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FOLIA MORPHOLOGICA

ISSN: 0015-5659

e-ISSN: 1644-3284

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DOI: 10.5603/FM.a2020.0067

Article type: ORIGINAL ARTICLES

Submitted: 2020-04-23

Accepted: 2020-06-07

Published online: 2020-06-09

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

Celiac trunk unusual variations

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Abstract

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

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

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

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

Key words: celiac trunk, variations, multidetector computed tomography angiography, MDCTA

INTRODUCTION

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

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

MATERIALS AND METHODS

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

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

RESULTS

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

Hepato-gastro-splenic trunk

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

Celiaco-mesenteric trunk type

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

Hepato-gastric trunk type

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

Hepatic artery variations

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

Celiac artery stenosis

In one case there was celiac artery stenosis resulting in the development of collateral mesenteric circulation i.e. celiac artery compression syndrome (CACS) (Fig. 6).
We also observed celiac artery stenosis with extended collateral mesenteric circulation and SMA originating from aorta slightly above the celiac trunk (Fig. 7).
In either case the stenosed celiac trunk corresponded with a hepato-gastro-splenic type in a false configuration.

DISCUSSION

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

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

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

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

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

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

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

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

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Table 1. Hepatic artery variations: Michel classification.

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

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

Figure 2. Celiaco-mesenteric trunk type. CT — celiac trunk, LGA — left gastric artery, CHA — common hepatic artery, SA — splenic artery, SMA — superior mesenteric artery.

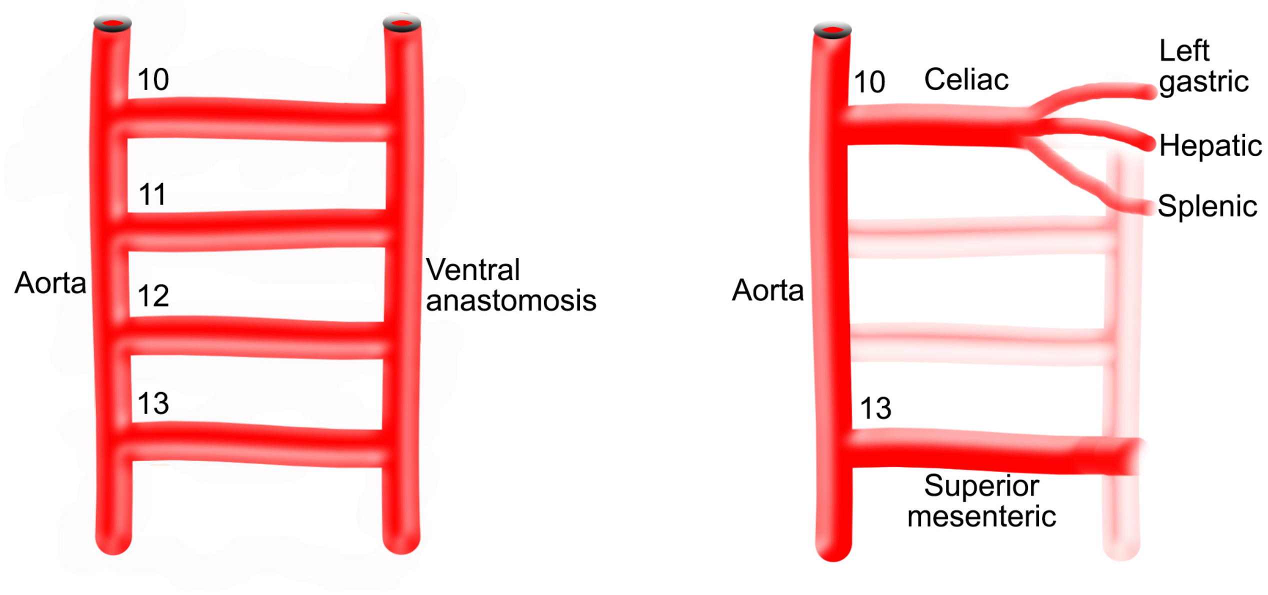
Figure 3. Hepato-gastric trunk type in association with the independent arising of SA. CT — celiac trunk, CHA — common hepatic artery, SA - splenic artery, LGA — left gastric artery, GDA — gastroduodenal artery, SMA — superior mesenteric artery.

Figure 4. Gastro-splenic trunk type in association with the common hepatic artery arising from the superior mesenteric artery. CT — celiac trunk, LGA — left gastric artery, SA — splenic artery, CHA — common hepatic artery, PHA — proper hepatic artery, GDA — gastroduodenal artery, SMA — superior mesenteric artery, aRRA — accessory right renal artery, CHA aneurysm — common hepatic artery aneurysm, aHA — accessory hepatic artery.

Figure 5. Gastro-splenic trunk in association with the common hepatic artery arising independently from aorta and accessory right hepatic artery originating from CHA. CHA — common hepatic artery, LGA — left gastric artery, SA — splenic artery, SMA — superior mesenteric artery, GDA — gastroduodenal artery, rRHA — replaced right hepatic artery, LHA — left hepatic artery.

Figure 6. Celiac artery stenosis resulting in the development of collateral mesenteric circulation. CT — celiac trunk, LGA — left gastric artery, CHA — common hepatic artery, SA — splenic artery, SMA — superior mesenteric artery, rRHA — replaced right hepatic artery, GDA — gastroduodenal artery, rLHA — replaced left hepatic artery.

Figure 7. Celiac artery stenosis with extended collateral mesenteric circulation and SMA originating from aorta slightly above the celiac trunk. CT — celiac trunk, LGA — left gastric artery, SA — splenic artery, CHA — common hepatic artery, PHA — proper hepatic artery, SMA — superior mesenteric artery.



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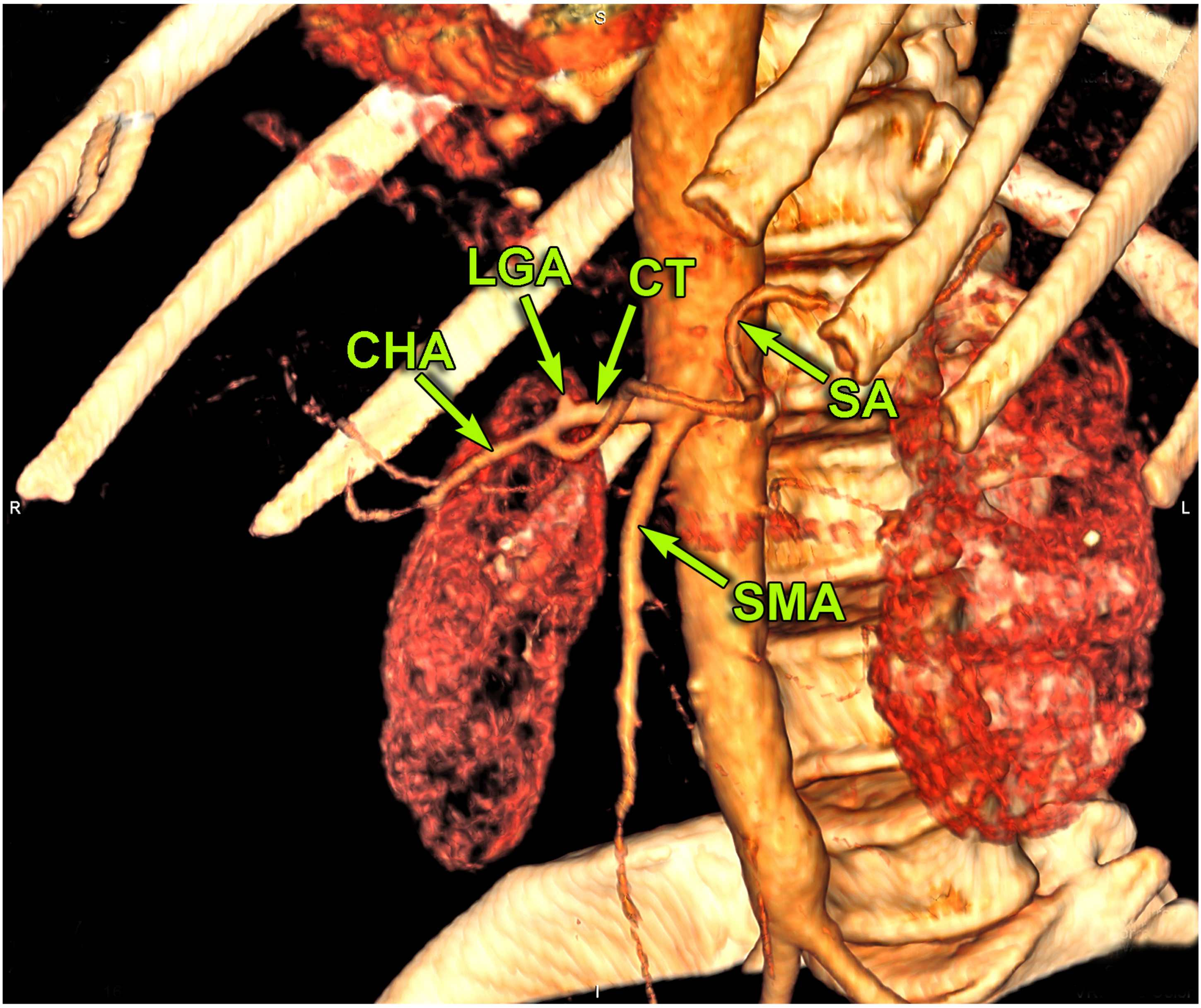
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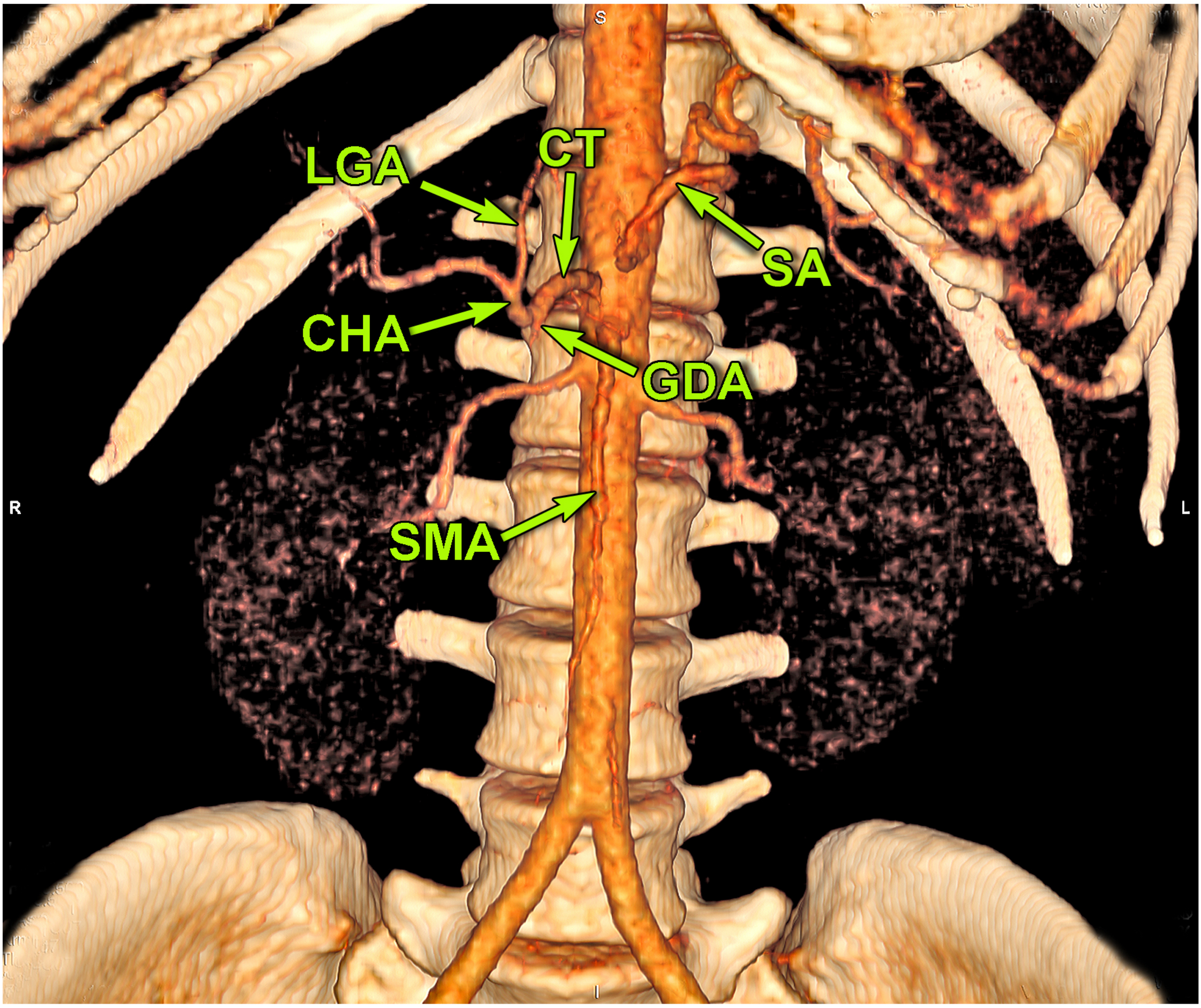
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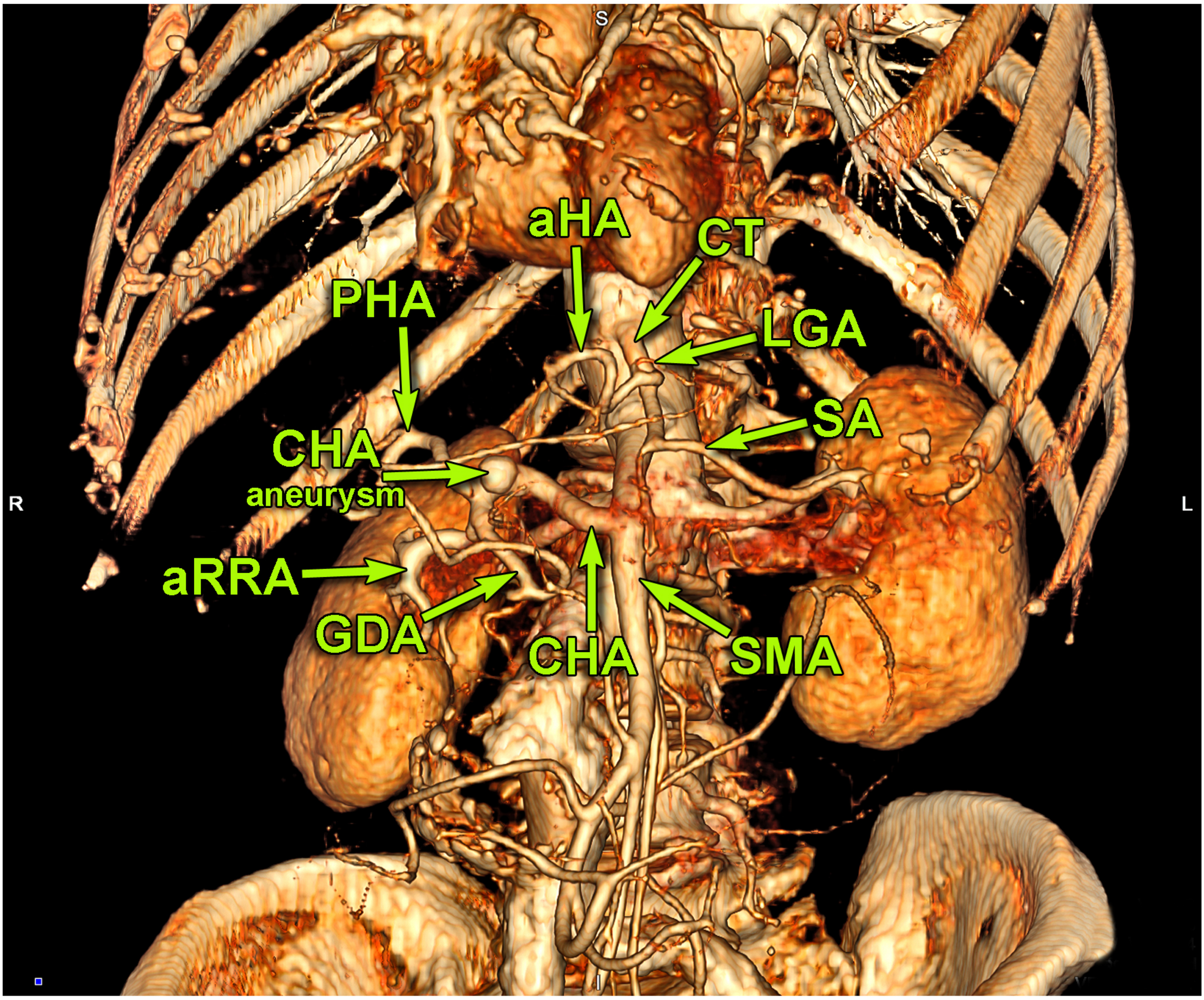

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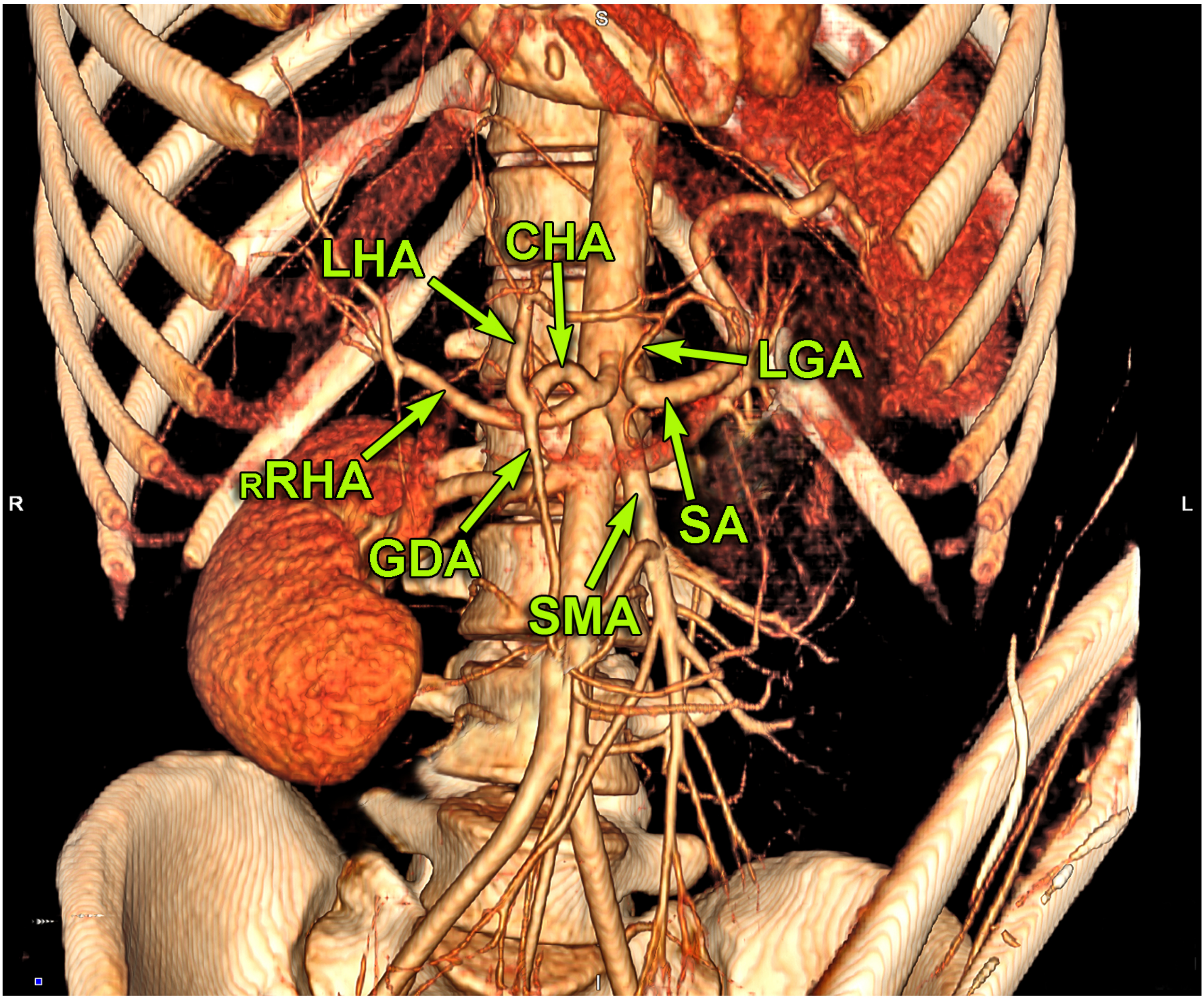
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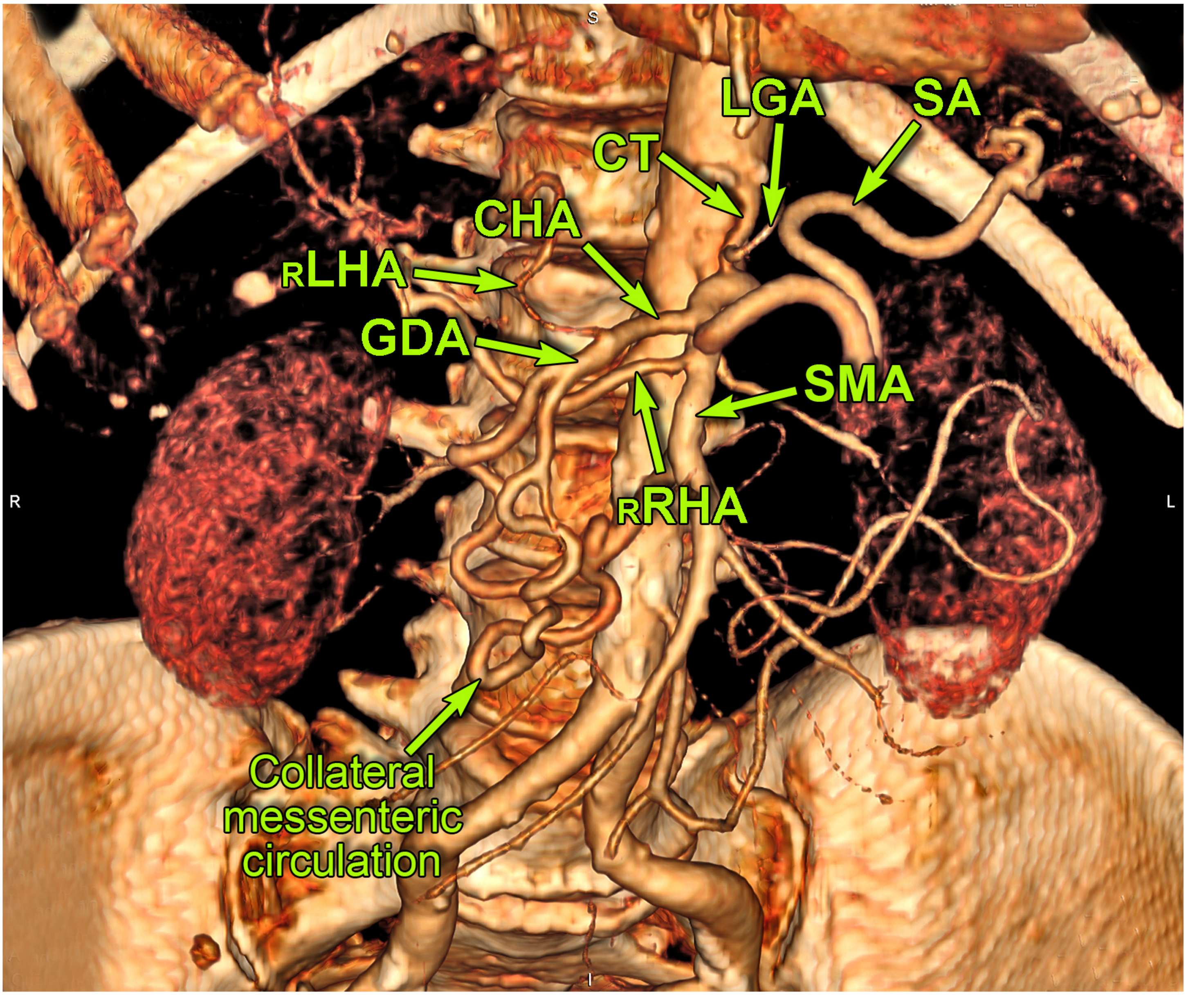
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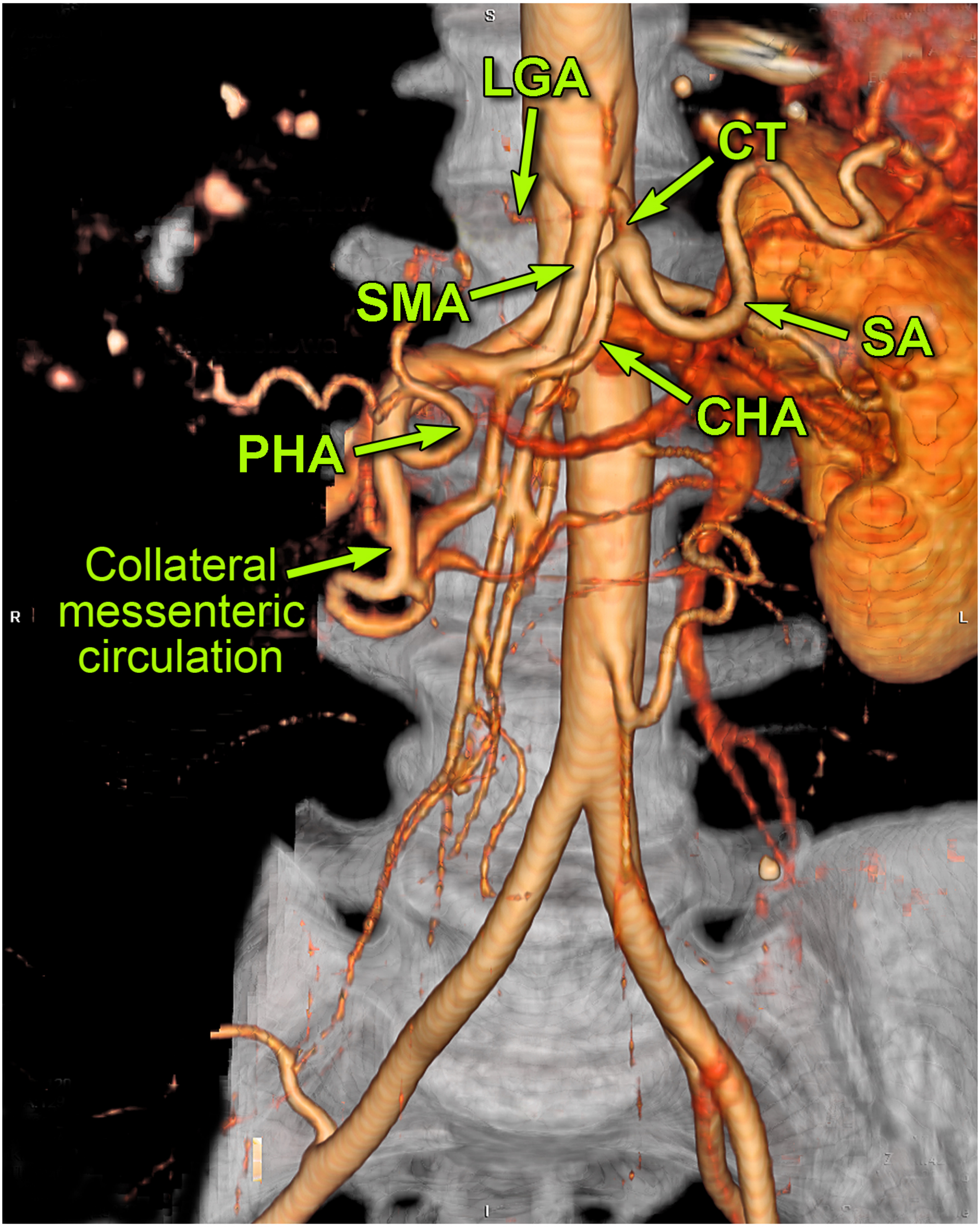

LGA
CT
SMA
SA
CHA
PHA
Collateral messenteric circulation
R
L
S