VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 79, No. 2, pp. 236–246
DOI: 10.5603/FM.a2019.0088
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ISSN 0015–5659
journals.viamedica.pl

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

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[Received: 12 May 2019; Accepted: 3 July 2019]

Background: *The splenic artery (SA) variations are rarely reported in the literature. Knowledge of the range of the SA and other arterial anomalies and their specific frequencies is very important ever for every visceral surgeon as well as for treatment of gastrointestinal bleeding, organ transplantation, transarterial chemoembolisation of neoplasm, infusion therapy, therapeutic arterial ligation, iatrogenic injuries. At the literature, there are more studies on the coeliac trunk, superior mesenteric artery and hepatic artery variations, but studies on the SA variations are uncommon. The studies on the SA 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 angiography between 2015 and 2017 were retrospectively evaluated for the SA variations. We created a new classification system to determine anatomic variations of the SA.*
Results: *Twenty-three different types were identified related to anatomic variations in the origin and branching pattern of the SA. While 596 (79.47%) patients had standard SA anatomy, 154 (20.53%) patients had variant SA anatomy.*
Conclusions: *The SA 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, embolisation of tumours of the abdominal organs, as well as other numerous diagnostic and therapeutic procedures, require detailed anatomical knowledge.* (Folia Morphol 2020; 79, 2: 236–246)

Key words: anatomic variations, splenic artery, multi-detector computed tomography

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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 [3, 5, 7, 19, 43, 47, 48, 53, 54]. 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 [20, 24, 42]. These branches are described as polar arteries that run to the upper or lower extremity of the spleen [8, 13, 14, 23].

According to literature studies, the SA 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 [42]. Knowledge of anatomical variations in the SA system is crucial in the context of liver and pancreas transplantation, arterial chemoembolisation for visceral organ tumours (especially, the treatment of gastric cancer and pancreas cancer), for hepato-biliary-pancreatic surgical procedures, general upper abdominal surgery, and SA steal syndrome [4, 11, 16, 32, 55]. Additionally, the SA embolisation has become a safe and effective intervention for the treatment of hypersplenism, cirrhosis with portal hypertension, hereditary spherocytosis, idiopathic thrombocytopenic purpura, splenic trauma, SA steal syndrome, and thalassemia. However, major complications may follow the SA embolisation including: splenic abscess which have been documented to occur in 6.8% of patients undergoing SA embolisation, splenic infarction, contrast-induced renal insufficiency, splenic cyst development, and non-target embolisation [1, 2, 4, 9, 12]. Splenic artery aneurysms, that are often asymptomatic and incidentally identified, are the most common of the visceral artery aneurysms with an incidence in the literature between 0.1% and 10.4%. The SA steal syndrome is one of the vascular complications after liver transplantation, its incidence has been reported at 3.1–5.9% of liver transplantations, or occurs due to liver ischaemia, hepatic artery thrombosis and stenosis. The SA embolisation is an effective treatment of this syndrome [21, 30]. If branches of the SA are injured or ligated accidentally during upper abdomen surgeon such as gastrectomy, it may be fatal leading to splenic abscess, haemorrhage, or rupture [20, 23, 44]. 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 SA [24].

In recent years, variations in vascular structures have become more important with the developments in image technology such as multi-detector computed tomography (MDCT) and 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 makes it possible to obtain high-quality three-dimensional images which are quite useful for demonstrating the details of visceral structures [22, 27, 33, 37, 40].

We created a new classification system to determine anatomic variations of the SA. Thus, we aimed to classify the anatomical variations of the SA 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 December 2015 to October 2017, anatomic variations in the SA of 800 patients who underwent abdominal computed tomography 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, a total of 750 cases were included in the analysis, 344 (45.87%) female and 406 (54.13%) male; age range was 16–93 years, mean age ± standard deviation was 50.6 ± ± 16.2 years.

MDCT technique

Multi-detector computed tomography angiography was done using Philips Brilliance 64-slice computed tomography 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 s, using the following parameters in all cases: collimation, 64 × 1 mm; step, 0.92; gantry rotation time, 0.75 s; section thickness 0.90 mm, and tube potential, 120 kV.

Computed tomography examinations and images interpretation

Multi-detector computed tomography 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 three-dimensionally reconstructed to confirm each assessment. We analysed the SA anatomy, including its origin site and proximal branching variants and classified these variants. Variants of 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 analysed using SPSS (v. 13.0 for Windows; Chicago, IL, USA). The overall results were expressed as mean ± standard deviation, frequencies, and percentages of the patients.

RESULTS

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

Table 1. Classification of origin and branching variations of the splenic artery

Types of the splenic artery	
Type 1	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
Type 2	SA originated from HST
Type 3	SA originated from HST and divided into LGA
Type 4	SA originated from GST
Type 5	SA originated from CMT
Type 6	SA originated from HSMT
Type 7	SA originated from AA
Type 8	SA originated from SMA
Type 9	SA absent
Type 10	SA (double pattern) (the presence of an accessory SA) (one originated from the CT, the other originated from a common root of the CHA and SA)
Type 11	SA and RRHA originated from a single common root from the aorta
Type 12	SA and RLHA originated from a single common root from the CT
	Branching variations of SA
Type 13	SA runs to the spleen as two branches
Type 14	SA originated from AA and divided into RLGA + RGDA
Type 15	SA originated from AA and divided into RLGA + RCH
Type 16	SA originated from AA and divided into RLGA + RLHA
Type 17	SA originated from AA and divided into RLGA + a common root of RLHA and RGDA
Type 18	SA originated from AA and divided into RLGA + RRHA + a common root of the RLHA and RGDA
Type 19	SA originated from AA and divided into RLGA + a common root of the RRHA and RGDA
Type 20	SA originated from CT and divided into RLIPA + RLGA + RPHA
Type 21	SA originated from AA and divided into RLGA + RLHA + RLIPA + RRIPA
Type 22	SA originated from CT and divided into RLCA
Type 23	SA originated from CT and divided into RMCA

AA — abdominal aorta; CHA — common hepatic artery; CMT — coeliacomesenteric trunk; CT — coeliac trunk; GDA — gastroduodenal artery; GST — gastrosplenic trunk; HSMT — hepatosplenomesenteric trunk; HST — hepatosplenic trunk; LCA — left colic artery; LGA — left gastric artery; LIPA — left inferior phrenic artery; MCA — middle colic artery; PHA — proper hepatic artery; RCHA — replaced common hepatic artery; RGDA — replaced gastroduodenal artery; RIPA — right inferior phrenic artery; RLCA — replaced left colic artery; RLGA — replaced left gastric artery; RLHA — replaced left hepatic artery; RLIPA — replaced left inferior phrenic artery; RMCA — replaced middle colic artery; RPHA — replaced proper hepatic artery; RRHA — replaced right hepatic artery; RRIPA — replaced right inferior phrenic artery; RSA — replaced splenic artery; SA — splenic artery; SMA — superior mesenteric artery

The SA had classical origin in 596 (79.47%) patients in our study; it arose from the CT 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, gastroduodenal artery [GDA], and common root of the right hepatic artery [RHA] + middle colic artery [MCA] in 3 (0.40%)

Table 2. Percentages of splenic artery types according to gender

Types of the splenic artery		Female	Male	Total: N (%)
Type 1	Classical SA (SA originated from CT and divided into the classic branches) (Fig. 1A–D)	276	320	596 (79.47%)
	Anatomic variations of SA (variations of origin and branching)			
	Variations of origin of SA			
Type 2	SA originated from HST (Fig. 2)	14	16	30 (4.00%)
Type 3	SA originated from HST and divided into RLGA (Fig. 3)	3	2	5 (0.67%)
Type 4	SA originated from GST (Fig. 4)	12	14	26 (3.47%)
Type 5	SA originated from CMT (Fig. 5)	2	6	8 (1.07%)
Type 6	SA originated from HSMT (Fig. 6)	0	2	2 (0.27%)
Type 7	SA (replaced) originated from AA (Fig. 7)	5	4	9 (1.20%)
Type 8	SA (replaced) originated from SMA (Fig. 8)	0	1	1 (0.13%)
Type 9	SA absent (Fig. 9)	4	0	4 (0.53%)
Type 10	SA (double pattern) (the presence of an accessory SA) (one originated from the CT, the other originated from a common root of the CHA and SA) (Fig. 10)	0	1	1 (0.13%)
Type 11	SA and RRHA originated from a single common root from the aorta (Fig. 11)	1	1	2 (0.27%)
Type 12	SA and RLHA originated from a single common root from the CT (Fig. 12)	0	1	1 (0.13%)
	Branching variations of SA			
Type 13	SA runs to the spleen as two branches (Fig. 13)	0	1	1 (0.13%)
Type 14	SA divided into RLGA + RGDA (Fig. 14)	10	15	25 (3.33%)
Type 15	SA divided into RLGA + RCHA (Fig. 15)	9	6	15 (2.00%)
Type 16	SA divided into RLGA + RLHA (Fig. 16)	1	4	5 (0.67%)
Type 17	SA divided into RLGA + a common root of the RLHA and RGDA (Fig. 17)	0	1	1 (0.13%)
Type 18	SA divided into RLGA + RRHA + a common root of the RLHA and RGDA (Fig. 18)	3	1	4 (0.53%)
Type 19	SA divided into RLGA + a common root of the RRHA + RGDA (Fig. 19)	3	3	6 (0.80%)
Type 0	SA divided into RLIPA + RLGA + RPHA (Fig. 20)	0	3	3 (0.40%)
Type 21	SA divided into RLGA + RLHA + RLIPA + RRIPA (Fig. 21)	0	1	1 (0.13%)
Type 22	SA divided into RLCA (Fig. 22)	0	2	2 (0.27%)
Type 23	SA divided into RMCA (Fig. 23)	1	1	2 (0.27%)
Total		344	406	750 (100%)

AA — abdominal aorta; CHA — common hepatic artery; CMT — coeliacomesenteric trunk; CT — coeliac trunk; GDA — gastroduodenal artery; GST — gastrosplenic trunk; HSMT — hepatosplenomesenteric trunk; HST — hepatosplenic trunk; LCA — left colic artery; LGA — left gastric artery; LIPA — left inferior phrenic artery; MCA — middle colic artery; PHA — proper hepatic artery; RCHA — replaced common hepatic artery; RGDA — replaced gastroduodenal artery; RIPA — right inferior phrenic artery; RLCA — replaced left colic artery; RLGA — replaced left gastric artery; RLHA — replaced left hepatic artery; RLIPA — replaced left inferior phrenic artery; RMCA — replaced middle colic artery; RPHA — replaced proper hepatic artery; RRHA — replaced right hepatic artery; RRIPA — replaced right inferior phrenic artery; RSA — replaced splenic artery; SA — splenic artery; SMA — superior mesenteric artery

cases, of the CT pentafurcation (into the SA, LGA, RHA, MCA, and common root of the left hepatic artery [LHA] + GDA) in 1 (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, ischaemia and necrosis [39]. The development of imaging technology regarding vessel variation has 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 [10, 31, 34, 51].

There are many research and classification investigating variations in hepatic arteries, superior mesenteric artery, and CT [15, 17, 26, 36, 52]. Whereas, very few researches has been done on the SA. We classified 23 types of SA with our research on 750 patients.

In our study, the SA took a classic origin from the CT in 596 (79.47%) patients (Fig. 1A–D). Standard CT anatomy, having the LGA, the SA and the CHA,

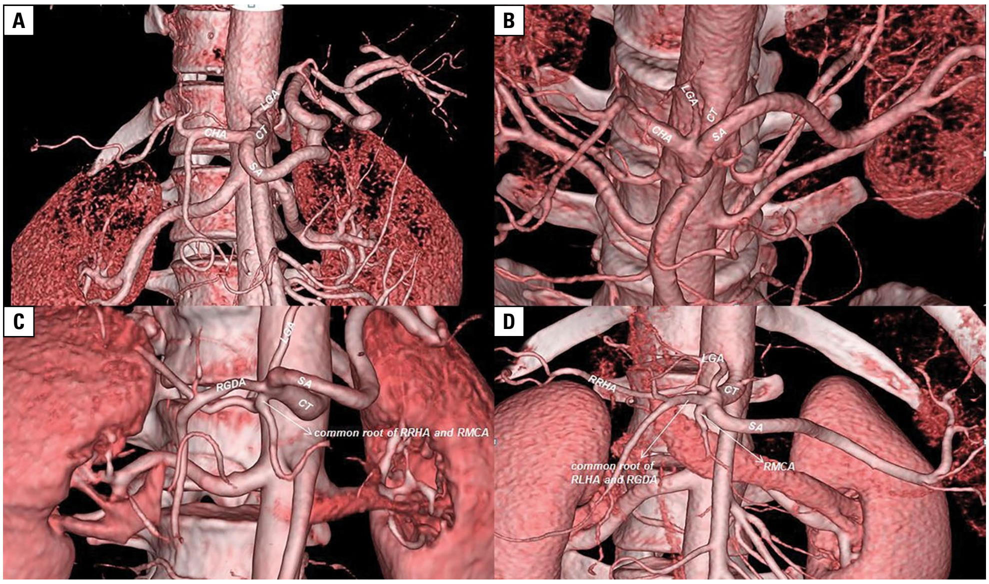

Figure 1. A. Classical splenic artery (SA) (SA originated from coeliac trunk [CT] and divided into the classic branches) (bifurcation of CT: SA + common hepatic artery [CHA]) (35 years, female); **B.** Classical SA (SA originated from CT as one of the three end branches of trifurcation of CT: left gastric artery [LGA] + SA + CHA) (36 years, male); **C.** Classical SA (SA originated from CT as one of the four end branches of tetrafurcation of CT: LGA + SA + replaced gastroduodenal artery [RGDA] + common root of replaced right hepatic artery [RRHA] and replaced middle colic artery [RMCA]) (55 years, male); **D.** Classical SA (SA originated from CT as one of the five end branches of pentafurcation of CT: LGA + SA + RRHA + RMCA + common root of replaced left hepatic artery [RLHA] and replaced gastroduodenal artery [RGDA]) (41 years, male).

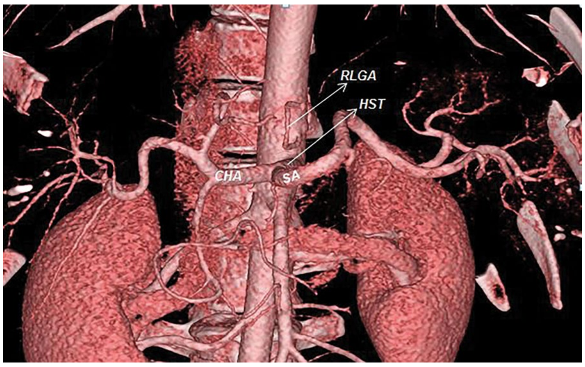

Figure 2. Splenic artery (SA) originated from hepatosplenic trunk (HST) (43 years, male); CHA — common hepatic artery; RLGA — replaced left gastric artery.

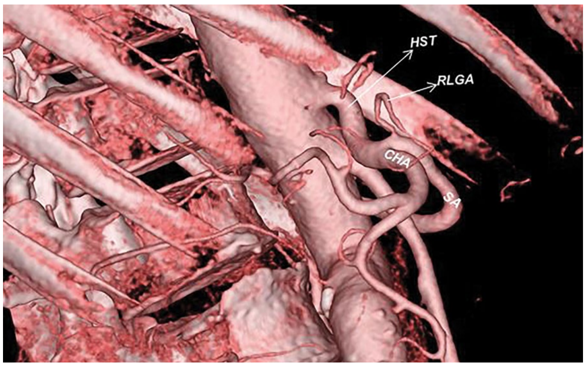

Figure 3. Splenic artery (SA) originated from hepatosplenic trunk (HST) and divided into replaced left gastric artery (RLGA) (34 years, male); CHA — common hepatic artery.

has been reported in 79.10% of the 604 patients in the studies of Koops et al. [26], 63.90% of the 607 patients in the studies of Farghadani et al. [10], and 75.70% of the 1000 patients in the studies of Hiatt et al. [15]. The SA originated from the hepatosplenic trunk (HST) 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 SA originated from the HST, but it also divided into LGA in addition to the classical branches (Fig. 3). Thangarajah et al. [49] found the HST in 8 (4%) patients of the 200 patients. Ugurel et al. [50] reported the HST in 3 (3%) of the 100 patients. Huang et al. [18] reported an abnormal LGA deriving from SA in 1 (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. [6], in 3 (1.10%) of the 275 cases by Nakamura et al. [38], in 143 (2.86%) of 5002 patients by Song et al. [46]. This variation pattern was found 26 (3.47%) in

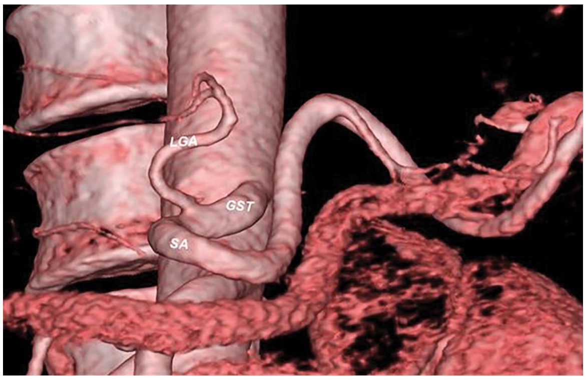

Figure 4. Splenic artery (SA) originated from gastrosplenic trunk (GST) (58 years, male); LGA — left gastric artery.

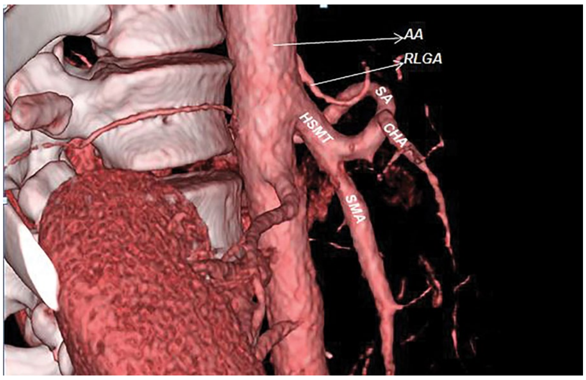

Figure 6. Splenic artery (SA) originated from hepatosplenomesenteric trunk (HSMT) (replaced left gastric artery [RLGA] originated directly from abdominal aorta [AA]) (32 years, male); CHA — common hepatic artery; SMA — superior mesenteric artery.

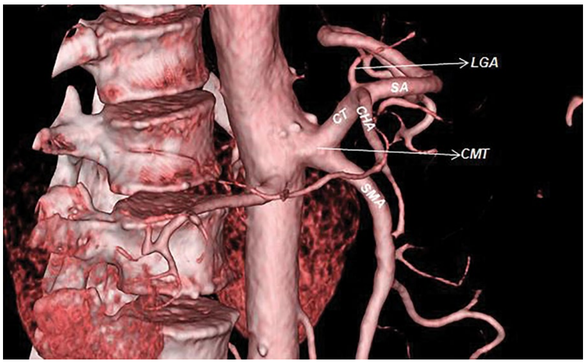

Figure 5. Splenic artery (SA) originated from coeliacomesenteric trunk (CMT) (65 years, male); HA — common hepatic artery; CT — coeliac trunk; LGA — left gastric artery; SMA — superior mesenteric artery.

Figure 7. Splenic artery (SA) (replaced) originated directly from abdominal aorta (AA) (55 years, male).

our study (Fig. 4). In 8 (1.07%) cases of our study, the SA arose from the coeliacomesenteric trunk (CMT), 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 (HSMT), which appeared as a HSMT 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 CMT are 2.38%, 1.00%, and 2.70% [51]. Kobayashi et al. [25] found that 14 (1.2%) cases had the CMT in 1200 cases. Song et al. [46] found that it originated from the CMT in 53 (1.06%), while the SA originated from the HSMT in 34 (0.68%) patients of the 5002 patients. The SA originated direct from AA in 9 (1.20%) cases in our study (Fig. 7). Iacob et al. [19], Matusz et al. [35], one each reported a case of the SA arising independently from the AA. The SA originated from the SMA in 1 (0.13%) cases in our study (Fig. 8). Ugurel et al. [50] found the splenomesenteric trunk in 1% of 100 patients. Absent of the SA was visualised in 4 (0.53%) cases of our study (Fig. 9); this was a rare variation in literature.

The presence of an accessory SA is quite rare and symptomatic. This variation of the SA is said to be due to intra-parenchymatous anastomosis between the inferior polar artery of SA and the splenic branches of left gastroepiploic artery [28, 42]. In presence of the accessory SA (double pattern) in our study: while one originated from CT, the accessory SA originated from a common root of the CHA and SA in 1 (0.13%) case of our study (Fig. 10). Padmalatha et al. [41] and Patel and Lowe [42], each one has reported an accessory SA, already a branch of main SA, in a cadaver in their cases. The SA (replaced) and RHA (replaced) originated directly from the aorta with

Figure 8. Splenic artery (SA) (replaced) originated directly from superior mesenteric artery (SMA) (55 years, male).

Figure 9. Splenic artery (SA) absent (replaced common hepatic artery [RCHA] + replaced left gastric artery [RLGA] originated directly from abdominal aorta, but SA absent) (20 years, female).

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

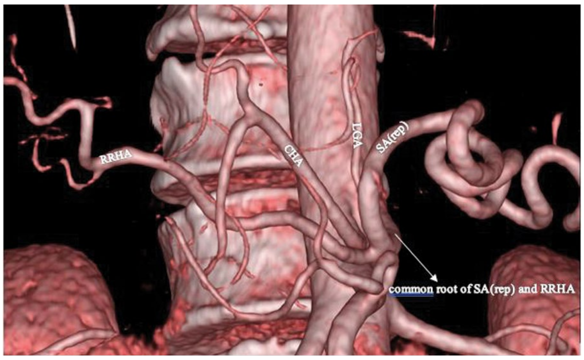

Figure 11. Splenic artery (SA) (replaced) and replaced right hepatic artery (RRHA) originated from a single common root from the aorta (46 years, male); CHA — common hepatic artery; LGA — left gastric artery.

Figure 12. Splenic artery (SA) (replaced) and replaced left hepatic artery (RLHA) originated from a single common root from the coeliac trunk (CT) (67 years, male); RRHA — replacement right hepatic artery.

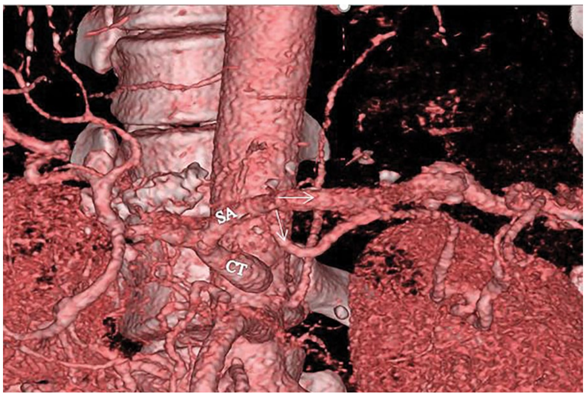

Figure 13. Splenic artery (SA) goes to the spleen in two branches (45 years, male); CT — coeliac trunk.

a single common root in 2 (0.27%) cases in our study, there is no report about this variation in literature (Fig. 11). Caruso et al. [4] 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).

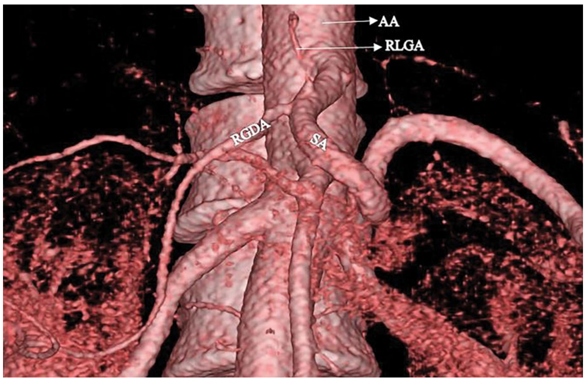

Figure 14. Splenic artery (SA) divided into replaced left gastric artery (RLGA) + replaced gastroduodenal artery (RGDA) (42 years, female); AA — abdominal aorta.

Figure 16. Splenic artery (SA) divided into replaced left gastric artery (RLGA) + replaced left hepatic artery (RLHA) (58 years, male); AA — abdominal aorta.

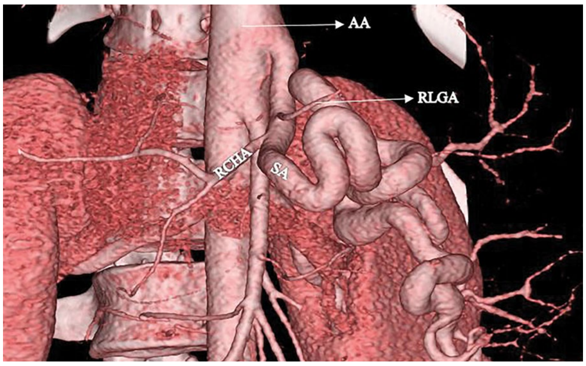

Figure 15. Splenic artery (SA) divided into replaced left gastric artery (RLGA) + replaced common hepatic artery (RCHA) (34 years, male); AA — abdominal aorta.

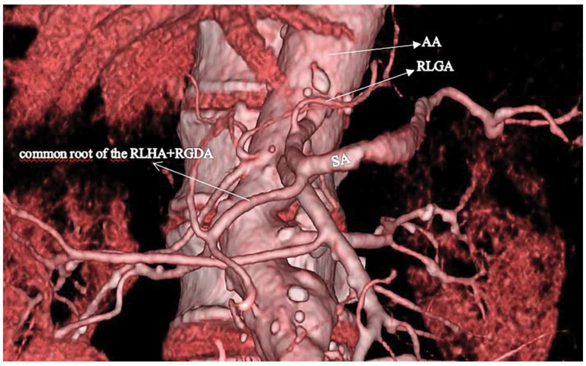

Figure 17. Splenic artery (SA) divided into replaced left gastric artery (RLGA) +common root of replaced left hepatic artery (RLHA) and replaced gastroduodenal artery (RGDA) (74 years, male); AA — abdominal aorta.

Our study showed that the SA had quite different branching patterns. In the most common 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 and Assaf [45] reported that the gastroduodenal artery originated from the SA in a case study. Li and Ren [29] 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 replaced left gastric artery (RLGA) and the replaced common hepatic artery (RCHA) arose from the SA originating directly from the AA in 15 (2.00%) cases of our study (Fig. 15). The RLGA and replaced left hepatic artery (RLHA) arose from the SA originating directly from the AA in 5 (0.67%) cases in our study (Fig. 16). The RLGA and a common root of the RLHA and replaced gastroduodenal artery (RGDA) arose from the SA originating directly from the AA in 1 (0.13%) in our study (Fig. 17). The SA originating directly from the AA divided into the RLGA, replaced right hepatic artery (RRHA), and a common root of RLHA and RGDA in 4 (0.53%) in our study (Fig. 18). The SA originating directly from the AA divided into the RLGA and a common root of the RRHA and RGDA in 6 (0.80%) in our study (Fig. 19). The SA originating directly from the AA divided into the RLIPA, RLGA, and replaced proper hepatic artery (RPHA) in 3 (0.40%) in our study (Fig. 20). The SA originating directly from the AA divided into the RLGA, RLHA, replaced left inferior phrenic artery (RLIPA), and replaced right inferior phrenic artery (RRIPA) in 1 (0.13%) in our study (Fig. 21). Kervancioglu et al. [24] found an accessory SA originating from the LGA, after its origin, it divided into the left and right inferior phrenic and the left hepatic arteries. The SA originating from the CT divided into the replaced left colic artery (RLCA) and the classical branches in 2 (0.27%) in our study

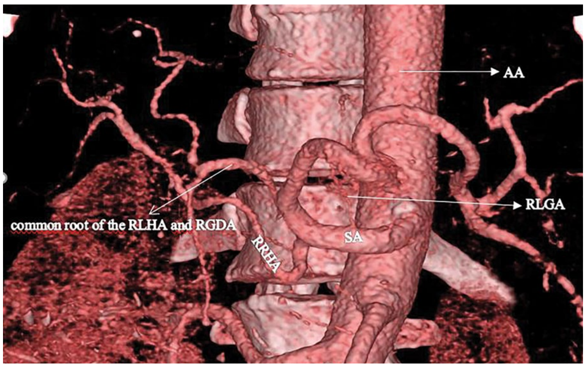

Figure 18. Splenic artery (SA) divided into replaced left gastric artery (RLGA) + replaced right hepatic artery (RRHA) + common root of the replaced left hepatic artery (RLHA) and replaced gastroduodenal artery (RGDA) (64 years, female); AA — abdominal aorta.

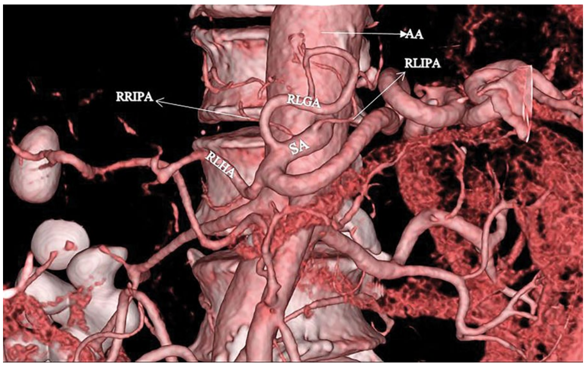

Figure 21. Splenic artery (SA) divided into RLGA + replaced left hepatic artery (RLHA) + replaced left inferior phrenic artery (RLIPA) + replaced right inferior phrenic artery (RRIPA) (63 years, male); AA — abdominal aorta.

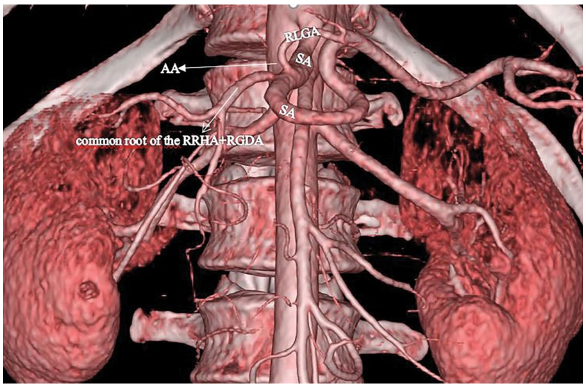

Figure 19. Splenic artery (SA) divided into replaced left gastric artery (RLGA) + common root of the replaced right hepatic artery (RRHA) + replaced gastroduodenal artery (RGDA) (55 years, male); AA — abdominal aorta.

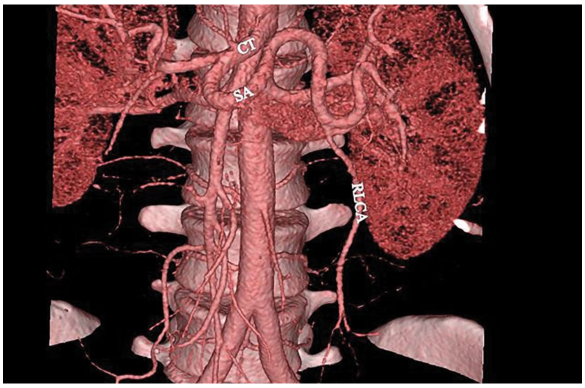

Figure 22. Splenic artery (SA) divided into replaced left colic artery (RLCA) (22 years, male); CT — coeliac trunk.

Figure 20. Splenic artery (SA) divided into replaced left inferior phrenic artery (RLIPA) + replaced left gastric artery (RLGA) + replaced proper hepatic artery (RPHA) (36 years, male); AA — abdominal aorta.

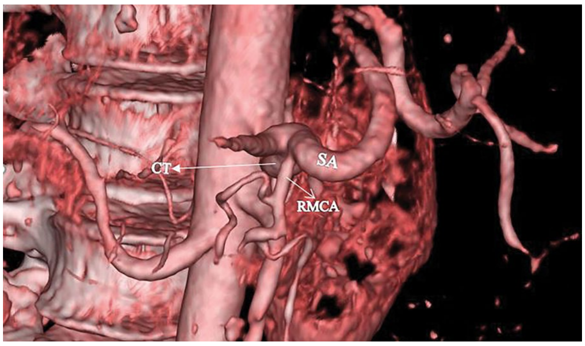

Figure 23. Splenic artery (SA) divided into replaced middle colic artery (RMCA) (45 years, female); CT — coeliac trunk.

(Fig. 22). The SA originating from the CT divided into the replaced middle colic artery (RMCA) 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 were evaluated retrospectively and only in the arterial phase. For this reason, we excluded some images that have poor quality owing to the fact that scanning was obtained in improper seconds.

CONCLUSIONS

In conclusion, in our study performed in 750 patients, anatomic variations of the SA were classified using a 23-type 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 chemoembolisation 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, ischaemia that can lead to major morbidity and mortality.

Acknowledgements

This project was supported by Dicle University Medical Faculty Ethics Committee for Noninterventional Studies (Project number: 55, Date: 21.12.2017).

REFERENCES

1. Banerjee A, Duane TM, Wilson SP, et al. Trauma center variation in splenic artery embolization and spleen salvage: a multicenter analysis. J Trauma Acute Care Surg. 2013; 75(1): 69–74; discussion 74, doi: 10.1097/TA.0b013e3182988b3b, indexed in Pubmed: 23778441.
2. Bundy JJ, Hage AN, Srinivasa RN, et al. Intra-arterial ampicillin and gentamicin and the incidence of splenic abscesses following splenic artery embolization: A 20-year case control study. Clin Imaging. 2019; 54: 6–11, doi: 10.1016/j.clinimag.2018.10.005, indexed in Pubmed: 30476679.
3. Caliskan E, Acar T, Ozturk M, et al. Coeliac trunk and common hepatic artery variations in children: an analysis with computed tomography angiography. Folia Morphol. 2018; 77(4): 670–676, doi: 10.5603/FM.a2018.0037, indexed in Pubmed: 29651794.
4. Caruso F, Dondossola D, Fornoni G, et al. Right hepatic artery from splenic artery: the four-leaf clover of hepatic surgery. Surg Radiol Anat. 2016; 38(7): 867–871, doi: 10.1007/s00276-016-1617-x, indexed in Pubmed: 26769020.
5. Chen H, Yano R, Emura S, et al. Anatomic variation of the celiac trunk with special reference to hepatic artery patterns. Ann Anat. 2009; 191(4): 399–407, doi: 10.1016/j.aanat.2009.05.002, indexed in Pubmed: 19540742.
6. Covey AM, Brody LA, Maluccio MA, et al. Variant hepatic arterial anatomy revisited: digital subtraction angiography performed in 600 patients. Radiology. 2002; 224(2): 542–547, doi: 10.1148/radiol.2242011283, indexed in Pubmed: 12147854.
7. Dăescu E, Sztika D, Lăpădatu AA, et al. Rare variant of celiac trunk branching pattern associated with modifications of hepatic arterial vascularization. Rom J Morphol Embryol. 2017; 58(3): 969–975, indexed in Pubmed: 29250676.
8. Daisy Sahni A, Indar Jit B, Gupta CNM, et al. Branches of the splenic artery and splenic arterial segments. Clin Anat. 2003; 16(5): 371–377, doi: 10.1002/ca.10172, indexed in Pubmed: 12903057.
9. Durusu Tanrıöver M, Peynircioğlu B, Ergan Arsava B, et al. Splenic artery embolization: An alternative approach in a critically ill patient with autoimmune hemolytic anemia. Turk J Haematol. 2011; 28(2): 135–138, doi: 10.5152/tjh.2011.30, indexed in Pubmed: 27264128.
10. Farghadani M, Momeni M, Hekmatnia A, et al. Anatomical variation of celiac axis, superior mesenteric artery, and hepatic artery: Evaluation with multidetector computed tomography angiography. J Res Med Sci. 2016; 21: 129, doi: 10.4103/1735-1995.196611, indexed in Pubmed: 28331515.
11. Fonseca-Neto OC, Lima HC, Rabelo P, et al. Anatomic variations of hepatic artery: a study in 479 liver transplantations. Arq Bras Cir Dig. 2017; 30(1): 35–37, doi: 10.1590/0102-6720201700010010, indexed in Pubmed: 28489166.
12. Gaba RC, Katz JR, Parvinian A, et al. Splenic artery embolization: a single center experience on the safety, efficacy, and clinical outcomes. Diagn Interv Radiol. 2013; 19(1): 49–55, doi: 10.4261/1305-3825.DIR.5895-12.1, indexed in Pubmed: 22875411.
13. García-Porrero JA, Lemes A. Arterial segmentation and subsegmentation in the human spleen. Acta Anat (Basel). 1988; 131(4): 276–283, doi: 10.1159/000146529, indexed in Pubmed: 3376732.
14. Gupta SB, Gupta SC, Gupta CD, et al. Vascular segments in the human spleen. J Anat. 1976; 121(Pt 3): 613–616, indexed in Pubmed: 1018011.
15. Hiatt JR, Gabbay J, Busuttil RW. Surgical anatomy of the hepatic arteries in 1000 cases. Ann Surg. 1994; 220(1): 50–52, doi: 10.1097/00000658-199407000-00008, indexed in Pubmed: 8024358.
16. Hlaing KP, Othman F. Complex pattern of a variant hepatic artery. Singapore Med J. 2012; 53(9): e186–e188, indexed in Pubmed: 23023911.
17. Huang CM, Chen RF, Chen QY, et al. Application value of a 6-type classification system for common hepatic artery absence during laparoscopic radical resections for gastric cancer: a large-scale single-center study. Medicine (Baltimore). 2015; 94(32): e1280, doi: 10.1097/MD.0000000000001280, indexed in Pubmed: 26266363.
18. Huang Y, Mu GC, Qin XG, et al. Study of celiac artery variations and related surgical techniques in gastric cancer. World J Gastroenterol. 2015; 21(22): 6944–6951, doi: 10.3748/wjg.v21.i22.6944, indexed in Pubmed: 26078572.
19. Iacob N, Pusztai AM, Miclăuş GD, et al. An anomalous origin of the gastrosplenic trunk and common hepatic artery arising independently from the abdominal aorta: a case report using MDCT angiography. Rom J Morphol Embryol. 2018; 59(1): 353–357, indexed in Pubmed: 29940649.
20. Ishikawa Y, Ehara K, Yamada T, et al. Three-dimensional computed tomography analysis of the vascular anatomy of the splenic hilum for gastric cancer surgery. Surg Today. 2018; 48(9): 841–847, doi: 10.1007/s00595-018-1679-y, indexed in Pubmed: 29858668.
21. Jayakumar L, Caputo FJ, Lombardi JV. Endovascular repair of a splenic artery aneurysm with anomalous origin from the superior mesenteric artery. Vasc Endovascular Surg. 2017; 51(3): 152–154, doi: 10.1177/1538574417690344, indexed in Pubmed: 28330438.
22. Jin GYu, Yu HC, Lim HS, et al. Anatomical variations of the origin of the segment 4 hepatic artery and their clinical implications. Liver Transpl. 2008; 14(8): 1180–1184, doi: 10.1002/lt.21494, indexed in Pubmed: 18668651.
23. Jung YJu, Seo HoS, Lee HH, et al. Splenic infarction as a delayed febrile complication following radical gastrectomy for gastric cancer patients: computed tomography-based analysis. World J Surg. 2018; 42(6): 1826–1832, doi: 10.1007/s00268-017-4401-0, indexed in Pubmed: 29270657.

24. Kervancioglu S, Yilmaz FG, Gulsen M, et al. Massive upper gastrointestinal bleeding from an accessory splenic artery mimicking isolated gastric varices. Folia Morphol. 2013; 72(4): 366–370, doi: 10.5603/fm.2013.0061, indexed in Pubmed: 24402761.
25. Kobayashi S, Otsubo T, Koizumi S, et al. Anatomic variations of hepatic artery and new clinical classification based on abdominal angiographic images of 1200 cases. Hepatogastroenterology. 2014; 61(136): 2345–2348, indexed in Pubmed: 25699380.
26. Koops A, Wojciechowski B, Broering DC, et al. Anatomic variations of the hepatic arteries in 604 selective celiac and superior mesenteric angiographies. Surg Radiol Anat. 2004; 26(3): 239–244, doi: 10.1007/s00276-004-0229-z, indexed in Pubmed: 14968265.
27. Kornafel O, Baran B, Pawlikowska I, et al. Analysis of anatomical variations of the main arteries branching from the abdominal aorta, with 64-detector computed tomography. Pol J Radiol. 2010; 75(2): 38–45, indexed in Pubmed: 22802775.
28. Kumar N, Patil J, Swamy RS, et al. Atypical arterial supply to the spleen by polar branches of splenic artery and accessory splenic artery - a case report. J Clin Diagn Res. 2014; 8(8): AD03–AD04, doi: 10.7860/JCDR/2014/8582.4656, indexed in Pubmed: 25302184.
29. Li J, Ren ZF. Gastroduodenal-splenic trunk: an anatomical vascular variant. Rom J Morphol Embryol. 2011; 52(4): 1385–1387, indexed in Pubmed: 22203950.
30. Liu DY, Yi ZJ, Tang Y, et al. Three case reports of splenic artery steal syndrome after liver transplantation. Transplant Proc. 2015; 47(10): 2939–2943, doi: 10.1016/j.transproceed.2015.10.037, indexed in Pubmed: 26707318.
31. López-Andújar R, Moya A, Montalvá E, et al. Lessons learned from anatomic variants of the hepatic artery in 1,081 transplanted livers. Liver Transpl. 2007; 13(10): 1401–1404, doi: 10.1002/lt.21254, indexed in Pubmed: 17902125.
32. Macchi V, Picardi EE, Porzionato A, et al. Anatomo-radiological patterns of pancreatic vascularization, with surgical implications: Clinical and anatomical study. Clin Anat. 2017; 30(5): 614–624, doi: 10.1002/ca.22885, indexed in Pubmed: 28395109.
33. Manyama M, Lukanima A, Gesase A. A case of celiacomesenteric trunk in a Tanzanian man. BMC Res Notes. 2013; 6: 341, doi: 10.1186/1756-0500-6-341, indexed in Pubmed: 23985367.
34. Matsuki M, Tanikake M, Kani H, et al. Dual-phase 3D CT angiography during a single breath-hold using 16-MDCT: assessment of vascular anatomy before laparoscopic gastrectomy. Am J Roentgenol. 2006; 186(4): 1079–1085, doi: 10.2214/AJR.04.0733, indexed in Pubmed: 16554582.
35. Matusz P, Miclaus GD, Ples H, et al. Absence of the celiac trunk: case report using MDCT angiography. Surg Radiol Anat. 2012; 34(10): 959–963, doi: 10.1007/s00276-012-0989-9, indexed in Pubmed: 22689084.
36. Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. Am J Surg. 1966; 112(3): 337–347, doi: 10.1016/0002-9610(66)90201-7, indexed in Pubmed: 5917302.
37. Miyaki A, Imamura K, Kobayashi R, et al. Preoperative assessment of perigastric vascular anatomy by multidetector computed tomography angiogram for laparoscopy-assisted gastrectomy. Langenbecks Arch Surg. 2012; 397(6): 945–950, doi: 10.1007/s00423-012-0956-2, indexed in Pubmed: 22562645.
38. Nakamura Y, Miyaki T, Hayashi S, et al. Three cases of the gastrosplenic and the hepatomesenteric trunks. Okajimas Folia Anat Jpn. 2003; 80(4): 71–76, doi: 10.2535/ofaj.80.71, indexed in Pubmed: 14964466.
39. Natsis K, Piagkou M, Lazaridis N, et al. The coexistence of both replaced proper hepatic and gastroduodenal arteries due to the common hepatic artery absence. Surg Radiol Anat. 2017; 39(11): 1293–1296, doi: 10.1007/s00276-017-1866-3, indexed in Pubmed: 28508279.
40. Natsume T, Shuto K, Yanagawa N, et al. The classification of anatomic variations in the perigastric vessels by dual-phase CT to reduce intraoperative bleeding during laparoscopic gastrectomy. Surg Endosc. 2011; 25(5): 1420–1424, doi: 10.1007/s00464-010-1407-1, indexed in Pubmed: 20976496.
41. Padmalatha K, Ramesh BR, Prakash BS, et al. Accessory splenic artery from left gastroepiploic artery. IJAV. 2010; 3: 106–107.
42. Patel SR, Lowe S. Accessory splenic artery: a rare cause of upper gastrointestinal bleeding. Cardiovasc Intervent Radiol. 2017; 40(7): 1115–1117, doi: 10.1007/s00270-017-1592-6, indexed in Pubmed: 28154918.
43. Raikos A, Paraskevas GK, Natsis K, et al. Multiple variations in the branching pattern of the abdominal aorta. Rom J Morphol Embryol. 2010; 51(3): 585–587, indexed in Pubmed: 20809044.
44. Sano T, Sasako M, Mizusawa J, et al. Randomized controlled trial to evaluate splenectomy in total gastrectomy for proximal gastric carcinoma. Ann Surg. 2017; 265(2): 277–283, doi: 10.1097/sla.0000000000001814.
45. Slaba S, Assaf S. Aberrant gastroduodenal artery with splenic origin. Surg Radiol Anat. 2018; 40(12): 1437–1440, doi: 10.1007/s00276-018-2112-3, indexed in Pubmed: 30324216.
46. Song SY, Chung JW, Yin YH, et al. Celiac axis and common hepatic artery variations in 5002 patients: systematic analysis with spiral CT and DSA. Radiology. 2010; 255(1): 278–288, doi: 10.1148/radiol.09090389, indexed in Pubmed: 20308464.
47. Sridhar Varma K, Pamidi N, Vollala VR, et al. Hepato-spleno-mesenteric trunk: a case report. Rom J Morphol Embryol. 2010; 51(2): 401–402, indexed in Pubmed: 20495765.
48. Sztika D, Zăhoi DE, Motoc A, et al. Anatomical variations of the hepatic portal vein associated with incomplete celiac trunk. Rom J Morphol Embryol. 2011; 52(2): 695–698, indexed in Pubmed: 21655663.
49. Thangarajah A, Parthasarathy R. Celiac axis, common hepatic and hepatic artery variants as evidenced on MDCT angiography in south indian population. J Clin Diagn Res. 2016; 10(1): TC01–TC05, doi: 10.7860/JCDR/2016/17045.7105, indexed in Pubmed: 26894140.
50. Ugurel MS, Battal B, Bozlar U, et al. Anatomical variations of hepatic arterial system, coeliac trunk and renal arteries: an analysis with multidetector CT angiography. Br J Radiol. 2010; 83(992): 661–667, doi: 10.1259/bjr/21236482, indexed in Pubmed: 20551256.
51. Yan J, Nagasawa Y, Nakano M, et al. Origin of the celiac and superior mesenteric arteries in a common trunk: description of a rare vessel variation of the celiacomesenteric trunk with a literature review. Okajimas Folia Anat Jpn. 2014; 91(2): 45–48, doi: 10.2535/ofaj.91.45, indexed in Pubmed: 25492844.
52. Yang Y, Jiang N, Lu MQ, et al. [Anatomical variation of the donor hepatic arteries: analysis of 843 cases]. Nan Fang Yi Ke Da Xue Xue Bao. 2007; 27(8): 1164–1166, indexed in Pubmed: 17715016.
53. Ye Z, Ye S, Zhou D, et al. A rare variation of celiac trunk and hepatic artery complicating pancreaticoduodenectomy: A case report and literature review. Medicine (Baltimore). 2017; 96(48): e8969, doi: 10.1097/MD.0000000000008969, indexed in Pubmed: 29310402.
54. Zagyapan R, Kürkçüoğlu A, Bayraktar A, et al. Anatomic variations of the celiac trunk and hepatic arterial system with digital subtraction angiography. Turk J Gastroenterol. 2014; 25 (Suppl 1): 104–109, doi: 10.5152/tjg.2014.5406, indexed in Pubmed: 25910286.
55. Zhu C, Kong SH, Kim TH, et al. The anatomical configuration of the splenic artery influences suprapancreatic lymph node dissection in laparoscopic gastrectomy: analysis using a 3D volume rendering program. Surg Endosc. 2018; 32(8): 3697–3705, doi: 10.1007/s00464-018-6201-5, indexed in Pubmed: 29725766.