Forensic Medicine and Anatomy Research, 2023, 11, 15-29
https://www.scirp.org/journal/fmar
ISSN Online: 2327-4107
ISSN Print: 2327-4115

An Anatomical and Radiological Study of Origins of the Arteries Forming the Celiac Trunk: Clinical and Embryological Implications

Fahrettin Fatih Kesmezacar[1], Cem Kopuz[2*], Onur Tutar[3], Kubilay Kınoglu[4], Erdoğan Kara[4]

[1]Vocational School of Health Services, Istanbul University-Cerrahpaşa, Istanbul, Türkiye
[2]Department of Anatomy, Medical Faculty, Kütahya Health Sciences University, Kütahya, Türkiye
[3]Department of Radiology, Cerrahpaşa Medical Faculty, Istanbul University-Cerrahpaşa, Istanbul, Türkiye
[4]Forensic Medicine Institution, Ministry of Justice, Istanbul, Türkiye
Email: *drkopuz@gmail.com

How to cite this paper: Kesmezacar, F.F., Kopuz, C., Tutar, O., Kınoglu, K. and Kara, E. (2023) An Anatomical and Radiological Study of Origins of the Arteries Forming the Celiac Trunk: Clinical and Embryological Implications. *Forensic Medicine and Anatomy Research*, **11**, 15-29.
https://doi.org/10.4236/fmar.2023.112002

Received: December 19, 2022
Accepted: April 16, 2023
Published: April 19, 2023

Abstract

The blood supply to the most of abdominal organs is provided by the branches of CT. The SMA supply caecum, ascends colon, all of the small bowels except the upper part of duodenum. Knowledge of variable anatomy of celiac axis and SMA may be useful in planning and executing radiological interventions such as celiacography and chemoembolization of hepatic and pancreatic tumors. In this study, the uncommon or low percentage cases of CT and SMA are presented in the light of clinical and embryological information. The celiac axises of a total of 30 adult corpses were examined. Dissections of abdominal region were performed in detail according to Cunningham's manual. Angiographic images of 100 consecutive adult patients who underwent celiac MDCT angiography were evaluated. During autopsies, an incomplete celiac trunk or bifurcation of celiac trunk associated with the hepatomesenteric and gastrosplenic trunks (0.7%) and a celiacomesenteric trunk associated with high origin superior mesenteric artery and gastrosplenic trunk were detected (0.7%). During MDCT angiography, a case of total absence of celiac trunk associated with a hepatosplenomesenteric trunk (0.7%) and also a case of total absence of celiac trunk alone were observed (0.7%). The persistence or unusual development of ventral splanchnic arteries (VSAs) or ventral longitudinal anastomosis may result in variations or the unusual trunks related to celiac axis and SMA. The anomalous trunks of the CT may be result of either the persistence of some parts of the VSAs or ventral longitudinal anastomose that normally disappear or disappearance of parts that normally persist. The prevalence of unusual trunks of celiac axis and SMA in this study is quite low in literature. These abnormal vessels pose problems for surgeons and radiologists. Such vascular anomalies may cause clinical complications following surgical and radiological procedures such as resection of tumor of the pancreatic head, lymphadenectomy, coeliacography, aortic replacement with reimplantation of the trunk and coembolization of pancreatic and liver tumors.

Keywords

Celiac Trunk, Superior Mesenteric Artery, Variation, Hepatosplenomesenteric Trunk, Celiacomesenteric Trunk, Embryology

1. Introduction

The classical anatomy textbooks state that the celiac trunk (CT) is divided into the left gastric (LGA), the common hepatic (CHA) and the splenic arteries (SA). This trifurcation of CT is known as Tripus Halleri, which was first detected by Haller in 1756 [1]. Numerous reports on branching patterns of celiac axis variations have been published [2]-[7], since understanding the distribution of the CT and the superior mesenteric artery (SMA) is essential for medical practice.

The incidence of normal branching form of the complete CT is 72% - 89% [5] [6] [7]. The absence of the CT has been reported with an incidence of less than 1% [5] [6] [8]. The frequency of an incomplete CT has been detected as 9% [8]. The incomplete CT group has been classified into different types: hepatosplenic trunk (HST), gastrosplenic trunk (GST), hepatogastric trunk (HGT), hepatosplenomesenteric trunk (HSMT), hepatomesenteric trunk (HMT), celiacomesenteric trunk (CMT) [2] [5] [6] [8] [9] [10] [11] [12]. Recently, HST is well known among them, varying from 1% to 8% of cases [5] [8] [10] [11]. On the other hand, the frequency of GST has been reported between 0.2% - 6.6% percent [6] [8] [12] [13] [14]. However, HMT, HSMT and CMT are rare (0.4% - 1%) [2] [9] [10] [12]. Very rarely, the CHA, SA and LGA arise from, separately abdominal aorta (AA) in 0.1% - 1% of cases [5] [6] [8] [12] [15].

Anatomical variations of the CT leave a person at high risk of injury due to arterial supply followed by severe liver ischemia, liver abscesses, biliary fistula or bleeding [16]. Therefore, accurate identification of these arterial variations will increase the likelihood of successful surgery or radiological intervention and reduce the complication rate after the complex surgical or radiological procedures.

These changes in the branching pattern of the CT can cause iatrogenic damage during surgical procedures such as total pancreatomy and resection of pancreatic head tumors [4] [17].

Extrahepatic arterial variations are precisely defined during liver surgery or transplantation to avoid injuries that may compromise full artery ligation [3]. The variations of anatomy of the arteries of the hepar, gaster, lien and bowels can be important in surgical success. The vascular variations are usually asymptomatic.

Knowledge of variable anatomy of celiac axis may be useful in planning and executing radiological interventions such as celiacography and chemoembolization of hepatic and pancreatic tumors [18] [19]. In this study, rare variations of arteries forming the celiac axis and their embryological reasons are presented in the light of clinical information.

2. Material and Methods

We carried out 30 dissections on adult corpses (age range: 18 - 55 years) and analyzed 100 MDCT (multidetector computed tomographic) angiographies (age range: 50 - 75 years). Transactions on human materials and collection of human material and data were performed in accordance with the principles of the Declaration of Helsinki after the approval of the ethics committee at Istanbul Training and Research Hospital (Reference number: 1968/August 29, 2019). Autopsy cases with abdominal trauma and chronic intra-abdominal organ disease were not included in the study. Dissections of abdominal region were performed in detail according to guidelines of Cunningham's Manual of Practical Anatomy. A midline skin incision from the xiphosternal junction to the pubic symphysis and a transverse incision from the xiphoid process to a point on the midaxillary line were performed. Skin incision was extended from pubic symphysis to anterior iliac spine to reflect the skin from medial to lateral. Fascias and muscles of abdominal wall and periton were incised from surface to deep, and reflected laterally, and thus peritoneal cavity was opened. The gaster, small intestines, transverse colon were retracted laterally to expose CT and its branches and SMA. The rare variations were recorded and photographed.

MDCT examination with intravenous contrast agent was performed using "Somatom Sensation 16 and 64 slice multi detector CT" (Siemens AG, Erlangen, Germany). MDCT images were got in a craniocaudal direction during the hepatic arterial, portal venous and balance phases. The scope arterial phase of MDCT images varied from the vault of the diaphragm to the symphysis pubis.

For the aims of this study, only the data got during the arterial phase was downloaded to an offline workstation for post-image processing and analysis. Post-image processing techniques such as multiplanar and 3-D reformation, volume rendering and maximum intensity projection were used. Images were reshaped, analyzed and evaluated for the anatomical location of AA and its major branches. The anomalies of the CT were analyzed separately and important anatomic variations were recorded.

3. Results

During the dissections and angiographic studies performed in a total of 130 adult corpses and patients, we detected each of the following variations in the branches of celiac axis of abdominal aorta in one case (0.7%).

3.1. Incomplete Celiac Trunk or Bifurcation of Celiac Trunk Associated with the Hepatomesenteric and Gastrosplenic Trunks

During dissection of the abdominal cavity in autopsy of a 22-year-old male corpse, an incomplete CT or the bifurcation of CT was encountered 0.6 cm after its origin from the AA and branched in an unusual manner. Three branches of CT did not originate from common trunk. At the level of the 12th thoracic vertebral body, CT was arising from the AA 1.5 cm above the origin of renal artery just on the right side from the median line of its anterior wall. It divided into GST and HMT which the length of 10 mm and 15 mm respectively. The external diameters of these trunks at its origin were 5 mm and 10 mm, respectively. The HMT gave rise to CHA and SMA. CHA was 5 cm long, and 5 mm diameter at its origin. It passed anterior to portal vein above the first part of duodenum and divided into proper hepatic and gastroduodenal arteries. Gastroduodenal artery was arising from the CHA, which passes posterior to the first part of the duodenum and bifurcated into right gastroepiploic artery and a common trunk for right gastric artery and anterior superior pancreaticoduodenal artery. The GST initially ran towards right for a short distance where divided into larger SA and a longer LGA. Left hepatic artery arose from the LGA and ascended upwards and towards right finally reached the porta hepatis of the liver. As usual LGA ran upwards retroperitoneally towards the esophageal hiatus, and descended along lesser curvature to anastamose with right gastric artery within lesser omentum. The SA from GST coursed towards left side and retroperitoneally along the superior border of pancreas and entered the spleen (Figure 1, Figure 5).

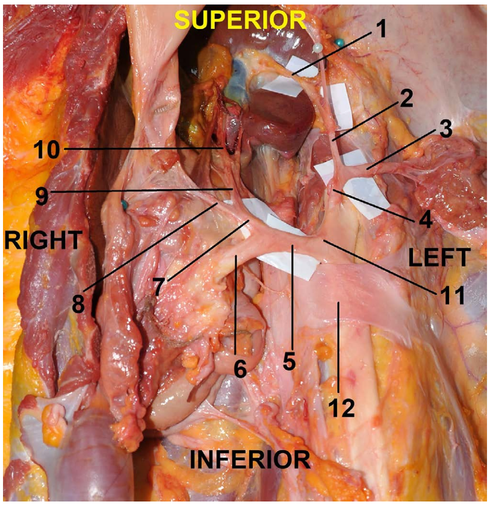


Figure 1. Incomplete celiac trunk or bifurcation of celiac trunk associated with the hepatomesenteric and gastrosplenic trunks: Abdominal cavity was opened to show the branches of celiac trunk, small and large intestines were removed from the right lateral side, and the stomach is pulled upwards to the left and back. 1-Left hepatic artery, 2-Left gastric artery, 3-Splenic artery, 4-Gastrosplenic trunk, 5-Hepatomesenteric trunk, 6-Superior, mesenteric artery, 7-Common hepatic artery, 8-Gastroduedonal artery, 9-Proper hepatic artery, 10-Right hepatic artery, 11-Common trunk of hepatomesenteric and gastrosplenic trunks (Celiac trunk), 12-Left renal vein (covering the abdominal aorta).

3.2. Celiacomesenteric Trunk Associated with High Origin Superior Mesenteric Artery and Gastrosplenic Trunk

During dissection of the abdominal cavity in autopsy of a 55-year-old male corpse, a bifurcation of CT (CMT) was encountered at the level of its origin from the AA, just below the aortic opening of the diaphragm and branched in an unusual manner. The CMT originated from AA at the level of the first lumbar vertebral body, at the level just above the origin of the right and left renal arteries, and it had a length of 20 mm. External diameter of the CMT, at its origin was 2.5 cm. The CMT was divided into CT and the SMA. The external diameters of these arteries at their origin were 9 mm and 8 mm, respectively. The SMA coursed downward as usual. The CT ascended 5 cm from the bifurcation and further was divided into LGA and HST as unusual. External diameters of these arteries, at their origins were 6 mm and 7 mm, respectively. The HST was divided into CHA and SA (**Figure 2**, **Figure 5**).

3.3. Total Absence of Celiac Trunk Associated with a Hepatosplenomesenteric Trunk

During DCT angiography of a 57-year-old male patient, a hepatosplenomesenteric trunk (HSMT) was encountered at the level of L2-L3 intervertebral discus. The HSMT arose from the anterior aspect of AA at 2.5 cm distal to the origin of renal artery separately. It was divided into CHA, SA and SMA at 2.7 cm distal to the point of its origin. On the other hand, CHA, SMA and SA originated from a common trunk (HSMT). The length of HSMT was 2.7 cm; its external diameter, at its origin was 7.6 mm. The diameters of CHA, SA and SMA at their origins were 5 mm, 4.6 mm, 7.4 mm, respectively. Interestingly, the RHA arose from the SMA. The LGA was originating as the first ventral branch directly from the anterior aspect of AA at 3.5 cm proximal to the origin of the HSMT. Its dimeter was 2.3 mm. These arteries that consists of HSMT and the LGA coursed as usual (**Figures 3(a)-(d)**, **Figure 5**).

3.4. Total Absence of Celiac Trunk

During MDCT angiography of an 82-year-old female patient, a case of total absence of CT was observed and it had the branching in an unusual manner. In the present case, the LGA arose from below the aortic opening, at the level of 12th thoracic vertebral body, separately. The CHA and SA were originating as the ventral branches from the anterolateral aspect of AA, from upper to lower independently, at the levels of T12-L1 intervertebral discus and first lumbar vertebral body, respectively. External diameters of LGA, CHA and SA at their origins were 3 mm, 5.3 mm and 5 mm, respectively. The SMA originated directly from the anterior aspect of AA at the level of third lumbar vertebral body and its diameter was 7.5 mm. Distances of LGA, SA and CHA from the origin of renal artery were 4.3 mm, 4.1 mm and 3.8 mm, respectively. These arteries were coursing as usual (**Figures 4(a)-(c)**, **Figure 5**).

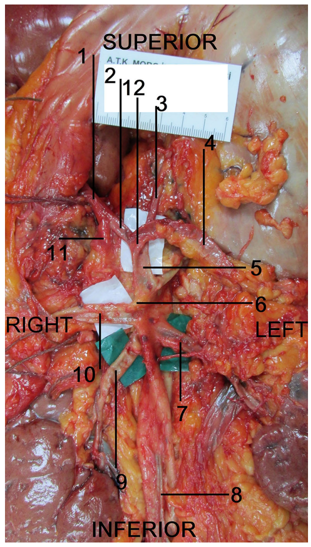
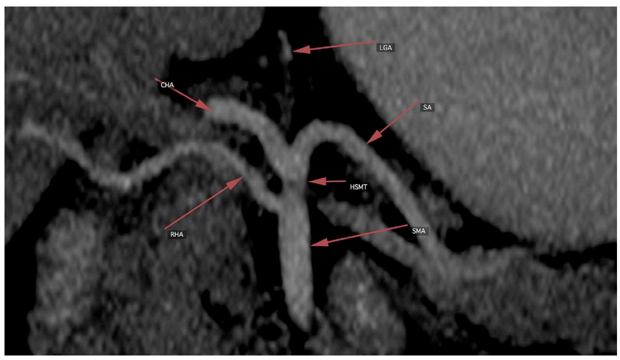
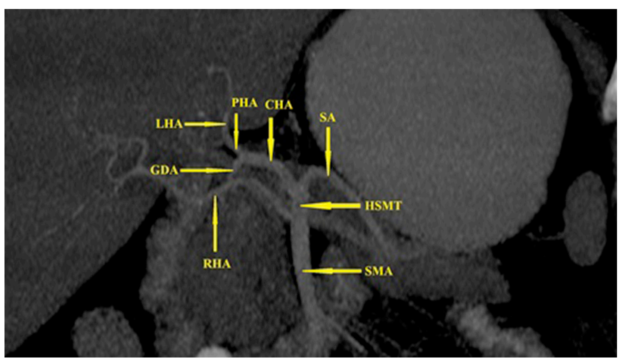


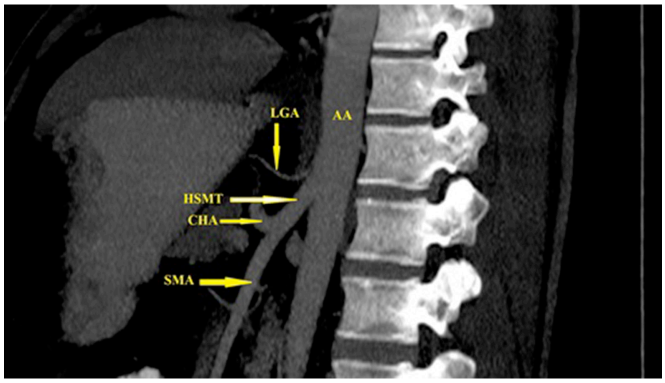
Figure 2. Celiacomesenteric trunk associated with high origin superior mesenteric artery and gastrosplenic trunk: The abdominal cavity was opened to show the mesenteric superior artery and the branches of celiac trunk, the lesser omentum was cut and the stomach was released and was pulled to the left lower-lateral to expose the bursa omentalis The small and large intestines were removed from the right lateral. 1-Proper hepatic artery, 2-Common hepatic artery, 3-left gastric artery, 4-Splenic artery, 5-Celiac trunk, 6-Celiacomesenteric trunk, 7-Left renal artery, 8-Inferior mesenteric artery, 9-Right renal artery, 10-High origin of superior mesenteric artery, 11-Gastroduodenal artery, 12-Gastrosplenic trunk.



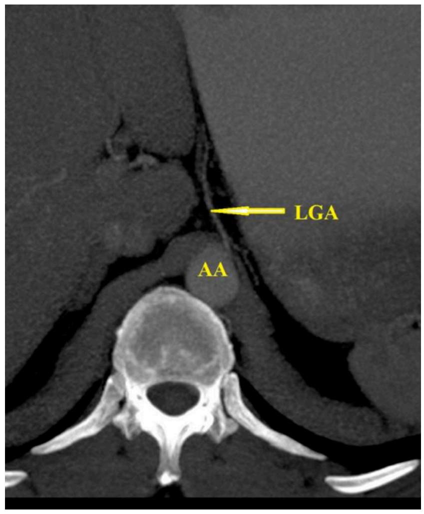
(a)



(b)

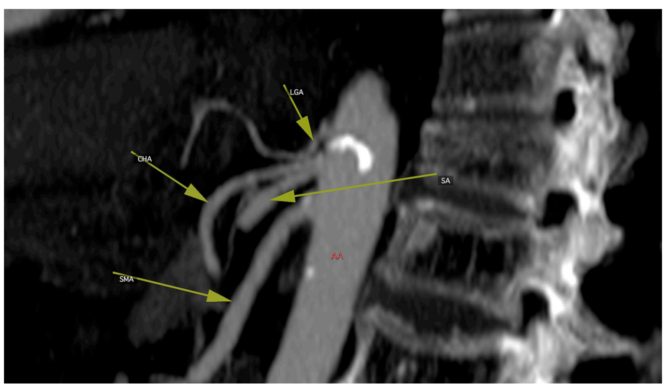


(c)

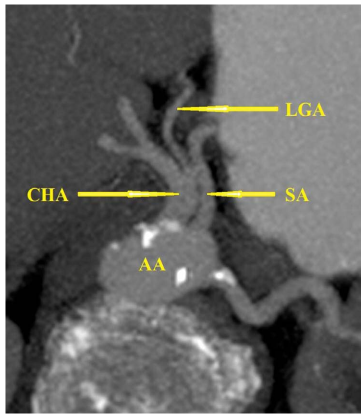


(d)

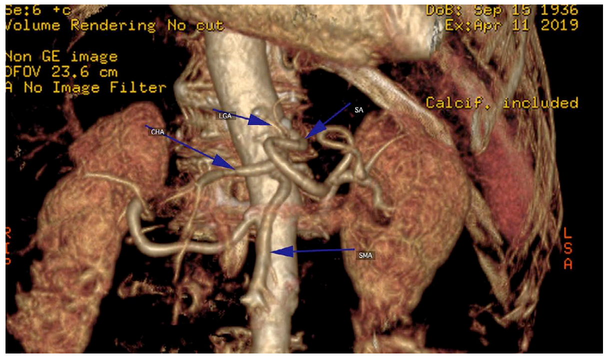
Figure 3. Coronal (a, b), sagittal (c) and axial (d) MIP images showing hepatosplenomesenteric trunk originated from abdominal aorta and its branches (superior mesenteric, splenic and common hepatic arteries); demonstrated by MDCT angiography. CHA: Common hepatic artery, LGA: left gastric artery, SA: Splenic artery, SMA: Superior mesenteric artery, HSMT: Hepatosplenomesenteric trunk, AA: Abdominal aorta, RHA: Right hepatic artery, LHA: Left hepatic artery, PHA: Proper hepatic artery, GDA: Gastroduodenal artery.



(a)



(b)



(c)

Figure 4. Sagittal MIP (a), axial MIP (b) and volume rendered (c) images showing superior mesenteric, splenic, common hepatic and left gastric arteries arising directly from abdominal aorta; demonstrated by MDCT angiography. CHA: Common hepatic artery, LGA: left gastric artery, SA: Splenic artery, SMA: Superior mesenteric artery AA, Abdominal aorta.

4. Discussion

The blood supply to the most of abdominal organs is provided by the branches of CT. The SMA supply caecum, ascends colon, all of the small bowels except the upper part of duodenum. The anatomic variations of arteries in intraabdominal region have been well documented by previous studies [2] [7] [8] [9] [20].

In adults, variations of intraabdominal vessels are thought to have an embryological basis. The gastrointestinal tract consists of three segments embryologically, based on its blood supply from the AA [21]. These arteries supply the derivatives of foregut, midgut and hindgut, respectively [22]. The CT is the first ventral branch of the AA which originates at the level of T12-L1 intervertebral discus [23]. It supplies the parts of the foregut like liver, stomach, pancreas, spleen and proximal part of duodenum [22].

In the early embryo, the dorsal aortae are still paired vessels [1] [22]. Each primitive dorsal aorta, even before the stage of its fusion, gives off somatic arteries (the umbilical arteries), lateral splanchnic arteries and ventral splanchnic arteries or vitelline. Initially, double ventral splanchnic branches supplies gut and its derivatives [1]. At the end of the fourth week of embryological development, the yolk is supplied by double vitelline arteries [22]. Later these arteries gradually fuse in the midline by the middle of 5th week and help in formation of the arteries dorsal to the mesentery of the gut. With the appearance of longitudinal anastomotic channels, a large number of ventral splanchnic arteries are withdrawn and only three trunks remain in the adult, as CT, SMA and inferior mesenteric artery [21] [22].

The four roots of the ventral splanchnic vessels are connected by ventral longitudinal anastomotic channels and as second and third roots disappear, these anastomoses connect the first and fourth roots. This anastomosis is usually separated between these roots. If this separation occurs at a level below the lowest branch of CT (CHA) or between fourth root (the future SMA) and CHA, any one of branches of CT can be displaced to the SMA. LGA, SA and CHA usually originate from the superior anastomosis from up to bottom, respectively, and the SMA from the fourth root [21]. In other words, the persistence or unusual development of ventral splanchnic arteries (VSAs) or ventral longitudinal anastomosis may result in variations or the unusual trunks related to celiac axis and SMA.

Also it has been suggested that the rotation of the mid-gut and its physiological herniation during development, displacement of spleen and hemodynamic changes of abdominal organs cause variable anatomy of the CT and SMA [24]. The anomalous trunks of the CT may be result of either the persistence of some parts of the VSAs or ventral longitudinal anastomose that normally disappear or disappearance of parts that normally persist.

In one of our cases, it is possible that the third root formed CT, and first, second, fourth roots disappeared and the longitudinal anastomosis connects first and fourth roots. In this anomaly, the separation of longitudinal anastomosis did not occur. The longitudinal anastomosis between second and fourth VSAs formed GST by fusion the LGA and SA, and HMT by fusion the CHA and SMA (**Figure 5**, **Figure 6**).

We suggest the following embryological interpretation for our other case: First three roots go away, and fourth root persistence and forms a CMT; ventral longitudinal anastomosis connects first and fourth VSAs and there is also no partition in this anastomosis. As a result of this, when the fourth root formed the SMA, the lower part of the anastomosis between the third and fourth roots formed the CT. HST was formed by the fusion of SA and CHA. The LGA arose from anastomosis between HST and CT. In this case, we also think that the origins of the main branches of CT are displaced, and lower parts of anastomosis persisted (**Figure 5**, **Figure 6**).

In one of our angiographic cases, second and third roots disappeared and first and fourth roots remained connected via longitudinal anastomoses. This longitudinal anastomosis separated between the first and second roots. The fourth root formed HSMT by fusion of SA, CHA and SMA via lower part of longitudinal anastomosis. First root formed the LGA and it originated directly from the AA (**Figure 6**).

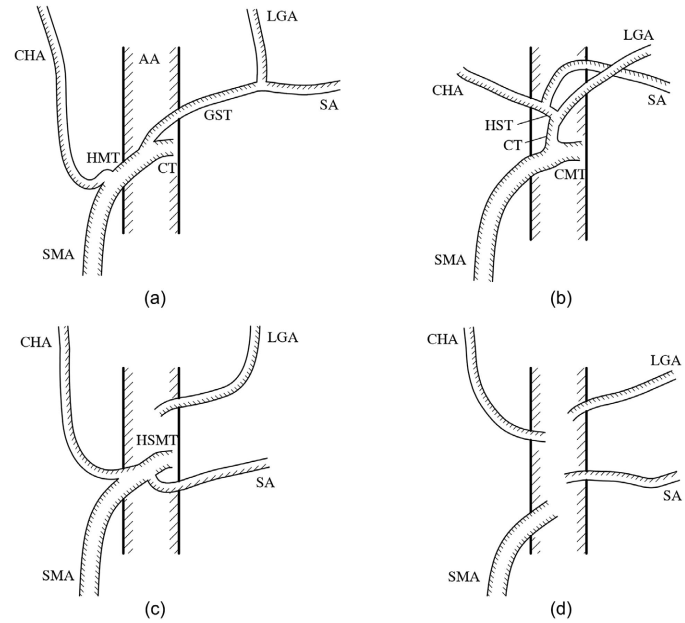


Figure 5. Schematic diagrams of **Figure 1(a)**, **Figure 2(b)**, **Figure 3(c)** and **Figure 4(d)** showing variations of celiac axis and its branches. CHA: Common hepatic artery, LGA: left gastric artery, SA: Splenic artery, SMA: Superior mesenteric artery, AA: Abdominal aorta, GST: Gastrosplenic trunk, HST: Hepatosplenic trunk, CMT: Celiacomesenteric trunk, CT: Celiac trunk, HMT: Hepatomesenteric trunk, HSMT: Hepatosplenomesenteric trunk.

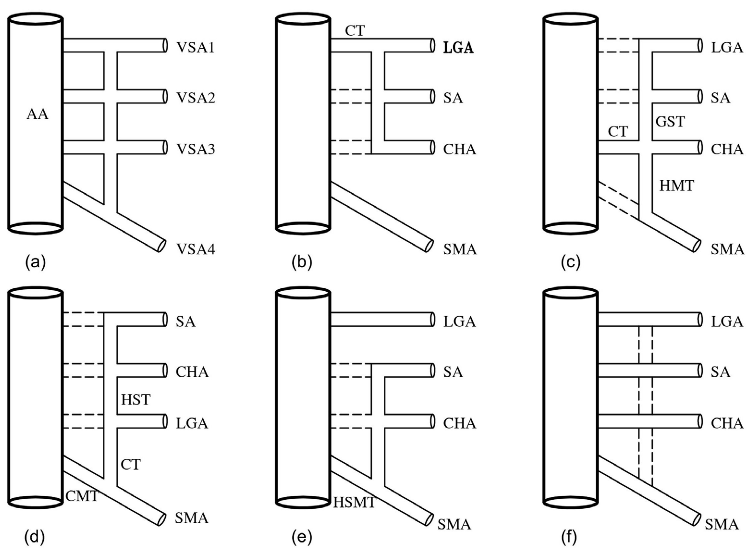


Figure 6. Schematic diagrams of embryologic development of celiac axis and mesenteric arterial vasculature. (a) Primitive arterial system, (b) Normal arrangement, (c) The formation of hepatomesenteric and gastrosplenic trunks, (d) The formation of celiacomesenteric and hepatosplenic trunks, (e) The forming of hepatosplenomesenteric trunk, (f) Its branches arising directly from abdominal aorta due to absence of celiac trunk. CHA: Common hepatic artery, LGA: left gastric artery, SA: Splenic artery, SMA: Superior mesenteric artery, AA: Abdominal aorta, GST: Gastrosplenic trunk, HST: Hepatosplenic trunk, CMT: Celiacomesenteric trunk, CT: Celiac trunk, HMT: Hepatomesenteric trunk, HSMT: Hepatosplenomesenteric trunk, LA: Longitudinal anastomotic arteries, VS: Ventral splanchnic arteries.

In our other angiographic case, it is possible that four roots of VSAs persisted as at the beginning of development, and ventral longitudinal anastomoses between roots disappeared. The fusion of three main branches of CT and SMA did not occur; as a result of this first, second, third and fourth roots formed LGA, SA, CHA and SMA as usual, respectively, and they originated directly from the AA (**Figure 6**).

There are studies that report the branching patterns of CT in different ways [2]-[7] [9]. Adachi [9] had classified the anatomic variations of CT into six types: This is as follows: Type I, classical trifurcation of the CT (87.7%); Type II, the LGA arose directly from the AA, with HST (5.5%); Type III, the LGA originated from the AA, independently, with a HSMT (1.2%); Type IV, the CMT originated from the AA (2.4%); Type V, with HMT and GST (0.4%); Type VI, the CHA arose from the SMA and run behind the portal vein and gave off gastroduodenal artery (2%). Chen *et al.* [2] found the incidences of six types of CT in dissection study of 974 corpses, respectively as 89.8%, 4.3%, 0.7%, 0.7%, 1.5% and 1.8%. Same authors have found the GST and CHA arising directly from the AA in five cases (0.6%), the HGT and splenomesenteric trunk originating from the AA separately in two cases (0.2%) (**Table 1**).

Table 1. The incidence of anatomical types of common trunks or arteries forming the celiac axis according to different authors in the literature.

Author	Number of cases	HST + LGA (%)	HSMT + LGA (%)	CMT (%)	HMT + GST (%)	HGT + SMT (%)	HGT + SA (%)	GST + CHA (%)	CHA + LGA + SA (%)	HMT + LGA + SA (%)
Adachi [9]	252	6.4	1.2	2.4	0.4	-	-	2	-	-
Chen [2]	974	4.3	0.7	0.7	1.5	0.2	0.3	2.4	-	-
Uğurel [6]	100	3	1	-	-	-	1	4	1	-
Petscavage [30]	-	-	-	<2	-	-	-	-	-	-
Vandamme [12]	156	6.4	6	-	6.4	-	6	6.6	1	1
Eaton [27]	206	4.4	-	-	-	-	-	4.9	-	-
Song [5]	5002	4.4	0.7	1	2.6	0.2	0.02	0.2	0.1	0.2
Araujo [25]	60	8.3	-	-	-	-	1.7	-	-	-
Petrella [13]	89	-	-	-	-	-	-	3.3	-	-
Selvaraj [14]	75	8	-	-	-	-	1	1.3	-	-
Lippert [8]	-	5	-	2	3	-	1	3	<1	-
Tsukamoto [11]	100	1	-	11	3	-	-	-	-	-
Shoumura [10]	450	2.9	0.4	1.1	2.0	-	-	-	-	-
Michels [20]	200	4	-	-	-	-	1.5	5.5	-	-
Lipshutz [26]	83	13.3	-	-	-	-	6	4.8	-	-
Present study	130	-	0.7	0.7	0.7	-	-	-	0.7	-

In the angiographic and cadaver studies the incidence of presence of the HGT has been detected as 0.02% - 6% [2] [6] [8] [12] [13] [14] [20] [25] [26] (**Table 1**). In a study performed on corpses, the GST was observed in 3.3% of cases [13]. The LGA may originate directly from the AA (6.7%) [27]. Previous studies have shown that the presence of HMT in 0.2% - 3.5% of cases [2] [7] [8] [20] or its presence associated with GST (1.6%) [28]. Nakamura [28] also found three cases of HMT with GST. The cases that a CHA originates from the SMA are rare (0.86%) [29]. In angiographic and cadaver studies, the CMT was encountered in 0.7% - 1% of individuals [5] [10] [30]. The cases that the SA arose from the SMA or the AA were detected at an incidence of 0.1% - 1% [5] [6] [12] [31]. Hemamalini [7] has detected a case of total absence of CT associated with an HMT, which gave rise the CHA and SMA. In his case the SA and LGA were arising from the AA, separately. Lippert and Pabst [8] have shown the gastrosplenic group and no trunk formation of incomplete CT, respectively as 3%, less than 1%. Michels [20] has found that a case of absence of CT associated with HMT. In this case, LGA, SA and HMT independently arose from the AA (**Table 1**).

The incidence of presence of HSMT was observed as 0.7% [2]. In 5002 angiographic examinations performing with DSA, the LGA and HSMT that also arose from the AA separately pattern were reported as 0.68% (34 cases) [5]. In another study performed by MDCT angiography it has detected in 1% of patients [6]. The cases that the LGA, CHA and SA arose from the AA were encountered in 0.1% - 1% of individuals [6] [8]. Devi *et al.* [3] has described a case of CT dividing into HGT and HST. Mburu *et al.* [4] non-classical trifurcation of CT which characterized by a common point of origin of the CHA and SA was reported as 29.3% [4]. In their study, the incidence of the bifurcation of CT with GST and HMT, and with HST (an aortic origin of the LGA) was found as 4.9% and 13.1%, respectively. A similar prevalence of these cases has been reported by Adachi [9] as 0.4% and 6.4%, respectively. The incidences of the trunks formed by the arteries related to the celiac axis are also presented in **Table 1**.

The prevalence of unusual trunks of celiac axis and SMA in this study is quite low in literature.

5. Conclusions

An incomplete CT or bifurcation of CT associated with the HMT and GST and a CMT associated with high origin SMA and GST and case of total absence of celiac trunk associated with a HSMT and also case of total absence of celiac trunk alone were each detected at a very low rate of 0.7%. The persistence or unusual development of VSAs or ventral longitudinal anastomosis may result in variations or the unusual trunks related to celiac axis and SMA. The anomalous trunks of the CT may be result of either the persistence of some parts of the VSAs or ventral longitudinal anastomose that normally disappear or disappearance of parts that normally persist.

Prior knowledge of vascular variations in the abdomen is important to successfully perform surgical and radiological procedures in patients who undergo abdominal angiography or surgery for gastrointestinal bleeding, celiac axis compression syndrome, and in liver transplantation. These abnormal vessels pose problems for surgeons and radiplogists. Such vascular anomalies may cause clinical complications following surgical and radiological procedures such as resection of tumor of the pancreatic head, lymphadenectomy, coeliacography, aortic replacement with reimplantation of the trunk and coembolization of pancreatic and liver tumors. Therefore, these variations should be kept in mind for successful surgery or radiological image interpretation. We believe that the cases and detailed information or comprehensive review presented in this study will contribute to the literature, and will help surgeons as well as radiologists.

Fund Support

No funding was received from any public or private institution for this study.

Acknowledgements

Preliminary part of this was presented at seventh anatomy winter days congress of anatomists and clinical anatomists, 21-23 January 2019, Denizli, Türkiye.

The author extends his thanks to architect Aysu Kopuz, for helping her to draw the schematic diagrams of this paper.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Standring, S. (2005) Gray's Anatomy: The Anatomical Basis of Clinical Practice. 40th Edition, Elsevier, Philadelphia, 1043-1044, 116-118.

[2] Chen, H., Yano, R., Emura, S. and Shoumura, S. (2009) Anatomic Variation of the Celiac Trunk with Special Reference to Hepatic Artery Patterns. *Annals of Anatomy*, **191**, 399-407. https://doi.org/10.1016/j.aanat.2009.05.002

[3] Devi, S.K., Sharmila, B.P. and Susan, P.J. (2011) Variant Anatomy of the Celiac Trunk and Its Branches. *International Journal of Morphology*, **29**, 581-584. https://doi.org/10.4067/S0717-95022011000200047

[4] Mburu, K.S., Alexander, O.J., Hassan, S. and Bernard, N. (2010) Variations in the Branching Pattern of the Celiac Trunk in a Kenyan Population. *International Journal of Morphology*, **28**, 199-204. https://doi.org/10.4067/S0717-95022010000100028

[5] Song, S.Y., Chung, J.W., Yin, Y.H., *et al.* (2010) Celiac Axis and Common Hepatic Artery Variations in 5002 Patients: Systematic Analysis with Spiral CT and DSA. *Radiology*, **255**, 278-288. https://doi.org/10.1148/radiol.09090389

[6] Ugurel, M.S., Battal, B., Bozlar, U., *et al.* (2010) Anatomical Variations of Hepatic Arterial System, Celiac Trunk and Renal Arteries: An Analysis with Multidetector CT Angiography. *The British Journal of Radiology*, **83**, 661-667. https://doi.org/10.1259/bjr/21236482

[7] Malini, H. (2018) Variations in the Branching Pattern of the Celiac Trunk and Its

Clinical Significance. *Anatomy & Cell Biology*, **51**, 143-149. https://doi.org/10.5115/acb.2018.51.3.143

[8] Lippert, H. and Pabst, R. (1985) Arterial Variations in Man: Classification and Frequency. JF Bergmann Verlag, Munchen, 30-41. https://doi.org/10.1007/978-3-642-80508-0_18

[9] Adachi, B. (1928) Das arteriensystem der japaner, Vol II. Kenkyusha Press, Kyoto, 11-74.

[10] Shoumura, S., Emura, S., Utsumi, M., Chen, H., *et al.* (1991) Anatomical Study on the Branches of the Celiac Trunk (IV). Comparison of the Findings with Adachi's Classification. *Kaibogaku Zasshi* (*Acta Anatomica Nipponica*), **66**, 452-461.

[11] Tsukamoto, N. (1929) The Branches of the Abdominal Visceral Arteries in Japanese. *Kaibogaku Zasshi* (*Acta Anatomica Nipponica*), **2**, 780-829.

[12] Vandamme, J.P. and Bonte, J. (1985) The Branches of the Celiac Trunk. *Acta Anatomica*, **122**, 110-114. https://doi.org/10.1159/000145991

[13] Petrella, S., Rodrigues, C.F.S., Sgrott, E.A., *et al.* (2006) Origin of Inferior Phrenic Arteries in the Celiac Trunk. *International Journal of Morphology*, **24**, 275-278. https://doi.org/10.4067/S0717-95022006000300024

[14] Selvaraj, L. and Sundaramurthi, I. (2015) Study of Normal Branching Pattern of the Celiac Trunk and Its Variations Using CT Angiography. *Journal of Clinical and Diagnostic Research*, **9**, AC01-AC04. https://doi.org/10.7860/JCDR/2015/12593.6523

[15] Yi, S.Q., Terayama, H., Naito, M., *et al.* (2007) Common Celiacomesenteric Trunk and a Brief Review of the Literature. *Annals of Anatomy*, **189**, 482-488. https://doi.org/10.1016/j.aanat.2006.11.013

[16] Feng, J., Chen, Y.L., Dong, J.H., *et al.* (2014) Post-Pancreaticoduodenectomy Hemorrhage: Risk Factors, Managements and Outcomes. *Hepatobiliary & Pancreatic Diseases International*, **13**, 513-522. https://doi.org/10.1016/S1499-3872(14)60276-9

[17] Gielecki, J., Zurada, A., Sonpal, N. and Jabonska, B. (2005) The Clinical Relevance of Celiac Trunk Variations. *Folia Morphologica* (*Warsz*), **64**, 123-129.

[18] Glück, E., Gerhardt, P., Schröder, J., *et al.* (1983) Value of Vascular Morphology for the Selection of Catheters in Selective Celiacography and Mesentericography. *Rofo*, **138**, 664-669. https://doi.org/10.1055/s-2008-1055808

[19] Aigner, K.R. and Gailhofer, S. (2005) Celiac Axis Infusion and Microembolization for Advanced Stage III/IV Pancreatic Cancer—A Phase II Study on 265 Cases. *Anticancer Research*, **25**, 4407-4412.

[20] Michels, N.A. (1966) Newer Anatomy of the Liver and Its Variant Blood Supply and Collateral Circulation. *The American Journal of Surgery*, **112**, 337-347. https://doi.org/10.1016/0002-9610(66)90201-7

[21] Tandler, J. (1904) Uber die Varietaten der Arteria coelia-ca und deren Entwickelung. *Anatomy and Embryology*, **25**, 473-500. https://doi.org/10.1007/BF02300762

[22] Schoenwolf, G.C., Bleyl, S.B., Brauer, P.R. and Francis-West, P.H. (2009) Larsen's Human Embryology. 4th Edition, Elsevier, London, 351-354, 408-410.

[23] Skandalakis, J.E. and Colborn, G.L. (2004) Surgical Anatomy: The Embryologic and Anatomic Basis of Modern Surgery. Vol. 1, Paschalidis Medical Publications, Athens, 587.

[24] Reuter, S.R. and Redman, H.C. (1977) Gastrointestinal Angiography. 2nd Edition, WB Saunders, Philadelphia, 31-65.

[25] Araujo, N.S.A., Franca, H.A., Mello, J.C.F., *et al.* (2015) Anatomical Variations of

the Celiac Trunk and Hepatic Arterial System: An Analysis Using Multidetector Computed Tomography Angiography. *Radiologia Brasileira*, **48**, 358-362. https://doi.org/10.1590/0100-3984.2014.0100

[26] Lipshutz, B. (1917) A Composite Study of the Celiac Axis Artery. *Annals of Surgery*, **65**, 159-169. https://doi.org/10.1097/00000658-191702000-00006

[27] Eaton, P.B. (1917) Celiac Axis. *The Anatomical Record*, **13**, 369-374. https://doi.org/10.1002/ar.1090130605

[28] Nakamura, Y., Miyaki, T., Hayashi, S., *et al.* (2003) Three Cases of the Gastrosplenic and the Hepatomesenteric Trunks. *Okajimas Folia Anatomica Japonica*, **80**, 71-76. https://doi.org/10.2535/ofaj.80.71

[29] Koplay, M. and Kantarci, M. (2011) Common Hepatic Artery Arising from the Aorta: Demonstration with Multidetector CT Angiography and Its Clinical Importance. *Archives of Medical Science*, **7**, 176-177. https://doi.org/10.5114/aoms.2011.20628

[30] Petscavage, J.M. and Maldjian, P. (2007) Celiomesenteric Trunk: Two Variants of a Rare Anomaly. *Australasian Radiology*, **51**, B306-B309. https://doi.org/10.1111/j.1440-1673.2007.01824.x

[31] Settembrini, P.G., Jausseran, J.M., Roveri, S., *et al.* (1996) Aneurysms of Anomalous Splenomesenteric Trunk: Clinical Features and Surgical Management in Two Cases. *Journal of Vascular Surgery*, **24**, 687-692. https://doi.org/10.1016/S0741-5214(96)70085-X