

CASE REPORT

Rare variant of celiac trunk branching pattern associated with modifications of hepatic arterial vascularization

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Abstract

The routine dissection of a male body revealed multiple anatomical variations of the celiac trunk and hepatic artery vascularization. The origin of the celiac trunk was on the left side of the abdominal aorta, next to the T₁₂–L₁ intervertebral disk. The celiac trunk gave off five branches: the left inferior phrenic artery, the left gastric artery, the accessory right hepatic artery, the common hepatic artery and the splenic artery (the last two arteries had a common origin in a hepatosplenic trunk). A right branch detached off the left gastric artery and anastomosed with the hepatic artery proper. The proper hepatic artery also anastomosed with the accessory right hepatic artery at the same level. Consequently, the entire hepatic arterial supply was from the celiac trunk – through two arteries directly and a third via the left gastric artery. The anatomical variant described in this case can be considered very rare. Thorough knowledge of such variants is important both for upper abdominal surgery and for imagistic and interventional radiology.

Keywords: anatomical variants, celiac trunk, accessory right hepatic artery, anastomoses of hepatic arterial sources.

Introduction

The celiac trunk is the first unpaired visceral branch of the abdominal aorta; whose branches supply the upper abdomen. Most frequently, it branches from the anterior side of the abdominal aorta and corresponds to the T₁₂–L₁ intervertebral disk, located 1 cm above the origin of the superior mesenteric [1]. The length of the celiac trunk – 1.5 to 2 cm – varies with its branching pattern and its caliber is between 0.5 and 0.8 cm.

The celiac trunk was first described by Haller, in 1756. His classic description showed the common origin of three arteries: the left gastric, the common hepatic and the splenic artery (Haller's tripod).

The morphological variations of the celiac trunk were recognized starting with the first studies about it. Although examined intensely as early as the beginning of the 20th century, the morphological variability of the celiac trunk in general or one of its branches in particular remains a topical issue due to the new surgical, imagistic and interventional techniques.

The emergence of the morphological variants can be explained through the development of the embryonic arterial system. The persistence and/or the abnormal regression of the vascular network components are the main causes of the multiple morphological variations of the celiac trunk.

This paper aims to present one such morphological variant of the celiac trunk. It is important for clinicians to be aware of multiple, including rare anatomical variants in order to avoid complications during the planning and execution of procedures they may perform.

Case presentation

The routine dissection of the upper abdomen of a 61-year-old male cadaver, performed in the Department

of Anatomy and Embryology, revealed multiple anatomical variations of the celiac trunk, in both the origin and the branching pattern. Five branches arose from the celiac trunk in the following order: the left inferior phrenic artery, one accessory right hepatic artery, the left gastric artery, the common hepatic artery and the splenic artery (with the last two having a common – a hepatosplenic trunk).

For a thorough dissection of the celiac trunk branches and their paths, the organs in the supramesocolic space were removed. After the identification of the five branches, their origin, path and destination were analyzed separately. Three arteries whose course continued to the hepatic pedicle were revealed. Two of them branched directly from the celiac trunk, while the third arose from the left gastric artery. Then, the relations of the three arteries with the hepatic pedicle and their path to the hepatic hilum were examined. Given the morphological particularities of the case, the examination focused on the celiac trunk origin and branching as well as on the three arterial sources for the hepatic vascularization and their morphological inter-relations at the level of the hepatic hilum. Photographs were taken from several angles for the accurate presentation of the aspects regarding the celiac trunk origin and the hepatic pedicle and a schematic overview was created to highlight all the particularities of the case.

In this case, the celiac trunk originated from the left side of the abdominal aorta, next to the T₁₂–L₁ intervertebral disk, 0.7 cm above the superior mesenteric artery (Figure 1). From its origin, the celiac trunk descended obliquely inferior and to the right, on the anterior side of the abdominal aorta. Five branches arose off the celiac trunk in the craniocaudal direction, as shown below (Figure 2).

The first branch, the left inferior phrenic artery, arose from the superior side of the celiac trunk; its level of origin

was about 0.45 cm from the origin of the celiac trunk. This artery did not have morphological particularities; after a short ascending path on the anterior side of the abdominal aorta, it shifted to the left, describing a curve towards the inferior side of the diaphragm.

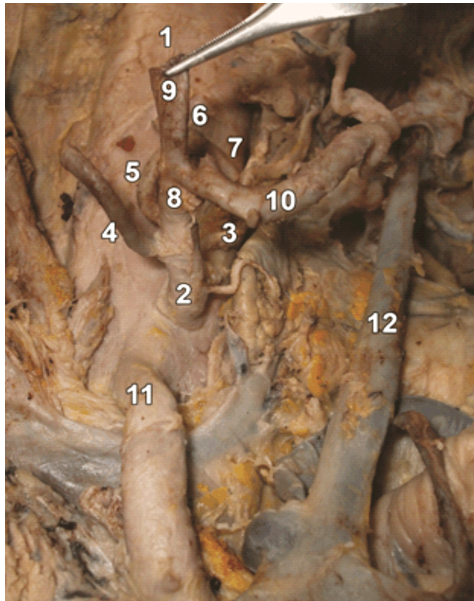


Figure 1 – Dissection revealing the origins of the celiac trunk, superior mesenteric artery and of the celiac trunk's branches. Antero-inferior view. 1. Abdominal aorta; 2. Celiac trunk; 3. Left inferior phrenic artery; 4. Accessory right hepatic artery; 5. Left gastric artery; 6. Right branch of the left gastric artery; 7. Left branch of the left hepatic artery; 8. Hepatosplenic trunk; 9. Common hepatic artery; 10. Splenic artery; 11. Superior mesenteric artery; 12. Splenic vein.

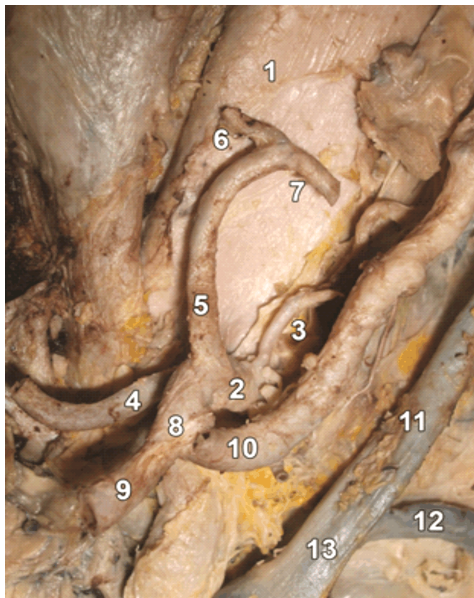


Figure 2 – Dissection revealing the origin and branching of the celiac trunk. Left antero-lateral view. 1. Abdominal aorta; 2. Celiac trunk; 3. Left inferior phrenic artery; 4. Accessory right hepatic artery; 5. Left gastric artery; 6. Right branch of the left gastric artery; 7. Left branch of the left hepatic artery; 8. Hepatosplenic trunk; 9. Common hepatic artery; 10. Splenic artery; 11. Splenic vein; 12. Inferior mesenteric vein; 13. Splenic-mesenteric venous trunk.

By point of origin, the second branch of the celiac trunk was the accessory right hepatic artery. This arose on the right margin of the celiac trunk, 0.9 cm from the origin of the trunk. Comparable in diameter with the left gastric artery, at first it ran obliquely inferior and to the right, to the right margin of the abdominal aorta, then it passed transversely towards the hepatic hilum.

The third branch of the celiac trunk, the left gastric artery, also arose from its superior side, about 1.95 cm from the origin of the trunk. At first, the left gastric artery followed an ascending course, describing an arc on the anterior side of the abdominal aorta; at about 2.8 cm from its origin, it branched in a T-shaped form, into a right branch with a transversal path and a left branch – the left gastric artery proper, which descended to the lesser curvature of the stomach.

After giving rise to the three branches, the celiac trunk ran downwards for about 0.65 cm, before dividing into two perpendicular branches: a right branch – the common hepatic artery – and a left branch – the splenic artery. This last segment of the celiac trunk can be considered a common hepatosplenic trunk.

The left inferior phrenic, left gastric, common hepatic and splenic arteries did not show morphological variations in their course or distribution, but the branches that supplied the liver showed several particular aspects.

The hepatic artery proper arose through the bifurcation of the common hepatic artery, next to the duodenal bulb and continued its ascending course in the free border of the lesser omentum. At about 1 cm from its origin, it anastomosed twice, with the accessory right hepatic artery (on the right border) and the right branch of the left gastric artery (on the left border). After the two anastomoses, the hepatic artery proper continued its ascending path and next to the hepatic hilum it divided into a right and a left branch (Figure 3).

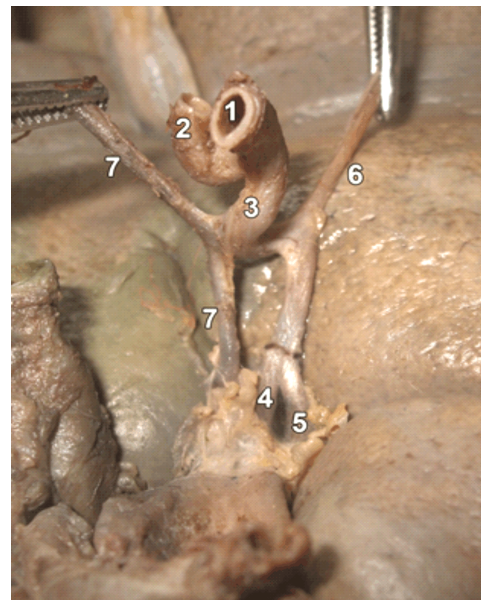


Figure 3 – Path and anastomoses of the hepatic arterial sources at the hepatic pedicle. Inferior view. 1. Common hepatic artery; 2. Gastroduodenal artery; 3. Hepatic artery proper; 4. Right branch of the hepatic artery proper; 5. Left branch of the hepatic artery proper; 6. Right branch of the left gastric artery; 7. Accessory right hepatic artery.

From its point of origin in the celiac trunk, the accessory right hepatic artery followed a transverse path towards the right (posterior and superior to the common hepatic artery), next to the origin of the gastroduodenal artery. From there, it shifted and ran upwards and to the right; it crossed obliquely behind the hepatic artery proper and passed to its right side. After the latero-lateral anastomosis with the hepatic artery proper, the accessory right hepatic artery ran upwards, parallel to the last segment of the hepatic artery proper, to enter the right hepatic lobe.

The right branch of the left gastric artery crossed the gastrohepatic ligament and ended its path at the free border of the lesser omentum, where it anastomosed with the left margin of the hepatic artery proper (Figure 4).

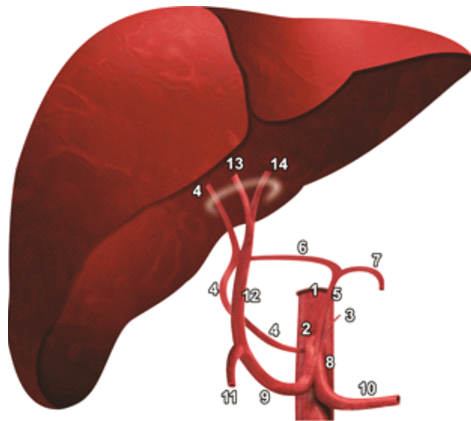


Figure 4 – Schematic overview of the case. 1. Abdominal aorta; 2. Celiac trunk; 3. Left inferior phrenic artery; 4. Accessory right hepatic artery; 5. Left gastric artery; 6. Right branch of the left gastric artery; 7. Left branch of the left hepatic artery; 8. Hepatosplenic trunk; 9. Common hepatic artery; 10. Splenic artery; 11. Gastroduodenal artery; 12. Hepatic artery proper; 13. Right branch of the hepatic artery proper; 14. Left branch of the hepatic artery proper.

Discussion

The particularities of this case require the analysis of the following aspects: the morphological variations of the celiac trunk, the morphological variations of the hepatic arterial sources and their anastomoses at the level of the hepatic pedicle.

The morphological variations of the celiac trunk and its branches are frequent 25–75%, according to Zagyan *et al.* [2] and 91% according to Weiglein [3]. They can affect the celiac trunk as a whole or its branches taken separately.

According to Adachi's first classification in 1928, there are six branching types of the celiac trunk: normal, hepatosplenic, hepatosplenomesenteric, hepatogastric, splenogastric, celiacomesenteric.

For a better description and classification, the morphological variants of the celiac trunk can be grouped according to the modified parameter: level of origin; how it arises; course; size (length and diameter); number of rising branches; how these branches arise; branch course and destination.

In our case, the origin of the celiac trunk was not anterior, but on the left border of the abdominal aorta, next to the T₁₂–L₁ intervertebral disk and 0.7 cm superior

to the origin of the superior mesenteric artery. A similar origin of the celiac trunk (at the same ventrolateral level) was reported by Kalthur *et al.* [4].

The origin level of the celiac trunk is variable between individuals, and in her study, Kozhevnikova (1997) cited by Gielecki *et al.* [5] showed that it also lowers with aging. In most cases, as Petrella *et al.* [6] found in their literature review, this origin level is situated between T₁₁ and L₁. As specialist studies indicate, the distance between the points of origin of the celiac trunk and that of the superior mesenteric artery varies between 0.1 and 1.1 cm [7], 0.1 and 1.8 cm [6], 0.1 and 2.2 cm [8], 0.5 and 3 cm (George, 1934 cited by Petrella *et al.*) [6], 1 and 2 cm [9].

As far as how the celiac trunk arises is concerned, most frequently, it is an unpaired median branch of the abdominal part of the aorta, but it may also have a common origin with other arteries, for instance, the superior mesenteric artery, forming a celiacomesenteric trunk [10, 11]. The incidence of such cases is small: 0.4–2.5% (Eaton, 1917; Adachi, 1928, cited by Mariani *et al.* [12]; another origin variant, a celiacobimesenteric trunk, was reported by Nonent *et al.* [13].

Some studies reveal another variant of origin of the three arteries (left gastric, common hepatic and splenic): two separate trunks, hepatogastric and hepatosplenic [14], gastrosplenic and hepatomesenteric [15], hepatogastric and splenomesenteric [12], while Dandekar & Dandekar [16] reported three separate origin trunks: gastrophrenic, hepatosplenic and hepatophrenic.

The celiac trunk can be absent as a morphological entity and the left gastric, common hepatic and splenic arteries originate separately, directly from the abdominal aorta. The incidence of this variant is low: 0.4% [17], 0.8% Rio Branco, 1912, cited by Petrella *et al.* [6], 1% [18, 19], 1.12% [6] or 1.25% [20], 0.1–2.6% [21].

The length of the celiac trunk is also variable, depending both on the branching pattern and the benchmarks. Most frequently, the celiac trunk is measured from its origin to the level of origin of the hepatic or splenic artery. Its length is 0.8–4 cm [22], 1.3–1.8 cm [23], 1–2.9 cm, with a mean of 1.23 cm in males and 1.18 cm in females [6], 1–3 cm [24].

In our case, the length of the celiac trunk measured from its origin to the shared origin of the common hepatic and splenic arteries was 2.6 cm. Higher values of its length – 4.3 cm – were reported by Cavdar *et al.* [10] and Yüksel *et al.* [25].

The most frequent morphological variants of the celiac trunk are those of its branching pattern. Studies have shown that the number of the celiac branches varies between two and seven. In our case, five branches were revealed: the left inferior phrenic artery, the accessory right hepatic artery, the left gastric artery, the common hepatic artery and the splenic artery (the last two arteries having a common origin in a hepatosplenic trunk). A case of penta-furcation of the celiac trunk was described by Krishna Chaitanya *et al.* [26]. Two phrenic arteries, one left and one right, were additional to the three classic branches.

Studies describe the classic trifurcation variant of the celiac trunk as having variable incidence: 62.5% [2],

75%, Lipshutz, 1917, cited by Petrella *et al.* [6], 82.02% [6], 84% [27], 86% [28], 87.7%, Adachi, 1928, cited by Mariani *et al.* [12], 89.8% [29], 90% [30], 91% [31].

The celiac trunk bifurcation (incomplete trunk) is reported with an average incidence of 13.3% [12]. Rio Branco, in 1912, cited by Petrella *et al.* described a gastrosplenic trunk in 4% of cases and a hepatosplenic trunk in 5% of cases [6]. Mburu *et al.*, in 2010, have revealed celiac trunk bifurcation in 17.9% of cases: gastrosplenic trunk in 4.9% cases and hepatosplenic trunk in 13% [32]. Araujo-Neto *et al.*, in 2015, reported a hepatosplenic trunk in 8.3% of cases and a hepatogastric trunk in 1.7% [33].

The unilateral or bilateral origin of the inferior phrenic arteries of the celiac trunk is relatively frequent: 4.9% [32], 6.25% [34], 10% [23], 28.12% [35], 34.83% [6], 37% [3], 40% [36], 46.8% [9], 50% [27].

In our case, only the left inferior phrenic artery arose from the celiac trunk. Most studies highlight a higher incidence of the left phrenic artery originating from the celiac trunk, rather than the right: 4%/2% [23], 21.35%/5.62% [6], 30.77%/0.5% [37] and 37.5%/18.75% [35].

The development of the embryo-fetal arterial vascular system, as well as its successive transformations can help us understand the causes of the frequent morphological variations of the abdominal arterial system.

The vascular system develops and remodels in correlation with the needs and the nutrition source of the embryo and the fetus. In the first stages, when the embryo is supplied nutrition through the vitelline duct, the vitelline vessels and circulation develop.

The first blood vessels and blood cells develop in the splanchnic extraembryonic mesoderm of the vitelline duct, starting with the 17th day, under the form of hemangioblastic aggregates adjacent to the endoderm. The endothelial cells precursors differentiate, organize and form a network, which gives rise to the vitelline arteries and veins. By the end of the third week, the capillary network supplies the vitelline duct, the fixation pedicle and the villous chorion [38].

Beginning with the 18th day, blood vessels start forming within the intraembryonic splanchnic mesoderm, through similar processes. The aorta develops during the third embryonic week, in connection with the endocardial tubes, each primitive aorta consisting of a ventral and dorsal segment. The dorsal aortas are paired and disposed along the length of the embryo. They remain separated in the aortic arch region and in the 4th week, the segments between T₄ and L₄ merge into a unique median vessel – the descending part of the aorta [39].

As the vitelline duct shrinks, the vitelline plexuses, initially paired, coalesce and give rise to arteries that anastomose with the vascular plexuses of the future intestinal tube and the dorsal aorta. These arteries, variable in number, become the ventral branches of the dorsal aorta that supply the primitive intestine – the primitive intestinal arteries (visible in the 32-mm long embryo). At first numerous, double and symmetrical, they are interconnected through vertical anastomoses (scalariform aspect); subsequently, they regress and disappear.

From this network, three vitelline arteries that remain in the infradiaphragmatic area will supply blood to the three embryonic portions of the primitive intestine. The

first artery, the superior one, is the celiac artery initially connected to the dorsal artery at C₇ level; later, the connection descends to T₁₂ level. The celiac artery gives rise to branches that supply the foregut, from the level of the abdominal portion of the esophagus to the descending part of the duodenum, then the liver, the gallbladder, the pancreas and the spleen. The second vitelline artery will form the superior mesenteric artery, while the third will form the inferior mesenteric artery.

This network of arteries that are interconnected through vertical anastomoses can undergo a series of perturbations of the modeling/transformation process consisting in the persistence or disappearance of segments at different levels, thus leading to numerous morphological variants.

The second particularity of our case is the hepatic arterial sources, which vary in number, origin and anastomoses. Three hepatic arterial sources were revealed, all of them interconnected branches of the celiac trunk.

The common hepatic artery arose from the terminal part of the celiac trunk, together with the splenic artery (through a hepatosplenic trunk). Its course and branching into the gastroduodenal and hepatic arteries were consistent with the classic descriptions.

The hepatic artery proper crossed the free border of the lesser omentum and divided at the pre-hilar level into the two terminal branches (left and right). One cm from its origin, it anastomosed with the other two arterial sources: that originating from the left gastric artery and the accessory right hepatic artery.

The accessory hepatic artery arose from the celiac trunk as well. Its place of origin was on the right margin of the celiac trunk, between the origin levels of the left gastric artery and of the common hepatic artery. On its course to the right, it ran superior and parallel to the common hepatic artery before crossing the posterior side of the hepatic artery proper diagonally upwards. Reaching the right border of the proper hepatic artery, the two arteries anastomosed latero-laterally; following the anastomosis, the accessory right hepatic artery continued its path parallel to the hepatic artery proper, to the hepatic hilum level before entering the right hepatic lobe.

The third hepatic arterial source originated from the celiac trunk as well, indirectly, as the right branch of the left gastric artery. It did not penetrate the liver parenchyma, but ended at the level of the left border of the hepatic artery proper. For this reason, we considered this branch as an anastomosis of the hepatic artery proper and the left gastric artery.

The incidence of the hepatic arteries variants is variable: 20–50% [40], 25–75% [41], 34% [42], 37% [3], 44% [20], 50% [27], 55% [43–45], 74.5% [46], 87.7%, Adachi, 1928 cited by Mariani *et al.* [12]; Song *et al.*, in 2010, describe common hepatic artery variations in 3.71% of cases [47].

The morphological variations of the hepatic arteries involve their origin (superior mesenteric artery, left gastric artery, aorta or other sources), number, course, caliber or branching pattern.

In 85% of cases, the common hepatic artery arises from the celiac trunk [17]. The numerical variations are of two types: accessory hepatic arteries (supernumerary) that add to the hepatic artery proper and its two terminal

branches, and replacing arteries that replace an absent branch and supply a lobe.

Our case revealed a hepatic artery proper and an accessory right hepatic artery, both arising from the celiac trunk. Other such cases, where the liver is irrigated by two arteries originating separately from the celiac trunk have also been presented by Fasel *et al.* [48] and Sethi *et al.* [49].

The information in the literature about numerical variants show that only one hepatic artery has been reported to be present in 51–74%, two in 20–55% of cases and three in 2–12.5% of cases [50].

When several arterial sources are present, the most frequent occurrences are of the right hepatic artery from the superior mesenteric artery and of the left hepatic artery from the left gastric artery – described in 18–22% of cases by Arslan *et al.* [51] and 20–30% by Okada *et al.* [52].

In 1756, Haller was the first to describe the morphological variants of the hepatic arteries, using the term “aberrant hepatic arteries”. The research work continued, the anatomical literature including comprehensive studies that used either the dissection or the imagistic method, for the purpose of revealing and classifying the morphological variants. Nevertheless, new variants are still revealed and must be reported and made known.

Michels, in 1966 [53], first classified the hepatic arterial variants into 10 types. His classification was accepted and many subsequent studies considered it a benchmark. Other widely cited and accepted classifications are those of Hiatt *et al.* (1994) [54], who found six types and Varotti *et al.* (2004) [55] with five.

Notwithstanding these classifications, the numerous anatomical and imagistic studies describe rare variants that cannot be included in morphological types – with an incidence of 16.6% [56] to 18% [57]. As in the case of the celiac trunk, such variants can be explained through the perturbations of the correlations of the abdominal viscera and arterial system morphogenesis processes.

According to Gillot, quoted by Douard *et al.*, 2006 [50] and Couinaud (1989) [58], the liver primordium consists of three segments: right, middle and left. Each part is vascularized by an artery:

- the right artery, arising from the superior mesenteric artery – for the right lateral segment;
- the common hepatic artery originated from the celiac trunk – for the median segment;
- the left artery arising from the left gastric artery – for the left lateral segment.

Most frequently, the right and left branches disappear following the regression and remodeling processes. If the right or left embryonic artery does not totally regress, it becomes the right or left aberrant hepatic artery.

Knowledge of the hepatic arteries morphological variants has become increasingly important as the number and variety of hepatic surgical interventions (especially transplants) increased. Such morphological variants have the potential to influence and complicate the surgical procedures, mainly the laparoscopies and those involving other organs such as the duodenum, the gallbladder and the pancreas that are supplied by hepatic arteries branches. They can also cause problems in transarterial chemoembolization therapy in liver cancer.

Another aspect that our case revealed was the presence of two anastomoses of the hepatic artery proper, one with the accessory right hepatic artery and one with the left gastric artery.

The congenital anastomoses of the hepatic arteries are described in the anatomical literature. They can be located between the hepatic artery branches (intra or extrahepatic); most commonly they are present in cases of arterial variations (accessory or replaced arteries) and are extrahepatic, situated close to the hilum [59]. The diameter of these anastomoses varies between 1.5 and 3 mm. The anastomoses can be right (linear) or tortuous.

The incidence of the congenital hepatic anastomoses described in the anatomical literature varies. Michels [30] describe anastomoses in 12% of cases, most often at type VI of the hepatic artery in his classification, namely the presence of an accessory right hepatic artery arising off the superior mesenteric artery. Miyaki *et al.* [60] report a 45% incidence in fetuses with aberrant hepatic arteries. In their angiographic study [59] revealed anastomoses only in 1.39% of cases; all cases had replaced hepatic artery, and the mean diameter of the anastomoses was 2.4 mm [3] also describes an anastomosis between the accessory right hepatic artery and the hepatic artery proper.

The percentage differences are caused by the age of the studied group (fetuses or adults), the presence of hepatic affections and the study methods. Embryological studies have revealed that fetal vascularization differs from adult vascularization. It undergoes a series of remodeling processes after which part of the vessels disappear. The anomalies of the regression process and the persistence of some vessels may be a cause of congenital arterial anastomoses.

The presence of anastomoses between the hepatic artery proper and the accessory or replaced hepatic arteries arising from the superior mesenteric arteries or the left gastric artery can be explained embryologically, through the persistence of longitudinal anastomoses between the anterior branches of the dorsal aorta or branches of the vitelline arterial network. The anastomoses become evident in individuals with hepatic affections (cirrhosis, tumors) and are clinically important in the hepatic artery chemoembolization therapy.

✎ Conclusions

This report presents a rare morphological variant of the celiac trunk, which in this case had five branches – through the additional presence of the left inferior phrenic artery and the accessory right hepatic artery. The case is also noteworthy for its’ hepatic arterial sources (their number and origin) and the presence of two anastomoses of the hepatic artery proper, one with the accessory right hepatic artery and one with the left gastric artery. The increasing number of surgical interventions and interventional radiological procedures require thorough knowledge of the possible celiac trunk anatomical variants and hepatic artery vascularization. The description of the rare vascular variants is always an interesting and useful topic for performing successful upper abdominal surgery, reducing the risk of complications and errors in imagistic interpretation.

Conflict of interests

The authors declare that they have no conflict of interests.

References

- [1] Standring S. Gray's anatomy: the anatomical basis of clinical practice. 39th edition, Elsevier-Churchill Livingstone, 2005, 1118.
- [2] Zagyapan R, Kürkçüoğlu A, Bayraktar A, Pelin C, Aytekin C. Anatomic variations of the celiac trunk and hepatic arterial system with digital subtraction angiography. *Turk J Gastroenterol*, 2014, 25(Suppl 1):104–109.
- [3] Weiglein AH. Variations and topography of the arteries in the lesser omentum in humans. *Clin Anat*, 1996, 9(3):143–150.
- [4] Kalthur SG, Sarda R, Bankar M. Multiple vascular variations of abdominal vessels in a male cadaver: embryological perspective and clinical importance. *J Morphol Sci*, 2011, 28(3):152–156.
- [5] Gielecki J, Zurada A, Sonpal N, Jabłońska B. The clinical relevance of coeliac trunk variations. *Folia Morphol (Warsz)*, 2005, 64(3):123–129.
- [6] Petrella S, Rodriguez CFS, Sgrott EA, Fernandes GJM, Marques SR, Prates JC. Anatomy and variations of the celiac trunk. *Int J Morphol*, 2007, 25(2):249–257.
- [7] Brunet C, Moutardier V, Di Marino V. La région dite du « bouton coelio-mésentérique », étude anatomo-chirurgicale [The so-called « coeliomesenteric button-hole » region; an anatomico-surgical study]. *J Chir*, 1993, 130(2):70–73.
- [8] Michels NA. The hepatic, cystic and retroduodenal arteries and their relations to the biliary ducts with samples of the entire celiacal blood supply. *Ann Surg*, 1951, 133(4):503–524.
- [9] Anson BJ, McVay CB. Surgical anatomy. 6th revised edition, W.B. Saunders Co., Philadelphia, 1984, 616–629.
- [10] Cavdar S, Sehirli U, Pekin B. Celiacomesenteric trunk. *Clin Anat*, 1997, 10(4):231–234.
- [11] Katagiri H, Ichimura K, Sakai T. A case of celiacomesenteric trunk with some other arterial anomalies in a Japanese woman. *Anat Sci Int*, 2007, 82(1):53–58.
- [12] Mariani GA, Maroni L, Bianchi L, Broccoli A, Lazzarini E, Marchegiani G, Mazzotti A, Mazzotti MC, Billi AM, Piccarini GG, Cocco L, Manzoli L. Hepato-gastric and spleno-mesenteric arterial trunks: anatomical variation report and review of literature. *Ital J Anat Embryol*, 2013, 118(2):217–222.
- [13] Nonent M, Larroche P, Forlodou P, Senecail B. Celiac-bimesenteric trunk: anatomic and radiologic description – case report. *Radiology*, 2001, 220(2):489–491.
- [14] Demirtas K, Gulekon N, Kurkcuoglu A, Yildirim A, Gozil R. Rare variation of the celiac trunk and related review. *Saudi Med J*, 2005, 26(11):1809–1811.
- [15] Kahraman G, Marur T, Tanyeli E, Yildirim M. Hepatomesenteric trunk. *Surg Radiol Anat*, 2001, 23(6):433–435.
- [16] Dandekar UK, Dandekar KN. Variant anatomy of the coeliac trunk – review of literature with a case report. *Int J Biomed Adv Res*, 2014, 5(10):480–484.
- [17] Bergman RA, Thompson SA, Afifi AK, Miyauchi R. Hepatic artery in illustrated encyclopedia of human anatomic variation: Opus II: Cardiovascular system: Arteries: Abdomen: Variations in branches of coeliac trunk. URL: <http://www.anatomyatlases.org> [Accessed on 03.05.16].
- [18] Ugurel MS, Battal B, Bozlar U, Nural MS, Tasar M, Ors F, Saglam M, Karademir I. Anatomical variations of hepatic arterial system, coeliac trunk and renal arteries: an analysis with multidetector CT angiography. *Br J Radiol*, 2010, 83(992):661–667.
- [19] Yi SQ, Terayama H, Naito M, Hirai S, Alimujang S, Yi N, Tanaka S, Itoh M. Absence of the celiac trunk: case report and review of the literature. *Clin Anat*, 2008, 21(4):283–286.
- [20] Vandamme JPJ, Bonte J, van der Schueren G. A revaluation of hepatic and cystic arteries. The importance of the aberrant hepatic branches. *Acta Anat*, 1969, 73(2):192–209.
- [21] Fahmy D, Sadek H. A case of absent celiac trunk: case report and review of the literature. *Egypt J Radiol Nucl Med*, 2015, 46(4):1021–1024.
- [22] Çiçekbaşı AE, Uysal II, Seker M, Tuncer I, Büyükmumcu M, Salbacak A. A rare variation of the coeliac trunk. *Ann Anat*, 2005, 187(4):387–391.
- [23] Tiwari S, Jeyanthi K. Study of coeliac trunk – length and its branching pattern. *IOSR J Dent Med Sci*, 2013, 8(6):60–65.
- [24] Gosai P, Kanani S, Patel J, Shah R, Nirvan A. A study of morphology of coeliac trunk in 100 cadavers. *Int J Med Sci Public Health*, 2013, 2(4):927–930.
- [25] Yüksel M, Yalin A, Weinfeld AB. Concurrent anomalies of the abdominal arteries: an extremely long coeliac trunk, an inferior phrenic trunk, and an aberrant right hepatic artery. *Kaibogaku Zasshi*, 1998, 73(5):497–503.
- [26] Krishna Chaitanya K, Sharada HR, Suseelamma D. Penta-furcation of the celiac trunk. *Anat Physiol*, 2012, S7:001.
- [27] Lippert H, Pabst R. Arterial variations in man: classification and frequency. J.F. Bergmann-Verlag, München, 1985, 31–41.
- [28] Vandamme JP, Bonte J. The branches of the celiac trunk. *Acta Anat (Basel)*, 1985, 122(2):110–114.
- [29] Chen H, Yano R, Emura S, Shoumura S. Anatomic variation of the celiac trunk with special reference to hepatic artery patterns. *Ann Anat*, 2009, 191(4):399–407.
- [30] Michels NA. Collateral arterial pathways to the liver after ligation of the hepatic artery and removal of the celiac axis. *Cancer*, 1953, 6(4):708–724.
- [31] Sureka B, Mittal MK, Mittal A, Sinha M, Bhambri NK, Thukral BB. Variations of celiac axis, common hepatic artery and its branches in 600 patients. *Indian J Radiol Imaging*, 2013, 23(3):223–233.
- [32] Mburu KS, Alexander OJ, Hassan S, Bernard N. Variations in the branching pattern of the celiac trunk in a Kenyan population. *Int J Morphol*, 2010, 28(1):199–204.
- [33] Araujo-Neto SA, Franca HA, de Mello-Júnior CF, Silva-Neto EJ, Negromonte GRP, Duarte CMA, Cavalcanti-Neto BF, Farias RDF. Anatomical variations of the celiac trunk and hepatic arterial system: an analysis using multidetector computed tomography angiography. *Radiol Bras*, 2015, 48(6):358–362.
- [34] Pulakunta T, Potu BK, Gorantla VR, Rao MS, Madhyastha S, Vollala VR. The origin of the inferior phrenic artery: a study in 32 South Indian cadavers with a review of literature. *J Vasc Bras*, 2007, 6(3):225–230.
- [35] Akhilandeswari B, Ranganath P. Variations in the source of origin of inferior phrenic artery: a cadaveric study. *J Anat Soc India*, 2013, 62(1):6–9.
- [36] Loukas M, Hullett J, Wagner T. Clinical anatomy of the inferior phrenic artery. *Clin Anat*, 2005, 18(5):357–365.
- [37] Patel BG, Gosai P, Shah RK, Kanani SD. A cadaveric study of origin of inferior phrenic artery from celiac trunk. *GCSMC J Med Sci*, 2013, 2(2):21–23.
- [38] Schoenwolf GC, Bleyl SB, Brauer PR, Francis-West PH. Larsen's human embryology. 5th edition, Elsevier Health Sciences, 2012, 402–410.
- [39] Moore KL, Persaud TVN. The developing human: clinically oriented embryology. 7th edition, Saunders, Philadelphia, 2003, 191–194.
- [40] Uva P, Arvelakis A, Rodriguez-Laiz G, Lerner S, Emre S, Gondolesi G. Common hepatic artery arising from the left gastric artery: a rare anatomic variation identified on a cadaveric liver donor. *Surg Radiol Anat*, 2007, 29(1):93–95.
- [41] Nelson TM, Pollak R, Jonasson O, Abcarian H. Anatomic variants of the celiac, superior mesenteric, and inferior mesenteric arteries and their clinical relevance. *Clin Anat*, 1988, 1(2):75–91.
- [42] De Cecco CN, Ferrari R, Rengo M, Paolantonio P, Vecchiotti F, Laghi A. Anatomic variations of the hepatic arteries in 250 patients studied with 64-row CT angiography. *Eur Radiol*, 2009, 19(11):2765–2770.
- [43] Michels NA. Blood supply and anatomy of the upper abdominal organs with a descriptive atlas. J.B. Lippincott Company, Philadelphia, 1955, 1–581.
- [44] Kadir S. Atlas of normal and variant angiographic anatomy. W.B. Saunders, Philadelphia, 1991, 297–364.
- [45] Winter TC 3rd, Nghiem HV, Freeny PC, Hommeyer SC, Mack LA. Hepatic arterial anatomy: demonstration of normal supply and vascular variants with three-dimensional CT angiography. *Radiographics*, 1995, 15(4):771–780.
- [46] Noah EM, Klinzing S, Zwaan M, Schramm U, Bruch HP, Weiss HD. [Normal variation of arterial liver supply in mesenterico-celiacography]. *Ann Anat*, 1995, 177(4):305–312.
- [47] Song SY, Chung JW, Yin YH, Jae HJ, Kim HC, Jeon UB, Cho BH, So YH, Park JH. Celiac axis and common hepatic artery variations in 5002 patients: systematic analysis with spiral CT and DSA. *Radiology*, 2010, 255(1):278–288.

- [48] Fasel JHD, Muster M, Gailloud P, Mentha G, Terrier F. Duplicated hepatic artery: radiologic and surgical implications. *Acta Anat (Basel)*, 1996, 157(2):164–168.
- [49] Sethi M, Rangrej SB, Kakar S. An unusual origin and branching pattern of accessory hepatic artery from celiac trunk with its significance in hepatobiliary surgeries. *OA Anatomy*, 2014, 2(2):13.
- [50] Douard R, Chevallier JM, Delmas V, Cugnenc PH. Clinical interest of digestive arterial trunk anastomoses. *Surg Radiol Anat*, 2006, 28(3):219–227.
- [51] Arslan K, Dogru O, Koksak H, Bakdik S. The unusual localization of right hepatic artery multiple anatomic variants in celiac axis. *Eur J Gen Med*, 2013, 10(Suppl 1):62–65.
- [52] Okada Y, Nishi N, Matsuo Y, Watadani T, Kimura F. The common hepatic artery arising from the left gastric artery. *Surg Radiol Anat*, 2010, 32(7):703–705.
- [53] Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. *Am J Surg*, 1966, 112(3):337–347.
- [54] Hiatt JR, Gabbay J, Basuttil RW. Surgical anatomy of the hepatic artery in 1000 cases. *Ann Surg*, 1994, 220(1):50–52.
- [55] Varotti G, Gondolesi GE, Goldman J, Wayne M, Florman SS, Schwartz ME, Miller CM, Sukru E. Anatomic variations in right liver living donors. *J Am Coll Surg*, 2004, 198(4):577–582.
- [56] Coşkun M, Kayahan EM, Ozbek O, Cakir B, Dalgıç A, Haberal M. Imaging of hepatic arterial anatomy for depicting vascular variations in living related liver transplant donor candidates with multidetector computed tomography: comparison with conventional angiography. *Transplant Proc*, 2005, 37(2):1070–1073.
- [57] Németh K, Deshpande R, Máthé Z, Szuák A, Kiss M, Korom C, Nemeskéri Á, Kóbori L. Extrahepatic arteries of the human liver – anatomical variants and surgical relevancies. *Transpl Int*, 2015, 28(10):1216–1226.
- [58] Couinaud C. *Surgical anatomy of the liver revisited: embryology*. Paris, 1989, 11–24.
- [59] Ibukuro K, Tsukiyama T, Mori K, Inoue Y. The congenital anastomoses between hepatic arteries: angiographic appearance. *Surg Radiol Anat*, 2000, 22(1):41–45.
- [60] Miyaki T, Sakagami S, Ito H. Intrahepatic territory of the accessory hepatic artery in the human. *Acta Anat (Basel)*, 1989, 136(1):34–37.

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