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Splenic artery angiography: clinical classification of origin and branching variations of splenic artery by multi-detector computed tomography angiography method

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Abstract

Background: The splenic artery (SA) variations are rarely reported in the literature. Knowledge of the range of the splenic artery and other arterial anomalies and their specific frequencies is very important ever for every visceral surgeon as well as gastrointestinal bleeding, organ transplantation, transarterial chemoembolization of neoplasm, infusion therapy, therapeutic arterial ligation, iatrogenic injuries. At the literature, there are more studies on the coeliac trunk (CT), superior mesenteric artery (SMA) and hepatic artery variations, but studies on the splenic artery variations are uncommon. The studies on the splenic artery variations are mostly in the form of case reports, but there are not many studies with large population on this issue. The purpose of this study was to

evaluate the SA alone and to determine the variations determined separately from the other arteries. Accurate awareness of all the possible anatomic variations is crucial in the upper abdomen surgery.

Materials and methods: Seven hundred fifty patients undergoing multi-detector computed tomography (MDCT) angiography between 2015 and 2017 were retrospectively evaluated about the splenic artery variations. We created a new classification system to determine anatomic variations of the splenic artery

Results: Twenty-three different types were identified related to anatomic variations in the origin and branching pattern of the splenic artery. While 596 (79.47%) patients had the standard the SA anatomy, 154 (20.53%) patients had variant the SA.

Conclusions: The splenic artery has quite different variation types and the practical context of the issue is of primary importance in surgery, gastroenterology, oncology and radiology. Liver and pancreas transplantation, splenectomy, embolization of tumours of the abdominal organs, as well as other numerous diagnostic and therapeutic procedures, require detailed anatomical knowledge.

Key words: anatomic variations, splenic artery, multidetector computed tomography

Introduction

In standard anatomy texts, the splenic artery (SA) is the largest branch of the coeliac trunk (CT) which is common name of the left gastric artery (LGA), the common hepatic artery (CHA), and the SA. The CT originates from the abdominal aorta (AA) at the level of the twelfth thoracic vertebrae and supplies the liver, stomach, pancreas, superior of duodenum, and the spleen (1-9). But, the main blood supply of the spleen is received via the SA. The SA turns inferiorly for a short distance after its origin, then turns left and runs horizontally behind the stomach, the upper border of the pancreas and it is divided into some branches leading to the stomach and the pancreas during this course. Finally, it enters in the lienorenal ligament as near the tail of the pancreas and divides into terminal branches that enter the hilum of the spleen (10-12). These branches are described as polar arteries that run to the upper or lower extremity of the spleen (13-16).

According to literature studies, the splenic artery may have origin variations that take direct origin from the AA, the CHA, the LGA or the superior mesenteric artery (SMA). Furthermore, abnormalities such as congenital absence, total duplication, intrahepatic course and variations of terminal branching pattern of the SA have all been reported in the literature (10). Knowledge of

anatomical variations in the splenic arterial system is crucial in the context of in liver and pancreas transplantation, arterial chemoembolisation for visseral organ tumours (especially, the treatment of gastric cancer and pancreas cancer), for hepato-biliary-pancreatic surgical procedures, general upper abdominal surgery, and splenic artery steal syndrome. (17-21). Additionally, the splenic artery embolization has become a safe and effective intervention for the treatment of hypersplenism, cirrhosis with portal hypertension, hereditary spherocytosis, idiopathic thrombocytopenic purpura, splenic trauma, splenic artery steal syndrome, and thalassemia. However, major complications may follow the splenic artery embolization including: splenic abscess which have been documented to occur in 6.8% of patients undergoing splenic artery embolization, splenic infarction, contrast-induced renal insufficiency, splenic cyst development, and non-target embolization. (17, 22-25). Splenic artery aneurysm, that are often asymptomatic and incidentally identified, is the most common of the visceral artery aneurysms with an incidence in the literature between 0.1% and 10.4%. The splenic artery steal syndrome is one of the vascular complications after liver transplantation, this incidence been reported is in 3.1%-5.9% of liver transplantations, or occurs due to liver ischemia, hepatic artery thrombosis and stenosis. The splenic artery embolization is an effective treatment of this syndrome (26-27). If branches of the splenic artery are injured or ligated accidentally during upper abdomen surgeon such as gastrectomy, it may be fatal leading to splenic abscess, hemorrhage, or rupture (11,14,28). For all these reasons, it is very important to determine variations of the SA. Most previous studies revealed that the SA has variations in the tortuosity, course, position and number of the branches. However, there is no a large population study about variation classification of the splenic artery (12).

In recent years, variations in vascular structures have become more important with the developments in image technology such as MDCT, magnetic resonance. Especially, MDCT angiography is a reliable and non-invasive tool for the diagnosis of normal and pathological conditions of arteries. Unlike classical angiography, MDCT angiography clearly shows the course of the vessels and the degree of impairment of blood vessels as well as the relationship of blood vessels with surrounding structures and organs and is possible to obtain high quality three-dimensional images which are quite useful for demonstrating the details of visceral structures (29-33).

We created a new classification system to determine anatomic variations of the splenic artery. Thus, we aimed to classify the anatomical variations of the splenic artery clinically on the basis of

abdominal angiographic images in a cohort of 750 patients and to contribute to the knowledge of the SA anatomy.

Materials and Methods

Patients

This study followed the Declaration of Helsinki principles and was approved by the Medical School Non-Interventional Clinical Research Ethics Committee (December 21, 2017; decision no: 55). From Dec 2015 to Oct 2017, anatomic variations in the splenic artery of 800 patients who underwent abdominal CT angiography at in the Department of Radiology of the Medical Faculty, University of Dicle, were retrospectively reviewed, but 50 cases in our study were excluded due to artefacts or history of major abdominal surgery. Finally, of the total 750 cases, 344 (45.87%) female and 406 (54.13%) male, age range was 16-93 years, mean age \pm standard deviation was 50.6 \pm 16.2 years.

Multi-detector CT technique

Multi-detector computed tomography angiography was done using Philips Brilliance 64-slice CT scanner by non-ionic contrast material that was injected into vein at 4 mL/s using an automated injector. Arterial phase images were obtained in 10-16 seconds. Using parameters in all cases: collimation, 64 \times 1mm; step, 0.92; gantry rotation time, 0.75 sec; section thickness 0.90 mm, and tube potential, 120 kV.

CT Examinations and images interpretation

Multi-detector CT angiography units were used in this study. The angiographic procedures were performed by two interventional radiologists. All angiography data were transferred to a workstation in order to evaluate vascular anatomy. The original scans were 3-dimensionally reconstructed to confirm each assessment. We analyzed the SA anatomy, including its origin site and proximal branching variants and classified these variants. Variants the SA with unclear origin and branching were not classified. Arterial variations in the origin and branching pattern of the SA were defined in Table 1.

Statistical analysis and classification

All data were analyzed using SPSS (v. 13.0 for Windows; Chicago, IL, USA). The overall results were expressed as mean \pm standard deviation, frequencies, and percentages of the patients.

Results

In our retrospective study, 22 different variations types were identified associated with anatomy of the splenic artery. A total of 750 patients, 596 (79.47%; 276 females and 320 males) were included in normal anatomy of the splenic artery and is classified as type I, different anatomical variations of the splenic artery were detected in 154 patients (20.53%; 68 females and 86 males) is classified as other 22 types (Table 1.). Percentage of splenic artery types according to gender differences were presented in the Table 2.

The splenic artery had classical origin in 596 (79.47%) patients in our study, which remove from the TC as four different types: The SA originated from the CT as a branch of the CT bifurcation (into the SA and CHA) in 510 (68.00%) cases, of the CT trifurcation (into the SA, CHA, and LGA) in 82 (10.94%) cases, of the CT quadrifurcation (into the SA, LGA, GDA (gastroduodenal artery), and common root of the RHA (right hepatic artery)+MCA (middle colic artery) in 3 (0.40%) cases, of the CT pentafurcation (into the SA, LGA, RHA, MCA, and common root of the LHA (left hepatic artery)+GDA) in one (0.13%) case.

Discussion

Variation of arterial anatomy is very common and occurs in nearly half of the population. Variations of abdominal vessels pose a higher risk of severe or even fatal complications, such as pancreatic leakage, ischemia and necrosis (34). The development of imaging technology regarding vessel variation have modified surgical and therapeutic approaches and arterial variations have become even more important. In variant patterns, vessels do not arise from their usual source and present as accessory or replaced vessels. Accessory vessel is a branch addition to the normal artery supply and replaced vessel is a branch that representing the primary blood supply to the organs, so replaced arteries must be strictly protected (35-38).

There are many research and classification investigating variations in hepatic arteries, superior mesenteric artery, and CT (39-43). Whereas, very few researches has been done on the splenic artery. We classified 23 types of splenic artery with our research on 750 patients.

In our study, the splenic artery took origin from classical displaced on the CT in 596 (79.47%) patients (Figs. 1a, 1b, 1c and 1d). Standard coeliac trunk anatomy, having the LGA, the splenic artery and the common hepatic artery, has been reported in 79.10% of the 604 patients in the studies of Koops et al. (40), 63.90% of the 607 patients in the studies of Farghadani et al. (37), and 75.70% of the 1000 patients in the studies of Hiatt et al. (41). The splenic artery originated from the HST (hepatosplenic trunk) and divided into the classical branches in 30 (4.00%) cases in our study (Fig. 2). In 5 (0.67%) cases of our study, the splenic artery originated from the HST, but it also divided into LGA in addition to the classical branches (Fig. 3). Thangarajah et al. (44) found the hepatosplenic trunk in 8 (4%) patients of the 200 patients. Ugurel et al. (45) reported the hepatosplenic trunk in 3 (3%) of the 100 patients. Huang et al. (46) reported a abnormal left gastric artery deriving from splenic artery in one (0.42%) of 238 cases. The gastrosplenic trunk, the LGA and SA originated from the aortic abdominal artery in a common root, was found in 12 (2.00%) of 600 patients by Covey et al. (47), in 3 (1.10%) of the 275 cases by Nakamura et al. (48), in 143 (2.86%) of 5002 patients by Song et al. (49). This variation pattern was found 26 (3.47%) in our study (Fig. 4). In 8 (1.07%) cases of our study, the splenic artery arose from the coeliacomesenteric trunk, in which both the SMA and CT originated as a common root from the aortic abdominal artery. (Fig. 5). Similar to this variation, the SA arising from the hepatosplenomesenteric trunk, which appeared as a hepatosplenomesenteric trunk and LGA originating separately from the aorta, was found in 2 (0.27%) cases of our study (Fig. 6). In the literatures, the reported incidences of the celiacomesenteric trunk are 2.38%, 1.00%, and 2.70% (35). Kobayashi et al. (50) found that 14 (1.2%) cases had the celiacomesentric type in 1200 cases. Song et al. (49) found that it originated from the CMT (coeliacomesenteric trunk) in 53 (1.06%), while the splenic artery originated from the HSMT (hepatosplenomesenteric trunk) in 34 (0.68%) patients of the 5002 patients. The splenic artery originated direct from AA in 9 (1.20%) cases in our study (Fig. 7). Jacob et al. (6), Matusz et al. (51), one each reported a case of the splenic artery arising independently from the AA. The splenic artery originated from the SMA in 1 (0.13%) cases in our study (Fig. 8). Ugurel et al. (45) found the splenomesenteric trunk in 1% of 100 patients. Absent of the SA was visualized in 4 (0.53%) cases of our study (Fig. 9), this was a rare variation in literature.

The presence of an accessory splenic artery is quite rare and symptomatic. This variation of the splenic artery is said to be due to intra-parenchymatous anastomosis between the inferior polar artery of SA and the splenic branches of left gastroepiploic artery (10, 52). In presence of the

accessory SA (double pattern) in our study: while one originated from CT, the accessory splenic artery originated from a common root of the CHA and SA in 1 (0.13%) case of our study (Fig. 10). Padmalatha et al. (53) and Patel et al. (10), each one have reported an accessory splenic artery, already a branch of main splenic artery, in a cadaver in their cases. The SA (replaced) and RHA (replaced) originated directly from the aorta with a single common root in 2 (0.27%) cases in our study, there is no report about this variation in literature (Fig. 11). Carusa et al. (17) found a RHA originating from the SA associated with both a CHA originating from the CT and a LHA originating from the LGA on a cadaveric organ donor. The SA and LHA (replaced) originated from a single common root from the CT 1 (0.13%) cases in our study (Fig. 12). The SA runs to the spleen as two branches 1 (0.13%) cases in our study (Fig. 13).

Our study was seen that the SA had quite different branching patterns. The most common in the branching pattern of the SA in our study, the SA originated from AA and divided into LGA, GDA, and the classical branches in 25 (3.33%) cases (Fig. 14). Slaba et al. (54) reported that the gastroduodenal artery originated from the splenic artery in a case. Li et al. (55) found that the GDA and SA originated as a common trunk from the anterior surface of the AA as gastroduodenal-splenic trunk a cadaver. The SA originated from AA and divided into the LGA, CHA, and the classical branches 15 (2.00%) cases in our study (Fig. 15). The SA originated from AA and divided into the LGA, LHA, and the classical branches 5 (0.67%) cases in our study (Fig. 16). The SA originated from AA and divided into the LGA, a common root of LHA and GDA, and the classical branches in 1 (0.13%) in our study (Fig. 17). The SA originated from AA and divided into the LGA, RHA, a common root of the LHA and GDA, and the classical branches in 4 (0.53%) in our study (Fig. 18). The SA originated from AA and divided into the LGA, a common root of the RHA and GDA, and the classical branches in 6 (0.80%) in our study (Fig. 19). The SA originated from CT and divided into the LIPA (left inferior phrenic artery), LGA, PHA (proper hepatic artery; a common root of RHA and LHA), and the classical branches in 3 (0.40%) in our study (Fig. 20). The SA originated from AA and divided into the LGA, LHA, LIPA, RIPA (right inferior phrenic artery) and the classical branches in 1 (0.13%) in our study (Fig. 21). Kervancioglu et al. (12) found an accessory splenic artery originating from the left gastric artery that after its origin, it divided into the left and right inferior phrenic and the left hepatic arteries. The SA originated from CT and divided into the LCA and the classical branches in 2 (0.27%) in our study (Fig. 22). The SA originated from TC (Trifurcation of CT) and divided into the MCA and the classical branches in 2

(0.27%) in our study (Fig. 23). In particular, the double pattern of the SA, the absence of the SA, and the SA originating from the SMA is rarely reported variations in the literature.

The limitation of our study is that the images are evaluated retrospectively and only in the arterial phase. For this reason, we excluded some images that have poor quality owing to scanning was obtained in improper seconds.

In conclusion, our study was performed in 750 patients, anatomic variations of the splenic artery have classified by a 23-types classification system. The presented study is one of the rare studies in the literature. The awareness of variation patterns in vessel anatomy of the abdomen is very important in surgery, gastroenterology, oncology and radiology procedures such as transcatheter arterial chemoembolization of neoplasm, gastrectomy, cholecystectomy, surgical procedures of the pancreaticoduodenal areas, laparoscopic surgery, liver and pancreas transplantation, splenectomy that are applied for diagnosis and treatment of abdominal problems. Additionally, the familiarity of vascular varieties is extremely important that it enables an efficient surgery and reduces the risk of complications such as upper gastrointestinal bleeding, ischemia that can lead to major morbidity and mortality.

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Table 1. Our description of the splenic artery

Types of the splenic artery	
<i>Type 1</i>	Classical SA (SA originated from CT and divided into the classic branches)
	Anatomic variations of SA (variations of origin and branching)
	Variations of origin of SA
<i>Type 2</i>	SA originated from HST (hepatosplenic trunk)
<i>Type 3</i>	SA originated from HST (hepatosplenic trunk) and divided into LGA
<i>Type 4</i>	SA originated from GST (gastrosplenic trunk)
<i>Type 5</i>	SA originated from CMT (coeliacomesenteric trunk)
<i>Type 6</i>	SA originated from HSMT (hepatosplenomesenteric trunk)
<i>Type 7</i>	SA originated from AA
<i>Type 8</i>	SA originated from SMA
<i>Type 9</i>	SA absent
<i>Type 10</i>	SA (double patern) (the presence of an accessory splenic artery) (one originated from the CT, the other originated from a common root of the CHA and SA)
<i>Type 11</i>	SA and RRHA originated from a single common root from the aorta
<i>Type 12</i>	SA and RLHA originated from a single common root from the CT
	Branching variations of SA

<i>Type 1a</i>	SA runs to the spleen as two branches
<i>Type 1b</i>	SA originated from AA and divided into RLGA+RGDA
<i>Type 1c</i>	SA originated from AA and divided into RLGA+RCHA
<i>Type 1d</i>	SA originated from AA and divided into RLGA+RLHA
<i>Type 1e</i>	SA originated from AA and divided into RLGA+a common root of RLHA and RGDA
<i>Type 1f</i>	SA originated from AA and divided into RLGA+RRHA+a common root of the RLHA and RGDA
<i>Type 1g</i>	SA originated from AA and divided into RLGA+a common root of the RRHA and RGDA
<i>Type 2a</i>	SA originated from CT and divided into RLIPA+RLGA+RPHA
<i>Type 2b</i>	SA originated from AA and divided into RLGA+RLHA+RLIPA+RRIPA
<i>Type 2c</i>	SA originated from CT and divided into RLCA
<i>Type 2d</i>	SA originated from CT and divided into RMCA

Table 2. Percentage of splenic artery types according to gender differences

Types of the splenic artery		Femal	Male	Total (N) (%)
		e		
<i>Type 1</i>	Classical SA (SA originated from CT and divided into the classic branches) (Figures 1a,1b,1c, and 1d)	276	320	596 (79.47%)
Anatomic variations of SA (variations of origin and branching)				
Variations of origin of SA				
<i>Type 2</i>	SA originated from HST (hepatosplenic trunk) (Figure 2)	14	16	30 (4.00%)

Type 3	SA originated from HST (hepatosplenic trunk) and divided into RLGA (Figure 3)	3	2	5 (0.67%)
Type 4	SA originated from GST (gastrosplenic trunk) (Figure 4)	12	14	26 (3.47%)
Type 5	SA originated from CMT (coeliacomesenteric trunk) (Figure 5)	2	6	8(1.07%)
Type 6	SA originated from HSMT (hepatosplenomesenteric trunk) (Figure 6)	0	2	2 (0.27%)
Type 7	SA (rep) originated from AA (Figure 7)	5	4	9 (1.20%)
Type 8	SA (rep) originated from SMA (Figure 8)	0	1	1 (0.13%)
Type 9	SA absent (Figure 9)	4	0	4 (0.53%)
Type 10	SA (double pattern) (the presence of an accessory splenic artery) (one originated from the CT, the other originated from a common root of the CHA and SA) (Figure 10)	0	1	1 (0.13%)
Type 11	SA and RRHA originated from a single common root from the aorta (Figure 11)	1	1	2 (0.27%)
Type 12	SA and RLHA originated from a single common root from the CT (Figure 12)	0	1	1 (0.13%)
Branching variations of SA				
Type 13	SA runs to the spleen as two branches (Figure 13)	0	1	1 (0.13%)
Type 14	SA divided into RLGA+RGDA (Figure 14)	10	15	25 (3.33%)
Type 15	SA divided into RLGA+RCHA (Figure 15)	9	6	15 (2.00%)
Type 16	SA divided into RLGA+RLHA (Figure 16)	1	4	5 (0.67%)
Type 17	SA divided into RLGA+a common root of the RLHA and RGDA (Figure 17)	0	1	1 (0.13%)
Type 18	SA divided into RLGA+RRHA+a common root of the RLHA and RGDA (Figure 18)	3	1	4 (0.53%)
Type 19	SA divided into RLGA+a common root of the RRHA+RGDA (Figure 19)	3	3	6 (0.80%)

<i>Type 20</i> SA divided into RLIPA+RLGA+RPHA (Figure 20)	0	3	3 (0.40%)
<i>Type 21</i> SA divided into RLGA+RLHA+RLIPA+RRIPA (Figure 21)	0	1	1 (0.13%)
<i>Type 22</i> SA divided into RLCA (Figure 22)	0	2	2 (0.27%)
<i>Type 23</i> SA divided into RMCA (Figure 23)	1	1	2 (0.27%)
Total	344	406	750 (100%)

LGA: left gastric artery; **RLGA:** replaced left gastric artery; **CHA:** common hepatic artery; **RCHA:** replaced common hepatic artery; **SA:** splenic artery; **RSA:** replaced splenic artery; **SMA:** superior mesenteric artery; **PHA:** proper hepatic artery; **RPHA:** replaced proper hepatic artery; **RHA:** right hepatic artery; **RRHA:** replaced right hepatic artery; **LHA:** left hepatic artery; **RLHA:** replaced left hepatic artery; **GDA:** gastroduodenal artery; **RGDA:** replaced gastroduodenal artery; **LIPA:** left inferior phrenic artery; **RLIPA:** replaced left inferior phrenic artery; **RIPA:** right inferior phrenic artery; **RRIPA:** replaced right inferior phrenic artery; **LCA:** left colic artery; **RLCA:** replaced left colic artery; **MCA:** middle colic artery; **RMCA:** replaced middle colic artery; **HST:** hepatosplenic trunk; **GST:** gastrosplenic trunk; **CMT:** coeliacomesenteric trunk; **HSMT:** hepatosplenomesenteric trunk; **Rep:** replaced; **Acc:** accessory

FIGURES LEGENDS

Figure 1a. Classical SA (SA originated from CT and divided into the classic branches) (bifurcation of CT: SA+CHA) (35 years, female).

Figure 1b. Classical SA (SA originated from CT as one of the three end branches of TC) (trifurcation of CT: LGA+SA+CHA) (36 years, male).

Figure 1c. Classical SA (SA originated from CT as one of the four end branches of TC) (tetrafurcation of CT: LGA+SA+RGDA+common root of RRHA and RMCA) (55 years, male).

Figure 1d. Classical SA (SA originated from CT as one of the five end branches of TC) (pentafurcation of CT: LGA+SA+RRHA+RMCA+ common root of RLHA and RGDA) (41 years, male).

Figure 2. SA originated from HST (hepatosplenic trunk) (43 years, male).

Figure 3. SA originated from HST (hepatosplenic trunk) and divided into RLGA (34 years, male).

Figure 4. SA originated from GST (gastrosplenic trunk) (58 years, male).

Figure 5. SA originated from CMT (coeliacomesenteric trunk) (65 years, male).

Figure 6. SA originated from HSMT (hepatosplenomesenteric trunk) (RLGA originated directly from AA) (32 years, male).

Figure 7. SA (rep) originated directly from AA (55 years, male).

Figure 8. SA (rep) originated directly from SMA (55 years, male).

Figure 9. SA absent (RCHA+RLGA originated directly from AA, but SA absent) (20 years, female).

Figure 10. SA (double pattern) (the presence of an accessory splenic artery) (one originated from the CT, the other originated from a common root of the CHA and SA) (40 years, male).

Figure 11. SA (rep) and RRHA originated from a single common root from the aorta (46 years, male).

Figure 12. SA (rep) and RLHA originated from a single common root from the CT (67 years, male).

Figure 10. SA goes to the spleen in two branch (45 years, male).

Figure 11. SA divided into RLGA+RGDA (42 years, female).

Figure 12. SA divided into RLGA+RCHA (34 years, male).

Figure 13. SA divided into RLGA+RLHA (58 years, male).

Figure 14. SA divided into RLGA+common root of RLHA and RGDA (74 years, male).

Figure 15. SA divided into RLGA+RRHA+common root of the RLHA and RGDA (64 years, female).

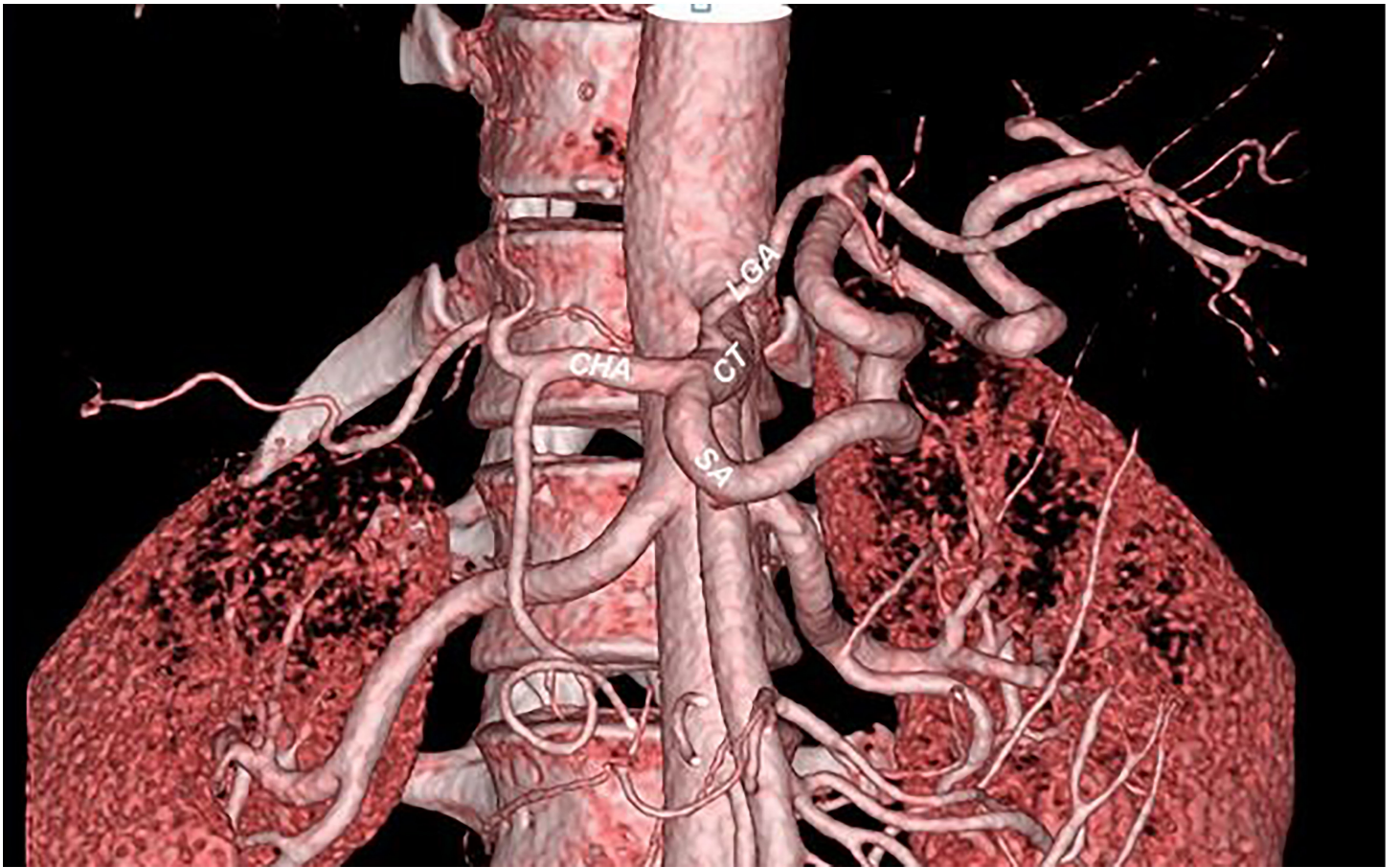
Figure 16. SA divided into RLGA+common root of the RRHA+RGDA (55 years, male).

Figure 20. SA SA divided into RLIPA+RLGA+RPHA (36 years, male).

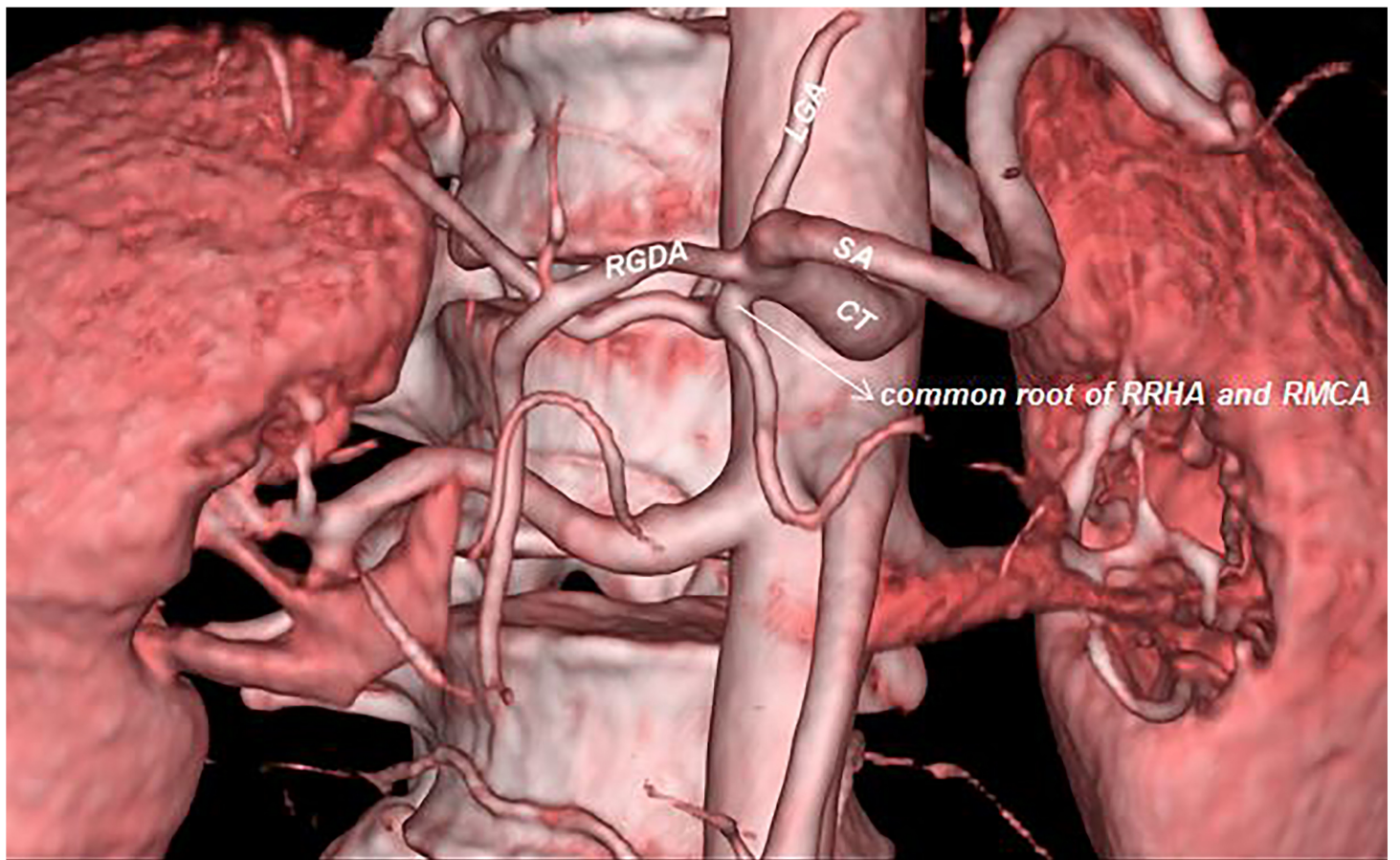
Figure 21. SA divided into RLGA+RLHA+RLIPA+RRIPA (63 years, male).

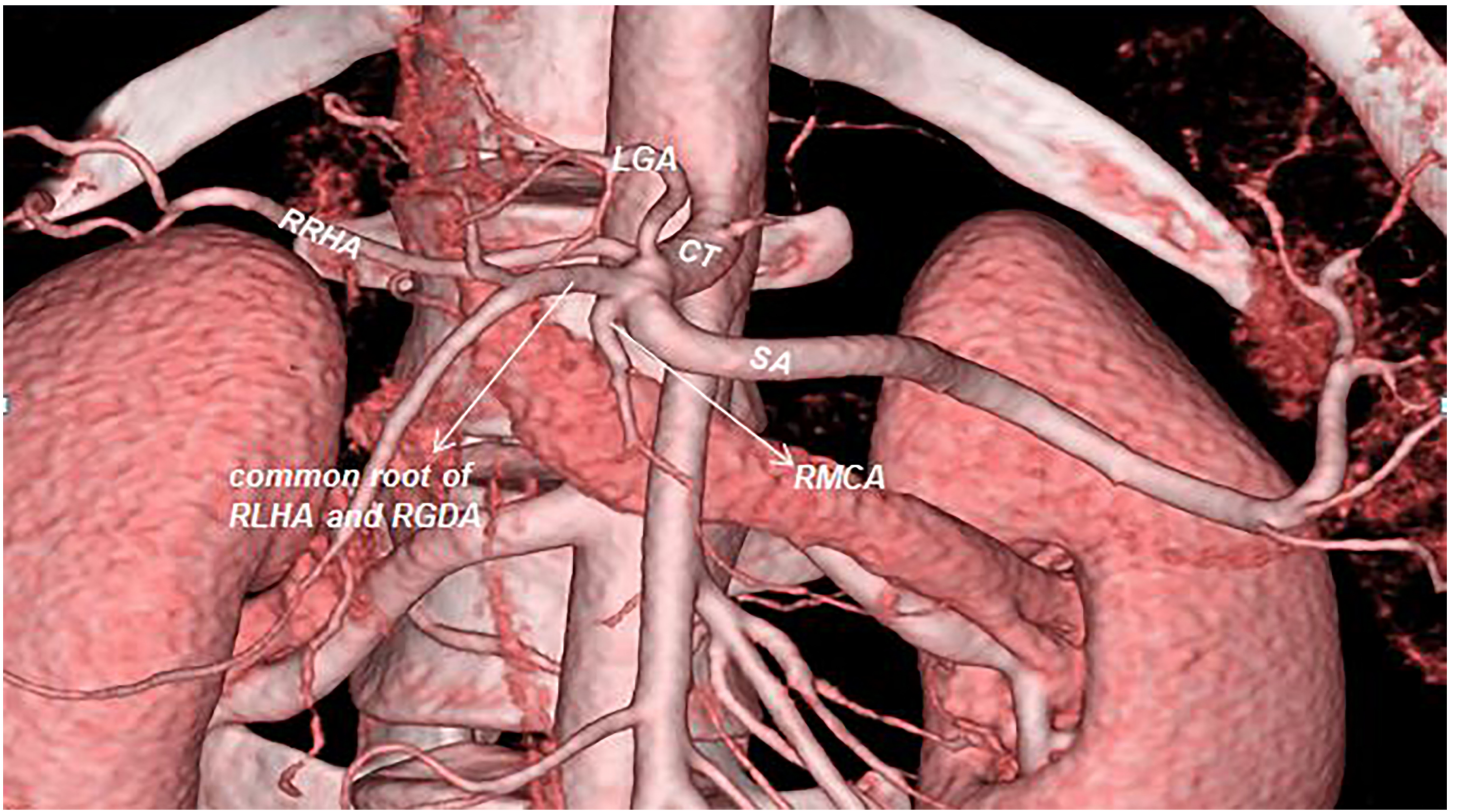
Figure 22. SA divided into RLCA (22 years, male).

Figure 17. SA divided into RMCA (45 years, female).

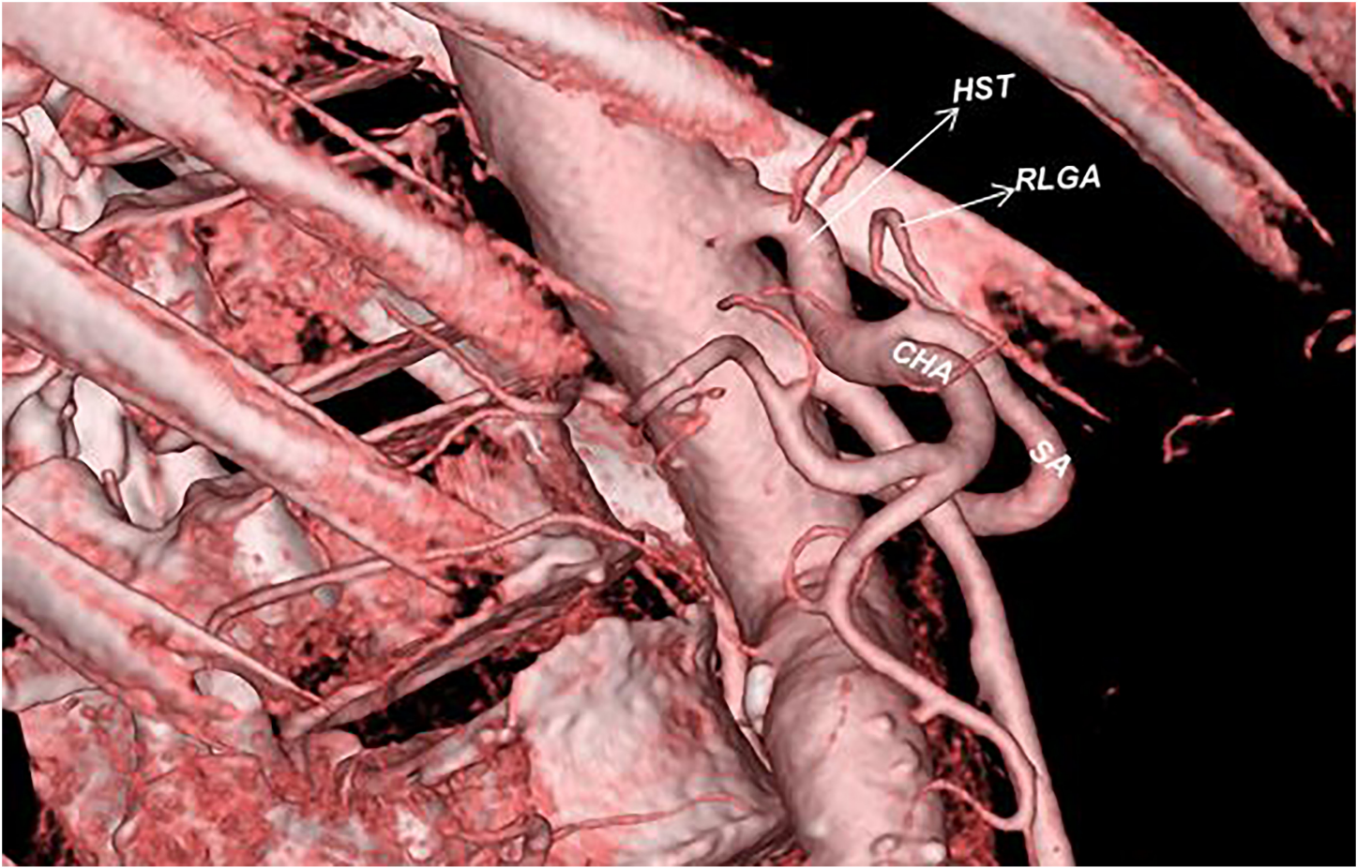




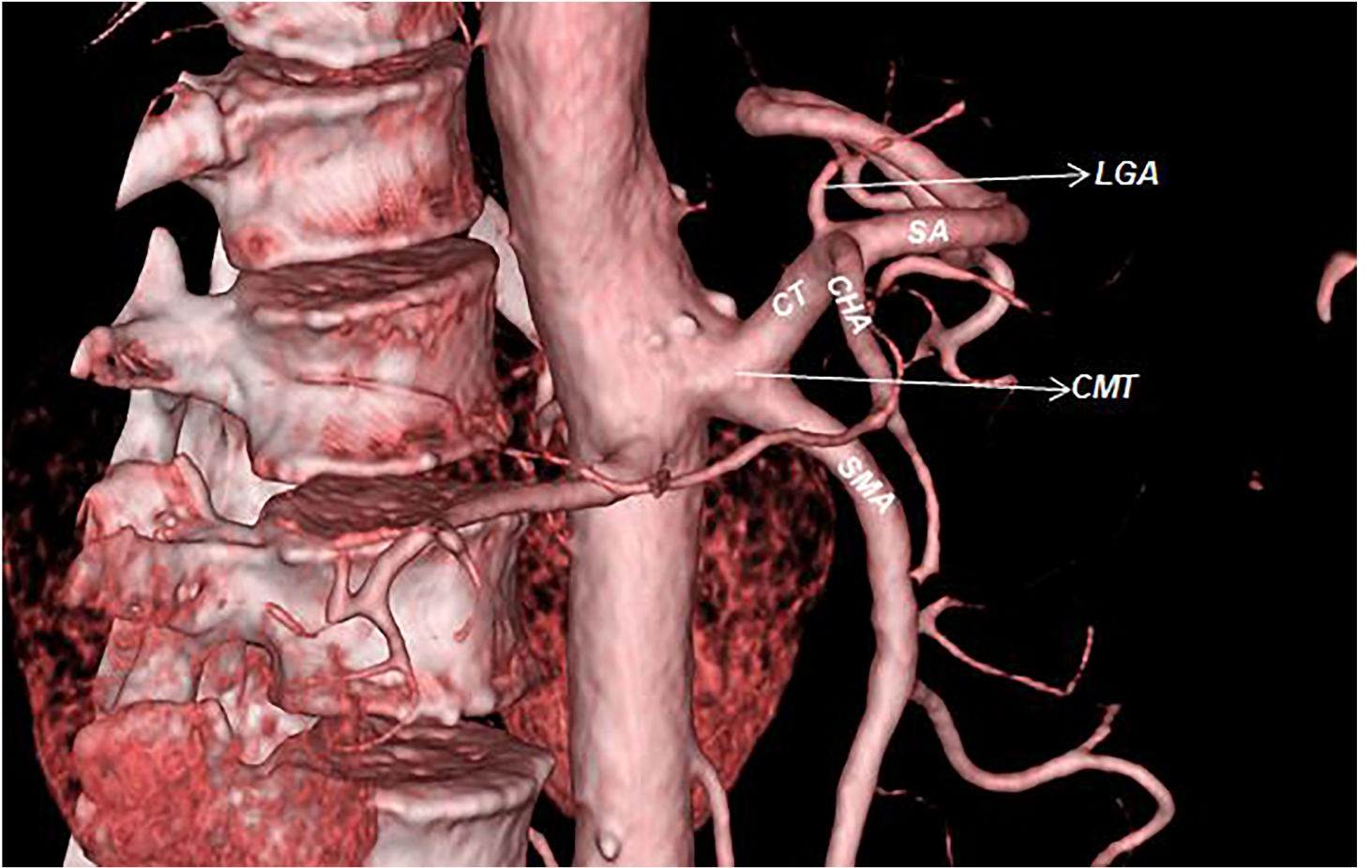


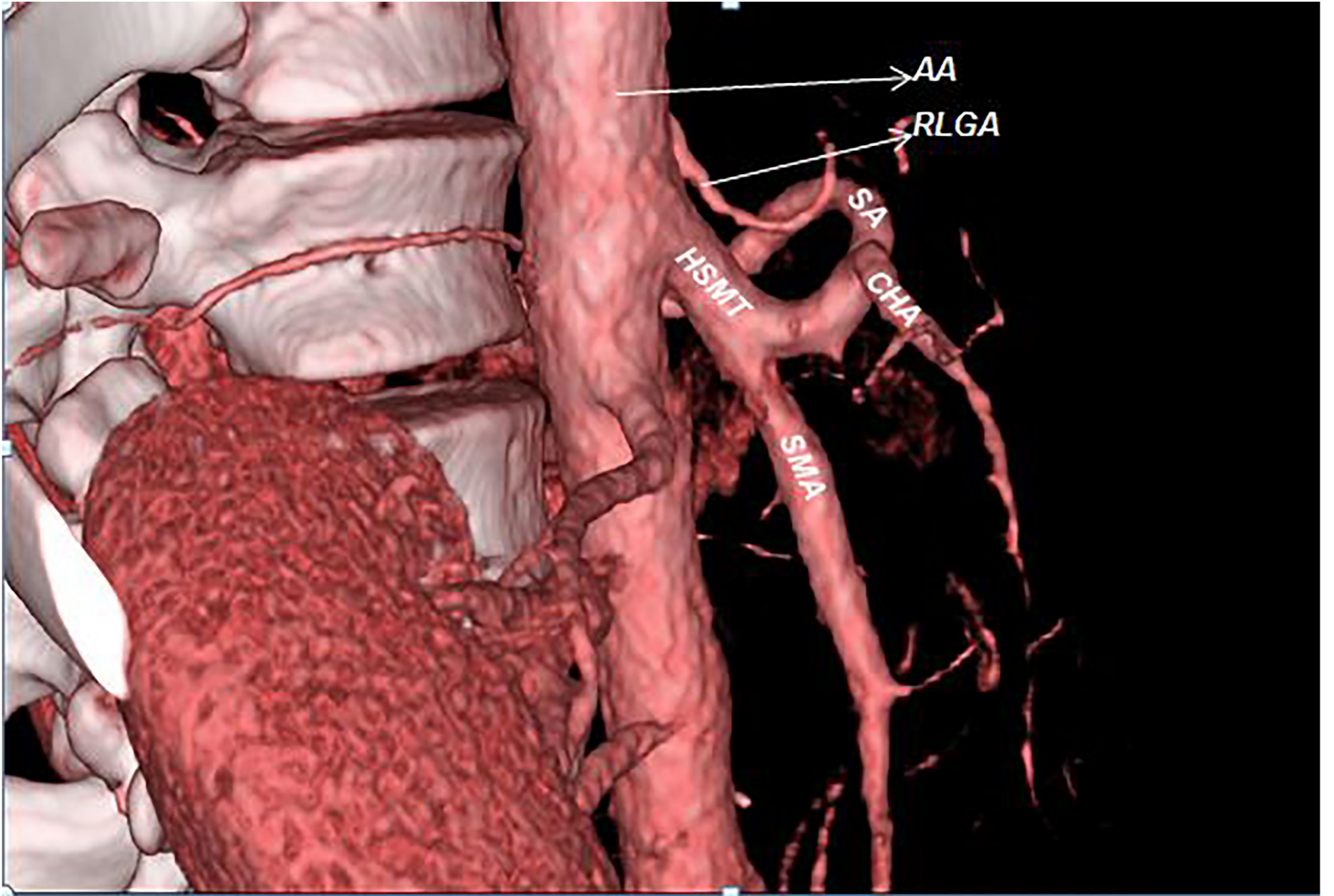


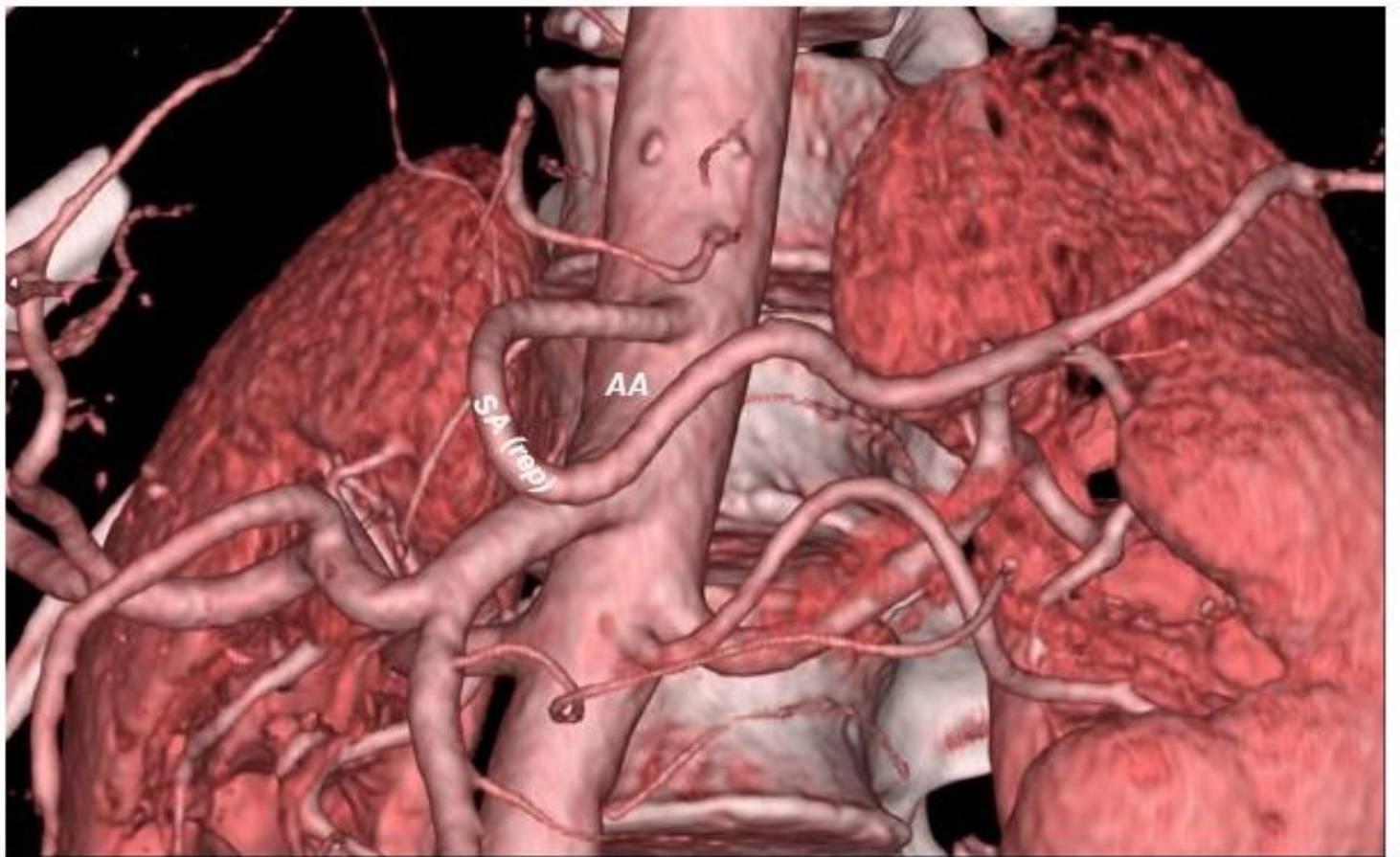


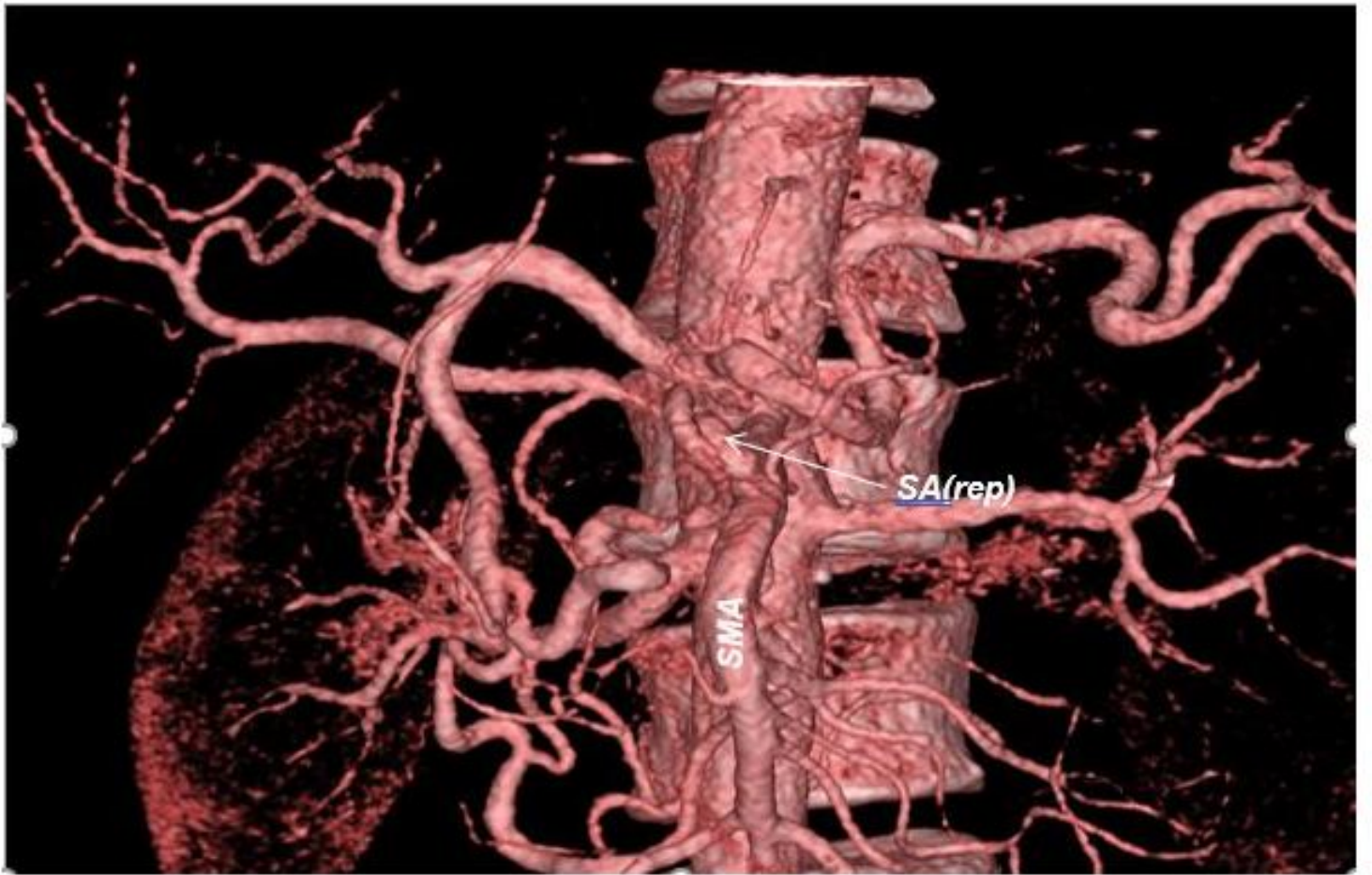


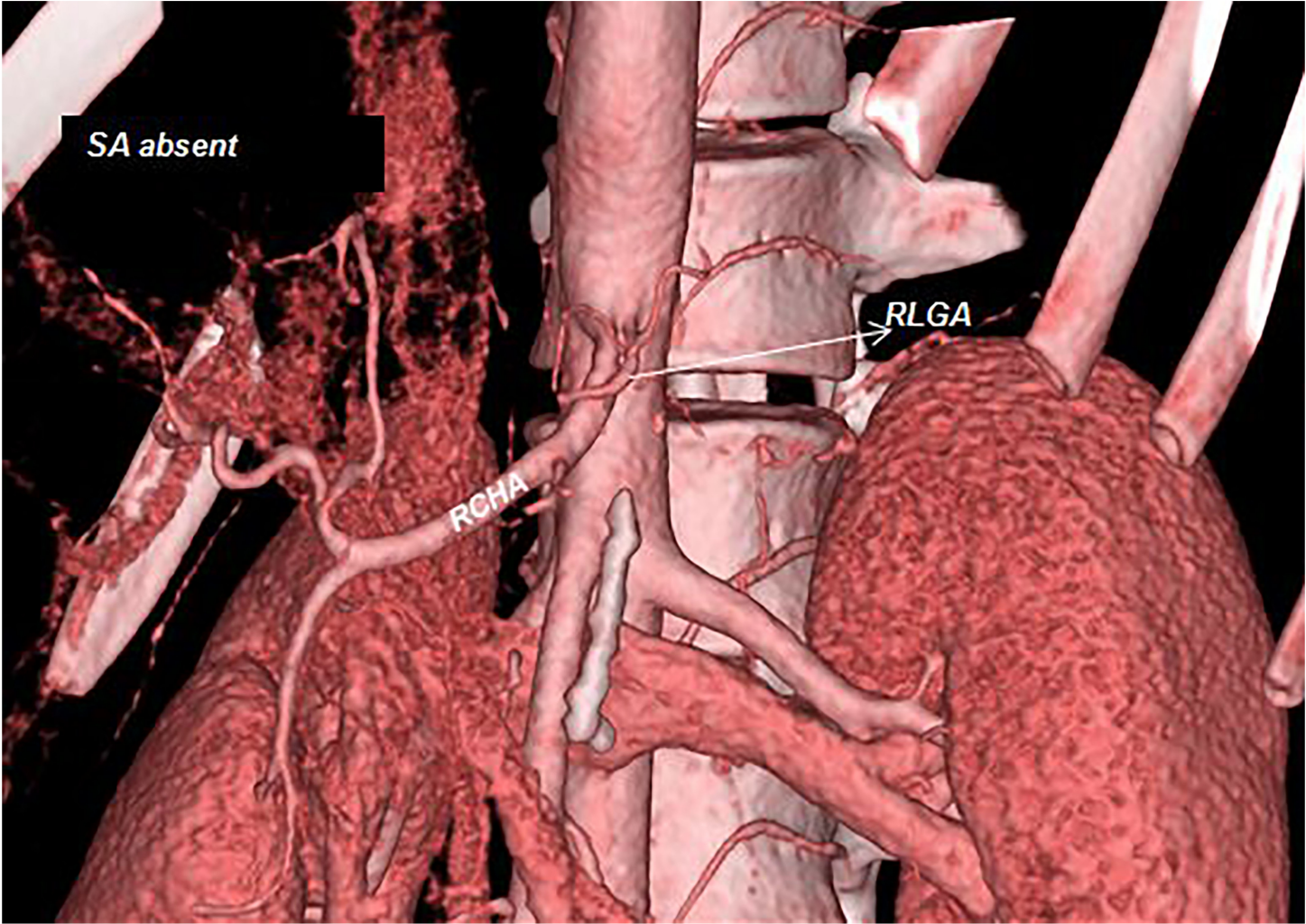












SA absent

RLGA

RCHA





