Surgical and Radiologic Anatomy (2019) 41:745–753
https://doi.org/10.1007/s00276-019-02214-x

ORIGINAL ARTICLE

Visualization of the fat planes between the pancreas and the adjacent organs and blood vessels using multi-detector computed tomography

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Received: 3 January 2019 / Accepted: 5 March 2019 / Published online: 13 March 2019

Abstract

Purpose To explore individual variations in visibility of the fat planes between the pancreatic parenchyma and adjacent organs and blood vessels using the multi-detector-computed tomography (MDCT).

Methods Abdominal contrast-enhanced MDCT examinations of 520 consecutive adult individuals were retrospectively analysed by exploring the presence of visible fat planes between the healthy pancreas and the following surrounding structures: stomach, descending duodenum (D2), splenic, portal, superior mesenteric vein (SV, PV, SMV), inferior vena cava (IVC), and coeliac trunk, common hepatic and superior mesenteric artery (CT, HA and SMA). Spearman's rank correlation coefficient (r_S) was used to assess the correlation of individual gender, age, body mass and BMI, and visible fat planes towards particular surrounding structures.

Results Fat planes between the pancreatic parenchyma and surrounding structures was visible as follows: stomach in 76%, D2 11.7%, SV 51.5%, PV 0%, SMV 28.8%, IVC 80.8%, CT 99.4%, HA 90.4% and SMA in 100% participants. The presence of visible fat planes significantly correlated ($p < 0.001$) with body mass for stomach ($r_S = 0.367$), D2 ($r_S = 0.247$), SV ($r_S = 0.355$), SMV ($r_S = 0.384$) and IVC ($r_S = 0.259$); BMI for stomach ($r_S = 0.292$), SV ($r_S = 0.248$), SMV ($r_S = 0.290$) and IVC ($r_S = 0.216$); age for D2 ($r_S = 0.363$), SV ($r_S = 0.276$) and SMV ($r_S = 0.409$); and male gender for stomach ($r_S = 0.160$) and SV ($r_S = 0.198$).

Conclusion Fat planes around the pancreatic parenchyma in the MDCT scan was almost always visible towards the adjacent magistral visceral arteries and IVC, always invisible towards the PV, and variably visible towards the SV, SMV, stomach and duodenum depending on the individual body mass, BMI, age and gender.

Keywords Pancreas · Anatomy · Fat planes · Multi-detector computed tomography · Cross-sectional imaging

Introduction

Pancreas is an organ located deep in the abdominal cavity, in front of the first and second lumbar vertebral bodies, so visualization of pancreas became possible only when cross-sectional imaging methods (ultrasonography, computed tomography and magnetic resonance imaging) were introduced into clinical practice. Since then, it has been observed that significant individual variations existed in the size and appearance of normal pancreas [7, 10–14, 16, 17, 19, 22]. Many studies in literature have described and analysed pathological changes of the pancreas using computed tomography (CT), but only a small number of studies addressing the normal pancreatic anatomy have been published [7, 10–14, 16, 17, 19, 22].

Pancreatic cancer and pancreatitis, the most common pathological conditions affecting this organ, almost always involve peripancreatic adipose tissue, which surrounds pancreas and separates it from the neighbouring organs and blood vessels [1, 5, 15, 18, 21, 23, 24]. Accordingly, we supposed that it is important to thoroughly explore normal

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cross-sectional anatomy of the pancreas, especially the relationships with the surrounding anatomic structures, organs and blood vessels [5, 12, 18, 24]. Typical appearance of the cross-sectional anatomy of the pancreas and the surrounding structures has been described in some referent books [14, 22]. Browsing through literature, we could not find studies investigating the inter-individual variability in visualization of the fat planes, which demarcates healthy pancreas from the adjacent blood vessels and organs by using CT. The aim of this study was to explore the normal cross-sectional anatomy of the pancreas by using MDCT, with an emphasis on the visibility of the fat planes between the pancreas parenchyma and adjacent organs (stomach and duodenum), and magistral blood vessels surrounding the pancreas (portal vein, splenic vein, superior mesenteric vein and artery, coeliac trunk, hepatic artery and inferior vena cava).

Materials and methods

Participants

This retrospective study was approved by the institutional review board, and an individual informed consent was waived. Contrast-enhanced (CE) MDCT examinations of the abdominal region were retrospectively analysed in 520 consecutive patients. Inclusion criteria were as follows: adult age (> 18 years-old) and CE-MDCT examination of the abdomen. Exclusion criteria were the following: any pathological change of the pancreas or in the peripancreatic region, insufficient post-contrast phase (absence of the arterial or portal venous phase), and motion, respiratory or those metal artefacts deteriorating the quality of images. The gender, age, height, body mass and body mass index (BMI) of every participant were recorded.

MDCT examination

CT examinations were performed with a 64-multi-detector row scanner (64-MDCT Aquilion, Toshiba), using helical mode, 0.5 mm section thickness, 120 kV tube voltage, 120–750 mAs in tube current modulation mode, 0.5 s rotation time, 26.5 mm/s table speed, 32-cm scan field of view, 1-mm and 5-mm reconstructed sections. Abdominal scanning was performed after the intravenous administration of 60–150 ml of non-ionic iodinated contrast medium (iopamidol 370 mg/ml of iodine, 1–1.5 ml of contrast/BMkg), which was injected using an automatic injector, at a flow rate of 3.5 ml/s followed by 30 ml of saline at the same flow rate, in the late arterial (LA) (i. e. pancreas parenchymal) and portal venous (PV) phase, performed with a scan delay of 30 s and 60 s, respectively. Immediately before the CT, the patients, candidates for scanning, were asked to drink 400 ml of water to distend the stomach.

Image analysis

CT scans were analysed by one of two junior readers: D. S., fourth-year radiology resident (150 CT examinations) or N. G., first-year radiology resident (370 CT examinations), in consensus with the senior radiologist (A. Dj-S., with 18-year experience in abdominal radiology). The presence of the fat planes between the pancreatic parenchyma and the following surrounding structures was explored in a series of axial 1-mm-reconstructed-thickness-section images in LA phase for arteries and PV phase for veins, stomach and duodenum, as follows:

1. Body of pancreas and posterior wall of the stomach (Fig. 1a, b).
2. Head of the pancreas and medial wall of the descending duodenum (D2) (Figs. 2a, b, 3a, b).
3. Body of the pancreas and splenic vein (SV) (Fig. 1a, b).
4. Neck/head of the pancreas and portal vein (PV) (Fig. 4a, b).
5. Head of the pancreas (uncinate process) and the superior mesenteric vein (SMV) (Figs. 2a, b, 3a).
6. Head of the pancreas (uncinate process) and the superior mesenteric artery (SMA) (Figs. 2a, 3a).
7. Body of the pancreas and the coeliac trunk (CT) (Fig. 5a).
8. Body of the pancreas and the common hepatic artery (HA) (Fig. 5b, c).
9. Head of the pancreas and the inferior vena cava (IVC) (Figs. 2a, b, 3a).

Fat planes were considered visible (present) if the fat tissue between the pancreatic parenchyma and adjacent organ or blood vessel had been visualized in all contagious axial slices. Fat planes were considered absent if it was seen that pancreatic parenchyma had been in direct contact with the adjacent organ or blood vessel without visible fat tissue between, in any of the contagious axial slices.

Statistical analysis

Continuous variables were presented as mean values ± standard deviation (SD), and minimum and maximum values. Student's t test was used to estimate differences in age, body mass and body mass index (BMI) between the male and female participants in the study group. Spearman's rank correlation coefficient (r_S) was used to assess the correlation of gender, age, body mass and BMI and visible fat planes between the pancreas parenchyma and particular surrounding structures.

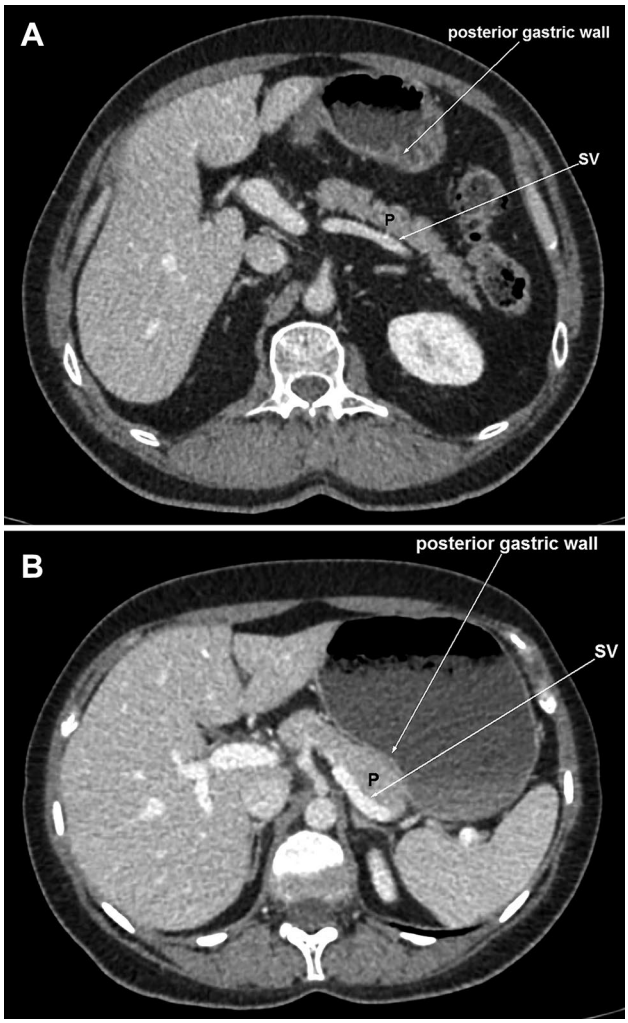

Fig. 1 **a, b** Visible fat planes between the pancreatic body (P) and posterior gastric wall ventrally, and splenic vein (SV) dorsally in a 68-year-old man with a body mass of 85 kg and BMI of 28.1 kg/m^2 (**a**), and invisible fat planes towards the posterior gastric wall and SV in a 38-year-old woman with a body mass of 60 kg and BMI of 20.8 kg/m^2 (**b**)

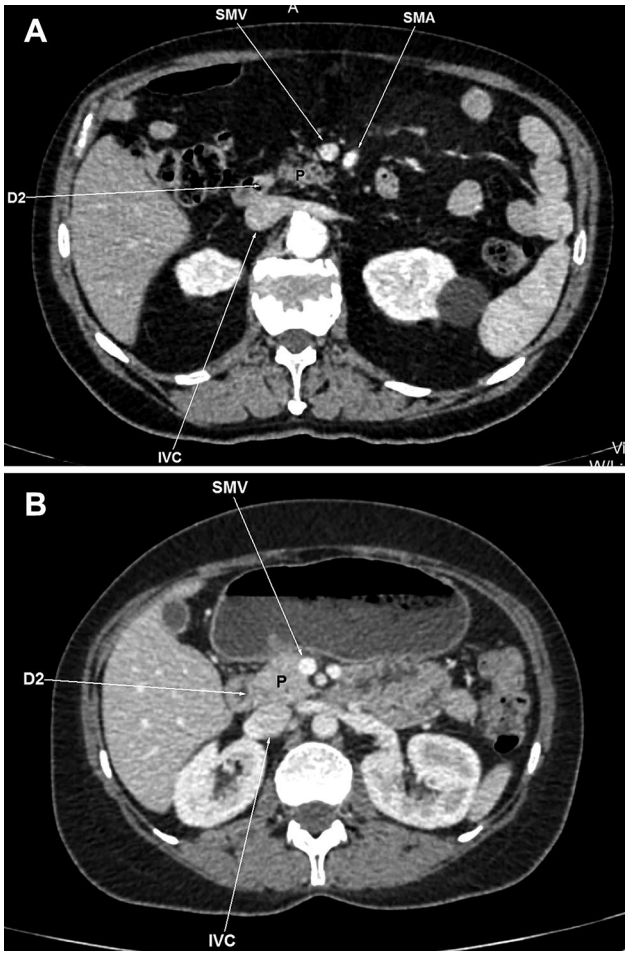

Fig. 2 **a**, **b** Visible fat planes between the fatty transformed pancreatic head (P) and medial wall of the descending duodenum (D2) laterally, IVC dorsally, and superior mesenteric vessels (SMV and SMA) medially in a 68-year-old man with a body mass of 85 kg and BMI of 28.1 kg/m^2 (**a**), and invisible fat planes towards the D2, IVC and SMV in a 38-year-old woman with a body mass of 60 kg and BMI of 20.8 kg/m^2 (**b**)

Results

The study group consisted of adult Caucasian people, 226 women and 294 men, from 19 to 85 years. Detailed characteristics of the study population are presented in Table 1.

There was no significant difference in age and BMI between the female and male participants in the study group, but men were on average significantly heavier than women (Table 1).

In all participants, fat planes towards the SMA were visible (100%), while they were absent towards the portal vein (0%). The fat planes between the pancreatic parenchyma and other surrounding structures were visible as follows: body of the pancreas and posterior wall of the stomach in 395 (76%) individuals, head of the pancreas and D2 in 61 (11.7%), body of the pancreas and SV in 268 (51.5%), head of the pancreas and SMV in 150 (28.8%), body of the pancreas and CT in 517 (99.4%), body of the pancreas and HA in 470 (90.4%), and head of the pancreas and IVC in 420 (80.8%) (Table 2; Fig. 6).

The presence of visible fat planes significantly correlated with body mass for stomach ($r_S = 0.367$), D2 ($r_S = 0.247$), SV ($r_S = 0.355$), SMV ($r_S = 0.384$) and ICV ($r_S = 0.259$) ($p < 0.001$), and BMI for stomach ($r_S = 0.292$), SV ($r_S = 0.248$), SMV ($r_S = 0.290$) and ICV ($r_S = 0.216$) ($p < 0.001$) (Table 2). Significant correlation with age was found for D2 ($r_S = 0.363$), SV ($r_S = 0.276$) and SMV ($r_S = 0.409$) ($p < 0.001$), and male gender for stomach ($r_S = 0.160$; $p < 0.001$), D2 ($r_S = 0.127$; $p = 0.004$), SV ($r_S = 0.198$; $p < 0.001$) and SMV ($r_S = 0.147$; $p = 0.001$) (Table 2).

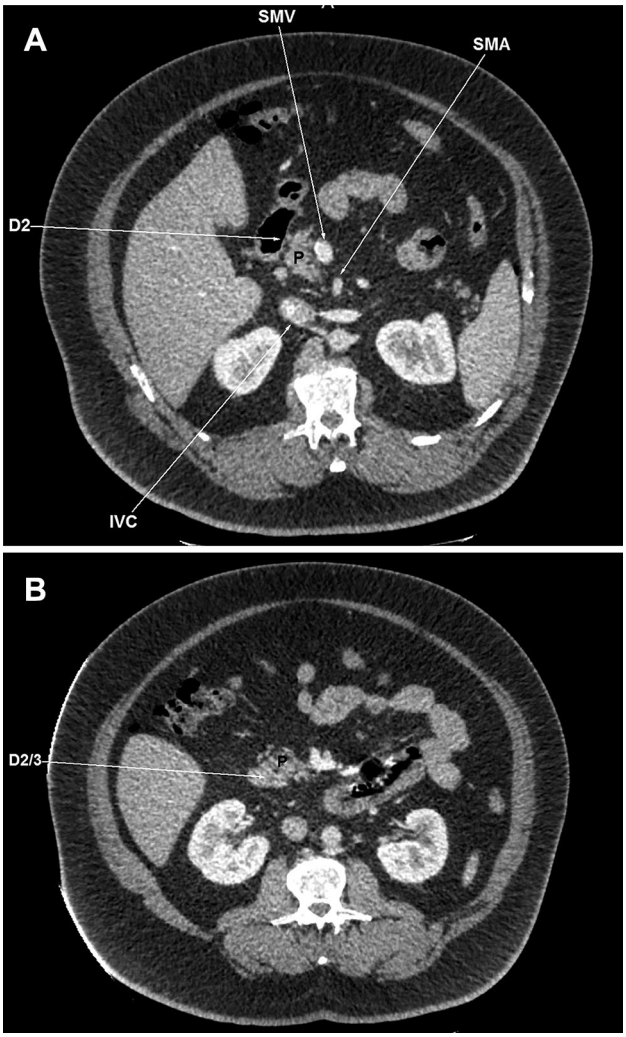

Fig. 3 **a, b** Visible fat planes between the pancreatic head (P) and medial wall of the descending duodenum (D2) laterally, IVC dorsally, and superior mesenteric vessels (SMV and SMA) ventrally in a 48-year-old obese man with a body mass of 150 kg and BMI of 46.3 kg/m^2 (**a**), but more caudally, invisible fat plane towards the medial duodenal wall at the level of the *genu inferior* (D2/3) in the same person (**b**)

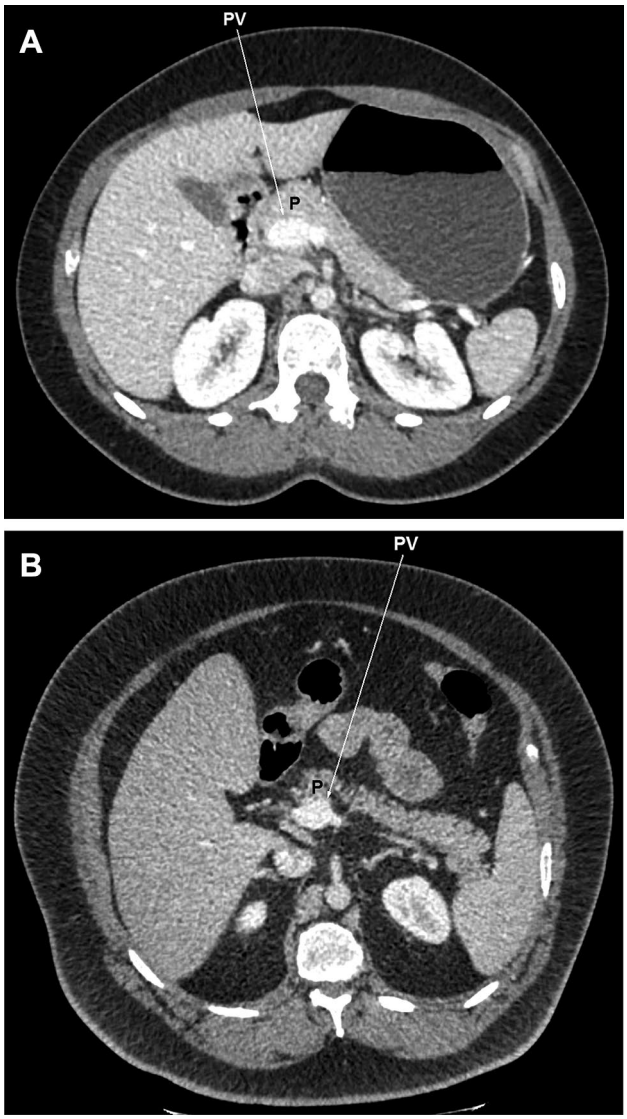

Fig. 4 **a, b** Invisible fat planes between the pancreatic neck (P) and portal vein (PV) in a 38-year-old lean woman with a body mass of 60 kg and BMI of 20.8 kg/m^2 (**a**), and in a 48-year-old obese man with a body mass of 150 kg and BMI of 46.3 kg/m^2 (**b**)

Discussion

Peripancreatic fat planes enable demarcation of the pancreas from the adjacent organs and blood vessels on the cross-sectional images taken either by CT or MRI. Out of the analysed neighbouring anatomical structures in our series of adult individuals, fat planes were always visible towards the arterial blood vessels, superior mesenteric artery and coeliac trunk, and in the majority of cases the common hepatic artery. Quite the opposite, fat planes towards the portal vein were always absent. For two other peripancreatic veins, which serve as the cross-sectional anatomical landmarks of pancreas, fat planes towards the splenic vein were visible in half of all individuals in the study group, and the SMV in one-third. The body of the pancreas was clearly demarcated from the posterior gastric wall by peripancreatic fat in the majority of the participants. However, fat planes between the pancreatic head and the medial wall of the descending part of the duodenum were visible in only 20% of cases. The inferior vena cava commonly was separated from the posterior part of the pancreatic head by visible retroperitoneal fat planes. These findings are in agreement with the general descriptions of typical cross-sectional anatomy of the pancreas and peripancreatic structures [14, 22].

Positive correlation of visible peripancreatic fat planes towards some of the adjacent organs or blood vessels

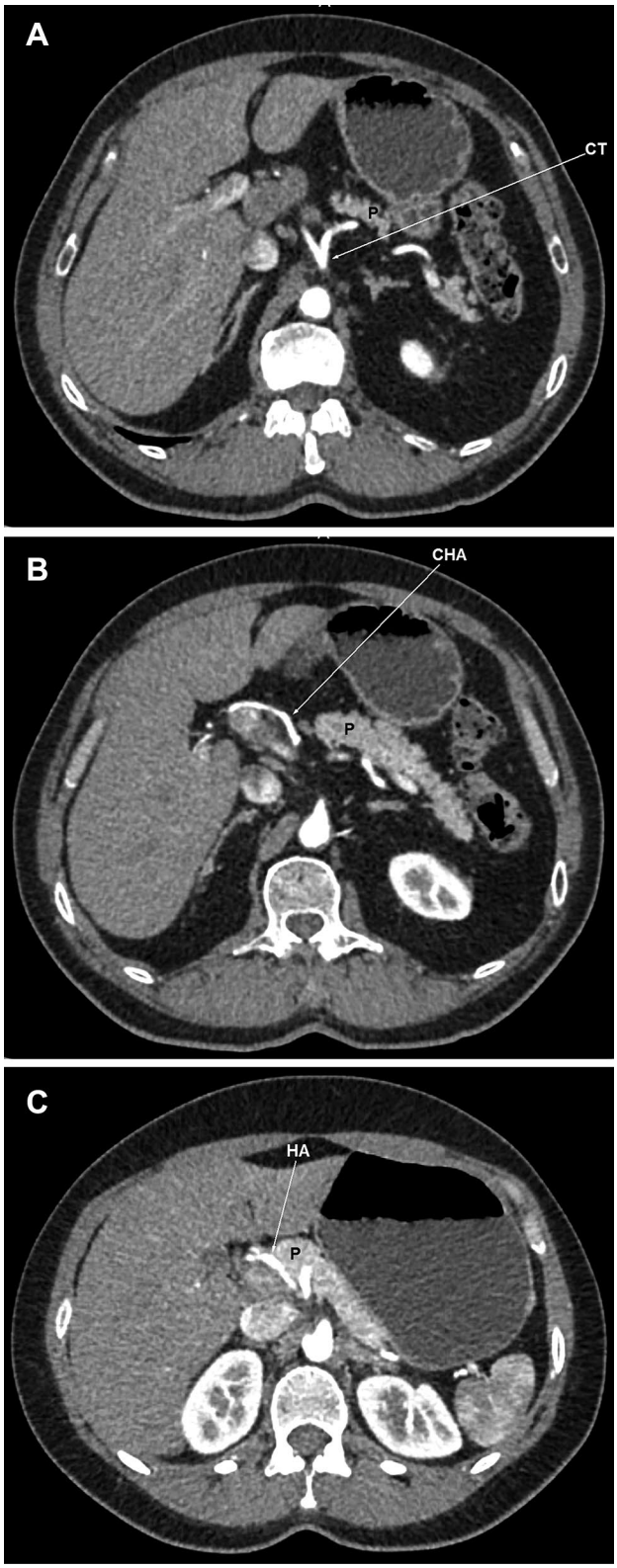

Fig. 5 **a**, **c** Visible fat planes between the pancreatic body (P) and coeliac trunk (CT) (**a**), and more caudally, towards the common hepatic artery (CHA) in a 61-year-old man with a body mass of 85 kg and BMI of 28.7 kg/m^2 (**b**). Invisible fat plane towards the hepatic artery (HA) in a 38-year-old lean woman with a body mass of 60 kg and BMI of 20.8 kg/m^2 (**c**)

(stomach, SV, SMV and IVC) with body mass, BMI, age and male gender found in our investigation was probably the consequence of larger amount of the abdominal visceral adipose tissue (VAT) in persons with higher body mass, older age and males in comparison with lean, young and female individuals that was documented in many anthropometric investigations which revealed that the amount of VAT increased with the increase of age, and the total amount of VAT was larger in men than women who had equal BMI [3, 8, 9]. However, an absence of visible fat planes between the pancreas and surrounding structures can also be a normal appearance in CT scan, especially in skinny or cachectic persons.

Since our study proved that fat planes between the pancreatic body and gastric wall were commonly visible in healthy individuals, the absence of fat planes between the body of pancreas and stomach shown by computed tomography in patients who had gastric or pancreatic cancer could be considered as probable infiltration of the neighbouring organ, suggesting clinically advanced stage of tumour (T4 according to TNM classification) [2]. In addition, it was revealed that visualization of the fat planes between the posterior gastric wall and pancreatic body most strongly correlated with the body mass. This could be explained by thicker peritoneal adipose tissue, which forms the lesser sac that separates the body of pancreas from the stomach in persons with greater body mass. However, the presence and width of the fat planes between the pancreatic body and the posterior gastric wall may depend on the degree of stomach distension by water, contrast media or air, which depends on the CT scanning preparation protocol. We performed the CT scanning protocol with the stomach filled with water, thus probably even more frequent visualization of the fat planes between the empty stomach and pancreas could be expected.

On the contrary, the fat planes between the lateral contour of the pancreatic head and medial wall of the descending duodenum were not completely visible in the majority of participants, independently of the body mass and BMI. In some individuals, it was visible between the pancreatic head and the cranial part of D2 duodenal wall, but typically pancreatic parenchyma was intimately coalesced to the medial duodenal wall below the level of the major papilla, without visible fat planes (Fig. 3a, b). Accordingly, an absence of visible fat plane between the cancer of the pancreatic head and duodenum does not default the neoplastic infiltration of the duodenal wall. The narrowing of the lumen and/or thickening of the medial duodenal wall adjacent to the pancreatic head neoplasm are the accurate cross-sectional imaging signs of duodenal infiltration by pancreatic adenocarcinoma [18]. Although duodenal invasion does not generally restrict tumour resectability, because pancreatic head and duodenum are en bloc resected by performing the Whipple's cephalic pancreaticoduodenectomy, it was shown that

Table 1 Characteristics of the population group: gender, age, body mass and BMI

	Study group ($n=520$)	Male ($n=294$)	Female ($n=226$)	Difference[§]
Age (years)	58 ± 14 (19–85)	57 ± 15 (20–85)	58 ± 13 (19–84)	$p=0.935$
Body mass (kg)	76 ± 17 (45–123)	85 ± 17 (50–123)	69 ± 14 (45–115)	$p<0.001$
BMI (kg/m^2)	26.1 ± 4.9 (16.3–43.8)	26.7 ± 4.6 (16.3–37.3)	25.7 ± 5.1 (16.5–43.8)	$p=0.221$

[§] p values estimated using the Student's t test for independent samples

duodenal infiltration had negative prognostic impact on the disease-free and overall survival [18]. Significant correlation of visible fat planes towards the medial duodenal wall with the increasing age was documented in our study, which could be explained by gradual shrinkage and fatty transformation of pancreas during ageing [11]. Subsequently, the distance between the head of the pancreas and duodenal wall increases and fat planes become visible more frequently in the elderly.

Direct invasion of the adjacent blood vessels by pancreatic adenocarcinoma is the main criteria of tumour resectability [2, 24]. Although precise criteria of vascular invasion by pancreatic carcinoma were proposed, the accuracy of the CT in predicting the resectability remained unsatisfactory, especially after the neoadjuvant therapy [4, 20]. However, clearance of the fat planes around the blood vessels has been established as a key hallmark of vascular invasion on the cross-sectional imaging. Few classification systems of vascular invasion by pancreatic adenocarcinoma are in use [24]. Portal and superior mesenteric vein invasion are assessed according to the degree of tumour–vein circumferential interface, i.e. degree of vein circumference which is in direct contact without visible fat planes between the neoplasm and the vein [21, 24]. Thus, the vein abutment by tumour that was defined as invisible fat planes towards the $\leq 180°$ of vein circumference, encasement ($> 180°$ of vein circumference) or complete encasement (whole vein circumference) predicts vein infiltration with the probability of 40%, 80% or 100%, respectively [24]. As our study found that fat planes between the healthy pancreatic tissue and portal vein were always invisible, it supported the conclusion that an absence of the fat planes between the tumour and portal vein in the pre-operative cross-sectional imaging did not necessarily indicate the PV infiltration. On the contrary, the fat planes around the adjacent magistral arteries—SMA, hepatic artery and coeliac trunk—were almost always visible, so any abutment of these arteries by neoplasm probably indicated vascular and/or perineural infiltration, which may generally restrict tumour resectability [21, 24]. Coeliac trunk together with the origin of the common hepatic artery commonly lies above the pancreas without direct contact, but in persons with the asthenic constitution, typically lean young women, HA can cross over the cranial surface of the pancreatic body with visible fat planes in most cases.

Out of all blood vessels that were analysed, visibility of the fat planes towards the SMV was most strongly influenced by body mass, BMI, age and gender, probably in association with the amount of the visceral abdominal fat. Weaker positive correlation with the body mass and BMI was revealed for the fat planes towards the IVC, probably as a consequence of larger amount of the retroperitoneal visceral adipose tissue between the pancreatic head and ICV.

Splenic vein is the most frequently invaded adjacent blood vessel in acute necrotizing pancreatitis [1, 20, 23]. As SV was separated from the pancreatic body and tail parenchyma with the visible fat planes in more than 50% of individuals in our series, obliteration of the fat planes in case of acute necrotizing pancreatitis could be a sign of vascular invasion, so it should be carefully followed up for making proper diagnosis of the splenic vein thrombosis, which is the most common vascular complication of severe acute pancreatitis [1]. Invasion of the portal vein and SMV in acute pancreatitis rarely occurred [23]. It was also revealed that fat stranding of the mesentery demonstrated by MRI corresponded to the severity of acute pancreatitis [6]. Therefore, the peripancreatic fat planes towards the splenic vein should be carefully analysed using CT scans in all patients with acute pancreatitis.

There were few limitations to our study. First, we did not use maximal and minimal intensity projection (MIP and MinIP) post-processing reconstruction tools, which might improve the visualization of the fat planes around the pancreatic tissue towards the neighbouring blood vessels and organs. Second, the degree of circumference with the absent fat planes towards the PV and VMS was not analysed in our study by using the available angle measuring tool. Furthermore, we did not test the correlation of visible fat planes around the pancreas with the visceral abdominal fat area or volume, which could be measured in MDCT scan in each person, but instead we did it with the standard anthropometric parameters (body mass and BMI), which served the surrogate indicators of the amount of the abdominal visceral adipose tissue in our present study. Possible improvements in visualization of the fat planes towards the surrounding anatomic structures by using the advanced post-processing MDCT imaging tools mentioned above need to be investigated in further studies. Finally, individual pancreatic volume and structure of pancreatic parenchyma, i.e. degree of

Table 2 Number (*n*) and percentage (%) of individuals with visible peripancreatic fat planes towards the surrounding organs and blood vessels in the abdominal MDCT scans, and correlations (r_S) with gender, age, body mass and BMI

$N=520$	*n*	%	Gender (male)	Age	Body mass	BMI
			r_S	r_S	r_S	r_S
Stomach	395	76.0	0.160**	0.108	0.367**	0.292**
D2	61	11.7	0.127	0.363**	0.247**	0.185**
SV	268	51.5	0.198**	0.276**	0.355**	0.248**
PV	0	0				
SMV	150	28.8	0.147	0.409**	0.384**	0.290**
SMA	520	100				
CT	517	99.4				
HA	470	90.4	0.156**	0.156**	0.149	0.066
IVC	420	80.8	0.064	0.082	0.259**	0.216**

r_S Spearman's rank correlation coefficient; **$p<0.001$

pancreas lipomatosis, were neither analysed in our study nor correlated to peripancreatic fat plane visualization.

Conclusion

In summary, we may conclude that the analysis of the contrast-enhanced abdominal MDCT examinations in adult individuals with healthy pancreas showed that fat planes around the pancreatic parenchyma were almost always visible towards the adjacent magistral visceral arteries (coeliac trunk, common hepatic artery and superior mesenteric artery) and inferior vena cava, variably visible towards the splenic vein, superior mesenteric vein and stomach, always invisible towards the portal vein and commonly invisible towards the medial duodenal wall. Positive correlation of visible peripancreatic fat planes towards some of the adjacent organs or blood vessels (stomach, D2, SV, SMV and IVC) with the body mass, BMI, age and gender was proven, with body mass being the strongest. The presented findings may improve the knowledge on individual variations of the CT anatomy of the normal pancreas, which may increase MDCT accuracy as the most commonly used imaging tool for pancreatic pathology in diagnosing the direct invasion of the surrounding magistral blood vessels and digestive organs by pancreatic cancer or acute pancreatitis.

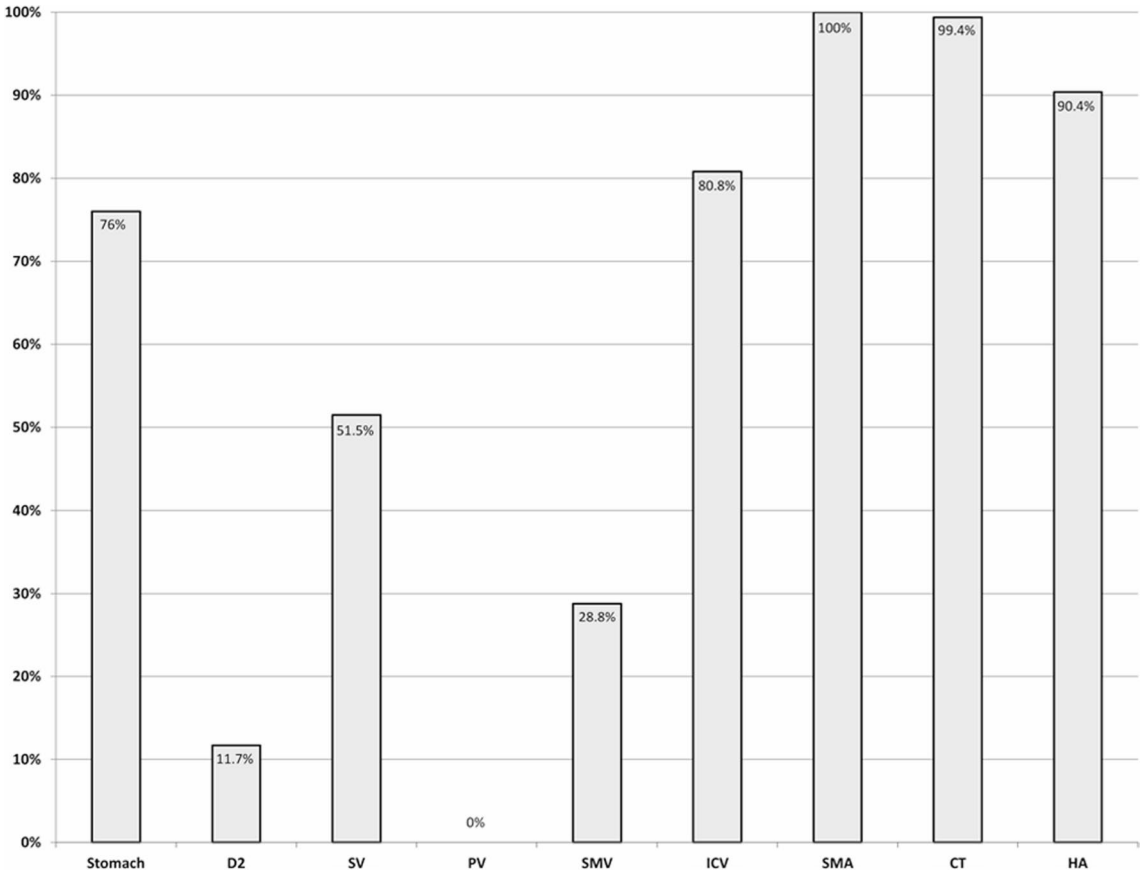

Fig. 6 Frequencies (percentages) of visible peripancreatic fat planes towards the surrounding organs and blood vessels on the abdominal MDCT scans of the study group

Author contributions AD-S: project and protocol development, data collection, data analysis and manuscript writing. NG: data collection and manuscript writing. DS: data collection. KK: data management. JD-K: project development and manuscript editing. SK: project development and manuscript editing.

Compliance with ethical standards

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

Ethical approval This was a retrospective study and formal consent was not required.

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