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Coeliac trunk and its anatomic variations: a cadaveric study

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Background: Coeliac trunk (CT) is the first major visceral branch of the abdominal aorta. The aim of this work was to present the CT division pattern and its anatomical variants in a sample of Polish population.

Materials and methods: Coeliac trunk dissection was performed in 50 adult cadavers in the Department of Anatomy, Jagiellonian University Medical College. Cadavers of Polish subjects were included. Cadavers with previous upper abdominal surgery, abdominal trauma, disease process that distorted arterial anatomy or signs of putrefaction were excluded. CT variations, accessory vessels, and vertebral level of origin were described. CT patterns were reported according to the Adachi classification. This study was reviewed and approved by the local Ethics Committee.

Results: Coeliac trunk consisting of the left gastric, common hepatic and splenic artery (type 1 according to the Adachi classification) was found in 82% of cadavers. The true tripod was found in 20% and the false one in 80%. Additional vessels were also found: greater pancreatic from the splenic artery and left inferior phrenic from the left gastric artery, which accounted for 2% sections. Type 2 according to the Adachi classification (i.e. the hepatosplenic trunk) was found in 16% of the sections. Other types of CT were not observed. The level of origin was found to be at the inter-vertebral disc between T12 and L1 in all of the cases.

Conclusions: Based on the analysis of the sectional material of the Department of Anatomy, it was found that the typical visceral segmental division is approximate to that observed by Adachi in its classification, whereas the second type of CT was twice as frequent and no other, less frequent types were found. (Folia Morphol 2021; 80, 1: 114–121)

Key words: tripod, anatomical variations, Adachi classification, coeliac trunk

INTRODUCTION

The coeliac trunk (CT) is the first anterior visceral branch of the abdominal aorta (AA) and it arises from AA immediately below the aortic hiatus at the level of T12-L1 vertebra. It measures 1.5–2 cm. It runs down, right and slightly forward, lying back from the lesser omentum. Its ending lies just above the upper border of the pancreas. CT is surrounded by the coeliac plexus. It was first described by Albrecht von Haller in 1756 [13], as "tripus Halleri", which represents the classical type of branching, known as trifurcation in the left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA). Anatomic variation of CT has been first classified by Adachi in 1928 [1], based on 252 dissections of Japanese cadavers, where six types of divisions were described (Fig. 1). However, two forms of trifurcation have been most commonly observed: a "true" tripod is considered when the

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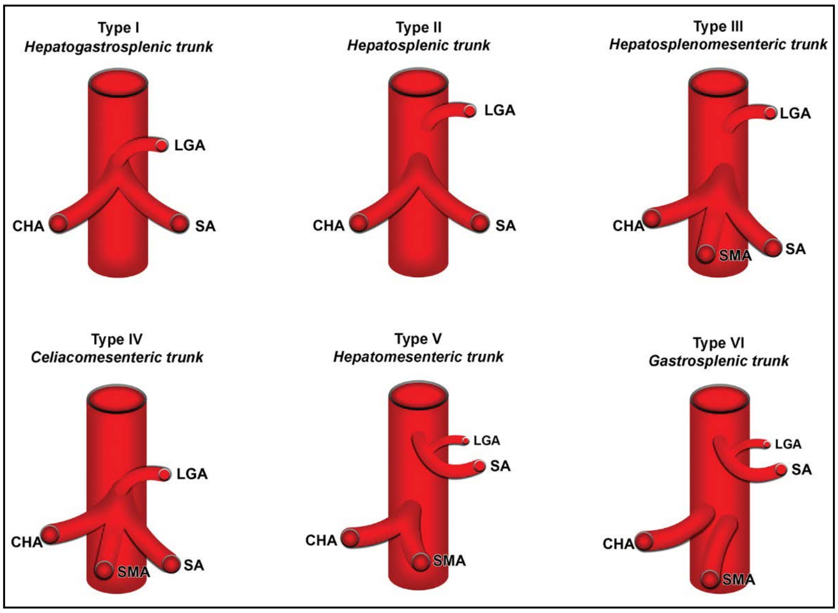

Figure 1. Coeliac trunk variations according to Adachi; CHA — common hepatic artery; LGA — left gastric artery; SA — splenic artery; SMA — superior mesenteric artery.

CHA, LGA and SA have a common origin, constituting a hepatogastrosplenic trunk. When one of these arteries arises before the remaining two in the course of the CT, it is called a false tripod [36]. CT supplies the structures derived from the foregut (liver, pancreas, abdominal part of the oesophagus, stomach and proximal duodenum). Surgery of the abdominal cavity requires an excellent knowledge of anatomical variations of the CT. Familiarity with the vascular supply of abdominal organs such as liver or pancreas is basic for numerous procedures (chemo-embolisation, liver resection, pancreatectomy) [15]. In the present modern era of imaging techniques, the cadaver still stands as an important and reliable mode of anatomical study [26, 51]. Hence, the aim of this cadaveric study was to analyse and report the vascular patterns of CT for the first time in a sample of Polish population according to the classification by Adachi [1].

MATERIALS AND METHODS

Dissection of the CT was performed in 50 formalin-fixed abdomen specimens in the Department of Anatomy, Jagiellonian University Medical College. The inclusion criteria were cadavers of Polish nationality subjects. The sex and age was not taken into account. Cadavers with previous upper abdominal surgery, abdominal trauma, disease process that distorted the arterial anatomy or signs of putrefaction were excluded. This study was reviewed and approved by the local Ethics Committee (no. 1072.6120.78.2019). Informed consent was not required. After dissection of the anterior abdominal wall, and entering the peritoneal cavity, the greater omentum of the stomach was dissected from the transverse colon, exposing the posterior wall of the stomach and opening the lesser sac. The pylorus was freed from adjacent connective tissue, and the omentum minus was opened along the minor curvature. Once the CHA, the LGA and the SA were identified, their course was followed to their site of origin. The presence of a "true tripod" or a "false tripod" was examined. CT variations, accessory vessels and site of origin were recorded and referred to Adachi's classification. Care was taken not to overlook a left hepatic artery. The LGA was exposed as well as the coronary vein. The pancreas was also dissected to expose the origin of the superior mesenteric artery (SMA). The vertebral level of the CT origin was determined by palpation in cephalic direction beginning from the fifth lumbar vertebral body. The structures of the AA, its branches and variations were photographed using a digital camera.

RESULTS

During routine dissection of abdomen we observed the following branching patterns of CT. Coeliac trunk divided into CHA, LGA and SA in 82% of the cadavers (41/50). This pattern corresponds to Adachi type I. Furthermore, two different trifurcation

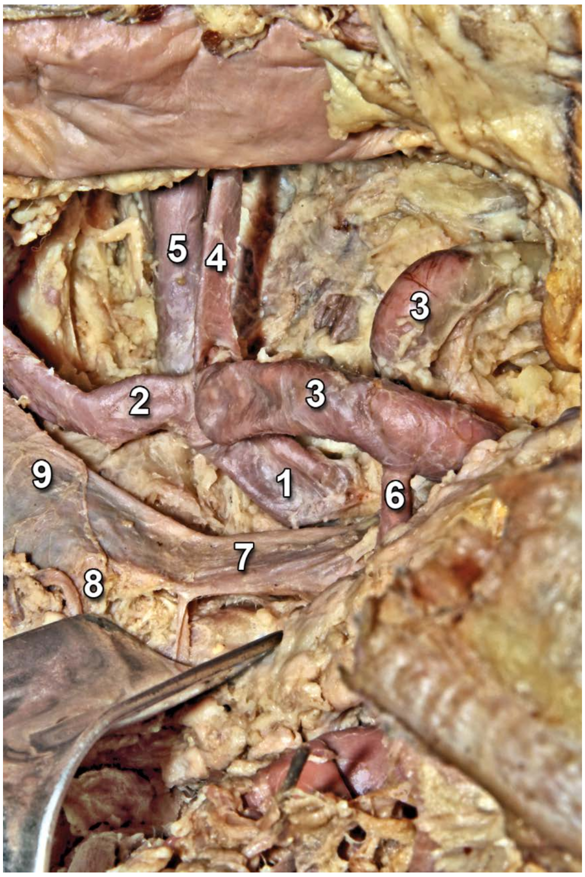

Figure 2. True tripod; 1 — coeliac trunk; 2 — common hepatic artery; 3 — splenic artery; 4 — left gastric artery; 5 — left gastric vein; 6 — greater pancreatic artery; 7 — splenic vein; 8 — superior mesenteric vein; 9 — portal vein.

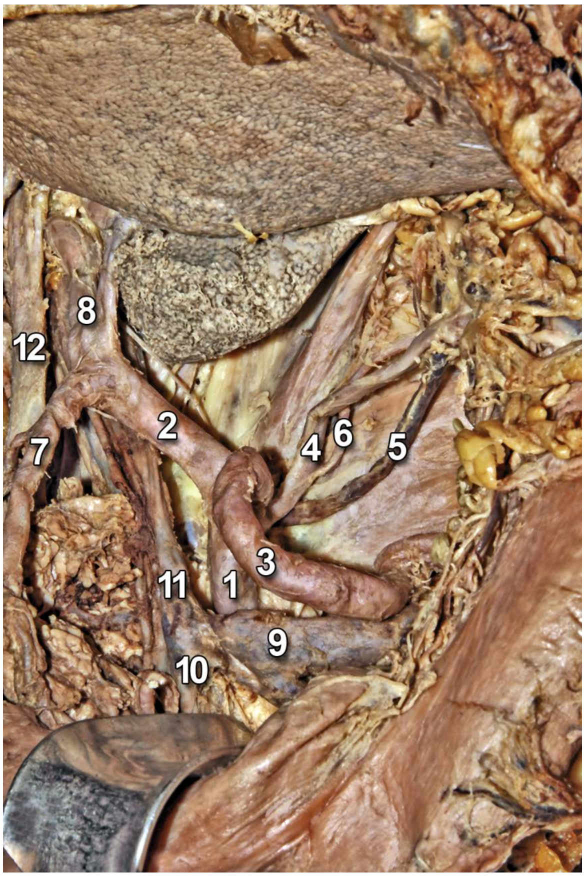

Figure 3. True tripod; 1 — coeliac trunk; 2 — common hepatic artery; 3 — splenic artery; 4 — left gastric artery; 5 — left gastric vein; 6 — right inferior phrenic artery; 7 — gastroduodenal artery; 8 — proper hepatic artery; 9 — splenic vein; 10 — superior mesenteric vein; 11 — portal vein; 12 — common bile duct.

patterns were observed; a classical or "true" tripod called "tripus Halleri" and a non-classical type. In the classical type, CHA, SA and LGA were found to arise from the CT. This was found in 20% of dissections (8/41) (Figs. 2, 3). In the non-classical type also known as "false" tripod the origin of LGA was located relatively proximal, between the AA and the bifurcation of CT, in 33 out of the 41 cadavers (80%) (Figs. 4, 5). Bifurcation of the CT (Adachi type II) was found in 16% of the cadaveric dissections (8/50). The CT divided into CHA and SA (hepatosplenic trunk) whereas LGA originated directly from the AA (Fig. 6). In 1 case, an accessory left inferior phrenic artery (LIPA) was found, rising from the LGA. The given variability was observed in 2%, which corresponds to 1/50 of cadavers. In addition, our attention was drawn by false tripod with two additional arteries: namely the LIPA from LGA and the greater pancreatic artery from SA. Such a variation occurred in 2% (1/50 of cadavers). The variations found in the present study in comparison to other cadaveric studies were summarised in Table 1. Considering the prevalence of using the computed tomography angiography (CTA) in analysing anatomical variations, we also compared our results with the radiological studies in Polish population (Table 2). Correlation between gender and CT variation is given in Table 3. The level of CT origin was found to be at the inter-vertebral disc between T12 and L1 in all of the cases. Level of origin CT in different variations presented in Table 4.

DISCUSSION

Anatomic variations of CT has been described by many authors in various classifications i.e. Rossi and Cova (1904) [38], Lariche and Villemin (1907) [23], Descomps (1910) [9], Picquand (1910) [35], de Rio Branco (1912) [37], Lipschutz (1917) [24], Eaton (1917) [10], Adachi (1928) [1], Tsukamoto (1929) [45], Imakoshi (1949) [16], Michels (1955) [27], Kozhevnikova (1977) [21], Katsume et al. (1978) [18], Vandamme and Bonte (1985) [46], Nelson et

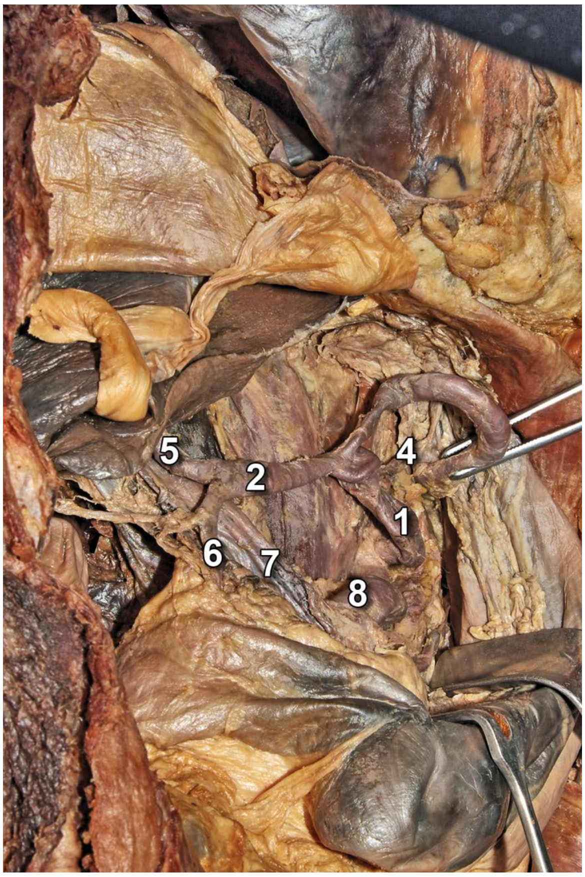

Figure 4. False tripod; 1 — coeliac trunk; 2 — common hepatic artery; 3 — splenic artery; 4 — left gastric artery; 5 — proper hepatic artery; 6 — gastroduodenal artery; 7 — portal vein; 8 — superior mesenteric artery.

Figure 5. False tripod; 1 — coeliac trunk; 2 — common hepatic artery; 3 — splenic artery; 4 — left gastric artery; 5 — proper hepatic artery; 6 — gastroduodenal artery.

al. (1988) [30], Kaneko (1990) [17], Chen (2009) [7], Shoumura et al. (1991) [40], Wadhwa Ambica (2011) [48], Panagouli (2013) [32], Olewnik et al. (2017) [31]. In our study we referred to Adachi [1] and Michels [27] who have classified the CT into six different types. However, these classifications do not include all observed variants of the CT as well as accessory or replaced hepatic arteries, both of them are still being mentioned and compared with newly described ones [8, 12, 26, 32, 34, 41, 44]. Furthermore, Adachi's and Michel's classifications described in textbooks were recently considered to create a scheme of the most frequent variants of the CT and anatomy of the hepatic circulation [7, 41]. Michel's classification was also used for depiction of CT and CHA variations in children [5]. Favelier et al. [11] mentioned that this classification provides the best anatomical approach. The types of CT according to Michels' classification are as follows: type 1 — normal branching; type 2 — hepatosplenic trunk and LGA from aorta; type 3 — hepatosplenomesenteric trunk and left gastric from aorta; type 4 — hepatogastric trunk and SA from SMA; type 5 — splenogastric type; splenic and left gastric from the CT and CHA from SMA; and type 6 — coeliacomesenteric trunk; splenic, left gastric, common hepatic and superior mesenteric arteries arise from a common trunk [27, 40]. Indeed, the most prevalent is type 1, which occurs in 86% of the population [13]. We observed this type in 83.33% of cadavers. Type 2 occurring in 8% of population, was found in our study in 16.67% of cases. We did not observe other less common types i.e. type 3 (hepatosplenovisceral trunk), type 4 (visceromesenteric trunk), type 5 (hepatomesenteric trunk), type 6 (gastrosplenic trunk). Absence of the CT is the most infrequent variation, with a mean prevalence of 0.38%. In many studies, no CT absence has been found [2, 7, 15, 24]. In our study, no case of absence of CT was found (Table 1). It is important to notice that Olewnik et al. [31] revealed a shedload of CT variations non-classified by Adachi (27%)

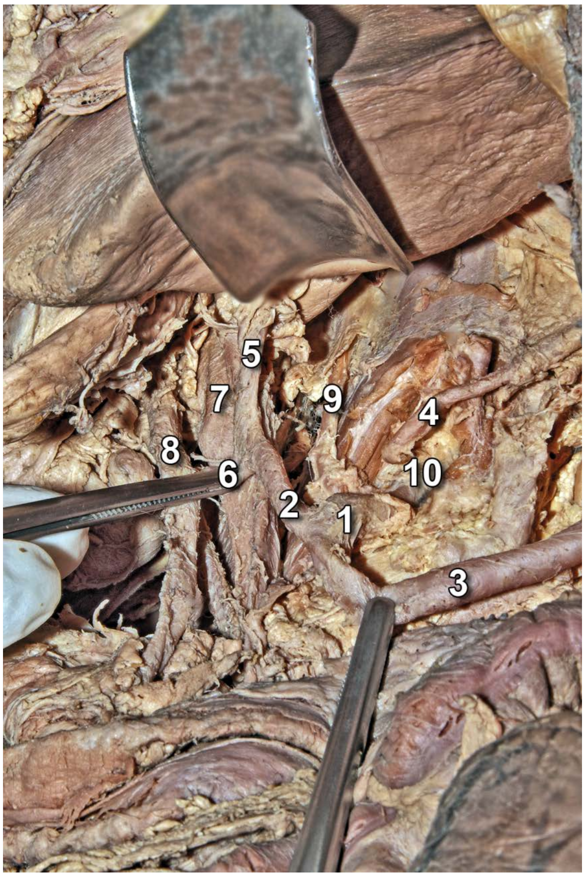

Figure 6. Hepatosplenic trunk + left gastric artery rising separately from abdominal aorta; 1 — coeliac trunk; 2 — common hepatic artery; 3 — splenic artery; 4 — left gastric artery; 5 — proper hepatic artery; 6 — gastroduodenal artery; 7 — portal vein; 8 — common bile duct; 9 — right inferior phrenic artery; 10 — abdominal aorta.

Table 1. Comparison between our study and the other cadaveric studies according to the Adachi's classification

Cadaveric study	I	II	III	IV	V	VI	Other
Our study	82.0%	16.0%	0.0%	0.0%	0.0%	0.0%	2.0%
Lipshutz [24]	73.5%	13.3%	0.0%	2.4%	0.0%	3.6%	7.2%
Adachi [1]	87.7%	6.4%	1.2%	2.4%	0.4%	2.0%	0.0%
Chen et al. [7]	89.8%	4.3%	0.7%	0.7%	1.5%	1.8%	1.0%
Marco-Clement et al. [26]	86.0%	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Olewnik et al. [31]	62.5%	10.0%	0.0%	0.0%	0.0%	0.0%	27.5%

such as: 1) quadrifurcation — normal trifurcation + accessory hepatic artery: 7.5%; 2) coeliacophrenic trunk — normal trifurcation + LIPA: 12.5%; 3) trifurcation — hepatosplenic artery + accessory hepatic artery: 5.0%; 4) absence of the CT: 2.5% [31], so we compared our results with other cadaveric studies of the non-Polish populations (Table 1).

Kornafel et al. [20] studied the variations of the main branches of the AA including CT and SMA using CTA and 64-detector computed tomography scanner in 201 patients. The authors did not base on the Adachi's or Michels' classification and observed 95.5% cases of the normal trifurcation. Other variations observed were hepatosplenic trunk (1.5%), coeliacomesenteric trunk (1.5%) and the gastrosplenic trunk (0.5%) [20]. Torres et al. [44] also analysed variations of the CT using multidetector computed tomography according to the Uflacker's classification. In this study the most common trifurcation was observed in 1455/1569 cases (92.7%), the other variants were: gastrosplenic trunk in 64/1569 cases (4.1%) and hepatosplenic trunk in 34 cases (2.2%). Coeliac-mesenteric trunk (8/1569; 0.5%), hepatogastric trunk (4/1569; 0.2%) were rarely observed. In 2 cases the absence of the CT was noted (0.1%). The hepatosplenomesenteric trunk and the coeliaco-colic trunk were not detected [44] Kurcz et al. [22] presented results of the study on 240 patients. The most common patterns were: trifurcation (87.5%), hepatosplenic trunk (8.33%) and gastrosplenic trunk (3.33%). In 1 case CT was absent (0.42%) and hepatogastric trunk was observed in 0.42%. We compared our results on cadavers with radiologic studies (Table 2).

Due to high number of articles describing variations of the CT, there was a necessity to find appropriate results evaluated in one review. Santos et al. [39] and Whitley et al. [50] presented results of the previous studies about the CT and their findings were used to elaborate and compare our results with the other studies focused on the Polish population or the cadaveric studies.

Anson et al. [2] showed in cadaveric studies that almost 75% of cases had CT origin at the level of inter-vertebral disc between T12 and L1. In our study, the site of origin was also found to be at the above-mentioned level in most of the cases, which does not differ from the population norm.

The most common additional branches of the CT are single or double inferior phrenic arteries, which were described in 40% of cases in the study by Loukas et al. [25]. In our study, additional vessels were found in 2.77% of cadavers. In one autopsy specimen, the inferior phrenic artery arising from LGA and greater pancreatic artery arising from SA were found. In CTA scans Srivastava et al. [42] revealed visceral trifurca-

Table 2. Comparison between our cadaveric study and radiological studies in Polish population

Type of variation	Present study N = 50	Kornafel et al. [20] N = 201	Torres et al. [44] N = 1569	Kurcz et al. [22] N = 240
Normal branching	83.33%	95.50%	92.70%	87.50%
Hepatosplenic trunk	16.67%	1.50%	2.20%	8.33%
Hepatosplenomesenteric trunk	0.0%	0.0%	0.0%	0.0%
Hepatogastric trunk	0.0%	0.0%	0.20%	0.42%
Gastrosplenic trunk	0.0%	0.50%	4.10%	3.33%
Coeliacomesenteric trunk	0.0%	1.50%	0.50%	0.0%
Absence of coeliac trunk	0.0%	0.0%	0.10%	0.42%
Other (for example coeliac-colic trunk)	0.0%	1.0%	0.0%	0.0%

N — number of patients

Table 3. Correlation between gender and variation of the coeliac trunk (n = 50)

Type of variation	Male	Female
Hepatogastrosplenic trunk	28	13
Hepatosplenic trunk	7	2
Hepatosplenomesenteric trunk	0	0
Coeliacomesenteric trunk	0	0
Hepatomesenteric trunk	0	0
Gastrosplenic trunk	0	0

Table 4. Level of origin coeliac trunk in different variations (n = 50)

Type of variation	T12 (n)	L1 (n)
Hepatogastrosplenic trunk	27	14
Hepatosplenic trunk	3	6
Hepatosplenomesenteric trunk	0	0
Coeliacomesenteric trunk	0	0
Hepatomesenteric trunk	0	0
Gastrosplenic trunk	0	0

tion in 28%, bifurcation in 8%, quadrifurcation in 36%, pentafurcation in 20%, hexafurcation in 4%, while in 4% of cases visceral trunk was absent.

Anatomical variations of the CT are secondary to the embryonic developmental changes in the ventral segmental arteries [43]. Primitive segmental branches arise from the dorsal aorta and form the CT and the SMA. These branches are connected to the ventral longitudinal anastomotic channel. Retention or disappearance of parts of this primitive arterial plexus will give rise to variations of the CT and the SMA [14].

In studies carried out by Venieratos et al. [47] and Chen et al. [7] no differences were found between genders. However, the occurrence of different types of CT can be influenced by ethnicity [32]. Our study was carried out on the cadavers of Polish nationality presenting a trifurcated CT, either a common origin or with one of the three arteries arising first. This incidence is higher than those observed in Korean (10.9%), Caucasian (8.6%), Japanese (10.7%), Indian (30%) and Afro-American population (39%) [36].

Detailed knowledge of normal CT anatomy and its variations is very important during surgery such as pancreatoduodenectomy, liver transplant as well as hepatic artery infusion chemotherapy. Preoperative imaging can help better preparation and planning by the surgical team. However, all arterial variations may not be detected in preoperative imaging (only up to 60–80% of cases). If detected, it can help the surgeons to identify the artery and prevent its injury during surgery and post-operative complications like bleeding and ischaemia [14]. Currently, arterial variations can also be predicted by the intrauterine ultrasonography examination and observations of the foetus' intestine position in the following stages of the foetal development [51]. Another modified ultrasonography examination — the three-dimensional contrast-enhanced ultrasonography — could be used in precisely non-invasive diagnosing the coeliac artery compression syndrome [49]. The pathologies of CT and SMA also could be detected by using new technique of the non-contrast magnetic resonance angiography [39].

Hepatic artery variations, such as anomalous right hepatic artery crossing posterior to the portal vein, are frequently seen (13%). These patients, when undergoing pancreatoduodenectomy, may require a change in the surgical approach to achieve an adequate resection. Preoperative imaging can clearly identify such variations and help to achieve a safer pancreatic head dissection with proper surgical planning [3]. In transarterial chemoembolisation (TACE) or radioembolisation of hepatic cancers and metastases it is essential to analyse hepatic and extrahepatic perfusion in order to prevent iatrogenic postprocedural complications such as radiation induced ulcers in the stomach and duodenum or severe pancreatitis [4, 6, 33]. The variations of the CT are also significant during TACE in therapy of the pancreas cancer (especially the variations of the CHA) [29]. Anatomical variations of the CT are also significant to know in planning the bariatric procedures such as LGA embolisation or the sleeve gastrectomy [19, 28].

CONCLUSIONS

Coeliac trunk variations are not uncommon findings, with different anatomic variants being reported. The classical visceral trifurcation was found in Polish population with a comparable frequency, as described by Adachi [1]. Only a low percentage of cases with additional vessels were found. Thus, the importance of knowing the possible variations of this structure is emphasized, which may have implications for surgical interventions and imaging studies related to the abdominal region.

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