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

Celiac trunk variants in MDCTA

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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.

Materials 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.

Conclusions: 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.

Key words: 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.

MATERIALS 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 ($\approx 35\%$, 325/930) and (b) a false tripod when the three arteries did not have a common origin ($\approx 65\%$, 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° to 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 ghrelin 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 [**Error! Reference source not found.**, 40, **Error! Reference source not found.**].

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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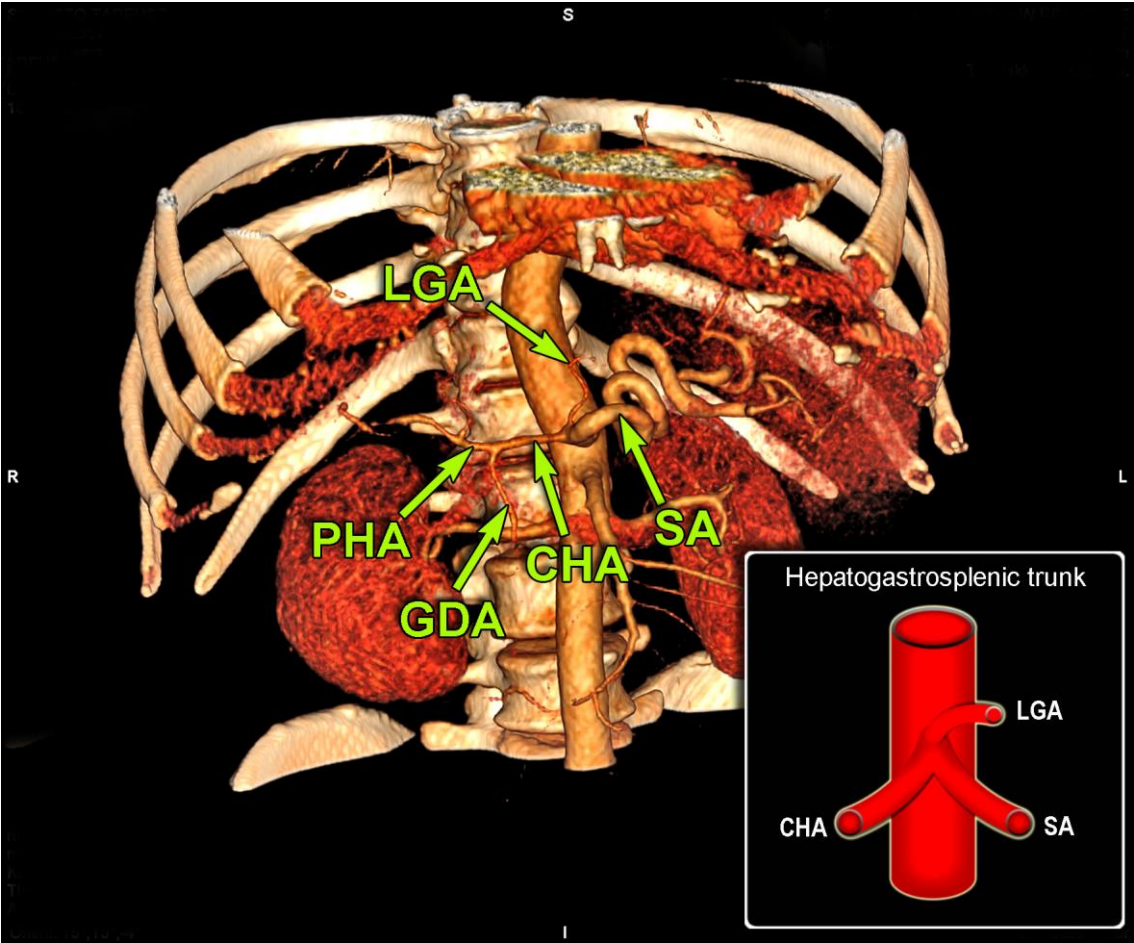
Table 1. Adachi's classification of celiac trunk variations

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.

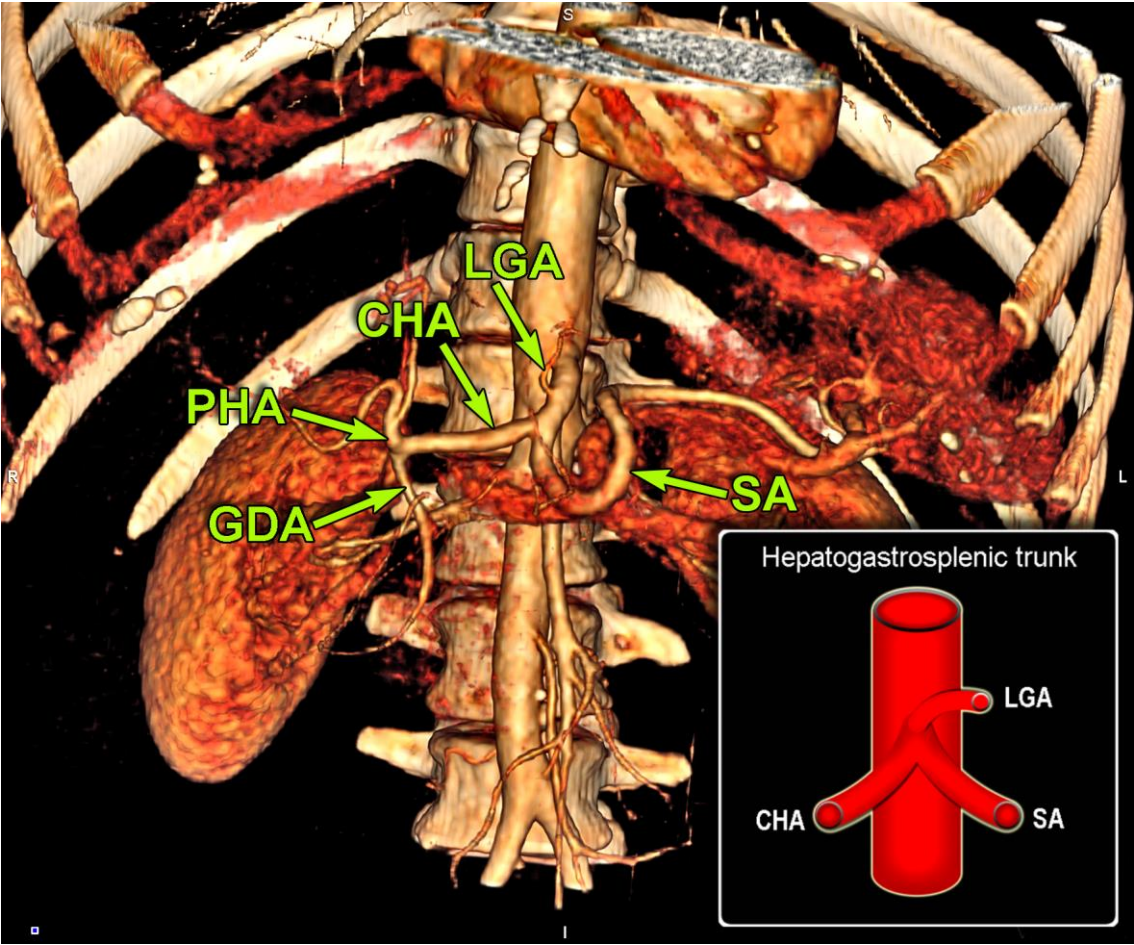
Trunk classification	Trunk classification number	Percentage
Hepatogastrosplenic	1	93%
Hepatosplenic	2	2,8%
Gastrosplenic	6	1,4%
Celiacomesenteric	4	1,1%
Hepatosplenomesenteric	3	0%
Hepatomesenteric	5	1,7%

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.

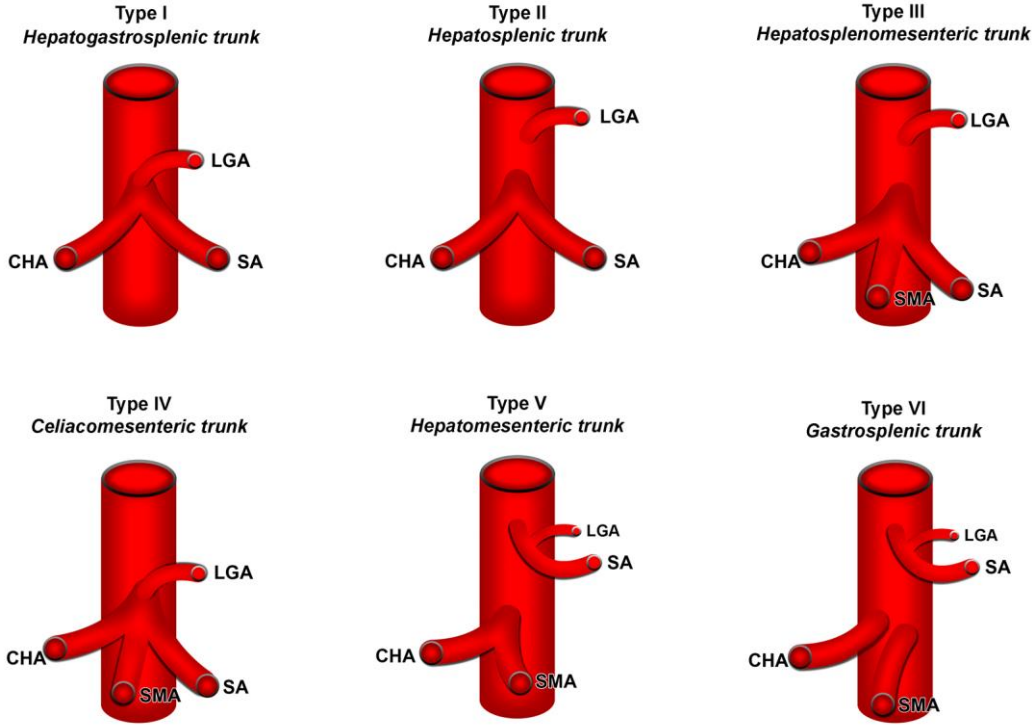


Figure 3. Hepatosplenic trunk.

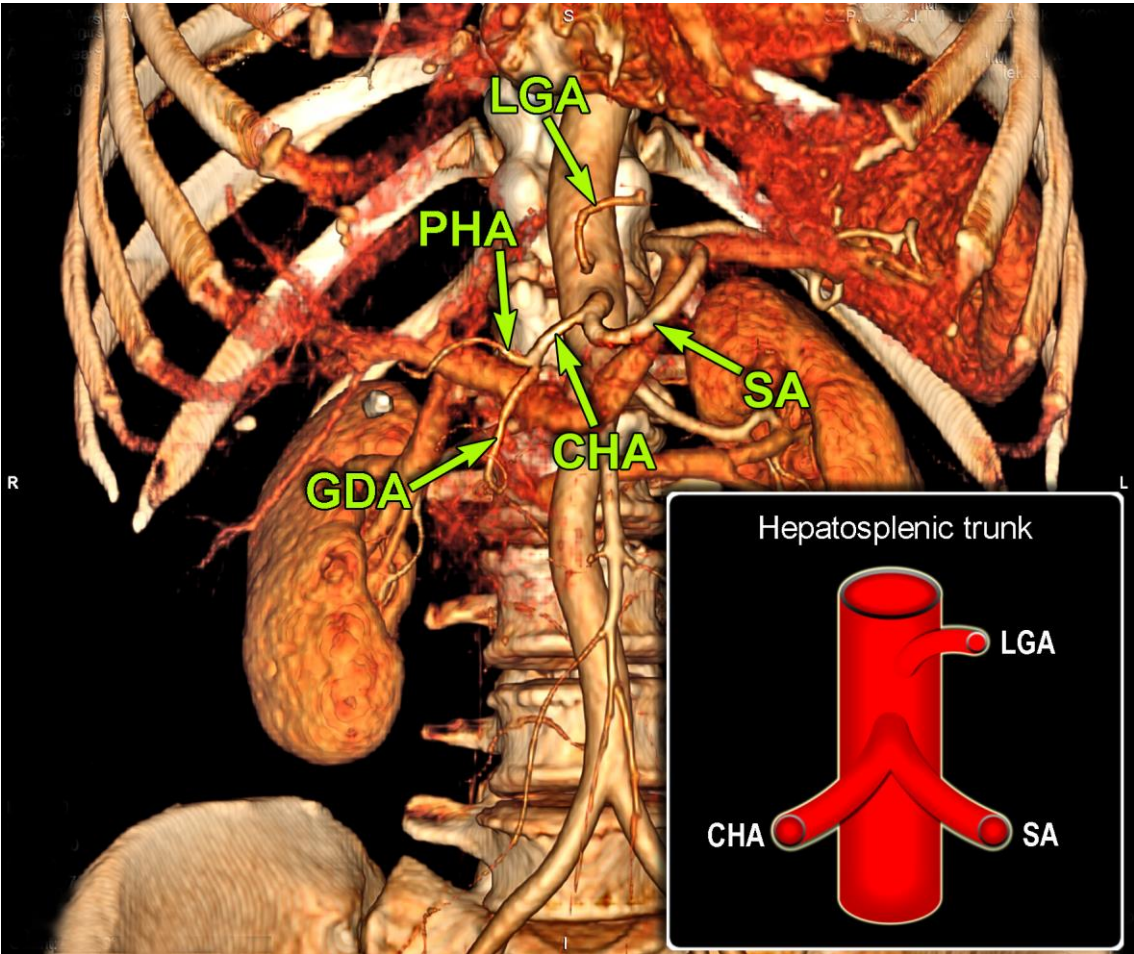


Figure 4. Celiacomesenteric trunk.

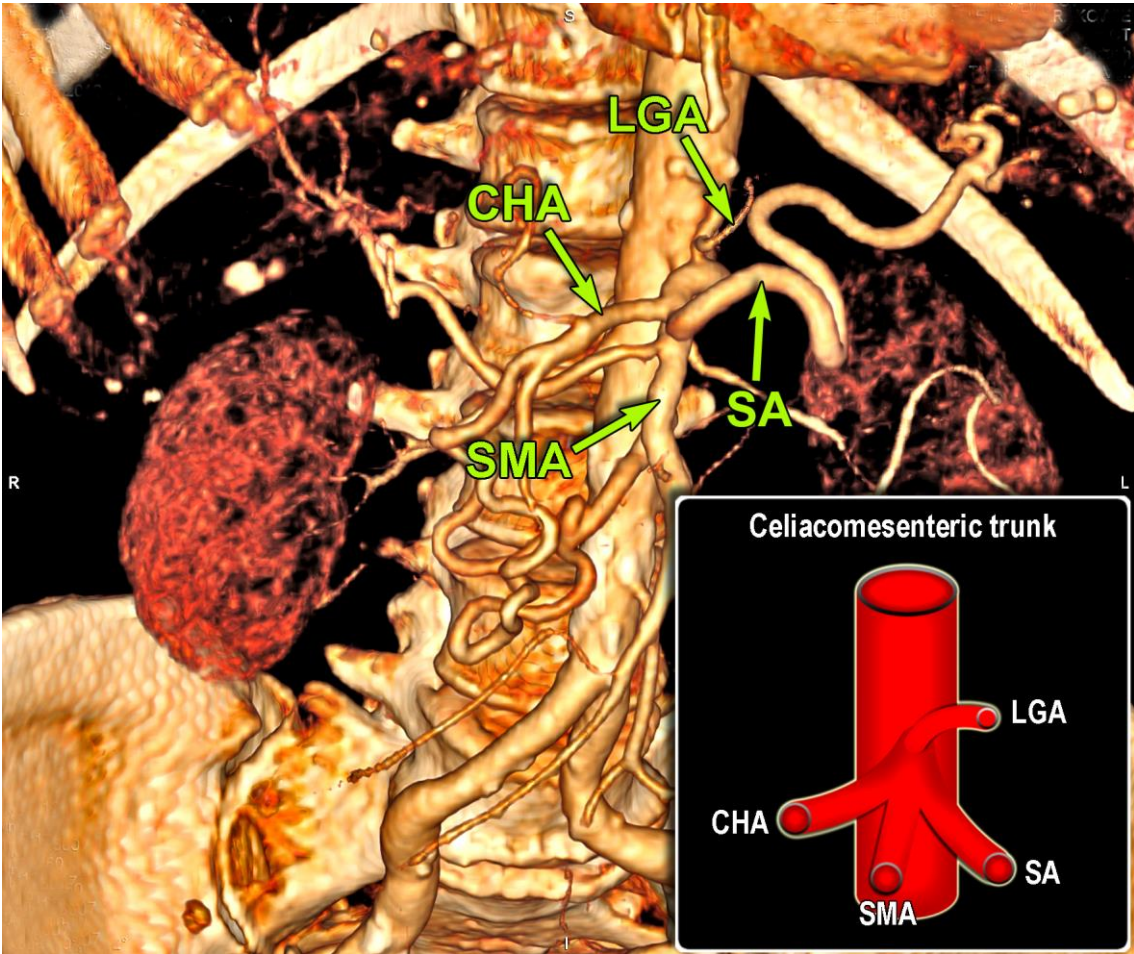


Figure 5. Hepatomesenteric trunk.

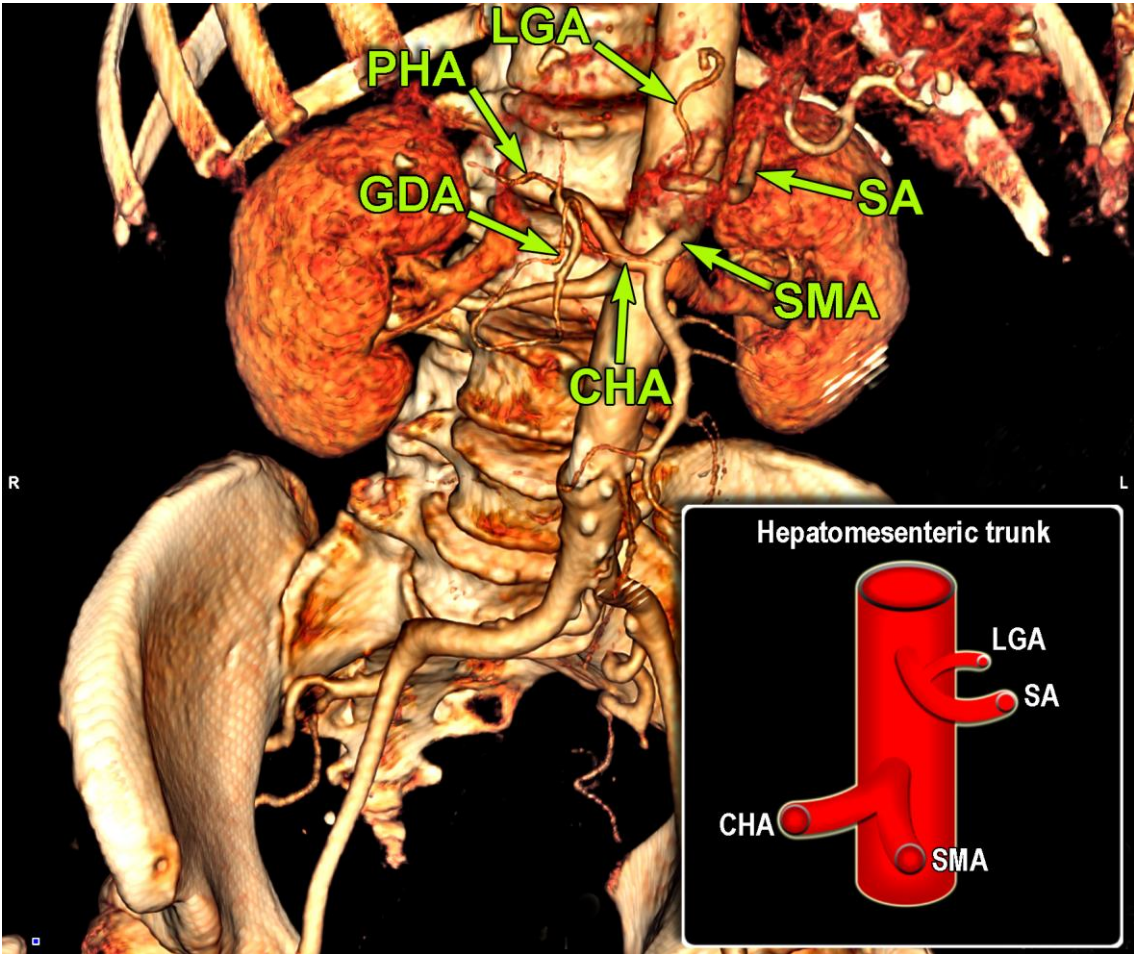


Figure 6. Gastrosplenic trunk.

