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ANATOMIC VARIATIONS

Unusual anatomical variation: tetrafurcation of the celiac trunk

Laura Grigoriță[1] · Nawwaf Sebastian Damen[2] · Monica Adriana Vaida[1] · Adelina Maria Jianu[1]

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Abstract
The celiac trunk is one of the main sources of vascularization of the supracolic abdominal compartment. It arises from the abdominal aorta, at the level of T12–L1 vertebrae and classically branches into the splenic artery, common hepatic artery, and left gastric artery. We report here an atypical branching pattern of the celiac trunk, found during the dissection of a 60-year-old female's formalin-fixed cadaver. The atypically celiac trunk gave rise to four branches: a common trunk for left and right inferior phrenic arteries, an accessory left gastric artery, the common hepatic artery, and a splenogastric trunk. Knowledge in detail about normal anatomy and variation in the branching pattern of the celiac trunk is important in surgical, oncological, and radiological interventional procedures and must be taken into account to avoid possible complications.

Keywords Anatomy · Variation · Celiac trunk · Phrenic artery · Splenogastric trunk

Introduction

The celiac trunk (CT) is the first ventral branch of the abdominal aorta, which arises from the aorta at the level of the intervertebral disk between T12 and L1 vertebrae. It was first described by Haller in 1756 [9], 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). Since the Haller description, many branching patterns have been reported in the literature (Table 1) and most of the researchers considered that branches other than the classical branches are referred to as collaterals and so they are several classifications of the CT [1, 11]. Our study supplements the knowledge about branching pattern variations of the celiac trunk and is of profound interest for a clinician during surgical intervention in the abdominal region.

✉ Monica Adriana Vaida
vaida.monica@umft.ro

[1] Department of Anatomy and Embryology, „Victor Babeş" University of Medicine and Pharmacy, 2 Eftimie Murgu Square, 300041 Timisoara, Romania

[2] Pediatric Surgery Clinic of Emergency Children's Hospital "Louis Țurcanu", Doctor Iosif Nemoianu 2, 300011 Timisoara, Romania

Anatomic variation

During routine dissection studies for medical students, in the Department of Anatomy and Embryology, "Victor Babeş" University of Medicine and Pharmacy, Timisoara, an atypically branching pattern of CT was found in a 60-year-old female's formalin-fixed cadaver. After dissection of the anterior abdominal wall, and entering the peritoneal cavity, the stomach was mobilized to expose the CT by following its branches to their origin (Fig. 1b). The pancreas was also dissected to expose the origin of the superior mesenteric artery (SMA). All the distances between the branches of CT were measured by a Vernier Caliper that was 150 × 0.02 mm. Photographs were taken from several angles and a drawing was made to reveal the branching pattern of CT (Fig. 2).

The CT appeared as a thick artery originating on the right part of the anterior surface of the abdominal aorta (AA), at the level of L1, at 0.4 cm above the origin of SMA. The first branch of the CT was a common trunk of inferior phrenic arteries (IPA). The trunk of inferior phrenic arteries arose 0.3 cm from the origin of the CT and bifurcated in a thicker right inferior phrenic artery (RIPA), and a thinner left inferior phrenic artery (LIPA), both ascending at the level of diaphragmatic pillars toward the diaphragm. The second branch of CT is an accessory left gastric artery (aLGA), which arose at 1.3 cm from the origin of the CT and followed an ascending course toward the cardia and the vertical part of the lesser curvature of the stomach. After giving

Table 1 Variation of the CT, according to the number of arteries arising from it—a review from the literature

Author, year	Type of branching	Description
Lipshutz, 1917 [11] Chitra, 2010 [6] Venieratos et al. 2013 [17] Pinal-Garcia et al. 2018 [13]	Bifurcation	LGA + SA; LGA + CHA; CHA + SA; hepatosplenic trunk; gastrosplenic trunk; hepatogastric trunk
Lipshutz, 1917 [11] Venieratos et al. 2013 [17] Pinal-Garcia et al. 2018 [13]	Trifurcation	LGA + CHA + SA; CHA + SA + CIPA RHA + LHA + SA
Chitra, 2010 [6] Venieratos et al. 2013 [17] Pinal-Garcia et al. 2018 [13]	Tetrafurcation	LGA + CHA + SA + RIPA; LGA + CHA + SA + LIPA; LGA + CHA + SA + CIPA LGA + CHA + SA + DPA; LGA + CHA + SA + MCA; LGA + CHA + SA + RHA; LGA + CHA + SA + LHA
Chitra, 2010 [6] Pinal-Garcia et al. 2018 [13]	Pentafurcation	LGA + CHA + SA + CIPA + MCA CHA + SA + LIPA + LGA + DPA
Chitra, 2010 [6] Pinal-Garcia et al. 2018 [13]	Hexafurcation	LGA + CHA + SA + CIPA + MCA + DPA LGA + CHA + SA + aLSRA + LIPA + aJA LGA + SA + CHA + LIPA + LIPA + DPA LGA + SA + CHA + LIPA + RIPA + LMAA
Rusu and Manta, 2018 [14] Pinal-Garcia et al. 2018 [13]	Heptafurcation	LIPA + RIPA + SA + LGA + CHA + RHA + DPA LGA + SA + CHA + LIPA + RIPA + LMAA + GDA
Venieratos, 2013 [17]	Agenesis	LGA, CHA, SA originated separately from the abdominal aorta
Lipshutz, 1917 [11] Çiçekcibaşi et al. 2005 [7] Yan et al. 2014 [18]	Celiaco-mesenteric trunk	CT + SMA
Nonent et al. 2001 [12]	Celiaco-bimesenteric trunk	CT + SMA + IMA
Hemanth et al. 2011 [10]	Hepatogastrophrenic trunk and Hepato-splenomesenteric trunk	CT = IPA + LGA + CHA and SMA = SA + CHA

CT celiac trunk, *CHA* common hepatic artery, *SA* splenic artery, *LGA* left gastric artery, *SMA* superior mesenteric artery, *IMA* inferior mesenteric artery, *LIPA* left inferior phrenic artery, *RIPA* right inferior phrenic artery, *CIPA* common trunk of inferior phrenic arteries, *RHA* right hepatic artery, *DPA* dorsal pancreatic artery, *MCA* middle colic artery, *aLSRA* accessory left suprarenal artery, *aJA* accessory jejunal artery, *LMAA* left middle adrenal artery, *GDA* gastroduodenal artery

rise to the first two branches, the CT ran downwards for 0.7 cm and divided into two branches, the CHA, and the splenogastric trunk. The CHA did not show morphological particularities in its course or distribution. The splenogastric trunk ran downwards and to the left and after 0.4 cm divided into LGA and SA (Fig. 1a). The LGA courses along the lesser curvature of the stomach and anastomoses with the aLGA (Fig. 1c, d).

Discussion

Anatomic variation of CT has been described by many authors resulting in various classifications. According to Adachi's classification [1], 6 types and 28 forms were described. In literature, cases of the celiac trunk with additional or accessory arteries have been described. The supernumerary arteries may be aberrant when an artery usually present has an abnormal course and distribution and accessory when an artery that generally does not exist was found [17].

The IPA is the most common source of extra-hepatic collateral blood supply for hepatocellular carcinoma and can be involved in other pathological conditions, like transarterial embolization in patients with hemoptysis [8]. So, knowledge about anatomical variation is very important during treatment procedures of all these pathological conditions. They usually arise from the abdominal aorta just above the celiac trunk. In the literature, the IPA are the most common additional arteries originated in the celiac trunk [4, 6, 7, 16, 17], by a common trunk, like the present case in 5.4% of cases with celiac axis variation and in 13.4% of cases without celiac axis variation [4] and were described as additional branches of the celiac trunk.

Regarding the aLGA, Chen [5] reported an aberrant or accessory left gastric artery arising from the CHA or IPA. We did not find in the literature any report regarding the aLGA with origin in the CT like in the present case. The accessory arteries may provide collateral circulation that becomes important during transplant surgeries [2].

Regarding the splenogastric trunk, in Adachi's classification [1], this variant was found in 3% of the overall

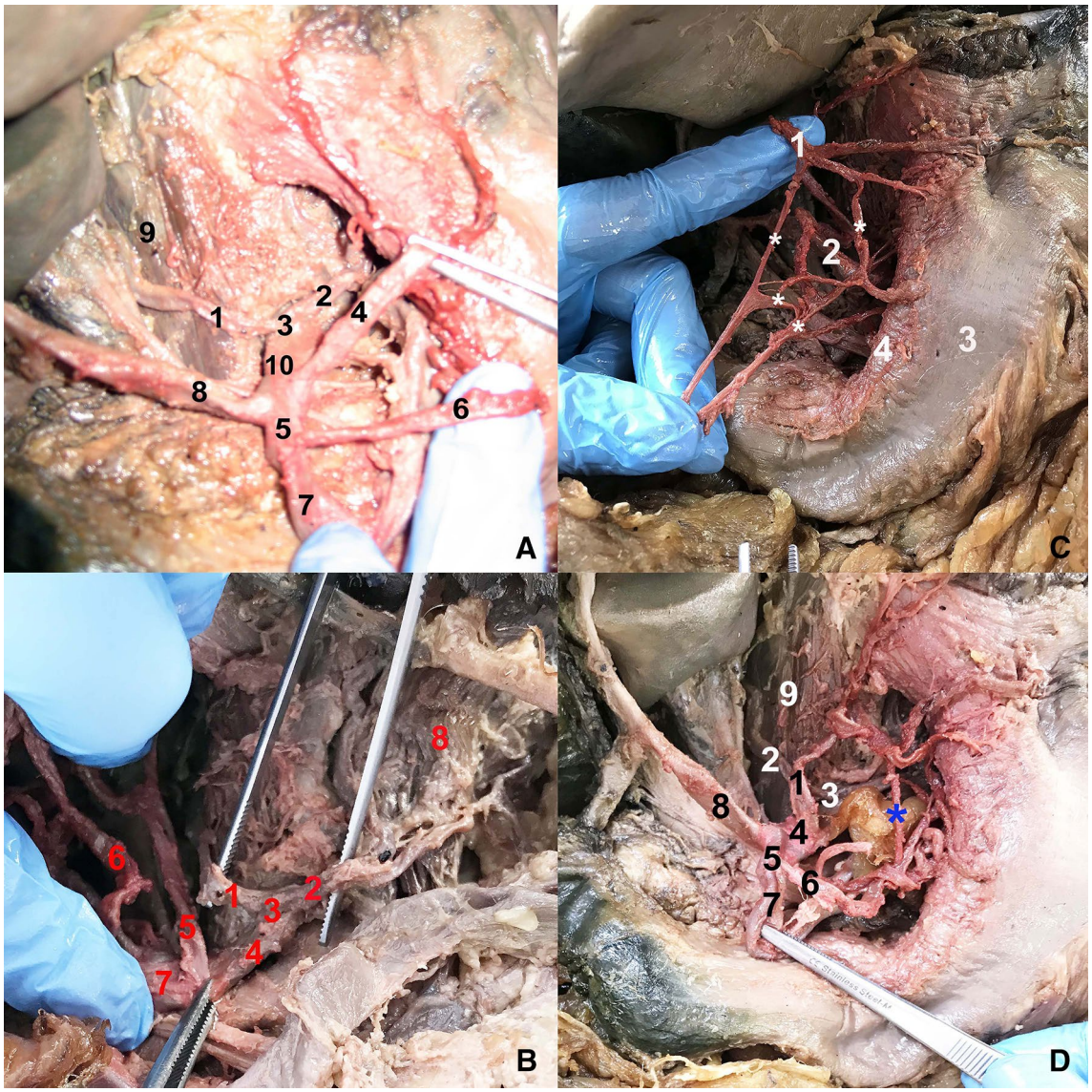

Fig. 1 Dissection revealing the origin and branching of celiac trunk. **a** 1. Right inferior phrenic artery; 2. left inferior phrenic artery; 3. trunk of the inferior phrenic arteries; 4. accessory left gastric artery; 5. splenogastric trunk; 6. left gastric artery; 7. splenic artery; 8. common hepatic artery; 9. right diaphragmatic crus; 10. celiac trunk. **b** 1. Right inferior phrenic artery; 2. left inferior phrenic artery; 3. trunk of the inferior phrenic arteries; 4. celiac trunk; 5. accessory left gastric artery; 6. left gastric artery; 7. splenogastric trunk; 8. left diaphragmatic crus. **c** 1. Accessory left gastric artery; 2. left gastric artery; 3. stomach; 4. lesser curvature of the stomach; *anastomoses between accessory left gastric artery and left gastric artery. **d** 1. Accessory left gastric artery; 2. right inferior phrenic artery; 3. left inferior phrenic artery; 4. celiac trunk; 5. splenogastric trunk; 6. left gastric artery; 7. splenic artery; 8 common hepatic artery; 9. right diaphragmatic crus; *anastomoses between accessory left gastric artery and left gastric artery

population and indicated the absence of common hepatic artery. In our case, the splenogastric trunk and the common hepatic artery both have their origin in the CT.

The anatomical variation of the pattern branching of the CT and the presence of additional branches, like IPA and accessory left gastric artery are due to the developmental changes in the branches of the dorsal aorta. The dorsal aorta creates three types of branches—dorsal (intersegmental) branches, lateral (visceral) branches, and ventral (splanchnic) branches. IPA emerge from the lateral branches of the descending aorta [3]. The ventral branches are fused and remain three vessels which pass by the mesentery to the gut and become the celiac artery, the SMA and the inferior mesenteric artery. If there is any communication between lateral and ventral branches, and the part of the lateral branches between origin and communication disappear, it can explain the origin of the IPA from the CT. The ventral branches are connected by longitudinal anastomotic channels

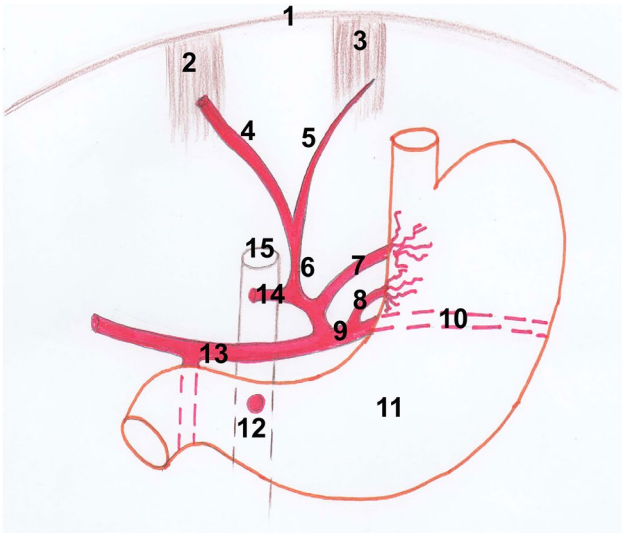

Fig. 2 Drawing illustrates the unusual celiac trunk tetrafurcation. 1. Diaphragm; 2. right diaphragmatic crus; 3. left diaphragmatic crus; 4. right inferior phrenic artery; 5. left inferior phrenic artery; 6. trunk of the inferior phrenic arteries; 7. accessory left gastric artery; 8. left gastric artery; 9. splenogastric trunk; 10. splenic artery; 11. stomach; 12. origin of superior mesenteric artery; 13. common hepatic artery; 14. celiac trunk; 15. abdominal aorta

along the ventral and the dorsal aspect of the digestive tube, forming dorsal and ventral splanchnic anastomoses. As the viscera supplied by these vessels descend in the abdomen, their origin migrates caudally by differential growth. The ventral splanchnic anastomoses form the right gastric artery, the LGA, and the CHA [15]. Reuter (1977) quoted in [2] discussed that the additional vessels may occur due to the persistence of some parts of the longitudinal anastomotic channels that usually disappear or due to the disappearance of parts that normally persist or due to other factors such as the rotation of the midgut, physiological herniation, leftward migration of the spleen and hemodynamic changes in the abdominal viscera.

In conclusion, new variants must be reported, because knowledge about CT branching pattern must be taken into account by gastroenterological surgeons, interventional radiologists, and oncologists to avoid complications during surgical and radiological abdominal procedures.

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Compliance with ethical standards

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

Ethical approval The research was conducted ethically in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

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