial Aberrations in Patients Undergoing Extended Pancreatic Resections: Correlation of CT Angiography with Findings at Surgery

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ABSTRACT

Context It is important to recognize arterial variants in the preoperative planning of extended pancreatic resections. The absence of surgical confirmation of radiological data is a limitation of the majority of angiographic or CT-angiographic studies of celiac and mesenteric arterial anatomy. **Objective** The purpose of this study was to test the accuracy of CT angiography in delineating the arterial architecture by comparing the resultant 3D images with findings at surgery and determining the frequency of different celiac and mesenteric arterial anatomy variants. **Methods** Abdominal CT angiographies of 350 patients were performed on a 64- and 256-MDCT scanner prior to major pancreatic or hepatobiliary surgery. Variants of celiac and mesenteric arterial anatomy were documented as 3D reconstructions. Radiological data were compared to operative photographs during extended pancreaticoduodenectomies and extended distal pancreatectomies in 59 cases. **Results** Only 197 patients (56.3%) had the classic arterial anatomy identified at CT angiography. The most common variants were a replaced or accessory right hepatic artery originating from the superior mesenteric artery (62 cases, 17.7%) and a replaced or accessory left hepatic artery (43 cases, 12.3%) originating from the left gastric artery. According to a comparison with operative photographs, CT angiography demonstrated 100% accuracy in identifying celiac and mesenteric arterial anatomy variants, stenoses, obstructions and aneurysms of the celiac and mesenteric branches, including those which were hemodynamically significant and which influence the choice and sequence of operative procedures. **Conclusion** The celiac and mesenteric arterial anatomy variants are fairly common and are of great significance in planning extended pancreatic resections. Radiological findings were fully corroborated by operative data, which means that CT angiography is a reliable tool for identifying celiac and mesenteric arterial anatomy aberrations and arterial lesions.

INTRODUCTION

According to the classic anatomic study of Michels [1], extensive angiographic, transplantation and CT angiography data [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18] of celiaco-mesenteric arterial aberrations were described in 22-48% of observations. The preoperative knowledge of variant celiaco-mesenteric arterial anatomy is of great value in planning extended pancreatic and multiorgan resections, and the importance of such awareness is conditioned by the necessity of wide periaortic and periarterial dissection and extensive vessel skeletonization during extended pancreaticoduodenectomy and extended distal pancreatectomy. This knowledge also facilitates upper abdominal surgery and helps avoid iatrogenic injury when the organ relationship is changed, visualization is limited or when the organs are too susceptible to ischemia, even if temporary [19, 20, 21, 22, 23, 24, 25, 26]. Modern MDCT enables a rapid acquisition of thin-slice high-resolution images of abdominal arteries during the phase of maximal contrast enhancement. Data processing during a routine CT examination allows 3D reconstructions to be immediately created, providing the surgeon with a 3D model of the patient's arterial anatomy [18, 27, 28, 29, 30]. In this study, the capability of CT angiography to identify celiac and mesenteric arterial anatomy aberrations were analyzed by comparing the CT angiograms with the pictures of the operative field.

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Key words Angiography; Celiac Artery; Hepatic Artery; Mesenteric Arteries; Pancreatectomy; Pancreaticoduodenectomy; Tomography; Spiral Computed

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MATERIALS AND METHODS

CT Angiography

In order to pre-surgically estimate individual vascular trees, 3D reformations of axial MDCT scans in the arterial phase of bolus contrast enhancement were used. A bolus of 100 mL of a contrast medium (350 mg/mL of iodine) followed by 50 mL of saline solution was administered into the antecubital vein by the power injector. The arterial MDCT acquisition phase starts in the 10^{th} second after achieving 150 HU threshold attenuation of the abdominal aorta.

A CT angiography database from July 2008 to February 2010 included 378 consecutive CT angiograms of 350 patients, all of whom were examined on 64- and 256-MDCT scanners (Brillians-64® and Brillians iCT®, Philips, Cleveland, OH, USA) for pancreatic or hepatobiliary malignant and non-malignant conditions. Each patient was included only once in the study. CT was performed to establish the diagnosis, determine tumor resectability in case of malignancy and to aid surgical planning. Three-dimensional reconstructions of CT angiograms were received using the software involved during a routine CT examination. All the CT angiographic images were read by the attending surgeon, and the variants of celiac and mesenteric arterial anatomy were recorded according to Michels' [1] and Hiatt's [10] criteria.

Procedure

A standard pancreaticoduodenectomy includes the removal of lymph nodes of the anterior and posterior pancreatoduodenal, pyloric, hepatoduodenal ligament, and superior and inferior pancreatic head and body lymph node stations.

An extended pancreaticoduodenectomy in our institution consists of the additional removal of all the lymph nodes from the hepatic hilum, along the aorta from the diaphragmatic hiatus to the inferior mesenteric artery and laterally to both the renal hila, clearance of the circumference of the origin of the celiac trunk and the superior mesenteric artery with total resection of the nerve plexus around the superior mesenteric artery and portal vein. The procedure includes removal of perivascular lymphatics and nerves and retroperitoneal connective tissue.

An extended distal pancreatectomy, which we usually perform "from the right to the left", consists of removal of the spleen, pancreatic neck, body and tail with the splenic vessels, all the lymph nodes from the hepatic hilum, along the aorta from the diaphragmatic hiatus to the inferior mesenteric artery, clearance of the circumference of the origin of the celiac trunk and the superior mesenteric artery with the resection of the nerve plexus to the left and to the right of the superior mesenteric artery. The procedure includes removal of perivascular lymphatics and nerves and retroperitoneal connective tissue. If malignancy is suspected during frozen section examination of the posterior border of the specimen, a left adrenalectomy with periglandular tissue is performed.

Over the same period of time, 59 patients with pancreatic neoplasms underwent extended pancreatico-duodenectomy, extended distal pancreatectomy or multi-organ resections for pancreatic ductal adeno-carcinoma (53 patients), intraductal papillary mucinous carcinoma (3 patients) and endocrine carcinoma (3 patients). After finishing the vessel dissection, operative fields were photographed and compared to CT angiogram at a later stage. Assessing and comparing the data, we regarded such a pattern as a "trifurcation" (division of the common hepatic artery into gastroduodenal, right and left hepatic arteries) and some other types not included in Michels' classification, such as a subtype of the classic anatomy.

ETHICS

Our institutional review board approved this prospective review and special patient informed consent, other than standard consent for the operation, was not required.

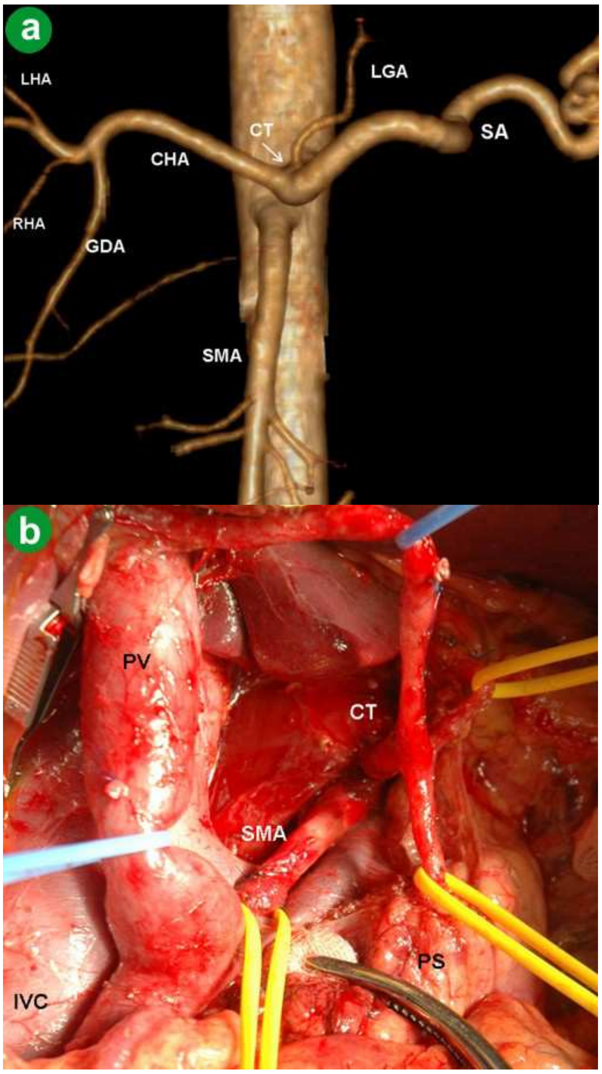

Figure 1. Michels' type I (classic) celiaco-mesenterial anatomy in a 47-year-old man with neuroendocrine carcinoma of the pancreatic head. **a.** 3D CT angiographic image after the removal of the renal artery image. **b.** View of the operating field after the extended pancreaticoduodenectomy.

CHA: common hepatic artery; CT: celiac trunk; GDA: gastroduodenal artery; IVC: inferior vena cava; LGA: left gastric artery; LHA: left hepatic artery; PS: pancreatic stump; PV: portal vein; RHA: right hepatic artery; SA: splenic artery; SMA: superior mesenteric artery

STATISTICS

Descriptive statistics were applied: absolute and relative frequencies.

RESULTS

All CT angiographic studies were considered to be of diagnostic quality. One hundred and ninety-seven out of the 350 patients (56.3%) had the classic arterial anatomy identified at CT angiography (Figure 1). The most common variant identified was a replaced right hepatic artery originating from the superior mesenteric artery, seen in 49 patients (14.0%) (Figure 2). The second most common variant was an accessory left hepatic artery originating from the left gastric artery, seen in 23 patients (6.6%). One hundred and thirty-one patients (37.4%) had a single arterial aberration, and 22 patients (6.3%) showed more than one arterial variant (Figure 3). Variations in the origin of the common hepatic artery were seen in 18 patients (5.1%): the common hepatic artery originated from the superior mesenteric artery in 9 patients (2.6%) (Figure 4) and the common hepatic artery originated from the abdominal aorta in 9 patients (2.6%) (Figure 5). An accessory right hepatic artery, originating from the celiac axis or the superior mesenteric artery was seen in 13 patients (3.7%) and originating from the aorta in one patient (0.3%). A left gastric artery originating from the aorta was identified in 3 patients (0.9%) and a

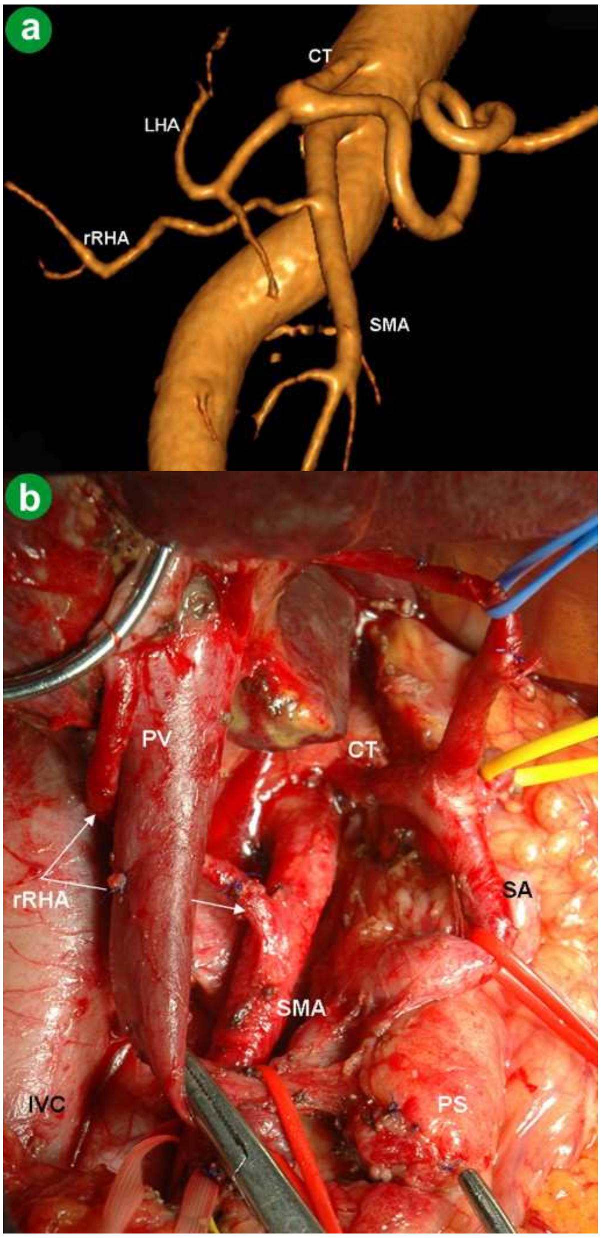

Figure 2. Michels' type III anatomy in a 75-year-old woman with pancreatic head adenocarcinoma. Replaced right hepatic artery (rRHA) originating from the superior mesenteric artery (SMA). **a.** 3D CT angiographic image after the removal of the renal artery image. **b.** View of the operating field after extended pancreaticoduodenectomy.
CT: celiac trunk; IVC: inferior vena cava; LHA: left hepatic arteries; PV: portal vein; PS: pancreatic stump; SA: splenic artery

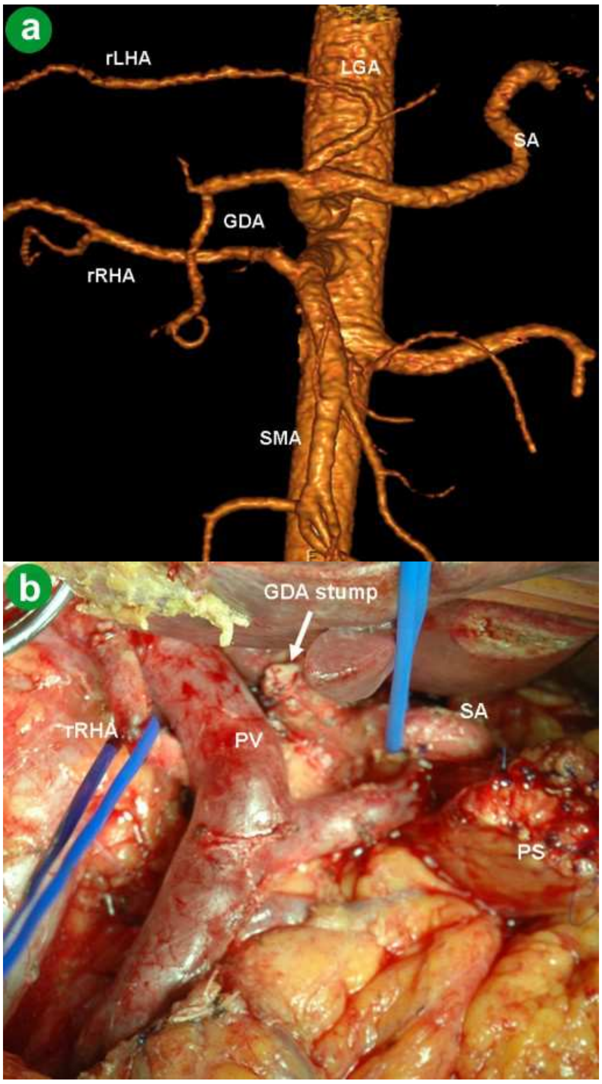

Figure 3. Michels' type IV anatomy in a 53-year-old woman with pancreatic head and body cystadenocarcinoma. Replaced right hepatic artery (rRHA) originating from the superior mesenteric artery (SMA) and replaced left hepatic artery (rLHA) originating from the left gastric artery (LGA). **a.** 3D CT angiographic image after the removal of the renal artery image. **b.** View of the operating field after pancreaticoduodenectomy and pancreatic body resection.
GDA: gastroduodenal artery; PS: pancreatic stump; PV: portal vein; SA: splenic artery

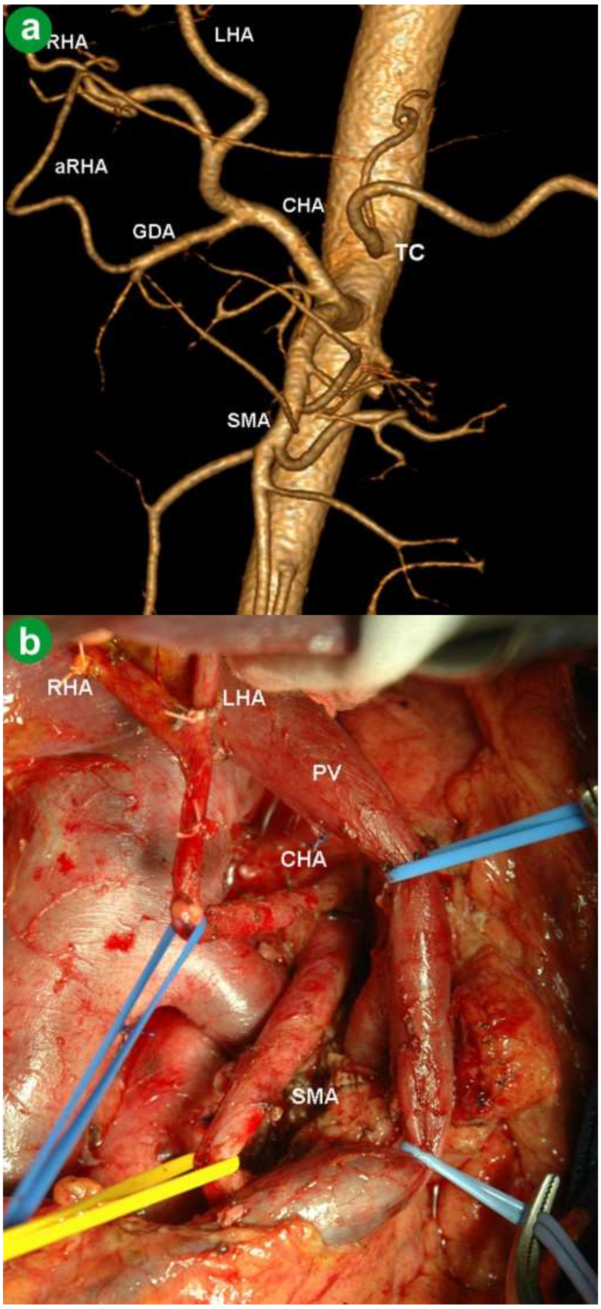

Figure 4. Michels' type IX (Hiatt's type V) anatomy in a 56-year-old man with pancreatic head adenocarcinoma. Replaced common hepatic artery (CHA) arising from the superior mesenteric artery (SMA). **a.** 3D CT angiographic image after the removal of the renal artery image. **b.** View of the operating field after extended pancreaticoduodenectomy.
aRHA: accessory right hepatic artery; CT: celiac trunk; GDA: gastroduodenal artery; LHA: left hepatic artery; PS: pancreatic stump; PV: portal vein; RHA: right hepatic artery; SA: splenic artery

left hepatic artery originating from the aorta was seen in one patient (0.3%). Different combinations of accessory hepatic arteries were identified in 45 patients (12.9%) (Figure 6). The frequencies of the different types of arterial variants identified are reported and compared with the data of other studies in Tables 1 and 2.
An example describing the importance of preoperative knowledge of the arterial architecture is shown in Figures 6 and 7; in a typical operative situation, after skeletonization of the hepatoduodenal ligament, the surgeon often finds a large artery to the right of the portal vein (Figure 6) and usually he or she has no idea what it is, where it comes from and where it is going. As is seen from the CT angiography in Figure7 which corresponds to the operative pictures, the origin and destination of these arteries are very different.
Celiac axis compression syndrome in 7 cases (2.0%) and atherosclerotic stenoses and obstructions of celiac and mesenteric arteries in 19 cases (5.4%) were indentified on CT angiography. Only one situation was clinically meaningful and required celiac trunk stenting (Figure 8) before a distal pancreatectomy. Five patients (1.4%) with non-malignant pancreatic lesions and 8 patients (2.3%) with miscellaneous liver diseases associated with celiac and mesenterial artery stenoses were operated on without additional procedures on the visceral arteries.
Aneurysms of celiac and mesenteric arterial branches were seen in 11 cases (3.1%). All the lesions except

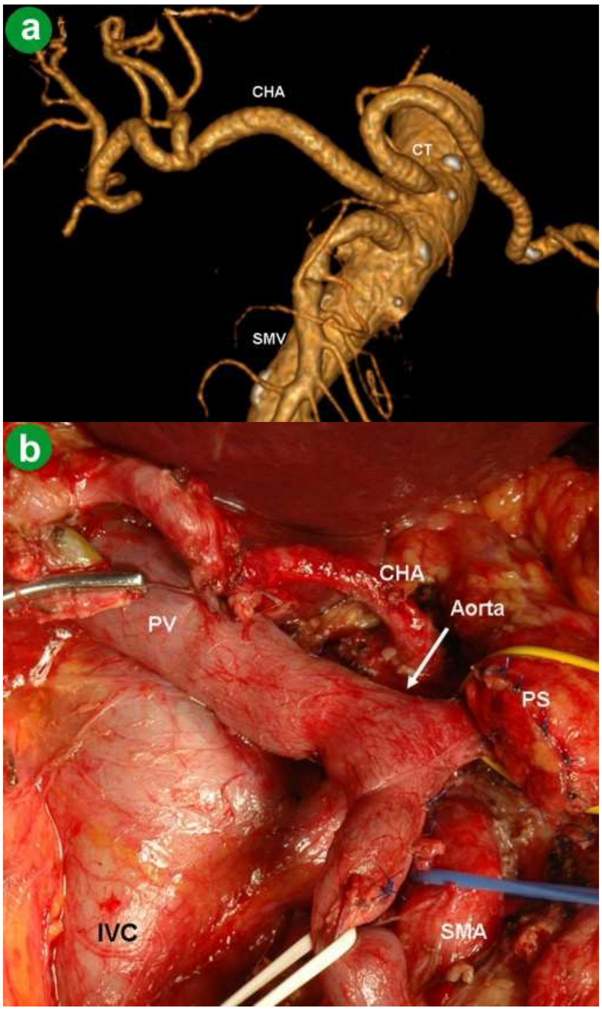

Figure 5. Unclassified by Michels, Hiatt's type X anatomy in a 63-year-old man with pancreatic head adenocarcinoma. Replaced common hepatic artery (CHA) arising from the aorta. **a.** 3D CT angiographic image after the removal of the renal artery image. **b.** View of the operating field after pancreaticoduodenectomy.
CT: celiac trunk; IVC: inferior vena cava; PS: pancreatic stump; PV: portal vein; SMA: superior mesenteric artery

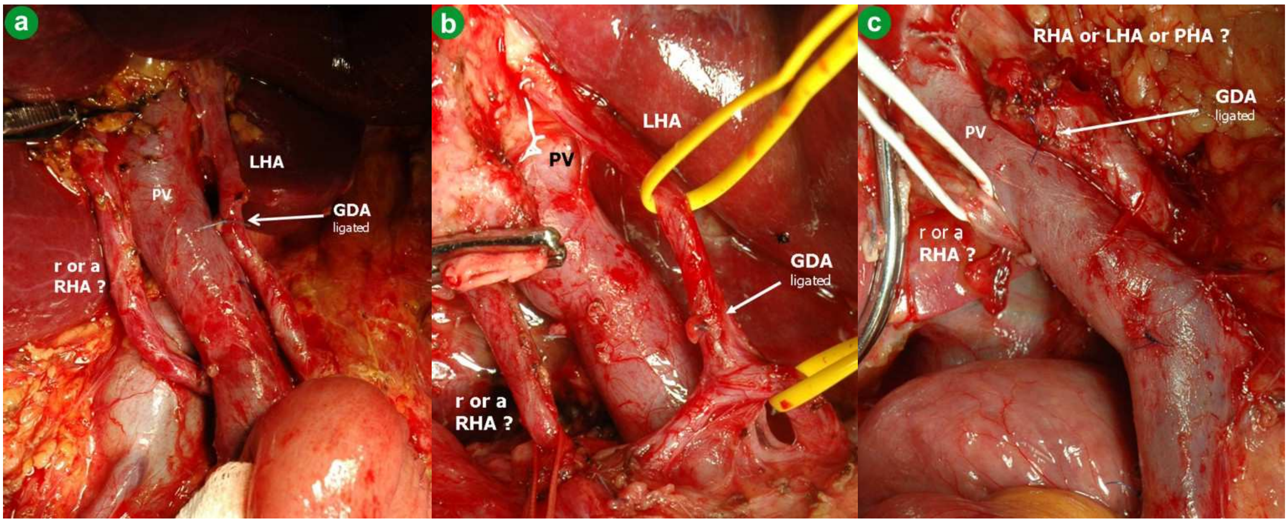

Figure 6. Views of the operating fields after the skeletonization of the hepatoduodenal ligament during pancreaticoduodenectomy. The surgeon discovers a large artery to the right of the portal vein which has a different origin in all three cases.
aRHA: accessory right hepatic artery; GDA: gastroduodenal artery; LHA: left hepatic artery; PHA: proper hepatic artery; PV: portal vein; RHA: right hepatic artery; rRHA: replaced right hepatic artery

Table 1. Hepatic arterial types in our study revealed by CT angiography and surgery according to Michels' classification (1955) [1].

Description by Michels	Michels (No. 200)	Our data	
		CT angiography (No. 350)	Operative data (No. 59)
1 Classic (normal)	110 (55.0%)	197 (56.3%)	36 (61.0%)
2 Replaced left hepatic artery from the left gastric artery	20 (10.0%)	16 (4.6%)	0
3 Replaced right hepatic artery from the superior mesenteric artery	22 (11.0%)	49 (14.0%)	7 (11.9%)
4 Replaced right hepatic artery + left hepatic artery	2 (1.0%)	5 (1.4%)	2 (3.4%)
5 Accessory left hepatic artery	16 (8.0%)	27 (7.7%)	3 (5.1%)
6 Accessory right hepatic artery	14 (7.0%)	13 (3.7%)	3 (5.1%)
7 Accessory right hepatic artery + left hepatic artery	2 (1.0%)	5 (1.4%)	2 (3.4%)
8 Replaced right plus accessory left hepatic arteries or replaced left plus accessory right hepatic arteries	4 (2.0%)	14 (4.0%)	2 (3.4%)
9 Common hepatic artery from superior mesenteric artery	9 (4.5%)	9 (2.6%)	3 (5.1%)
10 Common hepatic artery from left gastric artery	1 (0.5%)	0	0
- Other variants	-	15 (4.3%)	1 (1.7%)

Table 2. Hepatic arterial types according to Hiatt's classification (1994) [10].

Study, year	No. of cases	Hepatic arterial types					
		1 Classic	2 Replaced or accessory LHA	3 Replaced or accessory RHA	4 Replaced or accessory RHA plus replaced or accessory LHA	5 Common hepatic artery from superior mesenteric artery	6 Common hepatic artery from aorta
Nebesar R. 1966 [2]	300	166 (55.3%)	54 (18.0%)	48 (16.0%)	0	24 (8.0%)	8 (2.7%)
Suzuki T. 1972 [3]	200	116 (58.0%)	25 (12.5%)	15 (7.5%)	9 (4.5%)	6 (3.0%)	29 (14.5%) [b]
Daly J. 1980 [4]	200	140 (70.0%)	15 (7.5%)	23 (11.5%)	0	0	22 (11.0%) [b]
Rygaard H. 1986 [5]	216	163 (75.5%)	10 (4.6%)	29 (13.4%)	4 (1.9%)	3 (1.4%)	7 (3.2%)
Kemeny M. 1986 [6]	100	59 (59.0%)	17 (17.0%)	18 (18.0%)	2 (2.0%)	3 (3.0%)	1 (1.0%)
Rong G. 1987 [7]	120	64 (53.3%)	14 (11.7%)	25 (20.8%)	0	6 (5.0%)	11 (9.2%) [b]
Niederhuber J 1987 [8]	111	80 (72.1%)	11 (9.9%)	12 (10.8%)	2 (1.8%)	0	6 (5.4%) [b]
Curley S. 1992 [9]	180	130 (72.2%)	25 (13.9%)	23 (12.8%)	2 (1.1%)	0	0
Hiatt J. 1994 [10]	1,000	757 (75.7%)	97 (9.7%)	106 (10.6%)	23 (2.3%)	15 (1.5%)	2 (0.2%)
Burke D. 1995 [11]	74	63 (85.1%)	5 (6.8%)	6 (8.1%)	0	0	0
Santis M. 2000 [12]	150	78 (52.0%)	16 (10.7%)	26 (17.3%)	2 (1.3%)	6 (4.0%)	22 (14.7%) [b]
Covey A. 2002 [13]	600	368 (61.3%)	87 (14.5%)	61 (10.2%)	27 (4.5%)	12 (2.0%)	45 (7.5%) [b]
Allen P. 2002 [14]	265	167 (63.0%)	37 (14.0%)	19 (7.2%)	8 (3.0%)	0	34 (12.8%) [b]
Koops A. 2004 [15]	604	478 (79.1%)	18 (3.0%)	72 (11.9%)	8 (1.3%)	17 (2.8%)	11 (1.8%)
Balakhnin P. 2004 [16]	1,511	1,012 (67.0%)	148 (9.8%)	138 (9.1%)	59 (3.9%)	23 (1.5%)	131 (8.7%) [b]
Lopez-Andujar R. 2007 [17]	1,081	761 (70.4%)	147 (13.6%)	91 (8.4%)	47 (4.3%)	27 (2.5%)	8 (0.7%)
Winston C. 2007 [18] [a]	371	251 (67.7%)	45 (12.1%)	59 (15.9%)	0	8 (2.2%)	8 (2.2%)
Our data, 2010 [a]	350	197 (56.3%)	43 (12.3%)	62 (17.7%)	14 (4.0%)	9 (2.6%)	25 (7.1%) [b]
Total	**7,433**	**5,050 (67.9%)**	**814 (11.0%)**	**833 (11.2%)**	**207 (2.8%)**	**159 (2.1%)**	**370 (5.0%) [b]**

LHA: left hepatic artery; RHA: right hepatic artery
[a] CT angiography,
[b] In these cases, the variants unclassified by Hiatt were also included in type 6.

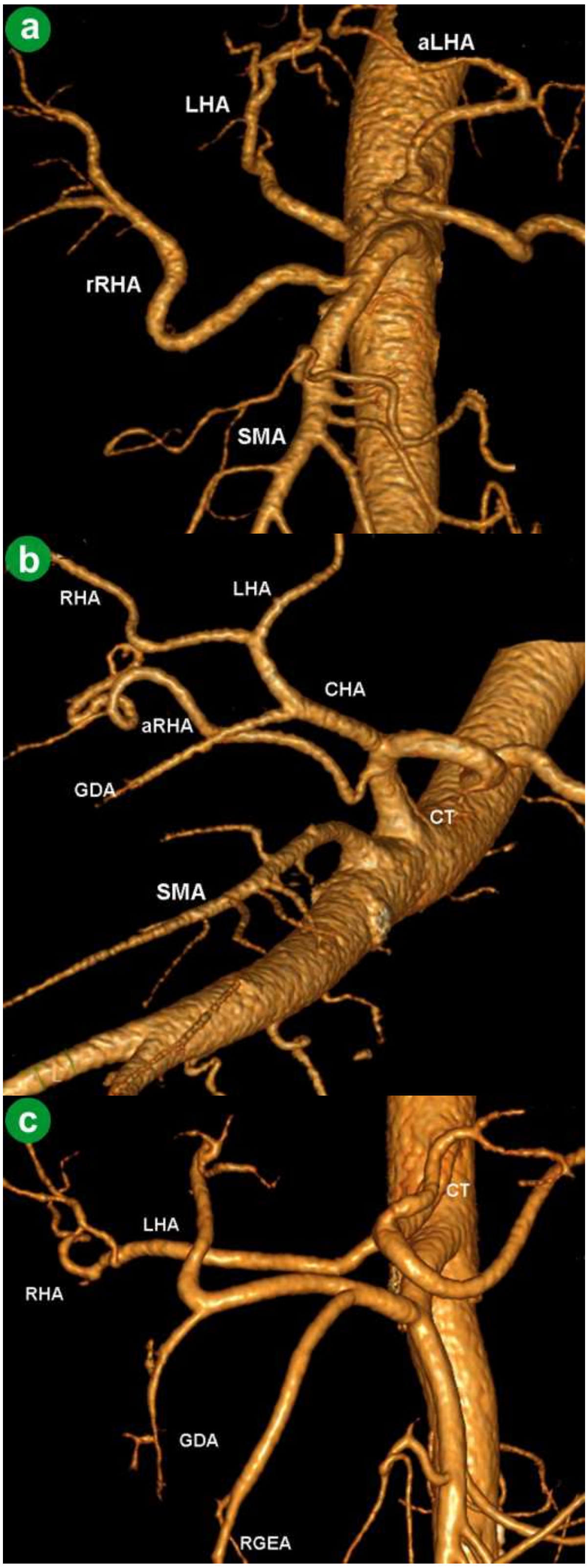

Figure 7. 3D CT angiographic image after the removal of the renal artery image. **a.** Michels' type VIII anatomy in a 47-year-old man with pancreatic head adenocarcinoma. Replaced right hepatic artery (rRHA) originating from the superior mesenteric artery (SMA) and accessory left hepatic artery (aLHA) originating from the left gastric artery. **b.** Michels' type VII anatomy in a 63-year-old woman with pancreatic head adenocarcinoma. Accessory right hepatic artery (aRHA) originating from the celiac trunk. **c.** Michels' type IV anatomy. Right hepatic artery (RHA) originating from the celiac trunk (CT) and replaced left hepatic artery (LHA) originating from the superior mesenteric artery (SMA).
CHA: common hepatic artery; GDA: gastroduodenal artery, RGEA: right gastro-epiploic artery; RHA: right hepatic artery

one (Figure 9) were associated with chronic pancreatitis, confirmed at surgery or angiography, and treated by embolization or surgically.

All operative pictures were considered descriptive. Thirty-six (61.0%) out of the 59 patients who underwent an extended pancreaticoduodenectomy or extended distal pancreatectomy had a classic celiaco-mesenteric anatomy. A replaced right hepatic artery originating from the superior mesenteric artery was seen in 7 (11.9%) patients. An accessory left hepatic artery originating from the left gastric artery, an accessory right hepatic artery originating from the celiac trunk or superior mesenteric artery and a common hepatic artery originating from the superior mesenteric artery (hepatomesenteric trunk) were encountered in 3 separate patients (5.1% each). Four patients (6.8%) had two arterial variants identified. Finally, in one case (1.7%), the left gastric and, in two cases (3.4%), the common hepatic artery originated from the aorta. We did not encounter an isolated replaced left hepatic artery in the surgical series. The frequencies of the arterial variant types identified are shown in Table 1.

According to a comparison of operative photographs and 3D CT angiography reconstructions, CT angiography demonstrated 100% accuracy in identifying celiaco-mesenterial anatomy variants.

In 3 cases of hepatomesenteric trunk and in 7 cases of a replaced right hepatic artery in the operative series, there were no cases of arterial involvement by a tumor. In two patients who were not operated on, CT angiography showed the hepatomesenteric trunks to be encircled by a tumor on a background of liver metastases. Other cases of these aberrations found on CT angiography were in patients with liver and non-malignant pancreatic lesions.

DISCUSSION

In different fields of surgery, knowledge of celiac and mesenteric arterial variants is of great significance [19, 20, 21]. During a standard pancreaticoduodenectomy, arterial anomalies can increase the operative complexity and invention of extended procedures demanding wide tissue dissection around the aorta and its visceral branches revealed that awareness of the celiac and mesenteric arterial anatomy is vitally important [22, 23, 24, 25, 26].

Michels' classification of 1955, based on an autoptic series of 200 dissections [1], as well as Hiatt's classification of 1994, based on 1,000 transplantations [10], are in general use in our institution for the description of celiac and mesenterial architecture. Because "*… no two arterial vascularization patterns of any of the organs above the transverse colon are ever the same …*" [1], Michels' and Hiatt's motivation was to "*… maximize the database of the surgeon performing procedures in and around the porta hepatis, to avoid injury to vascular and ductal structures …*" [10]. But this vast database cannot be used in each specific case exactly because of its size: "*… It is obvious that no one mind can possibly* *remember all of the arterial variations that have been encountered in any given extensive investigation …*" [1].

The current CT angiographic series (Table 1) shows almost the same incidence of variant patterns as was shown by Michels, except for a two-fold difference in the incidence between the accessorial left and the right hepatic arteries. We did not distinguish the common hepatic artery from the left gastric artery (Michels' type 10); we distinguished the common hepatic artery from the aorta which was not described by Michels fairly often (9 cases, 2.6%). As compared to our results, more normal scheme patterns were revealed in the CT angiographic series published in 2007 by Winston *et al.*, and no "doubled" aberrations were observed in that study [18].

Multidetector CT angiography is an effective tool not only for predicting tumor resectability [27, 28] but also for creating precise 3D reconstructions of the abdominal arteries during a routine CT examination in each specific case. It not only clearly delineates the course of the aberrant vessels, but also reveals the arterial stenoses and occlusions which may be critical if undiagnosed or if diagnosed during or after surgery

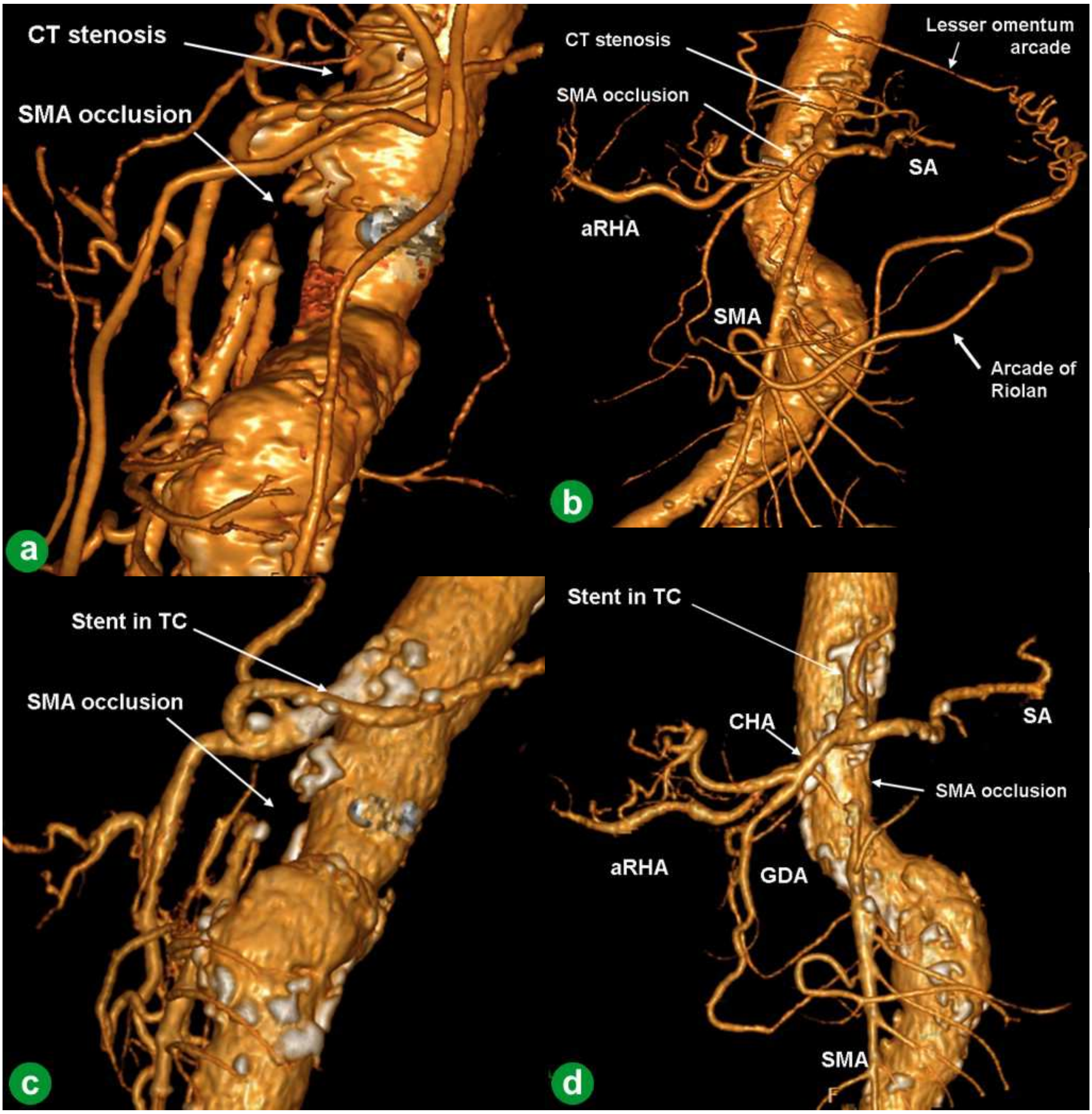

Figure 8. 3D CT angiographic image after the removal of the renal artery image in a 64-year-old woman with chronic pancreatitis and suspected pancreatic head adenocarcinoma. **a.** Celiac trunk (CT) stenosis and superior mesenteric artery (SMA) occlusion **b.** Upper abdomen blood supply from the minor pelvis through the arcade of Riolan. In the case of inadvertent damage of this arcade during abdominal surgery, notable intestinal necrosis is possible which necessitates celiac trunk stenting as a first stage procedure. **c. d.** Changes in functioning arterial collaterals after celiac trunk stenting. Arcade of Riolan is not defined and powerful hepatic arteries are visible.

aRHA: accessory right hepatic artery; CHA: common hepatic artery; GDA: gastroduodenal artery; SA: splenic artery

[31, 32, 33, 34, 35, 36, 37, 38]. Knowledge of the vascular anatomy is of great value because the organ relationship is usually changed and direct visualization of the surgical field is often limited in patients with large pancreatic tumors, in "border-line resectable" cases, in obesity, prominent local inflammation after biliary stenting and dense adhesions after prior surgery [19, 20, 21, 22, 23, 24, 25, 26]. Preoperative knowledge of variant arterial anatomy may obviate extensive dissection to identify the vessels and avert vascular damage [22] or, *vice versa*, allows the surgeon to excise vessels infiltrated by a tumor knowing in advance that it is accessorial, thus avoiding an erroneous judgment about tumor unresectability [23].

The policy of our institution is not to operate on pancreatic cancer cases involving the arteries, except for the indications regarding the modified Appleby procedure. And then, we usually detect arterial involvement before surgery using CT and endoscopic ultrasound. Our thinking on the subject of local involvement of only the hepatomesenteric trunk or replaced right hepatic artery from the superior mesenteric artery by pancreatic cancer is "to resect and repair" if it is not the site of origin from the superior mesenteric artery, but we did not encounter cases of isolated involvement of these arteries.

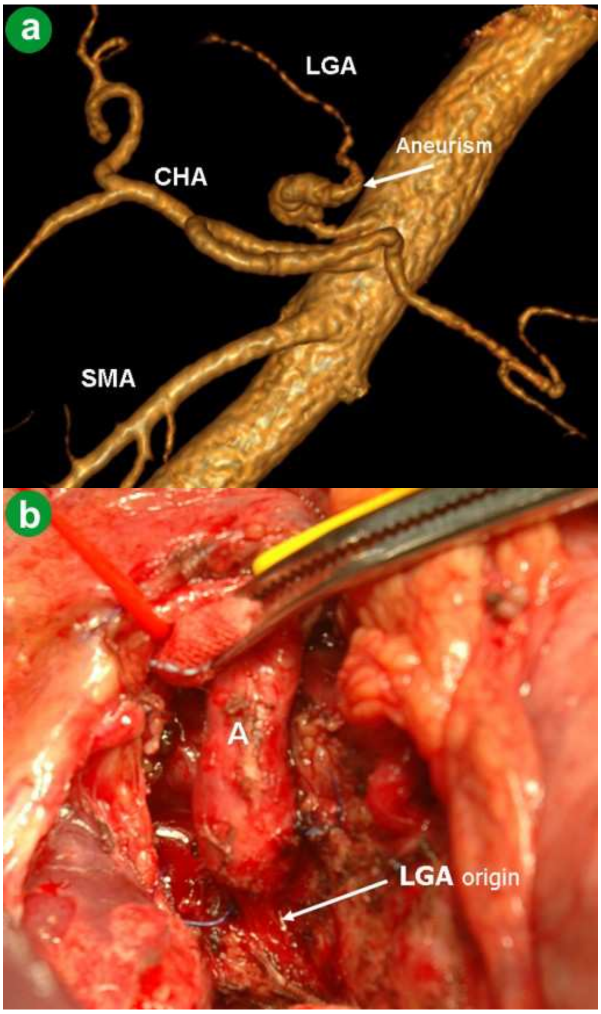

Figure 9. 3D CT angiographic image after the removal of the renal artery image in a 39-year-old man with pancreatic head adenocarcinoma. **a.** Left gastric artery (LGA) originating from the aorta with the aneurysm in its proximal part. **b.** View of the operating field during pancreaticoduodenectomy. The aneurysm was dissected away from the surrounding tissue and excised with the trunk of the left gastric artery.

A: aneurysm; CHA: common hepatic artery; SMA: superior mesenteric artery

The most common variation in the hepatic arterial anatomy is the presence of a replaced right hepatic artery originating from the superior mesenteric artery. This has been reported to occur in 11-21% of patients [39]. In our series, the hepatomesenteric trunk and replaced right hepatic artery (10 cases) passed laterally behind the portal vein and behind or above the pancreatic head and entered the hepatoduodenal ligament posterolaterally to the bile duct. However, there have been reports of such vessels traveling behind or through the head of the pancreas in which case they are susceptible to damage [22, 40]. A replaced hepatomesenteric trunk and right hepatic artery should be recognized and preserved. Typically, we encircled the root of the superior mesenteric artery after an extensive Kocher's maneuver. However, based on the experience presented in this series, it does not help much in preventing the hepatomesenteric trunk or replaced right hepatic artery going above or behind the pancreatic head from an inadvertent injury, especially in the case of a large tumor. Since the origin of the hepatomesenteric trunk or replaced right hepatic artery is not close to the aorta where the superior mesenteric artery usually taped, you cannot keep these arteries in direct vision between the right side of the portal vein and superior mesenteric artery until after the uncinate process is in place. In our opinion, the most reliable technique, which we use as a standard, is the following: detection of the artery to the right of the portal vein and, after transection of all organs including the pancreatic neck, disclosure of the superior mesenteric artery behind the superior mesenteric vein, and meticulous detachment of the uncinate process ligament from the right surface of the superior mesenteric artery. In so doing, there is no chance of missing the origin of the hepatomesenteric trunk or replaced right hepatic artery or to accidentally injure their branches to the pancreas. After the origin of the aberrant vessel is detected, it is much easier to free the vessel from the surrounding tissue. Yet, irrespective of the technique used, whether the vascular architecture is discovered preoperatively, knowledge of the arterial anatomy helps in dealing with the aberrant vessel.

There were no arterial injuries during surgery in this series. It is hard to say whether or not it was due to the 3D CT angiography, as we are only now able to compare this series with the previous one of standard Whipple procedures retrospectively. However, 3D CT angiography makes the surgeon more confident when working in the perivascular and periaortal spaces.

The absence of visual surgical confirmation of radiological data is a limitation of the majority of standard or CT angiographic studies of the celiac and mesenteric arterial anatomy. A comparison of the operative and radiological pictures presented in our series shows that CT angiography is absolutely reliable for identifying arterial variants and arterial lesions while planning and performing extended pancreatic or other complex surgery in the upper abdomen.

Conflict of interest The authors have no potential conflict of interest

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