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Anatomical variations of the celiac trunk in Polish population: cadaveric and radiological studies

Zmienność anatomii pnia trzewnego w populacji polskiej: badania sekcyjne i obrazowe

Praca doktorska

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SPIS TREŚCI

WYKAZ PUBLIKACJI STANOWIĄCYCH ROZPRAWĘ DOKTORSKĄ

Rozprawa doktorska pt. „Zmienność anatomii pnia trzewnego w populacji polskiej: badania sekcyjne i obrazowe" składa się z cyklu trzech prac oryginalnych i jednej pracy kazuistycznej:

1. **Celiac trunk and its anatomic variations – cadaveric study.**

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2. **Anatomical variants of celiac trunk in Polish population using multidetector computed tomography angiography.**

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3. **Rare combined variations of the celiac trunk, accessory hepatic and gastric arteries with co-occurrence of double cystic arteries: a case report.**

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4. **Unusual variations in the branching pattern of the celiac trunk and their clinical significance.**

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WSTĘP I UZASADNIENIE PODJĘTEJ TEMATYKI

Pień trzewny jest nieparzystym odgałęzieniem aorty brzusznej. Odchodzi on z przedniego obwodu aorty w przestrzeni zaotrzewnowej, na wysokości krążka międzykręgowego Th12/L1 i dzieli się na trzy gałęzie: tętnicę żołądkową lewą, wątrobową wspólną i śledzionową. Trifurkacja stanowi klasyczny wariant podziału opisany przez Hallera jako trójnóg - tripus Halleri. Anatomiczne zmienności pnia trzewnego zostały sklasyfikowane po raz pierwszy przez Buntaro Adachiego w 1928 roku w oparciu o badania przeprowadzone na 252 osobach pochodzenia japońskiego. Nieustanny rozwój chirurgii klasycznej i laparoskopowej oraz procedur radiologii interwencyjnej wykonywanych w górnym piętrze jamy brzusznej wymaga od operatora wiedzy na temat anatomii pnia trzewnego i jego głównych zmienności. Dlatego zasadnym wydaje się zbadanie anatomii pnia trzewnego i jego wariantów na próbie populacji polskiej.

CELE PRACY

Celem pracy doktorskiej była analiza anatomii rozgałęzień pnia trzewnego na próbie populacji polskiej w oparciu o ocenę materiału sekcyjnego. Stwierdzone warianty anatomiczne opisano w odniesieniu do klasyfikacji japońskiego anatoma Buntaro Adachi. W 82% przypadków dominował typ I rozgałęzienia w konstelacji zarówno prawdziwej jak i rzekomej. Opisano również przypadek zmienności gałęzi wątrobowych pnia trzewnego, istotnych z punktu widzenia chirurgii wątroby i transplantologii. Kolejnym celem było dokonanie oceny pnia trzewnego na podstawie analizy tomografii wielodetektorowej (MDCT) z użyciem kontrastu w grupie 1000 pacjentów. W rezultacie otrzymano trójwymiarowe rekonstrukcje modeli pnia trzewnego i jego odmian. Wobec istniejących zmienności pnia i jego rozgałęzień podkreślono zasadność wykonywania MDCT z kontrastem i rekonstrukcją 3D u pacjentów kwalifikowanych do procedur radiologii interwencyjnej oraz chirurgii laparoskopowej i tradycyjnej. Dzięki dużej liczbie analizowanych angiografii MDCT aorty brzusznej wyodrębniono rzadkie anatomiczne warianty pnia trzewnego i podkreślono ich znaczenie kliniczne.

MATERIAŁ I METODY

Pierwsza część pracy polegała na wypreparowaniu pnia trzewnego wraz z jego gałęziami na 50 zwłokach utrwalonych formaliną w Katedrze i Zakładzie Anatomii UJCM. Następnie opisano i sfotografowano wszystkie stwierdzone zmienności anatomiczne w zakresie pnia trzewnego. Druga część pracy dotyczyła oceny pnia trzewnego na podstawie analizy angiografii tomografii komputerowej w grupie 1000 pacjentów poddanym badaniu z różnych wskazań w Zakładzie Diagnostyki Obrazowej Szpitala Specjalistycznego im. J. Dietla w Krakowie.

1. ARTYKUŁ NR 1

Celiac trunk and its anatomic variations – cadaveric study

(Original article)

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Abstract

Introduction: Celiac trunk is the first major visceral branch of the abdominal aorta. The aim of this work was to present the celiac trunk division pattern and its anatomical variants in a sample of Polish population.

Materials and methods: Celiac 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. Celiac trunk variations, accessory vessels, and vertebral level of origin were described.

Celiac trunk patterns were reported according to the Adachi classification. This study was reviewed and approved by the local Ethics Committee.

Results: Celiac 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) were found in 16% of the sections. Other types of celiac trunk 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 celiac trunk was twice as frequent and no other, less frequent were found variety.

Keywords: anatomical variations, Adachi classification, celiac trunk (CT), common hepatic artery (CHA), splenic artery (SA), left gastric artery (LGA), left gastric vein (LGV), greater

pancreatic artery (GPA), splenic vein (SV), superior mesenteric vein (SMV), portal vein (PV), right inferior phrenic artery (RIPA), gastroduodenal artery (GDA), proper hepatic artery (PHA), common biliary duct (CBD), abdominal aorta (AA).

Introduction

The celiac 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 approximately 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 celiac plexus. It was first described by Albrecht von Haller in 1756 [1], 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, based on 252 dissections of Japanese cadavers, where six types of divisions were described [2] [Fig. 1]. However, two forms of trifurcation have been most commonly observed: a "true" tripod is considered when the 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 celiac trunk, it is called a false tripod [3]. CT supplies the structures derived from the foregut (liver, pancreas, abdominal part of the esophagus, stomach and proximal duodenum). Surgery of the abdominal cavity requires an excellent knowledge of anatomical variations of the celiac trunk. Familiarity with the vascular supply of abdominal organs such as liver or pancreas is basic for numerous procedures (chemo-embolization, liver resection, pancreatectomy) [4]. In the present modern era of imaging techniques, the cadaver still stands as an important and reliable mode of anatomical study [5, 6]. Hence, the aim of this cadaveric study was to analyze and report the vascular patterns of celiac trunk for the first time in a sample of Polish population according to the classification by Adachi.

Materials and methods

Dissection of the celiac trunk 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 /nr 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 common hepatic artery, the left gastric artery and the splenic artery were identified, their course was followed to their site of origin. The presence of a "true tripod" or a "false tripod" was examined. Celiac trunk 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 left gastric artery 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 celiac trunk 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 celiac trunk. CT derived in a common hepatic artery, a left gastric artery and a splenic artery in 82% of the cadavers (41/50). This pattern corresponds to Adachi type I. Furthermore, two different trifurcation 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 celiac trunk. This was found in 20% of dissections (8/41) (Fig. 2 and 3). In the non-classical type also known as „false" tripod the origin of LGA was located relatively proximal, between the abdominal aorta and the bifurcation of CT, in 33 out of the 41 cadavers (80%) (Fig. 4 and 5). Bifurcation of the celiac trunk (Adachi type II) was found in 16% of the cadaveric dissections (8/50). The celiac trunk divided into CHA and SA (hepatosplenic trunk) whereas LGA originated directly from the abdominal aorta (Fig. 6). In one case, an accessory left inferior phrenic artery 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 left inferior phrenic artery 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 summarized in the Table 1. Considering the prevalence of using the computed tomography angiography (CTA) in analyzing anatomical variations, we also compared our results with the radiological studies in Polish population (Table 2). Correlation between gender and celiac trunk variation is given in the 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 celiac trunk in different variations presented in the Table 4.

Discussion

Anatomic variations of CT has been described by many authors in various classifications i.e. Rossi and Cova (1904), Lariche and Villemin (1907), Descomps (1910), Picquand (1910), de Rio Branco (1912), Lipschutz (1917), Eaton (1917), Adachi (1928), Tsukamoto (1929), Imakoshi (1949), Michels (1955), Kozhevnikova (1977), Katsume et al. (1978), Vandamme and Bonte (1985), Nelson et al. (1988), Kaneko (1990), Shoumura et al. (1991), Ambica Wadhwa (2011), Panagouli (2013), Olewnik (2016) [2, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21]. In our study we referred to Adachi and Michels who have classified the celiac trunk into six different types [2, 12]. However, these classifications do not include all observed variants of the celiac trunk as well as accessory or replaced hepatic arteries, both of them are still being mentioned and compared with newly described ones [5, 20, 22, 23, 24, 25, 26]. Furthermore, Adachi's and Michel's classifications described in textbooks were recently considered to create a scheme of the most frequent variants of the celiac trunk and anatomy of the hepatic circulation [19, 24]. Michel's classification was also used for depiction of CT and CHA variations in children [27]. Favelier et al. mentioned that this classification provides the best anatomical approach [28]. The types of celiac trunk according to Michels' classification are as follows: Type 1: normal branching; Type 2: hepatosplenic trunk and left gastric artery from aorta; Type 3: hepatosplenomesentric trunk and left gastric from aorta; Type 4: hepatogastric trunk and splenic artery from superior mesenteric artery; Type 5: splenogastric type; splenic and left gastric from the coeliac trunk and common hepatic artery from superior mesenteric artery; and Type 6: celiacomesentric trunk; splenic, left gastric, common hepatic and superior mesenteric arteries arise from a common trunk [12, 21]. Indeed, the most prevalent is type 1, which occurs in 86% of the population [1]. We observed this type in 83.33% of cadavers. Type 2 occuring 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 celiac trunk is the most infrequent variation, with a mean prevalence of 0.38%. In many studies, no celiac trunk absence has been found [4, 10, 19, 29]. In our study, no case of absence of celiac trunk was found (Tab. 1). It is important to notice that Olewnik et al. revealed a shedload of celiac trunk variations non-classified by Adachi (27%) such as: 1) quadrifurcation – normal trifurcation + accessory hepatic artery – 7,5%; 2) coeliacophrenic trunk – normal trifurcation + left inferior phrenic artery – 12,5%; 3) trifurcation – hepatosplenic artery + accessory hepatic artery – 5,0%; 4) absence of the celiac trunk – 2,5% [11], so we compared our results with other cadaveric studies of the non-Polish populations (Tab. 1).

Kornafel et al. studied the variations of the main branches of the abdominal aorta including celiac trunk and superior mesenteric artery using CTA and 64-detector CT scanner in 201 patients [30]. 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%), celiacomesenteric trunk (1.5%) and the gastrosplenic trunk (0.5%) [30]. Torres et al. also analyzed variations of the celiac trunk using multidetector computed tomography according to the Uflacker's classification. In this study the most common trifucation 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 celiac trunk was noted (0.1%). The hepatosplenomesenteric trunk and the coeliaco-colic trunk were not detected [26]. Kurcz et al. presented results of the another study on 240 patients. The most common patterns were: trifurcation (87.5%), hepatosplenic trunk (8.33%) and gastrosplenic trunk (3.33%). In 1 case celiac trunk was absent (0.42%) and hepatogastric trunk was observed in 0.42% [31]. We compared our results on cadavers with radiologic studies [Table 2].

Due to high number of articles describing variations of the celiac trunk, there was a necessity to find appropiate results evaluated in one review. Santos et al. and Whitley et al. presented results of the previous studies about the celiac trunk and their findings were used to elaborate and compare our results with the other studies focused on the Polish population or the cadaveric studies [32, 33].

Anson et al. showed in cadaveric studies that almost 75% of cases had CT origin at the level of inter-vertebral disc between T12 and L1 [29]. In our study, the site of origin was also found to be at the abovementioned level in most of the cases which does not differs from the population norm.

The most common additional branches of the celiac trunk are single or double inferior phrenic arteries, which were described in 40% of cases in the study by Loukas et al. [34]. 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 angio-CT scans Srivastava et al. revealed visceral trifurcation in 28%, bifurcation in 8%, tetrafurcation in 36%, pentafurcation in 20%, hexafurcation in 4%, while in 4% of cases visceral trunk was absent [35].

Anatomical variations of the celiac trunk are secondary to the embryonic developmental changes in the ventral segmental arteries [36]. Primitive segmental branches arise from the dorsal aorta and form the celiac trunk and the superior mesenteric artery. 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 celiac trunk and the superior mesenteric artery [37].

In studies carried out by Venieratos et al. and Chen et al. no differences were found between genders [19, 38]. However, the occurrence of different types of celiac trunk can be influenced by ethnicity [20]. Our study was carried out on the cadavers of Polish nationality presenting a trifurcated celiac trunk, 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%) [3].

Detailed knowledge of normal CT anatomy and its variations is very important during surgery like pancreaticoduodenectomy, liver transplant as well as hepatic artery infusion chemotherapy. Preoperative imaging can help better preparation and planning by the surgical team. But 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 ischemia [37]. Currently, arterial variations can also be predicted by the intrauterine ultrasonography examination and observations of the fetus' intestine position in the following stages of the fetal development [6]. The another modified ultrasonography examination – the 3-D contrast-enhanced ultrasonography could be used in precisely non-invasive diagnosing the celiac artery compression syndrome (CACS) [39]. The patologies of CT and SMA also could be detected by using new technique of the non-contrast MR angiography [33].

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 [40]. In transarterial chemoembolisation (TACE) or radioembolisation of hepatic cancers and metastases it is essential to analyze hepatic and extrahepatic perfusion in order to prevent iatrogenic postprocedural complications such as radiation induced ulcers in the stomach and duodenum or severe pancreatitis [41, 42, 43]. The variations of the celiac trunk are also significant during TACE in therapy of the pancreas cancer (especially the variations of the common hepatic artery)

[44]. Anatomical variations of the celiac trunk are also significant to know in planning the bariatric procedures such as LGA embolisation or the sleeve gastrectomy [45, 46].

Conclusions

Celiac 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. Only a low percentage of cases with additional vessels was 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.

The authors declare no conflict of interest.

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Figure 1. Celiac trunk variations according to Adachi.

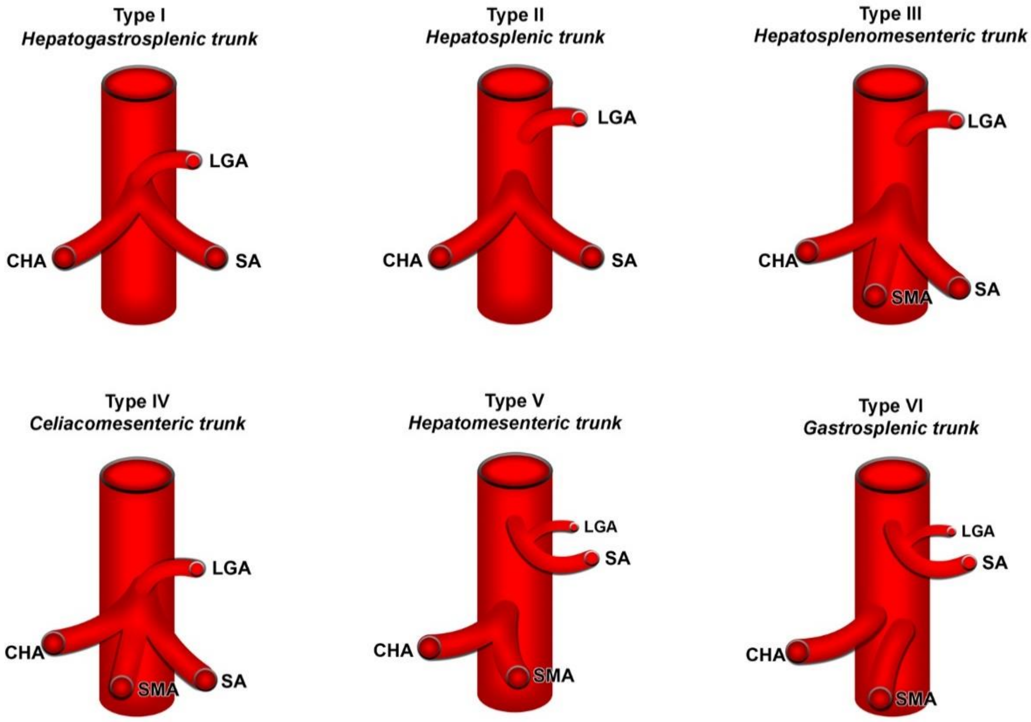

Figure 2. True tripod

1 – CT: celiac trunk, 2 – CHA: common hepatic artery, 3 – SA: splenic artery, 4 – LGA: left gastric artery, 5 – LGV: left gastric vein, 6 – GPA: greater pancreatic artery, 7 – SV: splenic vein, 8 – SMV: superior mesenteric vein, 9 – PV: portal vein.

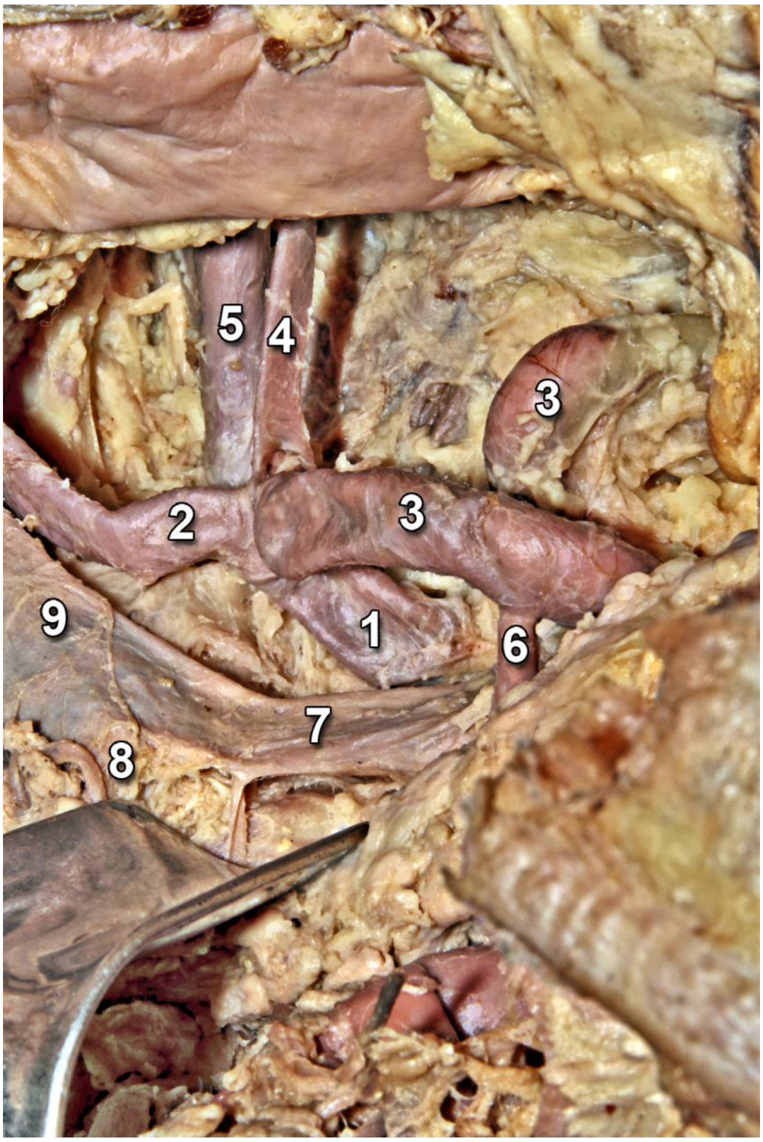

Figure 3. True tripod

1 – CT: celiac trunk, 2 – CHA: common hepatic artery, 3 – SA: splenic artery, 4 – LGA: left gastric artery, 5 – LGV: left gastric artery, 6 – RIPA: right inferior phrenic artery, 7 – GDA: gastroduodenal artery, 8 – PHA: proper hepatic artery, 9 – SV: splenic vein, 10 – SMV: superior mesenteric vein, 11 – PV: portal vein, 12 – CBD: common bile duct.

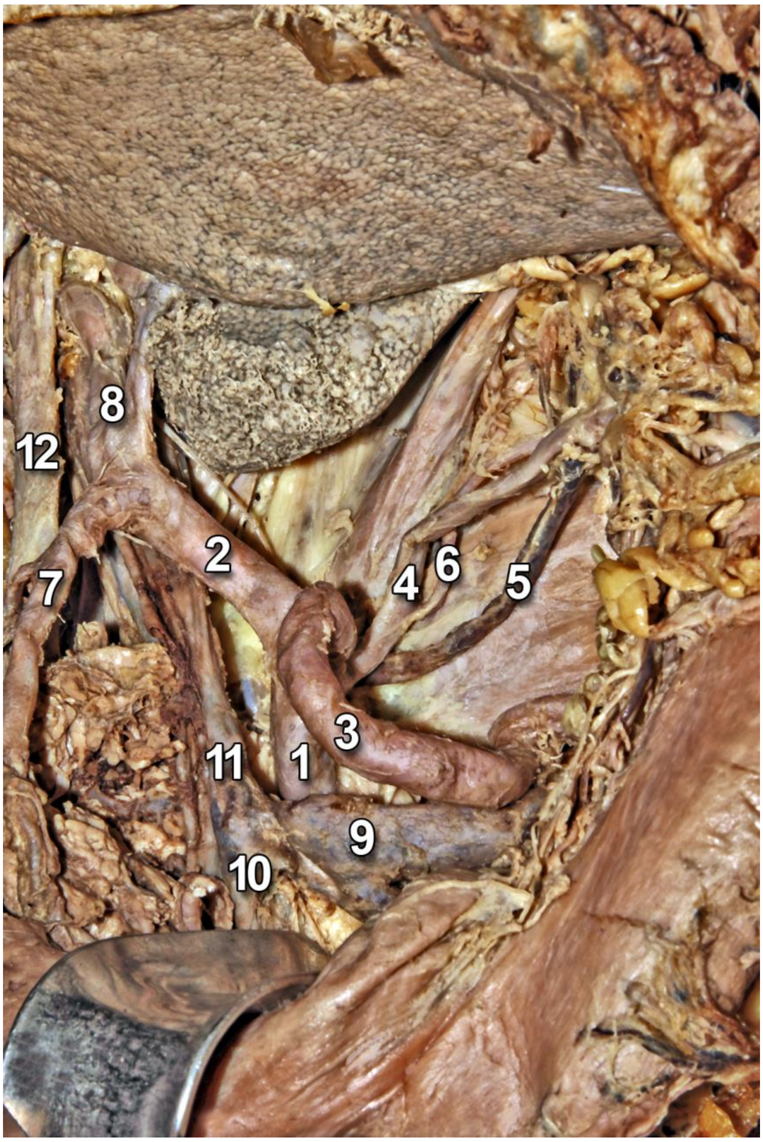

Figure 4. False tripod

1 – CT: celiac trunk, 2 – CHA: common hepatic artery, 3 – SA: splenic artery, 4 – LGA: left gastric artery, 5 – PHA: proper hepatic artery, 6 – GDA: gastroduodenal artery, 7 – PV: portal vein, 8 – SMA: superior mesenteric artery.

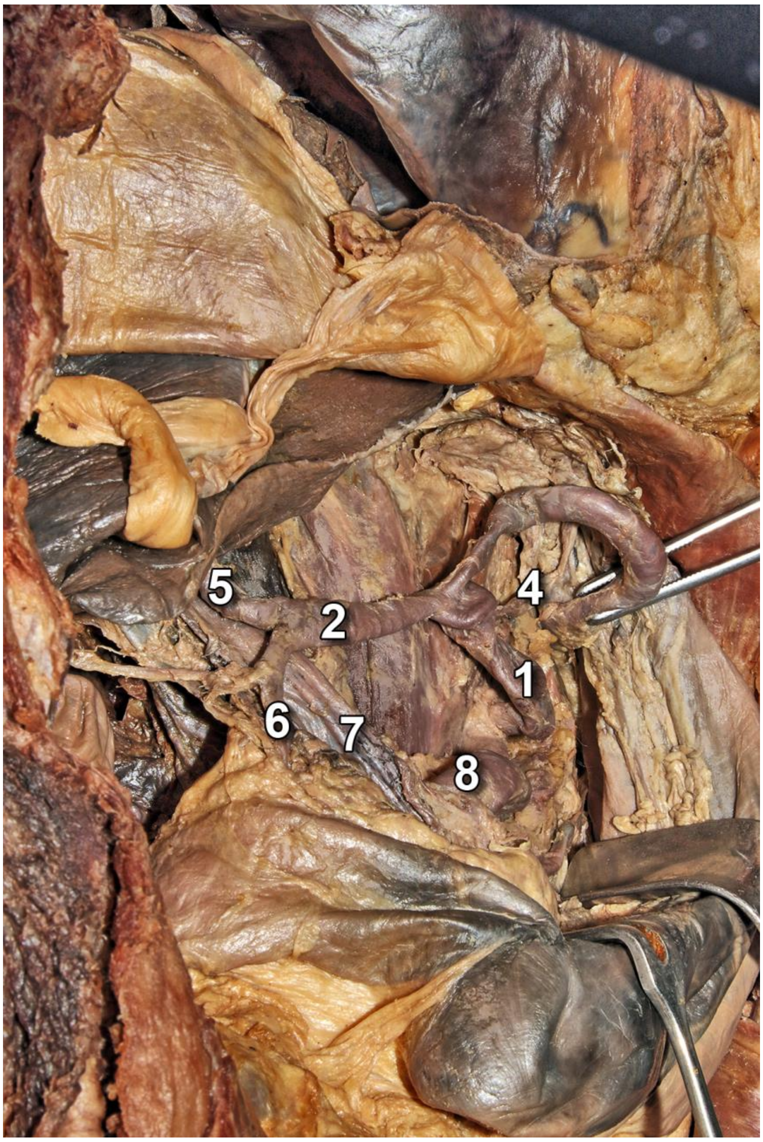

Figure 5. False tripod

1 – CT: celiac trunk, 2 – CHA: common hepatic artery, 3 – SA: splenic artery, 4 – LGA: left gastric artery, 5 – PHA: proper hepatic artery, 6 – GDA: gastroduodenal artery.

Figure 6. Hepatosplenic trunk + LGA rising separately from AA

1 – CT: celiac trunk, 2 – CHA: common hepatic artery, 3 – SA: splenic artery, 4 – LGA: left gastric artery, 5 – PHA: proper hepatic artery, 6 – GDA: gastroduodenal artery, 7 – PV: portal vein, 8 – CBD: common bile duct, 9 – RIPA: right inferior phrenic artery, 10 – AA: abdominal aorta.

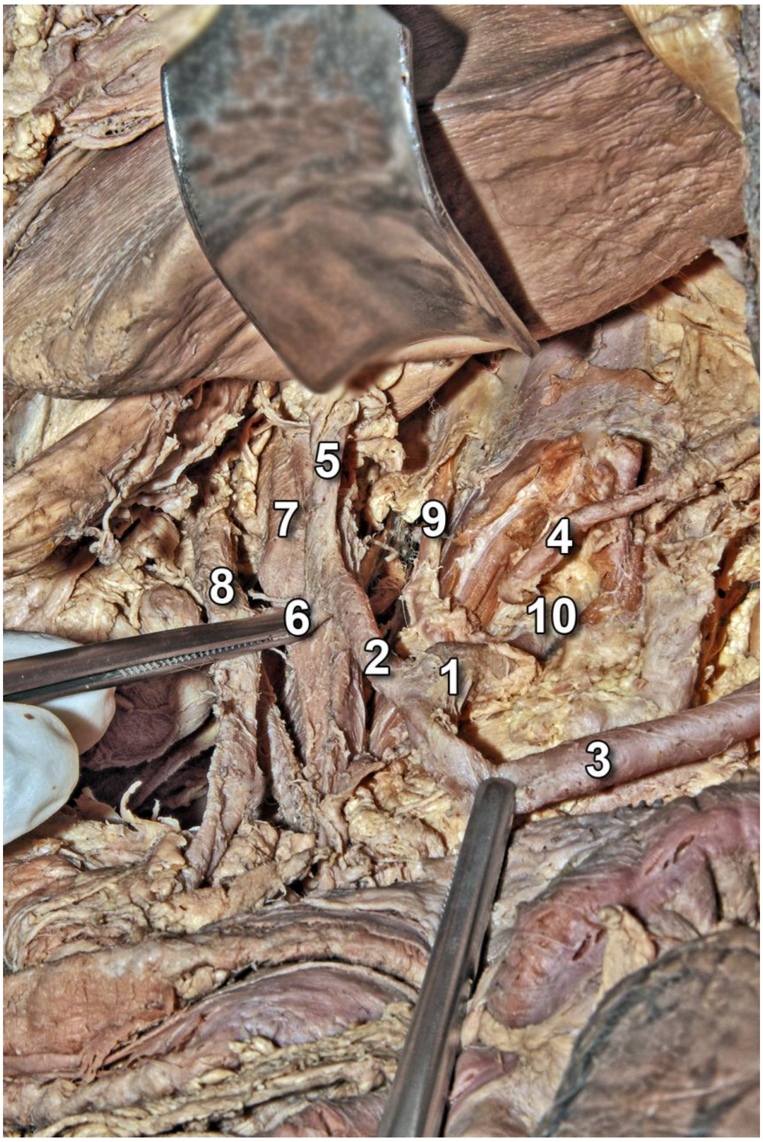

Table 1. Comparison between our study and the other cadaveric studies according to the Adachi's classification.

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	73.5	13.3	0.0	2.4	0.0	3.6	7.2
Adachi	87.7	6.4	1.2	2.4	0.4	2.0	0.0
Chen	89.8	4.3	0.7	0.7	1.5	1.8	1.0
Marco-Clement	86.0	14.0	0.0	0.0	0.0	0.0	0.0
Olewnik	62.5	10.0	0.0	0.0	0.0	0.0	27.5

Table 2. Comparison between our cadaveric study and radiological studies in Polish population. N – number of patients.

Type of variation	Present study (%) N=50	Kornafel et al.[49] (%) N=201	Torres et al.[50] (%) N=1569	Kurcz et al.[51] (%) 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
Celiacomesenteric trunk	0.0	1.50	0.50	0.0
Absence of celiac trunk	0.0	0.0	0.10	0.42
Other (for example celiac-colic trunk)	0.0	1.0	0.0	0.0

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

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

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

Type of variation	Th12 (n)	L1 (n)
Hepatogastrosplenic trunk	27	14
Hepatosplenic trunk	3	6
Hepatosplenomesenteric trunk	0	0
Celiacomesenteric trunk	0	0
Hepatomesenteric trunk	0	0
Gastrosplenic trunk	0	0

2. ARTYKUŁ NR 2

Anatomical variants of celiac trunk in Polish population using multidetector computed tomography angiography

(Original article)

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Abstract

Background: Multidetector Computed Tomography angiography (MDCTA) has become a major part in evaluation of normal anatomy and its variants in patients undergoing operative or interventional procedures. The purpose of this study was to assess the frequency of anatomical variation of celiac trunk in patients undergoing MDCT angiography of the abdominal aorta.

Material and methods: A descriptive, retrospective study was carried out on MDCT angiographies performed from January 2014 till January 2020 in Polish patients. Celiac trunk was studied and normal and anatomical variations were noted according to Adachi's classification. All patients with abnormalities affecting the vessels or a history of any vascular abnormality were excluded from the study.

Results: Out of total 1000 patients, hepatogastrosplenic trunk was found in 93.0%. True and false types of trifurcation were observed. Hepatosplenic trunk were found in 2.8%, celiacomesenteric trunk in 1.1%, hepatomesenteric trunk in 1.7% gastrosplenic trunk were found in 1.4%. We have not observed hepatosplenomesenteric trunk.

Conclusion: The type and knowledge of anatomy is of prime importance for an optimum preoperative planning in surgical or radiological procedure. MDCTA allows minimally invasive assessment of arterial anatomy with high quality 3D reconstruction images.

Keywords: Celiac trunk, Variations, Multidetector Computed Tomography angiography, MDCTA.

Introduction

The most common classical type of celiac trunk branching pattern is referred to as trifurcation (Fig. 1a, Fig. 1b) and was first observed by Haller [1] i.e. tripus Halleri. It has been considered to be the normal appearance of celiac trunk. According to Haller, celiac trunk divides into common hepatic artery (CHA), splenic artery (SA) and left gastric artery (LGA), which usually arises as a tributary elsewhere in this trunk, while the other divisions of celiac trunk rarely occur in human populations. The anatomical variations of celiac trunk were classified for the first time by Adachi in 1928 [2]. Investigations were performed on 252 people of Japanese origin and these formed the basis of Adachi's classification of the 6 types of division of celiac trunk and superior mesenteric artery (SMA) (Figure 2, Table 1). Knowledge of celiac trunk branching pattern is mandatory in laparoscopic surgery, liver transplants, radiological abdominal interventions and penetrating abdominal injuries [3]. Lack of familiarity with such variants can result in insufficient management and predispose patients to inadvertent injury during open surgical procedures or percutaneous interventions. In recent 20 years, with the widespread use of multidetector computed tomography (MDCT) and angiography, it is easy to collect a large sampling of data on the angiographic anatomy of the abdomen in daily radiological practice. Then, the variation patterns and radiological findings of celiac trunk can be classified and evaluated in detail by MDCT angiography. The main purpose of this study was to evaluate the frequency of normal and anatomical variations of celiac trunk in Polish patients undergoing multidetector CT angiography of the abdominal aorta for various clinical indications. The use of MDCT angiography allowed to identify its types and prevalence in a large study population. We also discussed their clinical implications and the probable embryological mechanisms by which the observed variations are achieved. It has become significant to be aware of the normal variations in the vascular supply of these organs, in order to prevent complications during and after surgery.

Material and methods

This study was conducted at the Institute of Diagnostic Imaging, J. Dietl Specialist Hospital in Cracow, Poland. One thousand patients referred to CT angiogram of abdominal aorta for various reasons irrespective of age and gender were included in this study. All the patients underwent multidetector abdominal CT angiography in a Aquilion 64, Toshiba Medical Systems Corporation, Tokyo, Japan. Local institutional ethical committee approval was obtained. Being a retrospective study, informed consent was not obtained as the data was collected retrospectively from the electronic medical record database. Abdominal CT angiographic images from 01.2014 till 01.2020 were studied for celiac trunk anatomical variation. The pattern of the aortic origin of branches of celiac trunk and its branches was analyzed.

Multiphase enhanced MDCT scan was performed after intravenous administration of contrast agent (Omnipaque 350; GE Healthcare AS, Oslo, Norway) at 350 mg of iodine per milliliter and 30 mL of sterile saline (0.9% NaCl) by using a power injector at a rate of 3-4 mL/s. The dose of the contrast agent was 1 mL/kg body weight and the upper limit of dose was set at 100 mL for every patient. Data obtained during the arterial phase were used to evaluate the anatomy of the celiac trunk. The raw axial images obtained from MDCT were processed on the workstation to obtain 3D reconstruction with maximum intensity projection (MIP) and volume rendering (VR). The analysis of the images was carried out by an experienced radiologist.

Identification of celiac trunk and its branches was possible in all patients examined. Patients with distorted anatomy due to previous abdominal surgery, degenerative spine conditions or any abnormality that involved the vessels were excluded. The pattern of the aortic origin of the four major arteries: left gastric, the common hepatic, splenic and superior mesenteric arteries were analyzed in the study. The instructional 3-dimensional (3D) models of the celiac trunk and its abnormalities were designed. Anatomical variations of the celiac trunk were reported according to Adachi classification (Table 1). Celiac trunk was also assessed for its diameter, distance from the superior mesenteric artery, angle of departure from the abdominal aorta and projection on the spine.

Statistical package for social sciences (SPSS) version 21 was used for statistical analysis. Mean and standard deviation was calculated for age of the patients. Frequency and percentages was calculated for normal anatomy and anatomical variations of celiac trunk. Comparison was done to see the relationship among celiac artery variant. Chi-square test was applied. p-value was taken as <0.05.

Results

Out of total 1000 patients, 510 (51%) were males and 490 (49%) were females. The mean age of the patients was 65.2±19.75 years. According to Adachi's first classification, there are six branching types of the celiac trunk: hepatogastrosplenic, hepatosplenic, hepatosplenomesenteric, hepatomesenteric, gastrosplenic, celiacomesenteric. Hepatogastrosplenic trunk (type I according to Adachi classification) dividing into 3 branches i.e. LGA, CHA and SA was found in 93.0% (930/1000). Two different types of this trifurcation were observed: (a) a true tripod when the celiac trunk ended in a complete trifurcation (≈35%, 325/930) and (b) a false tripod when the three arteries did not have a common origin (≈65%, 605/930) – figures 1a and 1b. Type II i.e. hepatosplenic trunk were found in 2.8% (28/1000) – figure 3. Type IV (i.e. celiacomesenteric trunk) were found in 1.1% (11/1000) – figure 4, type V (i.e. hepatomesenteric trunk) were found in 1.7% (17/1000) – figure 5, type VI (i.e. gastrosplenic trunk) were found in 1.4% (14/1000) – figure 6. We have not observed type III (i.e. hepatosplenomesenteric trunk). The level of celiac trunk origin was found to be at the inter-vertebral disc between T12 and L1 in all of the cases. The angle of departure of the celiac trunk from the abdominal aorta varied widely from 6.8° do 85.6°.

On average, the celiac trunk caliber was 11.7 mm, the largest with 18.1 mm and the smallest, 5.3 mm, and standard deviation of 0.13. The mean distance between the celiac trunk and the superior mesenteric artery was 15 mm, the largest - 22 mm, and the shortest - 3 mm, with standard deviation of 0.4.

Discussion

Anatomic variations of the celiac trunk and superior mesenteric artery occur due to anomalous embryogenesis of primitive ventral blood vessels originating from the abdominal aorta [4]. In our study, there were 4 types of celiac axis variation identified in 70 patients, with normal celiac axis anatomy in 930 (93%) patients as compared with 89% in the dissection study conducted by Michels [5]; 91% in the study conducted by Sureka et al. [6]; 86% in the study conducted by Sankar et al. [7]; 85.1%, 89.5%, and 95.4%, respectively, in cadaver studies, imaging studies, and liver transplantation studies, as reported by Panagouli et al. [8]; 89.1% in the study conducted by Song et al. [9]; 89.8% in the study conducted by Chen et al. [10], who analyzed a population defined as homogeneous in Japan; and 90% in the study conducted by Araujo-Neto et al. [11]. The hepatosplenic trunk (2.8%) was the most common celiac artery variation with separate origin of left gastric artery (LGA) and superior mesenteric artery (SMA) followed by celiacomesenteric trunk (1.1%) Gastrosplenic trunk with separate origin of SMA and CHA from aorta was not found in our study which was found in 0.22% and 0.83% in the studies of Song et al and Sureka et al., respectively [6, 9].

MDCTA has become a valuable tool for the visualization of normal vascular anatomy and its variants. Furthermore, reformatted three-dimensional MDCT images allow visualization of vascular structures in angiography equivalent planes other than the axial, which is useful for evaluation of complex vascular anatomy [12, 13]. Rapid volumetric acquisition of thin-slice high resolution images of the abdominal arteries during the phase of maximal contrast enhancement with the help of MDCT allows 3D reconstructions to be created, providing the radiologist and the surgeon with a 3D model of the patient's arterial anatomy. MDCT angiography has a reported accuracy of 97–98% compared with conventional angiography for detecting arterial variants [14]. The disadvantages include potential for contrast reactions, nephrotoxicity, and exposure to ionizing radiation.

Knowledge about the spectrum of celiac trunk variations is important for planning surgical or interventional procedures in the upper abdomen. Identification of celiac trunk variations may avoid vascular complications during medical procedures, such as hepatobiliary surgery, pancreatic surgery, gastrectomy and others like transcatheter arterial chemoembolization [15, 16, 17, 18, 19].

Many endovascular procedures require detailed acquaintance regarding specific features of the particular blood vessels. It is especially noticeable in planning embolization both as intervention to control hemorrhage and as bariatric procedure. Hemorrhages can occur in the course of many vascular and non-vascular pathologies such as ruptured aneurysms, pseudocysts (due to pancreatitis which commonly lead to erosion of the splenic artery [20, 21]) or posttraumatic injuries (very often due to splenic injuries [22]) and inflammatory diseases i.e. pancreatitis with related bleeding [23]. In most of the mentioned cases the procedure is done within splenic artery or its branches [22, 23] and it is crucial to be acquainted with variations of the course of this artery, especially when the surgeon is planning the proximal splenic artery embolization which is faster instead of the distal, recommended to focal lesions in the spleen [22].

The embolization is also used in bariatric treatment. Recent studies revealed that the procedure of embolization the left gastric artery could improve loss of weight, decreases the concentration of grelin and HbA1c [24, 25, 26] but the veritable efficacy is still investigated [25]. It is significant to take into account detailed features of the LGA (s-shape) and its variation of emerging from the celiac axis and notice that the position of the celiac trunk might be horizontal, parallel or inferior which could affect manipulation difficulties [24].

One should bear in mind various angles of departure of the celiac axis from AA. In our study angle varied widely from 6.8° do 85.6°. Besides a hepatectomy, systemic chemotherapy and arterial chemoinfusion therapy are used to treat primary and liver metastatic cancers. Catheter insertion is necessary for arterial infusion chemotherapy, and there are surgical and percutaneous catheter insertion methods. The catheter insertion route is selected depending on the branching angle (upward or downward) of the origin of the celiac artery in some cases, and assessments of the branching angle before catheter insertion may increase the reliability of the technique. In recent studies Tokue et al. measured the branching angle of the celiac trunk in 1200 patients aged 19-91 years with hepatocellular carcinoma [27]. Similarly to our results, the branching was downward in most of patients. Prior information of the branching angle before catheter insertion may increase the reliability of the insertion technique and the completion rate of the therapy.

Many recent studies about liver transplantation revealed that the knowledge about the anatomy of the hepatic and aberrant (accessory or replaced) hepatic arteries emerging directly from the celiac trunk or its branches is significant to prevent complications both at the recipients and the living donors. [28, 29, 30, 31, 32, 33]. The complications after donation which eventuate from imprecise analysis of hepatic arteries and the other vessels include: sepsis, acute hepatic failure, biliary leaks of stricture or vascular thrombosis [29]. Thus, there is a trend to preserve accessory and replaced hepatic arteries as well as it is possible if there is not insurance about the blood supply in the same area of liver. In some cases this preservation could not be equal at the recipient and the donor so that it is important to analyze meticulously distribution of arteries in both circumstances [28, 29, 30]. According to Michels' classification there are described cases of presence replaced left hepatic artery (10%) and accessory left hepatic artery (8%), both originating from left gastric artery [5]. The appropriate retaining of arteries supplying the left donor's lobe is essential to provide adequate regeneration of the rest of liver [28, 29]. During planning the surgery in some cases there could be difficulties to palpate the accessory hepatic artery branching of the LGA which could be resolved by finding the LGA which sometimes could not pass from the celiac axis (for example in the hepatosplenic trunk) [30]. The replaced right hepatic artery frequently originating from the proper hepatic artery (from CHA) but sometimes (11%) it passes from superior mesenteric artery [5] and it also should be considered in planning the transplant procedure.

The awareness of variations of the celiac axis is also significant in treatment for patients with diagnosed hepatocellular carcinoma (HCC) and the other primary hepatic cancers. Roma et al. revealed that the right inferior phrenic artery (RIPA) - one of the branches of the abdominal aorta or the celiac trunk (which is the second most common origin [34, 35]) is the part of the collateral circulation and supplies the liver cancer in the most cases. This fact has an impact on planning treatment the peripheral lesions such as the chemoembolisation procedure [36]. Maki et al. mentioned that this artery and the other (left inferior phrenic, gastric, internal mammary arteries and omental arteries) creating the collateral circulation of the liver should be preserved to avoid postoperative ALT elevation due to hepatic ischemia.

Considering the other oncological issues: gastric, esophageal and pancreatic cancer, the procedure of resection the neoplasms very often includes lymphadenectomy of the lymph nodes surrounding the celiac axis, LGA or the CHA and SA [29, 37, 38]. The variations of the celiac trunk and its branches could restrict surgeon's manipulations during dissecting lymph nodes and lead to prolong the operative time and increase the risk of iatrogenic complications [29, 37]. It is also crucial to analyze thoroughly the anatomy of the blood vessels which are considered to sacrifice during the procedure. Maki et al. noted that ligation the LGA during gastrectomy could lead to liver ischemia because of presence the accessory or replaced left hepatic artery [32] and Kim et al. suggested preservation of the accessory left hepatic artery if the diameter of the LGA is equal or larger than 5 mm [39].

Our study provides an insight into the anatomical patterns found in Poland. According to our finding, the prevalence of variations was significant, so we suggest to apply 3D reconstruction method for evaluation of variation at least in patients who are candidate for mentioned surgical or interventional procedures. Further studies of this nature could lead to better technical planning of surgical procedures and could avoid inadvertent injuries that might compromise the results of medical procedures, leading to complications. Better knowledge of anatomical variations could ultimately contribute to reducing the rates of morbidity and mortality in endovascular procedures, abdominal surgeries, and transplantations, especially those of the liver and pancreas [40, 41, 42].

Conclusions

Our study identified the variations in celiac trunk anatomy in a sample of Polish population using Adachi classification. Our results correlated well with studies in other populations. Adequate knowledge of these variations would be of great help to the interventional radiologist and hepatobiliary surgeon.

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Figure 1a. True tripod

LGA – left gastric artery, SA - splenic artery, CHA - common hepatic artery, PHA - proper hepatic artery, GDA - gastroduodenal artery.

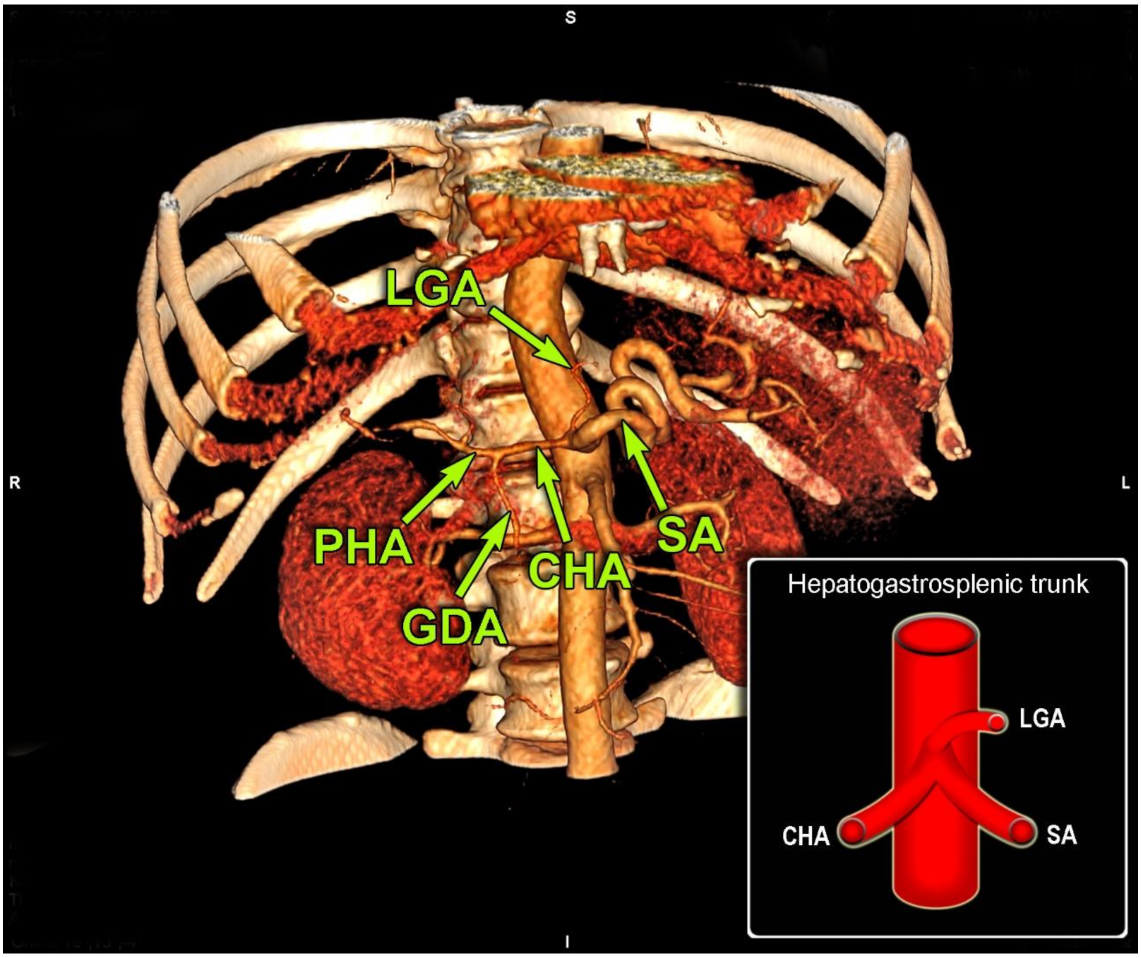

Figure 1b. False tripod

LGA – left gastric artery, SA - splenic artery, CHA - common hepatic artery, PHA - proper hepatic artery, GDA - gastroduodenal artery.

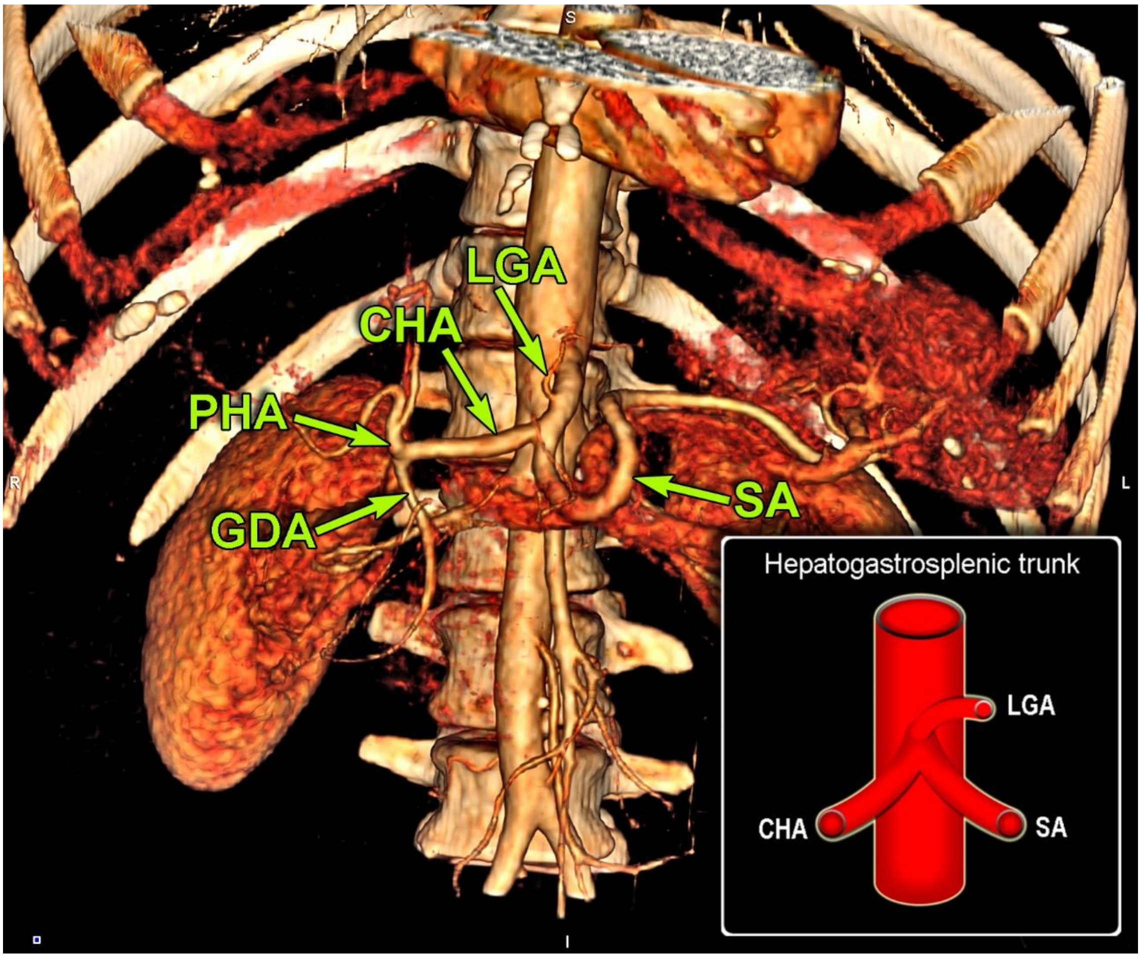

Figure 2. Celiac trunk trifurcation types according to Adachi.

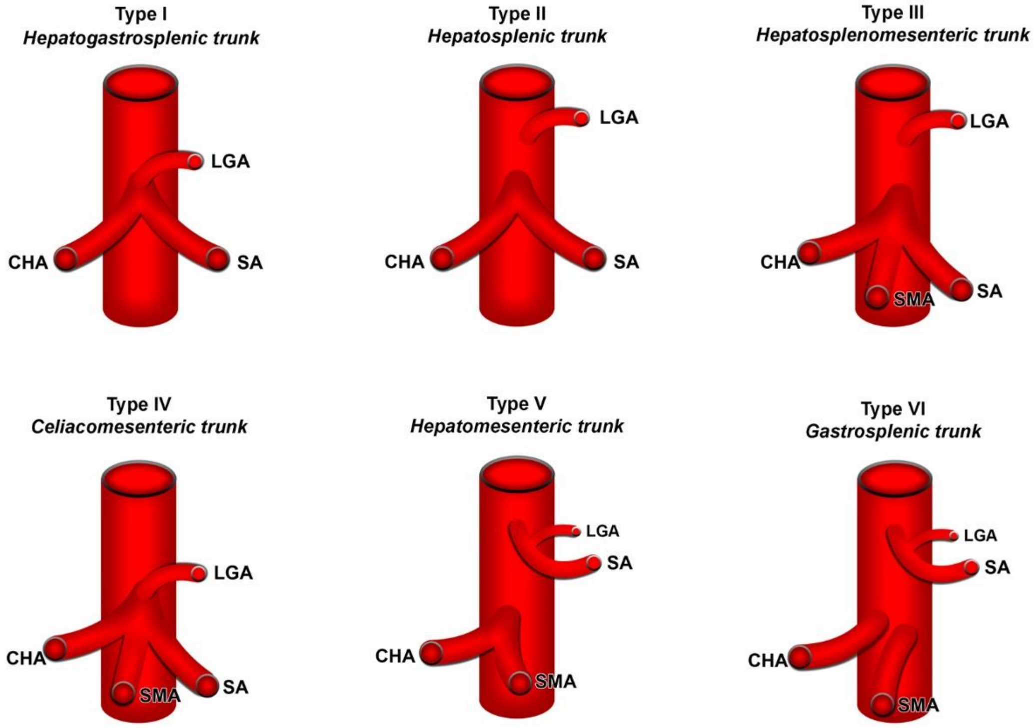

Figure 3. Hepatosplenic trunk.

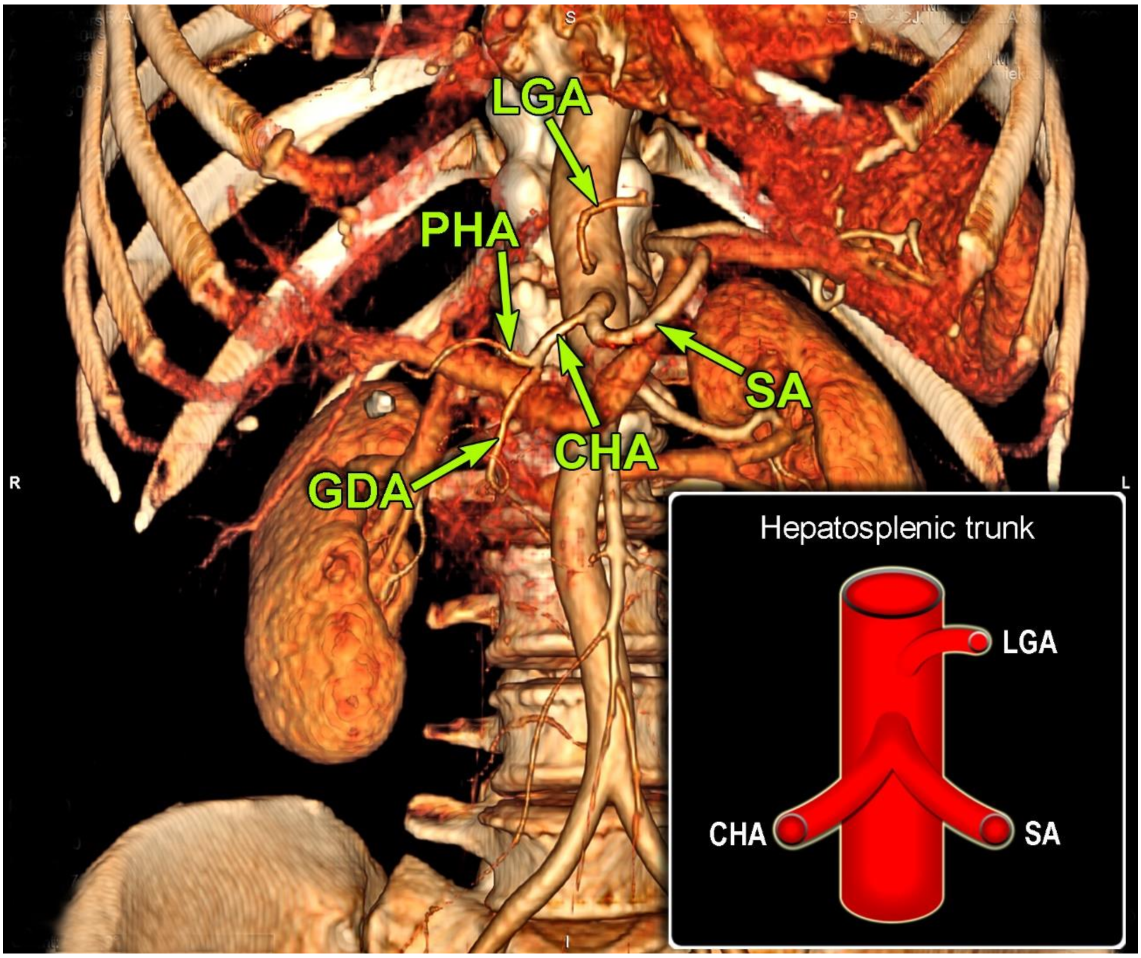

Figure 4. Celiacomesenteric trunk.

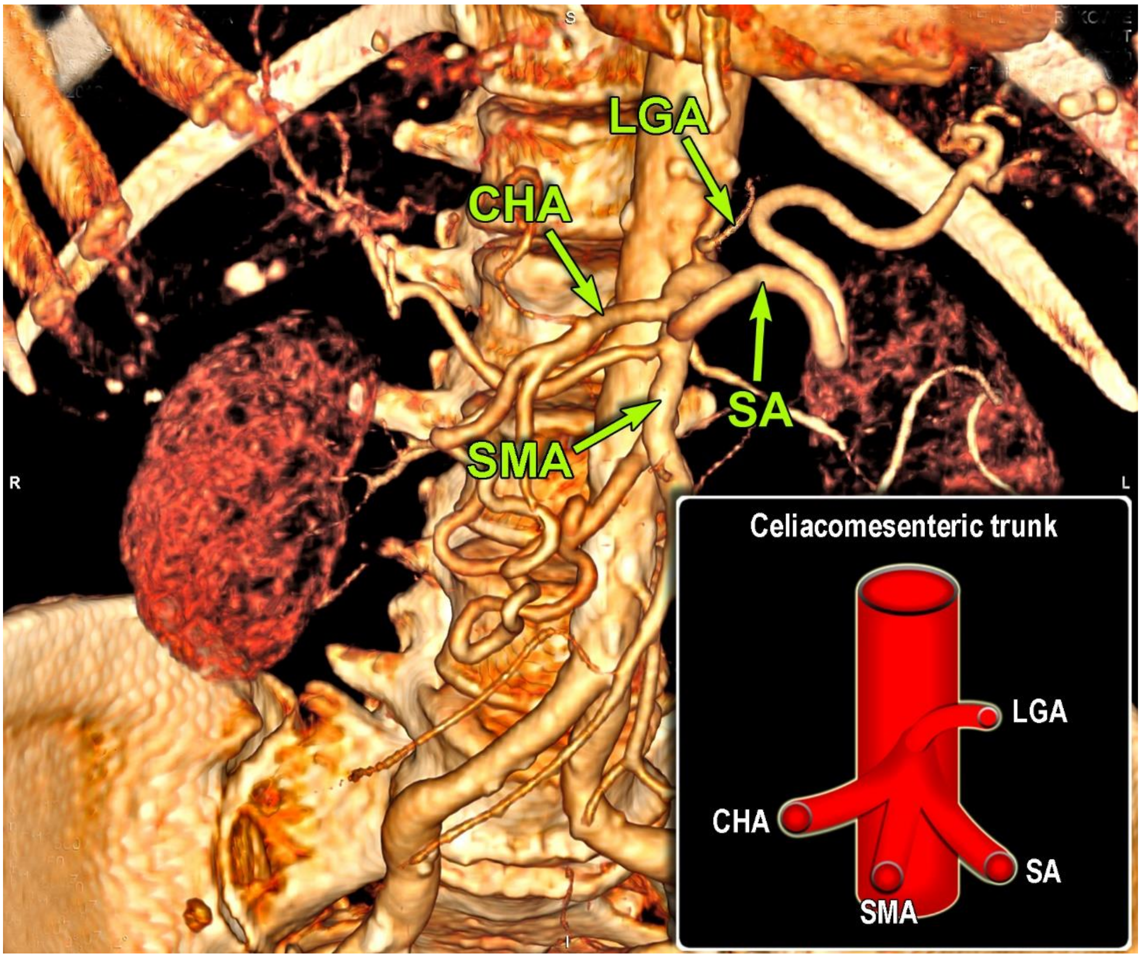

Figure 5. Hepatomesenteric trunk.

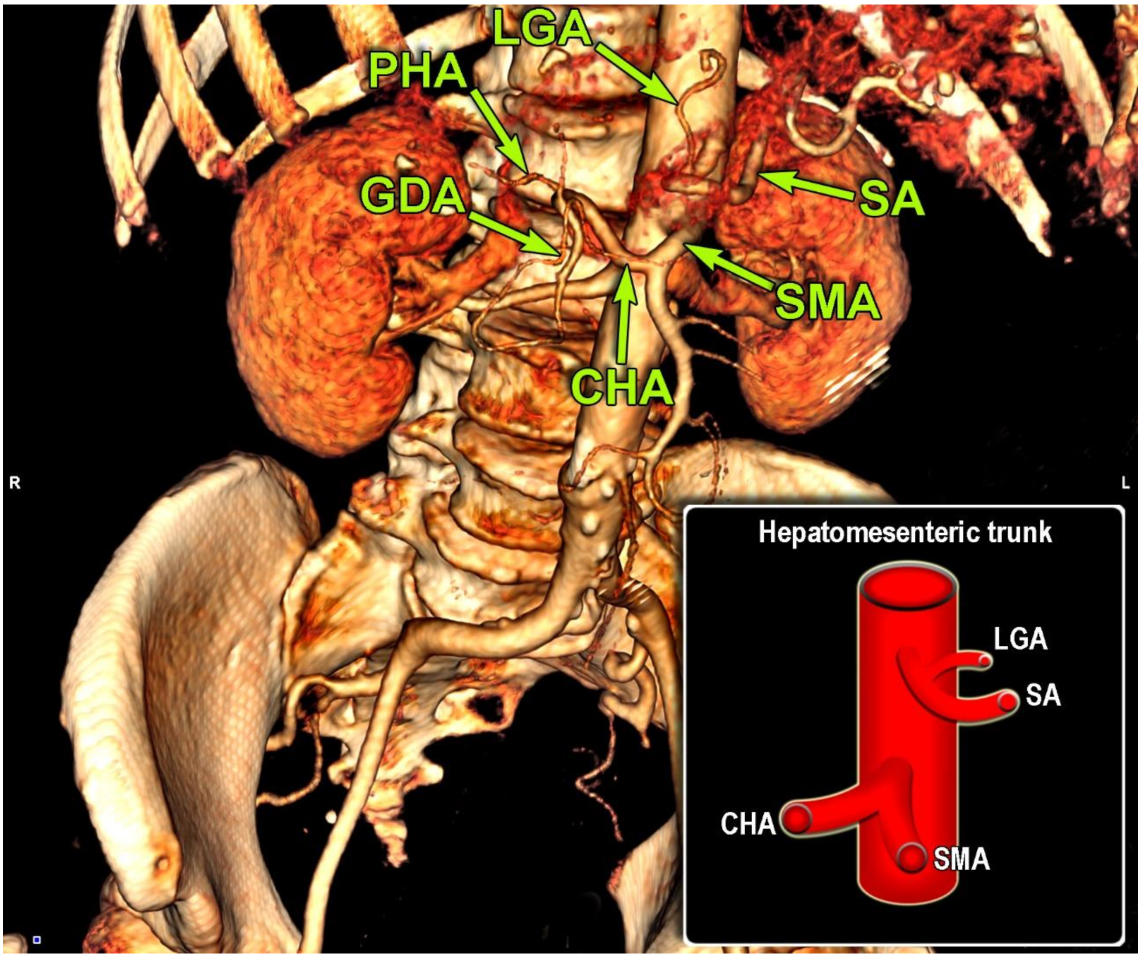

Figure 6. Gastrosplenic trank.

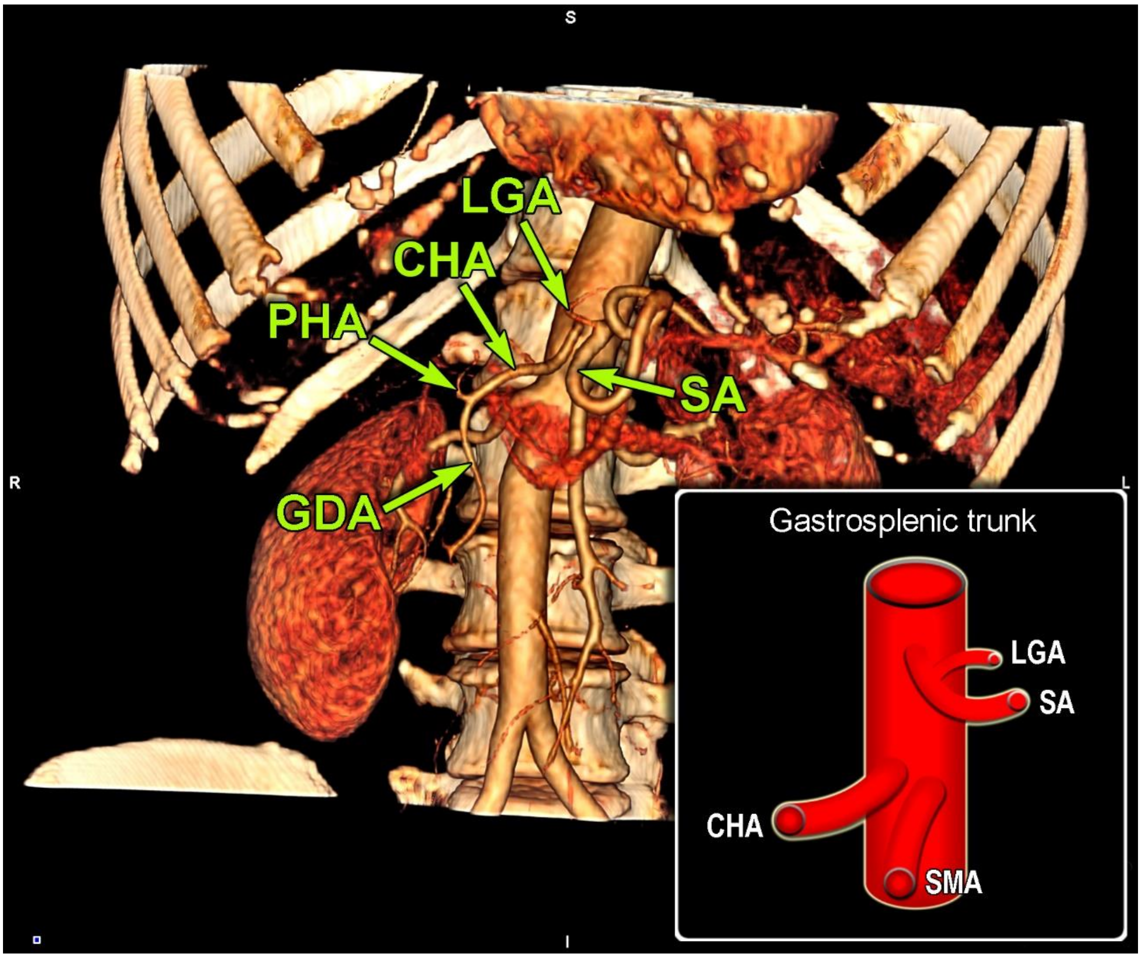

Table 1: Adachi's classification of celiac trunk variations

Trunk classification	Trunk classification number	Percentage
Hepatogastrosplenic	**1**	**86%**
Hepatosplenic	**2**	**8%**
Gastrosplenic	**6**	**3%**
Celiacomesenteric	**4**	**1.5%**
Hepatosplenomesenteric	**3**	**1%**
Hepatomesenteric	**5**	**0.5%**

Table 2. Celiac trunk variations according to Adachi classification found in the study.

Trunk classification	Trunk classification number	Percentage
Hepatogastrosplenic	**1**	**93%**
Hepatosplenic	**2**	**2,8%**
Gastrosplenic	**6**	**1,4%**
Celiacomesenteric	**4**	**1,1%**
Hepatosplenomesenteric	**3**	**0%**
Hepatomesenteric	**5**	**1,7%**

3. ARTYKUŁ NR 3

Rare combined variations of the celiac trunk, accessory hepatic and gastric arteries with co-occurrence of double cystic arteries: a case report.

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Abstract

Many variations of the celiac trunk and hepatic or gallbladder arterial supply have been reported before in many cadaveric and radiologic studies. In this case we present combined anomalies observed in dissected cadaver of a 73-years old female. The left gastric artery arises directly from the abdominal aorta and gives two branches: the right inferior phrenic artery in the proximal part and the accessory left hepatic artery in the distal part. The celiac trunk is bifurcated into the common hepatic artery and the splenic artery. The right gastric artery emerges from the left hepatic artery. The right hepatic artery gives two cystic arteries and the accessory right hepatic artery is noticed arising from the posterior superior pancreaticoduodenal artery. The deep cystic artery and the right inferior phrenic artery give hepatic branches. Also, we noticed small accessory biliary duct going to the cystic duct. This complexity of the arterial supply with anomaly of the biliary ducts have many surgical implications which will be herein discussed.

Keywords: anatomical variations, accessory hepatic artery, gastric artery, double cystic arteries, right inferior phrenic artery

Introduction

The importance of the arterial supply of the liver, gallbladder and upper gastrointestinal tract is noticed in plenty of surgical procedures. J.F. Calot (1891) was the first, who emphasized the position of the cystic artery during cholecystectomy [7]. Adachi (1928) elaborated the classification of variations of the celiac trunk, which is also used currently [1] and Michels was one of the first researches who described and classified the variability of the hepatic arterial supply [23]. According to recent reviews the most common variation in types of the incomplete celiac trunk was the hepatosplenic trunk present in 3,88% of cases with the left gastric artery originating from the abdominal aorta in 99.87% [35]. The right gastric artery most frequently goes from the proper hepatic artery – in 53% of cases [11]. Accessory or replaced hepatic arteries are observed in 30.8%. The accessory left hepatic artery which occurs in 8.2% mostly rises of the LGA (7.9%) and the accessory right hepatic artery described in 5.6% of cases with the most often origin from the superior mesenteric artery in 5.4% [17]. Double cystic arteries (or multiple cystic arteries) are observed in 8.9% [3]. The right inferior phrenic artery the most frequently originates from the abdominal aorta [32]. Our case comprises more or less frequent variations of all mentioned arteries with accessory branches to liver what makes it unique and allows to show the significance of them in clinical practice for example in transplantology, cholecystectomy or surgical oncology.

Abbreviations: aLHA – accessory left hepatic artery, aRHA – accessory right hepatic artery, CA – cystic artery, dCA – deep cystic artery, sCA – superficial cystic artery, CBD – common biliary duct, CD – cystic duct, CHA – common hepatic artery, CHD – common hepatic duct, GDA – gastroduodenal artery, IPA – inferior phrenic artery, LGA – left gastric artery, LHA – left hepatic artery, PHA – proper hepatic artery, PSPD – posterior superior pancreaticoduodenal artery, RGA – right gastric artery, RHA – right hepatic artery, RIPA – right inferior phrenic artery, SMA – superior mesenteric artery

Case report

During a routine dissection for teaching purpose of the 73-year old female 10% formalin-fixed cadaver many multiple anomalies were observed. In the abdominal cavity any previous surgical interventions were not noted. At the level of Th12-L1 the LGA (4.74 mm in diameter) arises separately from the abdominal aorta (18.15 mm in diameter) curving a geniculate flexure and branches off the RIPA (2.75 mm in width) at 8.51 mm from the origin and heading up gives the second branch i.e. the aLHA (2.89 mm in diameter) after 25.15 mm in length course from the proximal branching. The small hepatic branch (1.17 mm in diameter) arises from the RIPA at 18.18 mm distal from the beginning. The aLHA gives small esophageal branch only 1.30 mm in diameter (Fig.2). The hepatosplenic trunk (5.33 mm in width) originates from the abdominal aorta 4.39 mm below the LGA and divides into the CHA and the SA. The CHA (4.67 mm in width) courses along the upper margin of the pancreas and branches into the PHA and the GDA at 27.41 mm from the beginning. The PHA (3.68mm in diameter and 9.07 mm in length) ends up with bifurcating into the RHA and the LHA. The LHA (2.87 in width) branches to the RGA (1.79 mm diameter) at the 2.40 mm from the origin and the RGA runs down 25.94 mm to the lesser curvature crossing the CHA above (Fig.1). The RHA (3.34 mm in diameter) passes behind the CHD at the 15.46 mm from the beginning of its course and gives rise to the superficial CA (1.63 mm in width) 3.20 mm after crossing the CHD (diameter 7.07 mm), gives small branch to the liver and at the 5.24 mm from the first branching and gives the deep CA (1.48 mm in diameter) which from also arises a small hepatic branch (1.05 mm in width) (Fig. 3). The GDA at the 16.14 mm from the origin feeding branches to the right gastroepiploic artery (2.62 mm) and the anterior superior pancreaticoduodenal artery (1.95 mm diameter) and then the GDA runs down as the posterior PSPD along the head of pancreas giving the proximal branch (at the 16.37 mm from the previous branching), travels 9.89 mm and divides into the aRHA and the distal branch (1.93 mm). The aRHA (2.10 mm in diameter and 40.32 mm in length) runs parallel to the common bile duct and travels to the biliary fossa dividing into two branches before entering the liver. In the vicinity of this area the small accessory biliary duct (0.52 mm in width) going directly from V segment of the liver and at 14.58 mm from the origin merges to the cystic duct in the midway of its course (Fig. 4). Diameters of observed abnormal arteries were summarized in Table 1.

In this case, the arterial blood supply for the liver was supported by five arteries: RHA, LHA, aRHA gave off the PSPD, aLHA from the LGA, RIPA and the small branch arising from the dCA.

Discussion

The variations of the incomplete celiac trunk were repeatedly described by researches. As we mentioned, the hepatosplenic trunk was observed in 3.88% of cases with the abdominal aorta as the origin feeding of the LGA in 99.87% . More rarely the LGA arises from the SMA (0.76%) or it is absent (0.38%) [35]. The prevalence of the cases where the LGA gave off the RIPA is estimated of 2% to 4.1% [25]. Some of the researches distinguished the gastrophrenic trunk [16,22,26,28,32,37] as the common origin of the IPA and the LGA. The majority of the used classifications do not perceive it as a trunk and in most cases it is recognized in association of presence with the hepatosplenomesenteric trunk [16,22,26,28] but the co-occurrence with the hepatosplenic trunk also was described [32,37]. According to the classification proposed by Whitley et al. [35]. this type of trunk is not included but we came to the conclusion that it is important to mention this fact. Inferior phrenic arteries more frequently origin asymmetrically [5]. Right inferior phrenic arteries commonly arise from the abdominal aorta (49%) or the celiac trunk (41%), less frequently from the LGA or renal arteries (5.5%) [4,5,19]. Aslaner et al. noted higher frequency of the RIPA arising from the renal artery with co-occurrence of the incomplete celiac trunk [4].

The anomaly of the RGA arising from the LHA was observed by Yamagami et al. in 25.3% [36] of cases and the Eckmann et al. estimated the frequency to 15% [11].

Variations of the hepatic arteries were commonly described by many authors [9,17,23]. In the review presented by the Cirrochi et al. [9] the aLHA originating from the LGA was noticed in 3.60% (694/19284) of cases (including Michels' and Hiatt's findings). Jin et al. estimated the prevalence of the aLHA from the LGA as the origin to 8.2% (total cases 10211) . The aRHA was observed in 5.6% of cases . Although the cases of aRHA arising from the GDA were revealed in approximately 0.04% (4 of 10211 cases which also included branches of the GDA) [17], the pancreaticoduodenal artery branched the aRHA in some of them [2]. Juszczak and Sobolewski et al. presented similar interesting case wherein also both accessory hepatic arteries were observed, aLHA arising from the LGA which arose independently from the abdominal aorta and aRHA from SMA as the feeding origin but contradistinctively to our case the PHA did not divide into two hepatic arteries. Also, they observed both inferior phrenic arteries originating from the hepatosplenic trunk (positioned opposite to the vertebral L1 level) which both branched off superior adrenal arteries [18].

Andall et al. revealed the weighted percentage of the multiple cystic arteries circa 8.9% with the highest noted number of arteries as four [3] but some researchers found this variation in 30.2% [24] and 28.3% [6] of cases. Small accessory biliary duct emerging from the liver parenchyma found in our case is classified as cystohepatic duct and the incidence of its variation (also including the cholecystohepatic duct which directly drains to the gallbladder) ranges between 0.2 and 2.3%. This variation might occur with normal CHD and CBD anatomy likewise in our case [30,31]. Frequency of observed variations were presented in Table 2.

Variations observed in our case reflect processes during fetal development. The most common variation is trifurcation of the celiac trunk (LGA, CHA and SA) separately to the SMA which is generated by interruption of anastomosis between third and fourth ventral mesenteric root

[33]. The interruption between 1. and 2. mesenteric roots with termination of anastomosis between 3. and 4. roots cause occurrence of LGA independently originating from abdominal aorta with hepatosplenic trunk. Higher prevalence of some variations of hepatic arteries also could be explained by analyzing the embryological development. Primarily the LHA arises from the LGA and the RHA from SMA and absence of the PHA which originates from the CHA after its bifurcation. If hepatic branches of the LGA or SMA with division PHA into RHA and LHA are preserved, these branches are named as accessory left hepatic artery and accessory right hepatic artery respectively. This fact clarifies high frequency of aLHA originating from the LGA and aRHA from the SMA. Grugacz et al. reported case wherein all fetal origins of hepatic arteries were preserved with presence of the middle hepatic artery feeding IV segment of the liver [14]. In our findings we observed abnormal primary right hepatic artery arising from branch of the GDA transitioned during development to the aRHA. Mahajan et al. presented similar case of preserved fetal pattern of liver's blood supply, also they reported occurrence of esophageal branch arising from replaced LHA which emerged from LGA [21].

Doubled cystic arteries with co-occurrence of accessory hepatic arteries were reported by some authors. Loukas et al. described case wherein a small accessory CA arose from PSPD with aLHA originating from LGA which emerged independently from abdominal aorta and the hepatosplenic trunk also was observed [20]. Polguj et al. revealed variant of GDA which gave off both accessory CA and aRHA which also gave off CA. No other anomalies of celiac trunk and hepatobiliary vasculature were observed in this case [27]. Dolenšek described occurrence of doubled CAs (larger sCA and small dCA) which both arose from aRHA. Similarly to our case both accessory hepatic arteries were present but the aRHA emerged from the SMA and the PHA was trifurcated into left, middle and right hepatic arteries with coexistence of classical trifurcation of the celiac trunk [10]. According to Andall et al. the prevalence of CA arising from abnormal RHA (replaced or accessory) is estimated to 5.58%. In this research the frequency of GDA and PSPD as origin feeding of CA was 1.94% and 0.07% respectively [3].

Vascular abnormalities described in this case are significant in surgical practice. Using the Critical View of Safety method (CVS) during laparoscopic cholecystectomy the surgeon has to precisely indentify vascular structures in the hepatobiliary triangle. In cases, wherein the origin feeding of the cystic artery is different than the RHA (LHA or GDA) or course of the cystic artery is anteriorly to the common hepatic duct, there is a high risk of ligation. Also, in variant of multiple cystic arteries one of the CAs could be overlooked leading to uncontrolled bleeding [3]. Although the postcholecystectomy bile leaks occur in 0.2-2% of cases, the surgeon should be careful with presence of the subvesical ducts during the procedure, especially if this duct drains to the cystic duct [29,31].

Knowledge about variations of accessory or replaced hepatic arteries is crucial in planning intraarterial chemotherapy in treatment of cancers or metastases (mainly metastases of the colorectal cancer) in liver because it is essential to find appropriate artery feeding occupied lobe by neoplasm to accurately arrange hepatic arterial infusion pump (HAIP) placement and avoid infusion to arteries supplying the other organs. This procedure also include the embolisation of the extra-hepatic arteries, such as RGA , pyloric artery and GDA [8,13] and if accessory or replaced hepatic arteries arising from the embolized artery was not recognized it could cause hepatic ischemia. In procedures of chemo-embolisation and radio-embolisation it is significant to consider blood circulation in interested segment provided by the extra-hepatic arteries including inferior phrenic arteries which usually supply the I,II and VII segments. LGA and CA are also hepatic feeders, II, III segments and peri-vesicular region respectively [13]. The RIPA is mentioned as one of the main extrahepatic collateral arteries which are supplying the hepatocellular carcinoma (HCC) and usually in this case the diameter of the RIPA is larger than the diameter of the LIPA. The width of the RIPA feeding neoplasm in the liver ranged from 2 to 3.2 mm [5] and in another research the diameter greater than 2.5 mm was considered as indication of present collateral circulation [4].

Vascular anatomy of liver is also significant in transplantology, especially in living-donor liver transplantion, wherein right (adult recipient) or left lobe (pediatric recipient) is harvested because thorough analysis of liver vessels enables to preserve proper blood circulation in retained donor’s lobe and guarantees appropriate liver regeneration. In surgical practice preservation of all found anomalies of hepatic arteries is preferred [8,34] but some of them could be difficult to find during the procedure, for example the accessory left hepatic artery arising from the LGA [34]. Also, anomalies of the hepatic biliary vascularisation should be verified (especially in harvesting the right lobe) to avoid bile leakage in recipients which leads to graft rejection [8,12].

Conclusions

Anatomical variations of the arterial blood supply of upper part of the abdomen have great importance in many surgical procedures and they are strongly associated with embryological development. Acquaintance about branching patterns of cystic arteries and hepatic arteries is significant in planning cholecystectomy or liver transplantation and in these procedures existence of accessory biliary duct should be concerned to avoid postsurgical complications. Abnormal branches to liver or gallbladder arising from gastroduodenal artery or posterior superior pancreaticoduodenal artery are rarely observed and knowledge about them facilitate better understanding about vascularisation of these organs.

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Figure 1. Complex variations of the celiac trunk. LGA arises independently from the abdominal aorta and branches to the RIPA which gave off small hepatic branch and in the distal course from the LGA arises the accessory left hepatic artery. RGA originates from the LHA. aLHA – accessory left hepatic artery, GDA – gastroduodenal artery, LGA – left gastric artery, LHA – left hepatic artery, PHA – proper hepatic artery, RGA – right gastric artery, RHA – right hepatic artery, RIPA – right inferior phrenic artery, SA – splenic artery

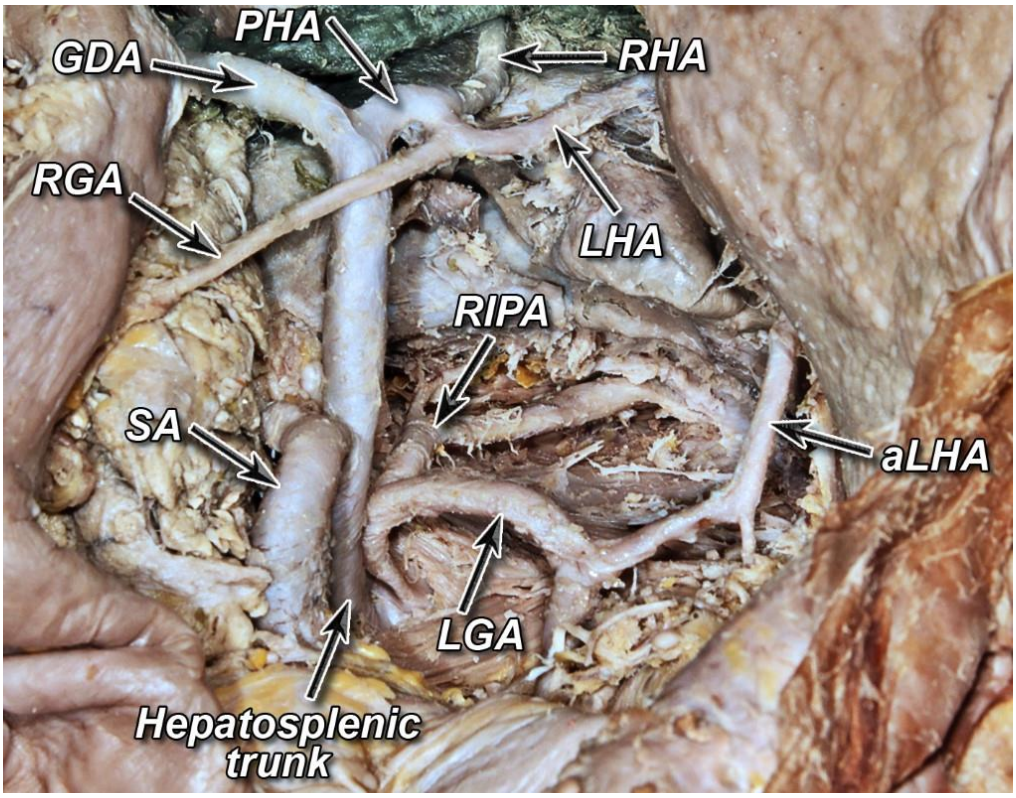


Figure 2. Emphasized small branches to the esophagus and the liver. aLHA – accessory left hepatic artery, LGA – left gastric artery, RIPA – right inferior phrenic artery, SA – splenic artery

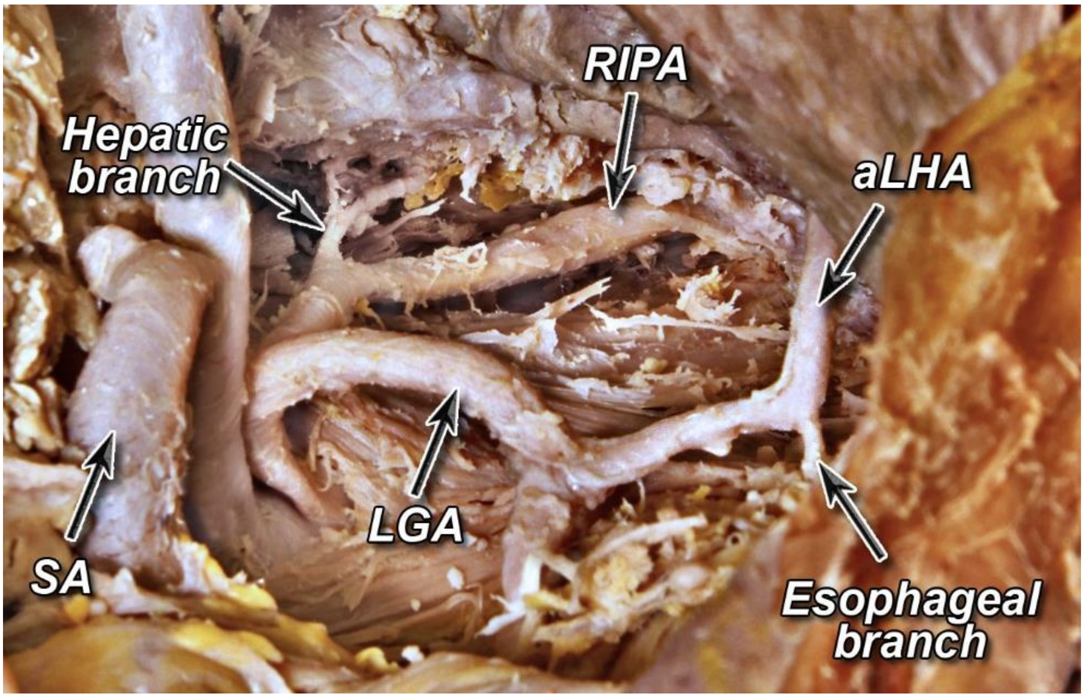
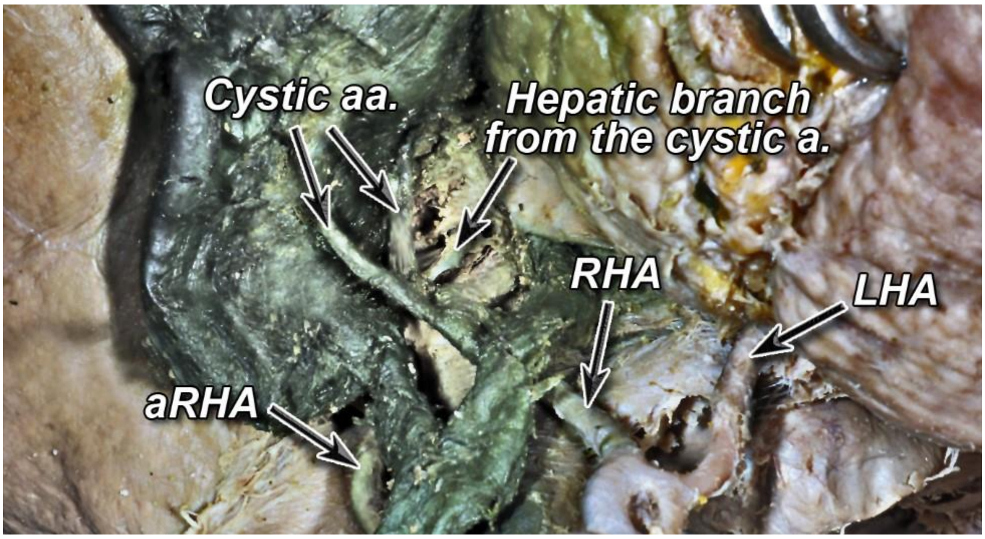


Figure 3. A, B. Cystic arteries with branches to the liver arising from the dCA and RHA. dCA – deep cystic artery, sCA – superficial cystic artery, LHA – left hepatic artery, aRHA – accessory right hepatic artery, RHA – right hepatic artery



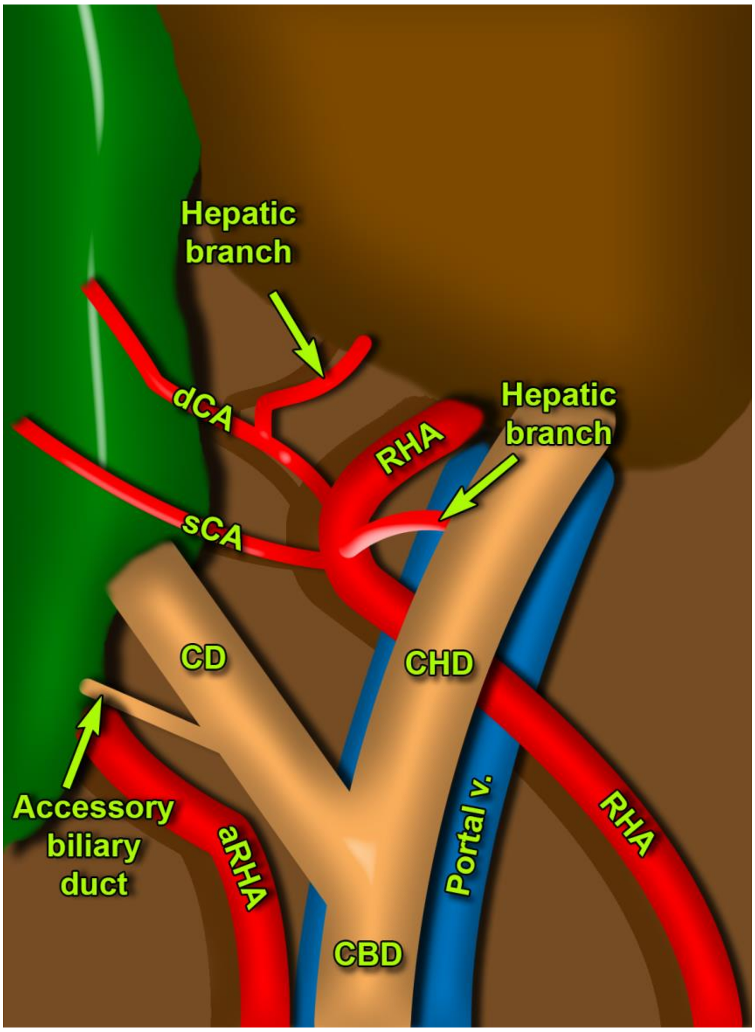


Figure 4. Accessory RHA emerges from the posterior superior pancreaticoduodenal artery and travels parallel to the common bile duct to the gallbladder fossa, dividing into right and left branch. Small accessory biliary duct (also known as cystohepatic duct) goes directly from the liver (V segment) and reaches the cystic duct at its halfway.

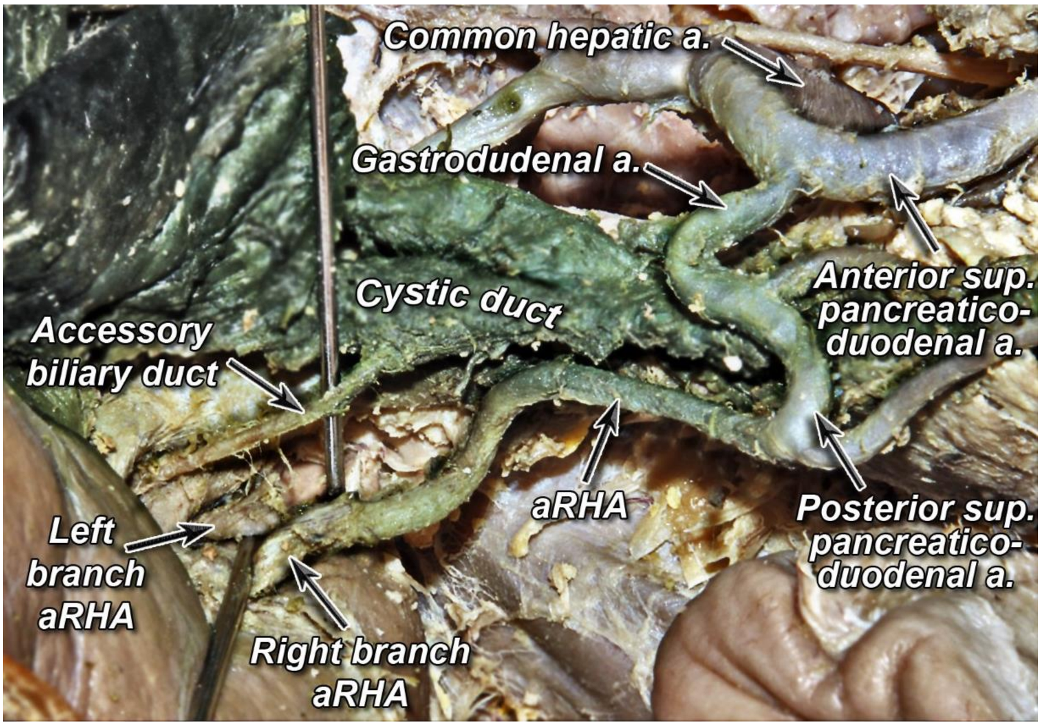


Table 1. Summarized measurements of abnormal arteries in our case.

Artery	Diameter [mm]
LGA	4,74
RGA	1,79
RIPA	2,75
aLHA	2,89
aRHA	2,10
dCA	1,48
sCA	1,63

Table 2. Prevalence of observed in our case variations.

Variation	Frequency (%)
RIPA from LGA	2 – 4.1
Hepatosplenic trunk (LGA from abdominal aorta)	3.87
RGA from HA	15 – 25.3
aLHA from LGA	3.6 – 8.2
aRHA from GDA	0.04
Multiple CAs	8.9
Cystohepatic duct (including cholecystohepatic duct)	0.2 – 2.3

4. ARTYKUŁ NR 4

Unusual variations in the branching pattern of the celiac trunk and their clinical significance
(Original article)

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Abstract

Background: The anatomical variations of the celiac trunk are due to developmental changes in the ventral segmental arteries. Multidetector computed tomography (MDCT) has been used to investigate vascular anatomy for scientific and diagnostic purposes. These studies allow for much larger sample sizes than traditional cadaveric studies. The aim of this research was to isolate rare anatomical variants of the celiac trunk and emphasize their clinical significance.

Material and methods: A descriptive, retrospective study was carried out on MDCT angiographies performed from January 2020 till March 2020 in Polish patients. Celiac trunk was studied and normal and anatomical variations were identified.

Results: Out of total 350 patients, hepatogastrosplenic trunk was predominant. However, we observed: celiaco-mesenteric and hepatogastric trunk type, hepatic artery variations and celiac axis stenosis with collateral mesenteric circulation.

Conclusion: Rare variations of the celiac trunk should always be anticipated before radiological and surgical interventions. Knowledge of unusual celiac trunk anatomy is important in hepatopancreatobiliary surgery, transplantology, and interventional radiology.

Keywords: Celiac trunk, Variations, Multidetector Computed Tomography angiography, MDCTA.

Introduction

The main mesenteric vessels, the celiac trunk (CT), the superior mesenteric artery (SMA), and the inferior mesenteric artery (IMA) develop from the primitive ventral segmental (splanchnic) branches, which are originally paired vessels. They become next the unpaired after the fusion of two dorsal aortae and next nourish the gut tube (after yolk sac incorporation) [1]. There is regression of all segmental arteries as development proceeds, except for three of these primitive communications, with only precursors to the three major mesenteric vessels and longitudinal anastomotic vessels remained. The 10th segmental artery gives rise to the celiac trunk, the 13th segmental artery gives rise to the superior mesenteric artery, and the 21st or 22nd artery gives rise to the inferior mesenteric artery. The longitudinal anastomotic vessels between the celiac trunk and SMA, and between the SMA and IMA disappear [2, 3, 4, 5]. Persistence, incomplete regression, or disappearance of parts of these primitive ventral segmental arteries could give rise to numerous variations of SMA (Fig. 1) [6, 7]. Understanding the different anatomical variations of mesenteric circulation is mandatory in various diagnostic and surgical procedures in the upper abdomen. Nowadays, evaluation of arteries branching from the abdominal aorta is possible owing to a minimally invasive examination – the multidetector computed tomography angiography (CTA). The latest 64-row CT scanners allow for a very high spatial resolution (up to 0.4 mm) and a temporal resolution of only a few seconds. These technical developments have made it possible to acquire detailed knowledge of the abdominal vasculature prior to surgery. This makes the technique indispensable for surgeons, for example, in planning liver transplantation surgery or, more commonly, in fashioning intestinal anastomoses, the success of which is dependent on adequate vascularity [8].

The purpose of this study is to determine arterial branches of the celiac trunk by using noninvasive imaging technique, MDCT angiography of the abdominal aorta. Owing to the large number of the analyzed examinations, it was possible to isolate rare anatomical variants of celiac trunk and emphasize their clinical significance.

Material and methods

A computer search was performed to identify all the patients who had undergone MDCT angiography of the abdominal aorta at the Institute of Diagnostic Imaging, J. Dietl Specialist Hospital in Cracow, Poland between January 2020 and March 2020. A total of 350 CT angiographies of abdominal aorta of patients was included in our study and retrospectively reviewed to evaluate the visibility of the celiac trunk and its branches. All patients met the following inclusion criteria: performance of CT scan in the arterial and venous phase for a variety of clinical indications. Exclusion criteria were the presence of any condition likely to affect normal vascular anatomy, such as prior gastric resection surgery; extended jejunoileal resections; colonic resections; anterior rectal resection; partial pancreaticoduodenectomy; bariatric surgery; liver, pancreas, bowel or multiorgan transplants; and major hepatic resections. Patients were also excluded if they had aneurysmal disease of the splanchnic arteries, severe aortic atherosclerosis, arteritis with possible involvement of the vessels being studied (Kawasaki's disease, polyarteritis nodosa, Takayasu's arteritis, Churg-Strauss syndrome). The study was reviewed and approved by the local Ethics Committee /nr 1072.6120.78.2019/. The requirement for informed patient consent was waived due to the retrospective nature of the study. CT images were obtained with a 64-channel MDCT scanner (Aquilion 64, Toshiba Medical Systems Corporation, Tokyo, Japan). The contrast medium used was iohexal (Omnipaque 350; GE Healthcare AS, Oslo, Norway), which was administered intravenously by injection pump at a rate of 3-4 mL/s. The dose of the contrast agent was 1 mL/kg body weight and the upper limit of dose was set at 100 mL for every patient.

Image analysis was done on a dedicated Toshiba console equipped with reconstruction software. We used multiplanar reconstructions (MPRs) in the three spatial planes and three-dimensional reconstructions using maximum intensity projection (MIP) and volume rendering (VR). The arterial phase was used to create vascular maps of the celiac axis including the origin(s) of the hepatic artery and origin of the superior mesenteric artery. Images were interpreted by a radiologist with 15 years of experience in abdominal and vascular imaging. Statistical analysis was done with the Statistical Package for the Social Sciences (SPSS) version 21.

Results

The study population comprised 198 women (56,6%) and 152 men (43,4%) aged between 46 and 88 years (mean age 62,7 ± 15,3). According to Adachi and Michels classification different types of normal anatomy or anatomic variants were described.

Hepato-gastro-splenic trunk

This is the classical trifurcation of the celiac trunk, detected in a total of 340 patients of our series (97,14%). The typical variant was defined as: the vascular trunk located approximately 1 cm above the superior mesenteric artery and splitting into 3 branches: left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA).

Celiaco-mesenteric trunk type

Common origin of the celiac trunk and of the superior mesenteric artery – the celiaco-mesenteric trunk – was observed in 5 patients (1,4%) (Fig. 2).

Hepato-gastric trunk type

Common hepatic and left gastric arteries origin from a common trunk whereas the splenic artery originates from the aorta (1/0, 28%) (Fig. 3).

Hepatic artery variations

The following two hepatic arterial variants were observed: the gastro-splenic trunk with the common hepatic artery arising from the superior mesenteric artery (Michels classification type IX). (Fig. 4) and the gastro-splenic trunk with the common hepatic artery arising independently from aorta and accessory right hepatic artery originating from CHA (Fig. 5).

Celiac artery stenosis

In one case there was celiac artery stenosis resulting in the development of collateral mesenteric circulation i.e. celiac artery compression syndrome (CACS) (Fig. 6).

We also observed celiac artery stenosis with extended collateral mesenteric circulation and SMA originating from aorta slightly above the celiac trunk (Fig. 7).

In either case the stenosed celiac trunk corresponded with a hepato-gastro-splenic type in a false configuration.

Discussion

Most of anatomical reports on the variation of CT are cadaver based studies [9, 10, 11, 12, 13, 14]. However, in recent years MDCT has been used to investigate vascular anatomy for scientific and diagnostic purposes. These studies allow for much larger sample sizes than traditional cadaveric studies.

The anatomical variations of the CT, SMA and IMA are due to developmental changes in the ventral segmental arteries [15]. Incomplete fusion or malfusion of the vitelline arteries during the developmental stage may be responsible for the variations of the celiac trunk.

A celiacomesenteric trunk (CMT) occurs when the 10th to 12th vitelline arteries regress and a large portion of the ventral anastomosis persists to connect the celiac artery and branches to the SMA. The common trunk of the celiac artery and the SMA is a rare variation and according to the earlier studies, it has been found in <2% of patients [1, 16]. A patient with CMT is at risk of mesenteric ischemia because there lack some of the protective benefits of dual-origin vessels with multiple mutually supporting anastomoses [17, 18, 19]. Anything that compromises the single common trunk arising from the abdominal aorta puts the entire vascular region of the major abdominal viscera at risk of ischemia [20]. Furthermore, CMT variant could change the SMA angle from the aorta, thus increasing or decreasing the potential for compression of the third portion of the duodenum [20]. Pathologies involving celiacomesenteric trunk are very rare and include stenosis and aneurysms of the common trunk [21, 22]. A common celiacomesenteric trunk thus has a strong potential for development and progression of atherosclerosis along the trunk, which can have severe consequences as it results in ischemia of the regions supplied by both the celiac trunk and superior mesenteric artery. Review of the literature reveals several cases of celiacomesenteric stenosis [23, 24, 25, 26, 27, 28, 29]. In these case reports, one patient had an open bypass graft, two had percutaneous angioplasty/stenting, one underwent open surgical endarterectomy with patch-graft angioplasty, one underwent open thrombectomy and one had extra-anatomic right iliac retrograde SMA bypass grafting. The CMT has been reported to be affected by aneurysms, atherosclerotic degeneration, thrombosis, and nutcracker syndrome [30].

The types of hepatic artery variation have been detailed described in Michel's classification [31] and other studies, [32, 33, 34] as well as anatomical monographs [35]. According to Michels classification, the most common variant observed was a replaced right hepatic artery originating from the superior mesenteric artery (Michels III), identified in 9.3% of patients. It is important to recognize a replaced right hepatic artery when performing pancreaticoduodenectomy and for porta hepatis dissection during hepatic resection. Therefore, if a head or uncinate process pancreatic cancer involves a replaced right hepatic, it precludes the patient from surgical resection. The second most common arterial variant identified was a replaced left hepatic artery originating from the left gastric artery, seen in 5.9% of patients (Michels II). It is important to detect this variant prior performing left hepatectomy because this vessel must be identified and ligated; the knowledge of this variant facilitates portal dissection because the major arterial branch to the left liver does not need to be found in the porta hepatis. A replaced left hepatic artery (LHA) arising from LGA, may provide a source for collaterals during obstruction of structures in porta hepatis. In addition, it may get damaged during esophagogastrectomy. This may lead to increased mortality due to hepatic necrosis [36]. Only patients with chronic liver diseases and a reduction of liver reserve functions are most susceptible to ischemia caused by the replaced LHA ligation; in effect, Huang suggested that the replaced LHA should be preserved in these cases [37]. In order to reduce these ischemic liver complications, some surgeons suggested a number of techniques for the preservation of the replaced LHA: preservation and peeling of the LGA along with the low tie of the LGA [38]. The LGA' branches, directed towards the lesser curvature and the oesophagus, are ligated separately to preserve the LGA and replaced LHA. Next, the LGA is ligated distal to the origin of the replaced ALHA. The third most common arterial variant observed was the common hepatic artery arising from the superior mesenteric artery, seen in 3.6% of cases (Michels IX). We identified this variant in our study. Michels' IX variant requires a twisting in anastomosis' order since the artery has be sutured before the portal vein because of its deeper location posterior to the vein. An accessory left hepatic artery originating from the left gastric artery was found (Michels V). This accessory artery provides an additional source of arterial blood to the left hepatic lobe and may be sutured without compromising the arterial supply to the left hepatic lobe [39]. Knowledge of the variant hepatic arteries is of greatest importance in liver transplantation, since appropriate technical adjustments must be made both in organ procurement and in re-anastomosis in the recipient [40].

Patients with stenosis or occlusion of a single mesenteric artery seldom develop symptoms of chronic mesenteric ischemia. It is commonly accepted that this is due to the extensive mesenteric arterial collateral circulation. However, mesenteric ischemia may occur in these patients, for example, in patients with celiac artery compression syndrome (CACS, Dunbar syndrome). This is nonatherosclerotic, respiration-dependent anatomical compression of the celiac artery by the median arcuate ligament (MAL) and diaphragmatic crura, that leads to extensive mesenteric collateral circulation. This extrinsic compression causes a constellation of symptoms including nausea, vomiting, weight loss, and postprandial epigastric pain [41]. Extensive collaterals are likely to have a compensating function preventing ischemia in the celiac artery outflow region [42].

Several studies have demonstrated successful treatment of CACS with CA release through release of the arcuate ligament [43, 44, 45, 46, 47].

Regarding gastrectomy with D2 lymphadenectomy for cancer, it is necessary during surgery to ligate at the root and cut off the left gastric artery, which may affect the hepatic tissue supplied by the replaced/accessory left hepatic artery deriving from the left gastric artery, thus influencing hepatic function, especially for the replaced right hepatic artery [48, 49, 50]. Therefore, accurate preoperative assessment of whether the abnormal left hepatic artery is replaced by the right hepatic artery or accessory right hepatic artery is especially important.

Preoperative knowledge of variant arterial anatomy may reduce extensive exploration during surgery and consequently decrease the risk of vascular damage [51]. According to our current and previous findings, we suggest to apply reconstruction method for evaluation of variations at least in patients who are candidate for mentioned surgical or interventional procedures [52, 53]. Preoperative MDCT angiography with 3D reconstruction should be performed before any major surgery on the upper gastrointestinal organs to identify all vascular variations to allow optimal preoperative planning.

Conflict of interests

The authors declare that they have no conflict of interests.

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Figure 1. The embryologic origin of the visceral arteries. A. Primitive ventral segmental arteries. B. Normal anatomy demonstrating the celiac trunk arising from the 10th and SMA from 13th segmental artery, respectively.

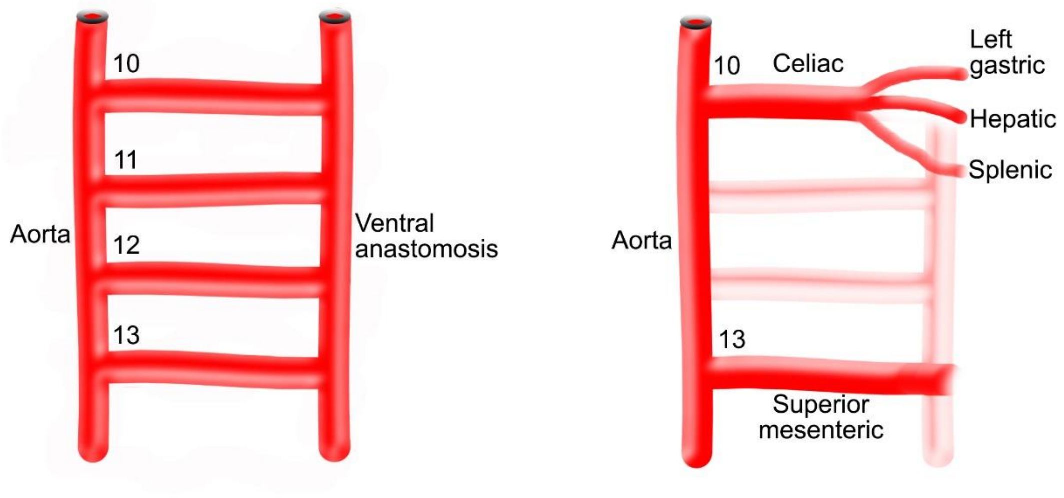

Figure 2. Celiaco-mesenteric trunk type.

CT - celiac trunk, LGA - left gastric artery, CHA - common hepatic artery, SA - splenic artery, SMA - superior mesenteric artery.

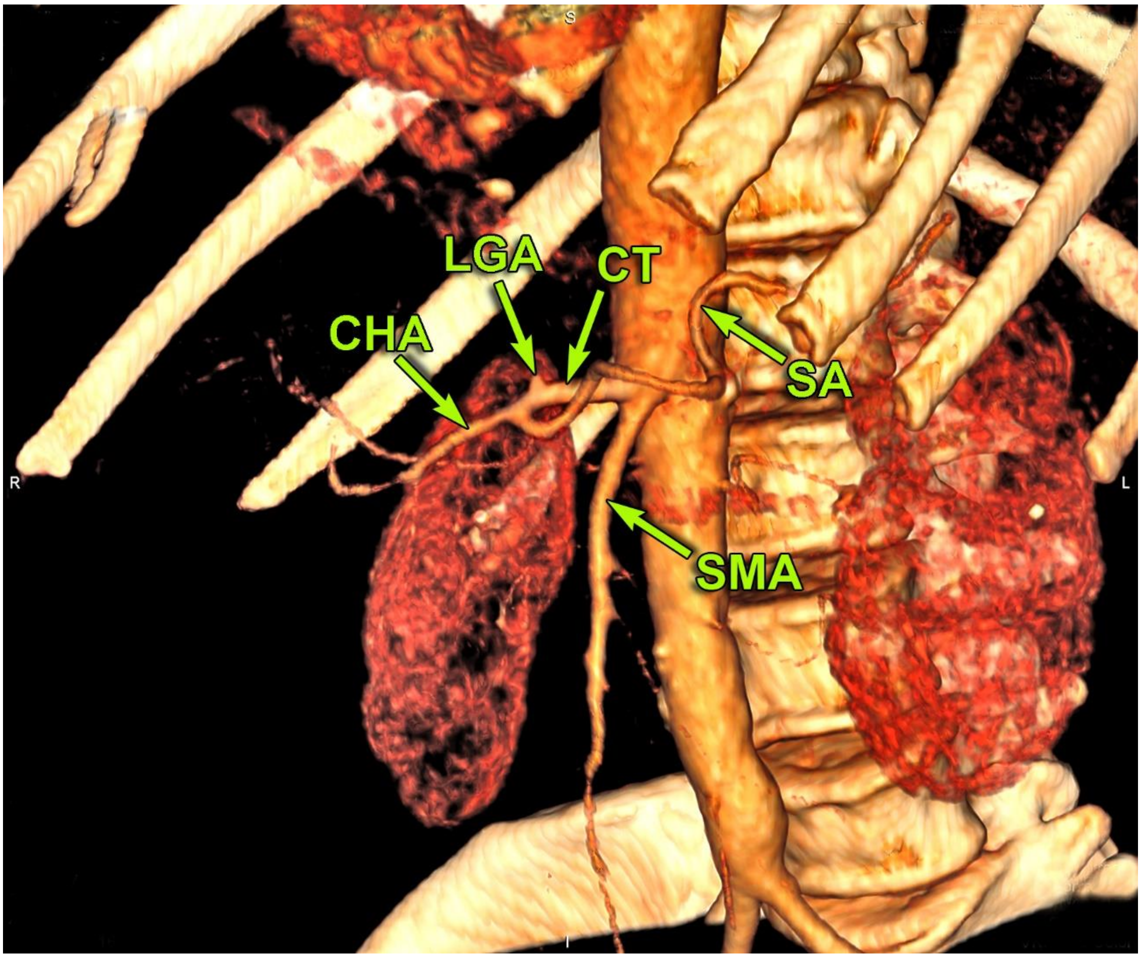

Figure 3. Hepato-gastric trunk type in association with the independent arising of SA.

CT - celiac trunk, CHA - common hepatic artery, SA - splenic artery, LGA - left gastric artery, GDA - gastroduodenal artery, SMA - superior mesenteric artery.

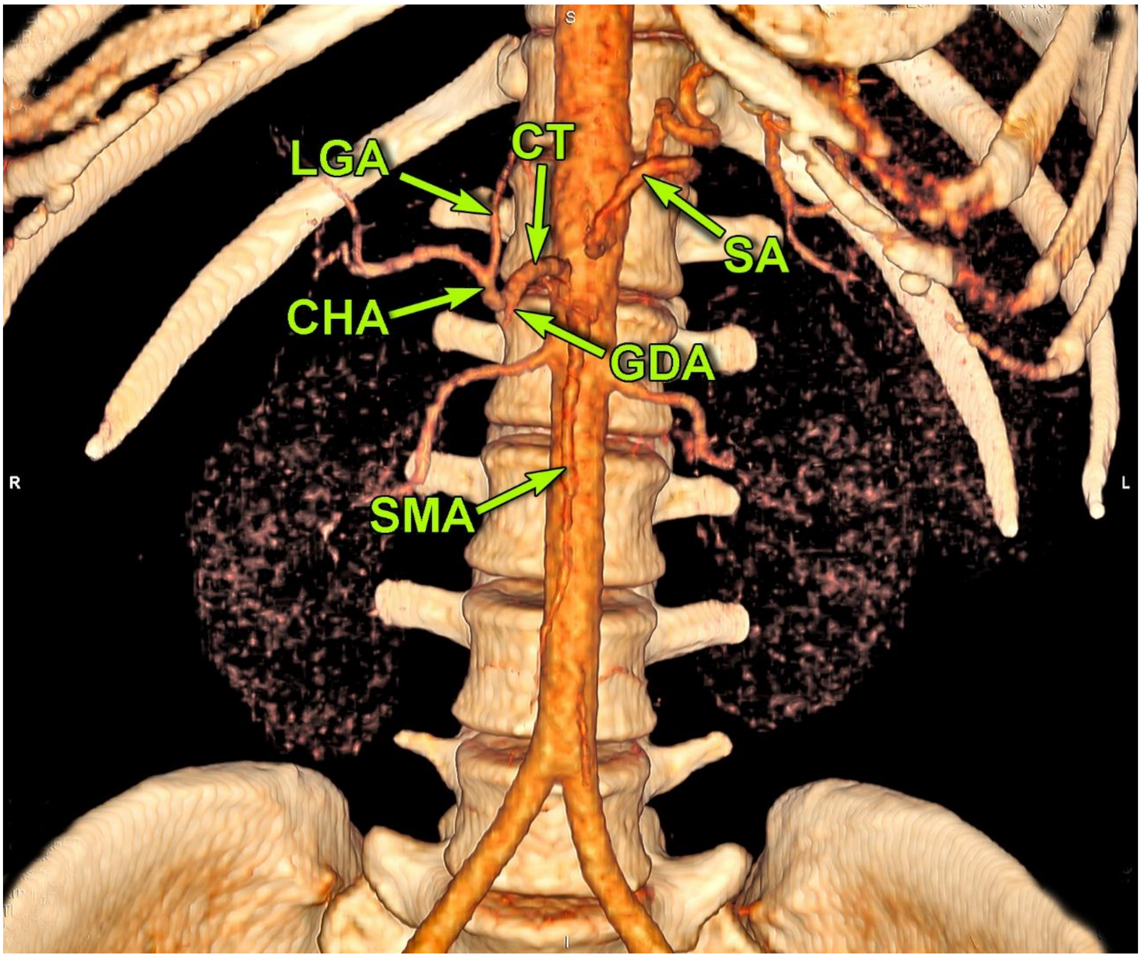

Figure 4. Gastro-splenic trunk type in association with the common hepatic artery arising from the superior mesenteric artery.

CT - celiac trunk, LGA - left gastric artery, SA - splenic artery, CHA - common hepatic artery, PHA - proper hepatic artery, GDA - gastroduodenal artery, SMA - superior mesenteric artery, aRRA- accessory right renal artery, CHA aneurysm - common hepatic artery aneurysm, aHA – accessory hepatic artery.

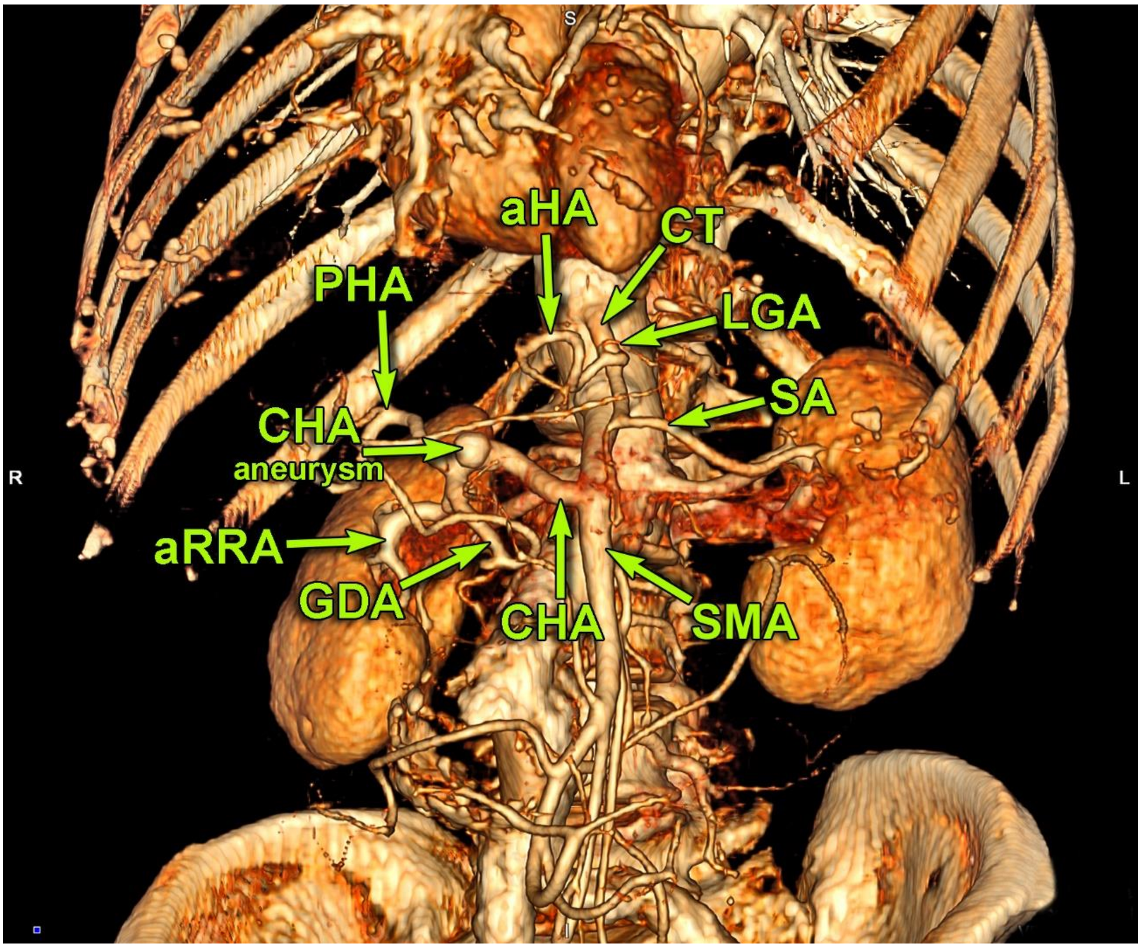

Figure 5. Gastro-splenic trunk in association with the common hepatic artery arising independently from aorta and accessory right hepatic artery originating from CHA.

CHA - common hepatic artery, LGA - left gastric artery, SA - splenic artery, SMA - superior mesenteric artery, GDA - gastroduodenal artery, rRHA – replaced right hepatic artery, LHA – left hepatic artery.

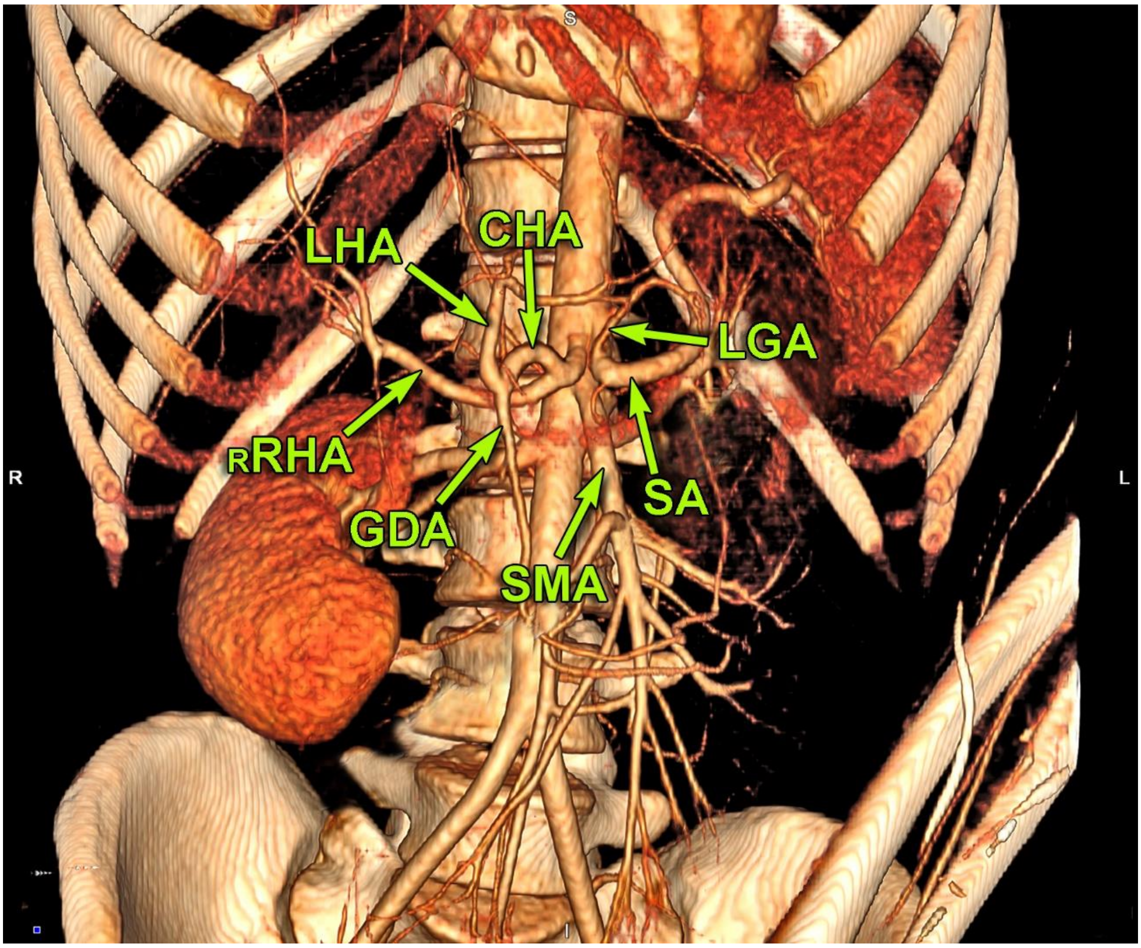

Figure 6. Celiac artery stenosis resulting in the development of collateral mesenteric circulation.

CT - celiac trunk, LGA - left gastric artery, CHA – common hepatic artery, SA - splenic artery, SMA - superior mesenteric artery, rRHA – replaced right hepatic artery, GDA - gastroduodenal artery, rLHA – replaced left hepatic artery.

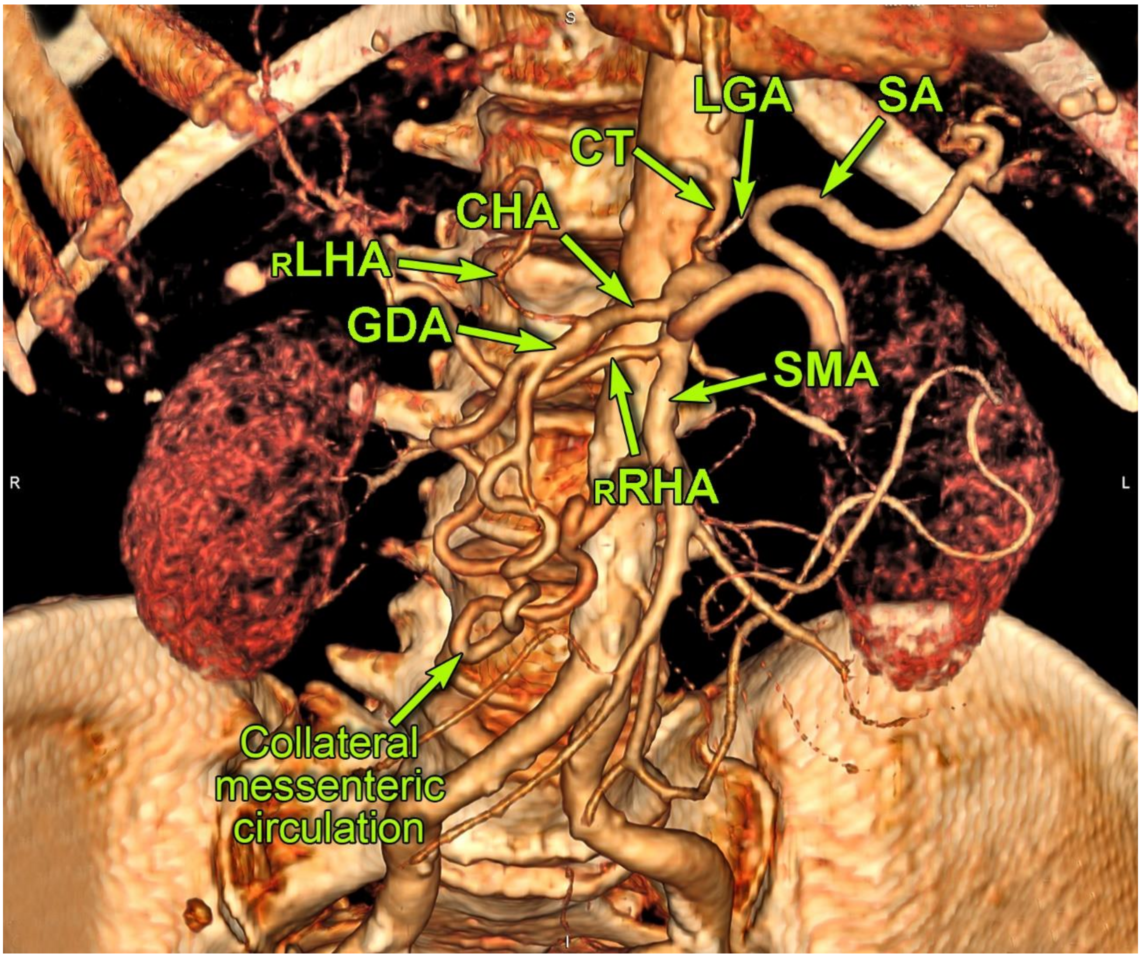

Figure 7. Celiac artery stenosis with extended collateral mesenteric circulation and SMA originating from aorta slightly above the celiac trunk.

CT - celiac trunk, LGA - left gastric artery, SA - splenic artery, CHA - common hepatic artery, PHA - proper hepatic artery, SMA - superior mesenteric artery.

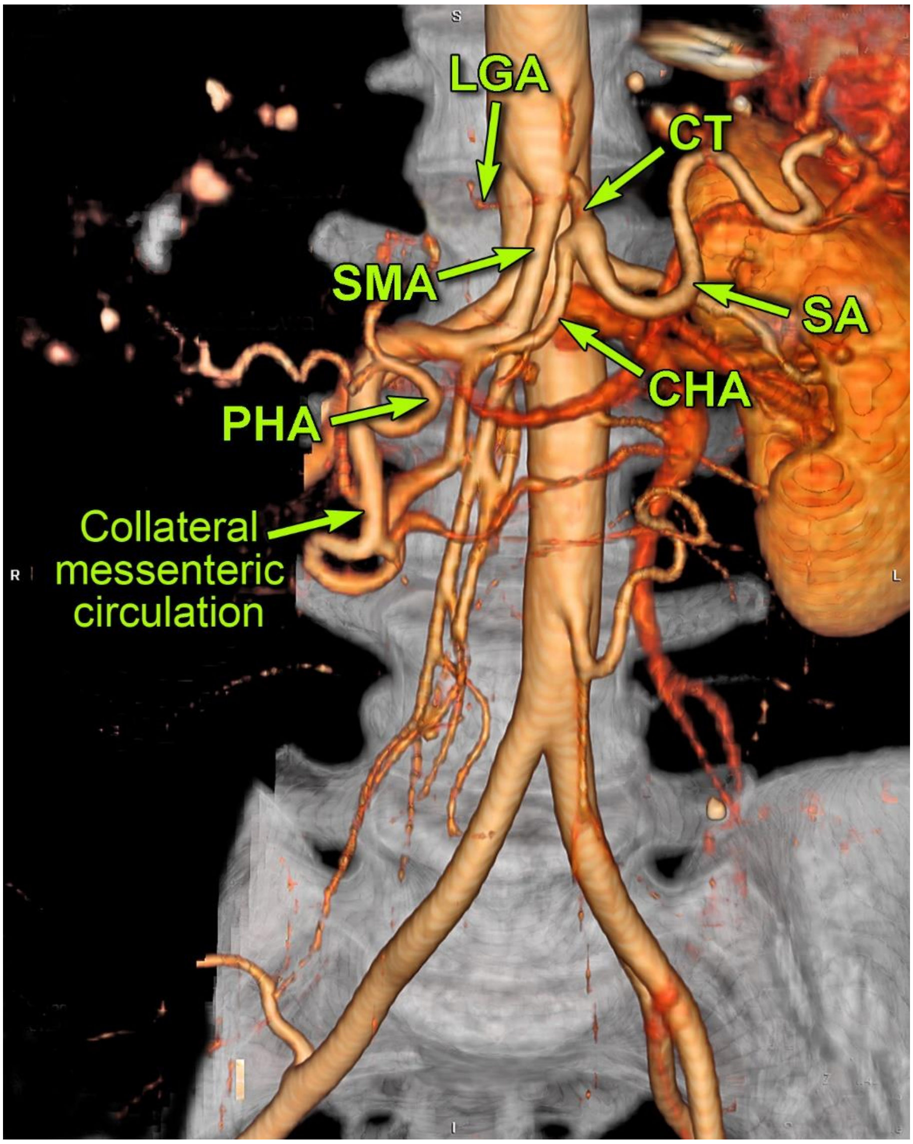

Table 1: Hepatic artery variations: Michel classification.

Description	**Type**
Normal anatomy	I
Replaced left hepatic artery arising from left gastric artery	II
Replaced right hepatic artery arising from superior mesenteric artery	III
Coexistence of Type I and Type II	IV
Accessory left hepatic artery arising from left gastric artery	V
Accessory right hepatic artery arising from superior mesenteric artery	VI
Coexistence of Type V and Type VI	VII
Replaced right hepatic artery and accessory left hepatic artery or replaced left hepatic artery and accessory right hepatic artery	VIII
Common hepatic artery arising from SMA	IX
Common hepatic artery arising from the left gastric artery	X

PODSUMOWANIE WYNIKÓW I WNIOSKI

W badaniach sekcyjnych na próbie populacji polskiej wykazano, że w 82% przypadków dominował typ I rozgałęzienia pnia trzewnego wg Adachi (trifurkacja) w konstelacji zarówno prawdziwej (20%) jak i rzekomej (80%). Bifurkację pnia z samodzielnym odejściem tętnicy żołądkowej lewej od aorty (typ II w Adachi) stwierdzono u 16% przypadków.

W obrazie angiografii tomografii komputerowej stwierdzono następujące typy pnia trzewnego:

Hepatogastrosplenic (typ I wg Adachi) u 93% badanych: 35% jako odmiana prawdziwa i 65% jako odmiana rzekoma;

Hepatosplenic (typ II wg Adachi) u 2.8% badanych;

Celiacomesenteric (typ IV wg Adachi) u 1.1% badanych;

Hepatomesenteric (typ V) u 1.7% badanyh;

Gastrosplenic (typ VI) u 1.4% badanych

Nie obserwowano obecności typu III (hepatosplenomesenteric). We wszystkich przypadkach odejście pnia trzewnego od aorty miało miejsce na poziomie krążka międzykręgowego Th12/L1. Kąt odejścia pnia od aorty wynosił od 6.8° do 85.6°, przeciętna średnica naczynia 11.7 mm i jego odległość od SMA - 15 mm.

Wobec istniejących zmienności pnia i jego rozgałęzień należy podkreślić zasadność wykonywania MDCT z kontrastem i rekonstrukcją 3D u wszystkich pacjentów kwalifikowanych do procedur radiologii interwencyjnej oraz chirurgii laparoskopowej i tradycyjnej.

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STRESZCZENIE W JĘZYKU POLSKIM

Celem pracy była analiza anatomii rozgałęzień pnia trzewnego na próbie populacji polskiej w oparciu o ocenę materiału sekcyjnego. Stwierdzone warianty anatomiczne opisano w odniesieniu do klasyfikacji japońskiego anatoma Buntaro Adachi. W 82% przypadków dominował typ I rozgałęzienia w konstelacji zarówno prawdziwej jak i rzekomej. Opisano również przypadek zmienności gałęzi wątrobowych pnia trzewnego, istotnych z punktu widzenia chirurgii wątroby i transplantologii. Następnie dokonano oceny pnia trzewnego na podstawie analizy tomografii wielodetektorowej (MDCT) z użyciem kontrastu w grupie 1000 pacjentów. W rezultacie otrzymano trójwymiarowe rekonstrukcje modeli pnia trzewnego i jego odmian. Wobec istniejących zmienności pnia i jego rozgałęzień podkreślono zasadność wykonywania MDCT z kontrastem i rekonstrukcją 3D u pacjentów kwalifikowanych do procedur radiologii interwencyjnej oraz chirurgii laparoskopowej i tradycyjnej. Dzięki dużej liczbie analizowanych angiografii MDCT aorty brzusznej wyodrębniono rzadkie anatomiczne warianty pnia trzewnego i podkreślono ich znaczenie kliniczne.

STRESZCZENIE W JĘZYKU ANGIELSKIM

The aim of the study was to analyze the anatomy of celiac trunk branching pattern on a sample of the Polish population based on cadaveric dissections. The anatomical variants were described with reference to the classification of the Japanese anatomist Buntaro Adachi. In 82% of cases, type I predominated in both the true and false celiac trunk configurations. The case of hepatic artery variations, significant for liver surgery and transplantology has also been described. The celiac trunk was then assessed based on multi-detector tomography (MDCT) analysis using contrast in a group of 1000 patients. As a result, three-dimensional reconstructions of celiac trunk models and its varieties were obtained. In view of the existing variations of the trunk and its branches, the legitimacy of performing MDCT with contrast and 3D reconstruction in patients qualified for interventional radiology, laparoscopic and traditional surgery procedures was emphasized. Due to the large number of MDCT abdominal angiographs analyzed, rare anatomical variants of the visceral trunk were distinguished and their clinical significance was highlighted.

Kraków, dnia 17.06.2020 r.

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OŚWIADCZENIE

1. Jako współautor pracy*:. Juszczak A, Mazurek A, Walocha JA, Pasternak A. Celiac trunk and its anatomic variations: cadaveric study. Folia Morphol (Warsz). 2020;10.5603/FM.a2020.0042. doi:10.5603/FM.a2020.0042.

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2. oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji wynosi 5% i polegał na**:

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Jednocześnie wyrażam zgodę na przedłożenie w/w pracy przez lek. Aleksieja Juszczaka jako część rozprawy doktorskiej w formie spójnego tematycznie zbioru artykułów opublikowanych w czasopismach naukowych.

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- opracowywaniu pomysłu badań.
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- przygotowaniu manuskryptu pracy.

Artur Pasternak
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(podpis współautora)

*należy podać tytuł, nazwę czasopisma, wolumen, rok, strony

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Kraków, dnia 17.06.2020 r.

Dr hab. med. Artur Pasternak
Katedra Anatomii UJ CM

OŚWIADCZENIE

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Kraków, dnia 17.06.2020 r.

Agata Mazurek
Katedra Anatomii UJ CM

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oświadczam, iż mój własny wkład merytoryczny w przygotowanie, przeprowadzenie i opracowanie badań oraz przedstawienie pracy w formie publikacji wynosi 30% i polegał na**:
- opracowaniu wyników pracy.

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- opracowaniu wyników pracy.

Jednocześnie wyrażam zgodę na przedłożenie w/w pracy przez lek. Aleksieja Juszczaka jako część rozprawy doktorskiej w formie spójnego tematycznie zbioru artykułów opublikowanych w czasopismach naukowych.

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- opracowywaniu pomysłu badań.
- opracowaniu i interpretacji wyników pracy.
- przygotowaniu manuskryptu pracy.

Jednocześnie wyrażam zgodę na przedłożenie w/w pracy przez lek. Aleksieja Juszczaka jako część rozprawy doktorskiej w formie spójnego tematycznie zbioru artykułów opublikowanych w czasopismach naukowych.

Oświadczam, iż samodzielna i możliwa do wyodrębnienia część ww. pracy wykazuje indywidualny wkład lek. Aleksieja Juszczaka polegający na**:

- opracowaniu koncepcji badań,
- przygotowaniu manuskryptu pracy.

Agata Mazurek
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(podpis współautora)

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Kraków, dnia 17.06.2020 r.

Lek. med. Jan Czyżowski
Szpital Specjalistyczny im. J. Dietla w Krakowie
(Zakład Diagnostyki Obrazowej)

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- interpretacji wyników pracy.

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