CASE REPORT

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Hepato-spleno-mesenteric trunk, in association with an accessory left hepatic artery, and common trunk of right and left inferior phrenic arteries, independently arising from left gastric artery: case report using MDCT angiography

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Abstract

The authors report the case of a 53-year-old male found to have an extremely rare case of a triple anatomical variation highlighted by multidetector computed tomography (MDCT) angiography, with the presence of a hepato-spleno-mesenteric trunk (HSMT) in association with an accessory left hepatic artery (ALHA) and a common trunk origin of right (RIPA) and left (LIPA) inferior phrenic arteries from left gastric artery (LGA) arising independently from the abdominal part of aorta (AA). The HSMT with an endoluminal diameter of 10.9 mm at its origin, and a length of 4 mm arose from the anterior wall of the AA at the level of 1/2 upper part of the L1 vertebral body. From the distal portion of HSMT, give birth to the hepato-splenic trunk (HST) and to the superior mesenteric artery (SMA). HST, with a diameter at origin of 9.2 mm and 22.3 mm long, has an upward trajectory and done with the anterior face of AA an open angle to the top of 69°. From the distal part of the HST, arise common hepatic artery (CHA) and splenic artery (SA). The LGA, with an endoluminal diameter of 4.2 mm at origin, arose directly from the anterior wall of the AA at the level of the lower 1/3 of T12 vertebral body, 8.2 mm above the origin of the HSMT. It ran upwards in front of the AA and after 59.5 mm gave rise to an ALHA. At 18.6 mm from its aortic origin, LGA gives birth to an inferior phrenic artery trunk (IPAT), which has at origin an endoluminal diameter of 2.6 mm and a length of 2.4 mm. The RIPA and LIPA have to origin a diameter of 2.3 mm and 1.7 mm, respectively. Knowledge of this anatomical variation is important for anatomists, interventional radiologists, vascular medicine experts, oncologists, vascular, and hepatic surgeons.

***Keywords*:** hepato-spleno-mesenteric trunk, left gastric artery, accessory left hepatic artery, common trunk of right and left inferior phrenic arteries, development, medical implications.

Introduction

According with Standring [1], the arterial supply of the abdominal organs is assured of the three median visceral branches of the abdominal aorta (AA): the celiac trunk (CT), the superior (SMA) and inferior (IMA) mesenteric arteries. Of these, CT and SMA are the most important because they vascularize most of the gastrointestinal tract [2]. In a literature study, in 445 cases, Matusz *et al.* [3] highlight the maximum frequency of CT origin in the range of intervertebral disc T12–L1 and superior one third of L1, and for SMA in the superior one third of L1 and inferior one third of L1. The CT, the classical "tripod of Haller" first described by von Haller [4], it ends up being divided into: left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA). The SMA arising from anterior aspect of AA 1 cm below the CT, runs downwards including in the aorto-mesenteric angle the left renal vein and the third part of the duodenum [5].

Although quite rare as frequency, the individual or combined variations of CT and SMA show great diversity. In 2013, Matusz *et al.* [6], analyzing the prevalence of the complete and incomplete CT and celiacomesenteric trunks (CMTs) in a large case series of literature (7058 cases), reported the presence of hepato-spleno-mesenteric trunk (HSMT) in association with independent aortic origin of the LGA with a prevalence of 0.67% (0.14% by anatomical dissection and 0.53% by radiological procedures). HSMT was included in the classification of morphological variability of CT and CMT performed by: Adachi (1928), Morita (1935) and Michels (1955) (quoted by [7, 8]), Uflacker [9], Chen *et al.* [10], Dilli Babu & Khrab [11]. Isolated cases of an HSMT in association with an independent aortic origin of the LGA has also been identified by anatomical dissection [2, 12], and by radiological procedures [13]. Association of HSMT with a hepato-gastro-phrenic trunk has been described by Hemanth *et al.* [14], and an association with a gastro-bifrenic trunk by Matusz *et al.* [6]. HSMT cases in the context of the analysis of the CT and CMT morphological variability across different study groups were published by: Imakoshi in 1949 (quoted by Chen *et al.* [10]), Iezzi *et al.* [15], Chen *et al.* [10], Song *et al.* [16], Ugurel *et al.* [17], Natsume *et al.* [18].

Aim

The aim of the current study was to document, by multidetector computed tomography (MDCT) angiography, the presence of a HSMT in association with an accessory left hepatic artery (ALHA) and a common trunk origin of right (RIPA) and left (LIPA) inferior phrenic arteries from LGA arising independently from the AA, highlighted by MDCT angiography. After our knowledge, this is the second case of HSMT with a ALHA arising from LGA, after the case contained in the casuistry of Chen *et al.*, from 2009 [10] (1/974 cases); the second case of a common trunk of RIPA and LIPA (inferior phrenic artery trunk – IPAT) from LGA, after the case contained in the casuistry of Aslaner *et al.*, in 2017 [19] (1/1000 cases), and the first case which sums up the two hepatic and inferior phrenic arterial variants originated in LGA associated with the presence of an HSMT. Such cases with multiple vascular variations of the abdomen should be considered in planning and performing surgical procedures.

Case presentation

We report the case of a 53-year-old male patient with peripheral vascular disease of the lower limbs for six years. For mapping of the extent and location of arterial disease of the lower limbs, and to highlight any associated variations, the clinical examination was completed with infradiaphragmatic MDCT angiography. The angiographic evaluation was performed at Neuromed Diagnostic Imaging Centre (Timişoara, Romania) by using a 64-slice MDCT system (SOMATOM Sensation, Siemens Medical Solutions, Forchheim, Germany).

We found that this case has independently of the vascular disorders of the lower limbs, the presence of a HSMT in association with LGA arising independently from the AA. From LGA are arising an ALHA and an IPAT (Figure 1, A and B).

The HSMT with truncated cone look, with an endo-luminal diameter of 10.9 mm at its origin, and a length of 4 mm arose from the anterior wall of the AA at the level of 1/2 upper part of the L1 vertebral body (Figure 2). From the distal portion of HSMT (with 15 mm diameter), give birth to the hepato-splenic trunk (HST) and to the SMA. HST, with a diameter at origin of 9.2 mm and 22.3 mm long, has an upward trajectory and done with the anterior face of AA an open angle to the top of 69°. From the distal part of the HST, arise CHA and SA. From the origin, CHA turns right and after 33.7 mm is divided into gastroduodenal artery (GDA), right hepatic artery (RHA) and medial branch (artery of segment IV). SA descend of the distal part of the HST to the left, having an italic *S* tract, and after 72.1 mm it gives birth to branches that penetrate the spleen hilum (Figure 3). The SMA originate in the lower distal portion of HSMT having a diameter of 7.5 mm. SMA's downstream trajectory performs with the anterior face of AA an open lower angle of 58°. In the aortic-mesenteric angle are placed the left renal vein and the horizontal part of duodenum (D3).

With an endoluminal diameter of 4.2 mm at origin, the LGA arose directly from the anterior aspect of the AA, at the level of the lower 1/3 of T12 vertebral body, 8.2 mm above the origin of the HSMT. It ran upwards in front of the AA and after 59.5 mm gave rise to an ALHA. At 18.6 mm from its aortic origin, LGA gives birth to an IPAT, which has at origin an endoluminal diameter of 2.6 mm and a length of 2.4 mm. The RIPA and LIPA have at origin a diameter of 2.3 mm and 1.7 mm, respectively (Figures 4 and 5).

Consent

For the X-ray examination by using a 64-slice MDCT system, and of iodinated contrast agents, a written informed consent was requested from the patient. Also, a written informed consent has been obtained for publication of this case report and images.

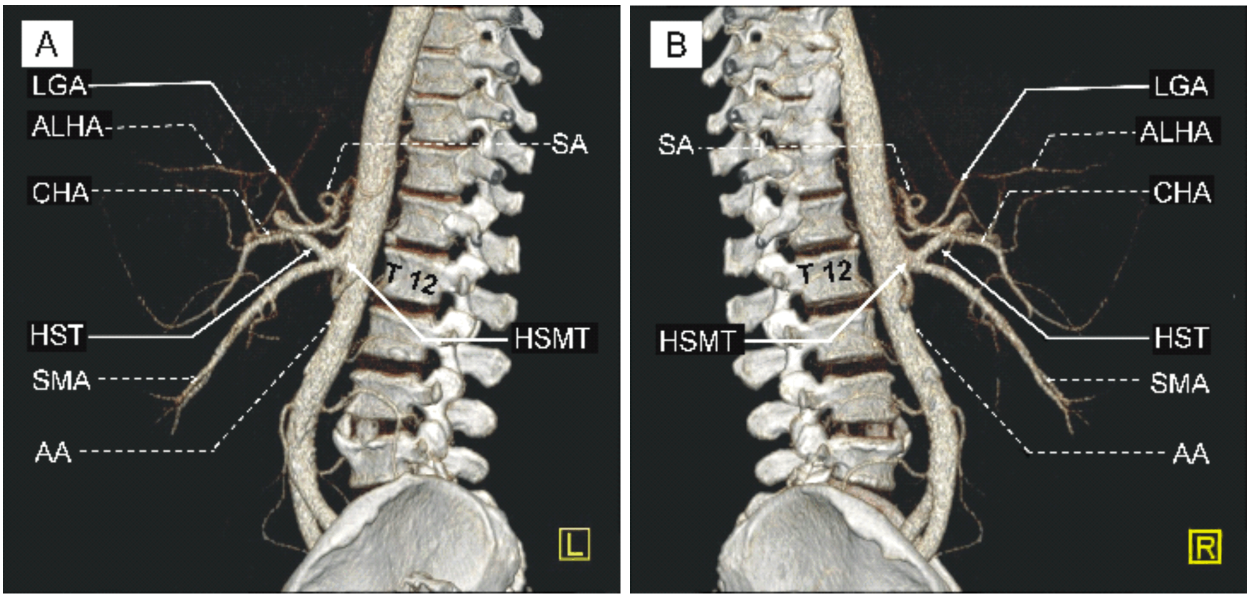

Figure 1 – ***MDCT angiography of the AA. Rendered 3D images show the LGA and HSMT originating from the AA: (A) Left aspect; (B) Right aspect. MDCT: Multidetector computed tomography; AA: Abdominal part of aorta; 3D: Three-dimensional; LGA: Left gastric artery; HSMT: Hepato-spleno-mesenteric trunk; HST: Hepato-splenic trunk; CHA: Common hepatic artery; SA: Splenic artery; SMA: Superior mesenteric artery; ALHA: Accessory left hepatic artery.***

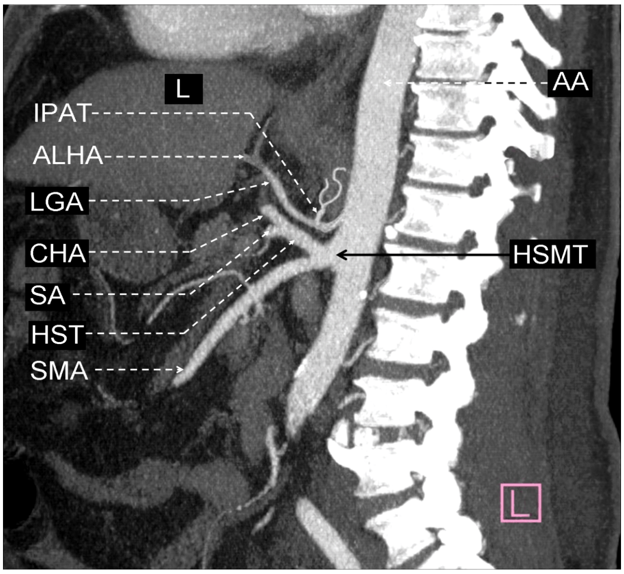

Figure 2 – ***MDCT angiography of the AA. MIP image shows the AA with LGA and HSMT: sagittal image. MDCT: Multi-detector computed tomography; AA: Abdominal part of aorta; MIP: Maximum intensity projection; LGA: Left gastric artery; HSMT: Hepato-spleno-mesenteric trunk; L: Liver; HST: Hepato-splenic trunk; SMA: Superior mesenteric artery; SA: Splenic artery; CHA: Common hepatic artery; ALHA: Accessory left hepatic artery; IPAT: Inferior phrenic artery trunk.***

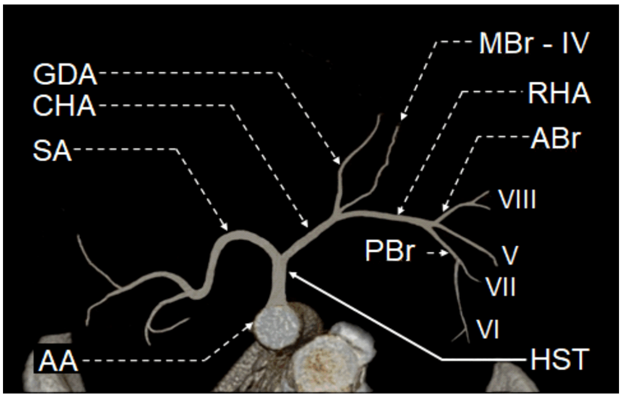

Figure 3 – ***MDCT angiography of the AA. Rendered 3D images show the HST: superior aspect. MDCT: Multi-detector computed tomography; AA: Abdominal part of aorta; 3D: Three-dimensional; HST: Hepato-splenic trunk; SA: Splenic artery; CHA: Common hepatic artery; GDA: Gastroduodenal artery; MBr: Medial branch; RHA: Right hepatic artery; ABr: Anterior branch; PBr: Posterior branch; IV–VIII: Segmental branches.***

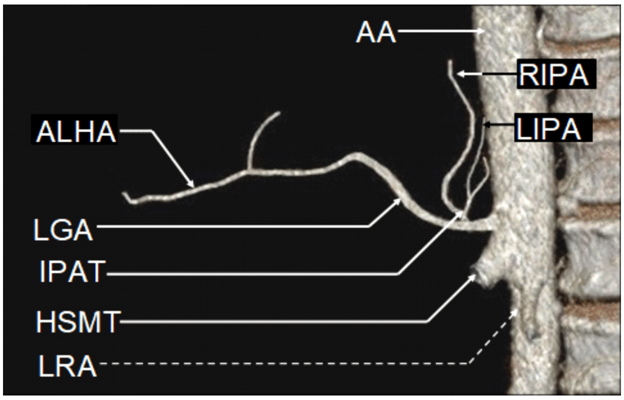

Figure 4 – ***MDCT angiography of the AA. Rendered 3D images show the LGA with IPAT (with RIPA and LIPA) and ALHA: left aspect. MDCT: Multidetector computed tomography; AA: Abdominal part of aorta; 3D: Three-dimensional; LGA: Left gastric artery; IPAT: Inferior phrenic artery trunk; RIPA: Right inferior phrenic artery; LIPA: Left inferior phrenic artery; ALHA: Accessory left hepatic artery; HSMT: Hepato-spleno-mesenteric trunk; LRA: Left renal artery.***

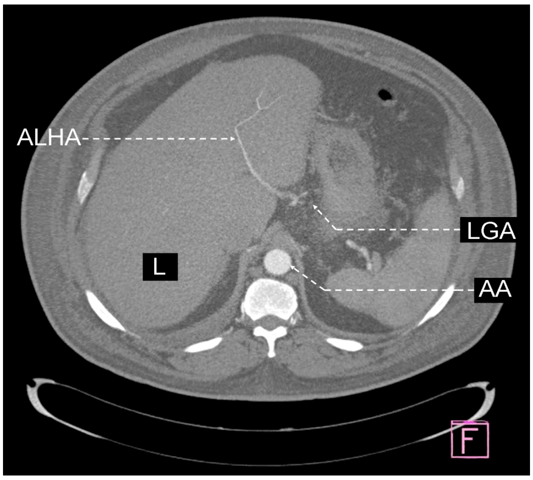

Figure 5 – ***MDCT angiography of the AA. MIP image shows the liver, AA with LGA and ALHA: transversal image. MDCT: Multidetector computed tomography; AA: Abdominal part of aorta; MIP: Maximum intensity projection; LGA: Left gastric artery; ALHA: Accessory left hepatic artery; L: Liver.***

Discussions

Embryology

HSMT in association with LGA originating independently from the AA

The most important stages of vascular development occur during the first trimester of the embryo-fetal period. During the third week of this period, during the stage with two dorsal aortae, the abdominal organs are fed by numerous bilateral ventral segmental arteries (VSAs). During the next two weeks (the 4th and 5th), the right and left dorsal aortae fuse in the middle. During the next stages, the two VSAs (right and left) of the same metamer fuse also in the midline [20]. The cranio-caudal shift of the VSAs origin level and the decrease in the number of the VSAs also occur at that moment. These important morphological changes are produced by complex fusion and/or vascular obliteration processes of one of them at the level of each metamer (usually the left VSAs) [20]. The first five ventral abdominal segmental arteries are involved in the occurrence of the unpaired branches of the AA. From top to bottom: the first primitive root (10th VSA) becomes LGA; the second (11th VSA) becomes SA; the third (12th VSA) becomes CHA; the fourth (13th VSA) becomes SMA and the fifth (19th VSA) becomes IMA. Following the theory of Tandler (1904), the four primitive ventral abdominal segmental arteries (10th–13th) are connected to the "longitudinal anastomosis" running in front of the AA. Within the embryo-fetal evolution calendar, depending on the development of resorption/ retention of VSAs roots and various portions of longitudinal anastomosis, numerous anatomical variations of CT and SMA may appear. The most common situation is the occurrence of CT, situation in which the 10th-to-12th VSAs are united by longitudinal anastomose, in association with the regression of the 10th and 11th VSAs roots, and the persistence of the 12th VSA root. Extreme situations are represented by the CMT and the absence of CT as a morphological entity. In case of CMT, the longitudinal anastomosis persists completely and connects the 10th-to-13th VSAs, associated with regulation of the 10th-to-12th VSAs roots. The only root that does not regress is the 13th root, which will become the proximal part of the CMT. In the absence of CT, LGA, SA and CHA arise independently from the AA. This morphological entity appears due to the complete regression of the longitudinal anastomosis, associated with non-regulation of the VSAs roots; the 10th primitive roots of the VSA it forms the LGA; the 11th it forms the SA; the 12th it forms the CHA [21, 22]. Based on Tandler's hypothesis, Morita, in 1935 (cited by [23]), shares the variational pattern of these VSAs, and suggested five types and 15 forms (five forms for CT and 10 for CMT).

In our case, with the presence of a HSMT in association with the distinct origin of the LGA from AA, corresponding to the Morita type II, the process of resorption/retention of VSAs roots and various portions of longitudinal anastomosis in this situation is represented by: persistence of the longitudinal anastomosis between the 11th VSA (that becomes SA), the 12th VSA (that becomes CHA) and the 13th VSA (that becomes SMA); regression of the 11th and 12th VSAs; persistence of the 13th VSA root, which will become the proximal part of the HSMT and that connects the HSMT to the anterior aspect of AA; persistence of the entire 10th VSA (that becomes LGA), with the origin in the AA; resorption of the upper portion of the longitudinal anastomosis between 10th and 11th VSAs.

Common trunk of RIPA and LIPA independently arising from LGA

By the peculiarities of the distribution territory, the inferior phrenic arteries (IPAs) can be assigned to each of the three metamerical arteries: anterior arch (visceral ach), because it contributes to the vascularization of the gastric fundus; lateral arch (genitourinary arch), because it contributes to the adrenal gland vascularization; posterior arch (vertebro-parietal arch), because they supply the diaphragmatic crura [20].

The IPAs develop in the meshwork of ventro-lateral vessels supplying the mesonephros of the embryo [24]. According with Miclaus *et al.* [25], two theories, that of Felix (1912) and that of Bremer (1915), seeks to explain the variants origins of the IPAs. Felix (1912) believes that an embryo with complete degeneration of the mesonephros (18 mm length) has nine lateral mesonephric arteries, divided into three groups: cranial (the 1st and 2nd arteries), middle (the 3rd to 5th arteries) and caudal (the 6th to 9th arteries) [6, 24]. On each side, the IPAs arise from the cranial group of mesonephric arteries. The independent evolution of the mesonephric arteries from the cranial group at the level of lateral aspect of AA leads to the appearance of the IPAs with aortic origin [25]. According to the theory of Bremer (1915) in the early development of the embryo in the suprarenal territory, the periaortic arterial plexus brings into communication the ventral, lateral and dorsal branches of the AA. Before it disappears, during the remodeling process, this periaortic arterial plexus can connect the IPAs with the CT or its branches [6, 25]. A small percent can connect to the right or left renal arteries (LRAs), aberrant suprarenal artery, contralateral IPA, spermatic artery and SMA [24].

In our case, with the presence of an IPAT, independently arising from LGA, according with the theory of Bremer (1915), the remodeling process of the periaortic arterial plexus connects the two IPAs to one another, with the formation of an IPAT; this it's connecting later with the LGA (arising from the anterior aspect of AA).

Accessory left hepatic artery

According to Douard *et al.* [20], the liver anlage has three distinct parts: a lateral right part (future right lateral division – segments VI and VII), a middle part (future right medial division – segments V and VIII and left medial division – segment IV) and a lateral left part (future left lateral division – segments II and III). Each of the three volumes of fetal liver parenchyma is served by a primary hepatic artery: embryonic RHA, arises from the omphalomesenteric artery (upcoming SMA); embryonic middle hepatic artery, arises from the CHA and represented by the hepatic artery proper (HAP); embryonic left hepatic artery (LHA), arising from the LGA. In the next development stages, these three embryonic hepatic arteries are connected at the level of the hepatic hilum by Tandler longitudinal anterior primitive anastomosis. While the elements of the embryonic middle artery develop, and take over the distribution territories of the other two embryonic hepatic arteries (right and left), the right and left embryonic hepatic arteries regress to lead to appearance of the typical hepatic arterial distribution after the eighth week of the embryo-fetal life [20, 26–28].

Different aspects of persistence (partial or complete) of the fetal pattern could result in anatomical variations of vascularization of the liver, with the appearance of aberrant liver arteries (replaced or accessory) [26, 27].

If the embryonic RHA does not regress completely, they are developed as replaced (RRHAs) or accessory (ARHAs) right hepatic arteries, usually arising from the SMA. In case of RRHA, the normal celiac right hepatic is missing while the RHA arises from another source, supplying the right part of the liver (segments V–VIII). In case of ARHA, an extra RHA is present in association with one part of the normal celiac RHA; in this situations, the ARHA serves the right lateral hepatic division (segments VI and VII), and the anterior branch of HAP (from common hepatic, from CT) serves the right medial hepatic division (segments V and VIII) [1, 29].

Also, if the embryonic LHAs does not completely regress, they are developed as RRHAs or ALHAs, usually arising from the LGA. In case of left branch of the right hepatic artery (LRHA), the normal celiac left hepatic is missing, while the LHA arises from another source, supplying the left part of the liver (segments II–IV). In case of ALHA, an extra LHA is present in association with one part of the normal celiac LHA; in this situation the ALHA serves the left lateral hepatic division (segments II and III), and the medial branch of HAP (from common hepatic, from CT) serves the left medial hepatic division (segment IV) [1, 29].

Reviewing literature, Liang *et al.* [30] describe the origin of ARHA and RRHA also from the level of: CT, LGA, SA, CHA, HAP, GDA, LHA, superior pancreatico-duodenal artery (SPDA), right phrenic artery (RPA), renal artery (RA), SMA, IMA, or directly from the AA. Migration of origin of the aberrant right renal arteries (ARHA and/or RRHA) from the primitive SMA level is achieved through the remodeling process of the periaortic arterial plexus (as in the case of IPAs).

In our case, with the presence of an ALHA arising from the LGA, the vascularization of the three liver anlage undergo complex changes of regression and remodeling; after connecting to the hepatic hilum of the three embryonic hepatic arteries, there is a significant development of embryonic middle hepatic artery; through the right branch, the embryonic middle hepatic artery (which will become HAP) will take over the vascularization of the right lateral division of the primitive hepatic parenchyma (segments VI and VII), concomitant with the regression and disappearance of the embryonic RHA (from the upcoming SMA).The persistence of the embryonic LHA (from the LGA), which serves the left lateral division of the primitive hepatic parenchyma (segments II and III), leads to the appearance of the ALHA; the persistence of this artery makes it the left branch of the HAP continue intraparenchymatously only with the medial branch, serving the left medial division of the liver (segment IV).

Anatomical variations and clinical implications

Reviewing anatomo-surgical literature, in 16 172 cases over 13 studies (Table 1) highlighted the CT prevalence in 89.321% of cases, the CMT in 0.445% of cases, CT absent as a morphological entity, with the separate origin of the LGA, CHA, SA and SMA from AA in 0.247% of cases and the HSMT in association with the independent origin of LGA from AA in 0.897% of cases (with variation between 0 and 1.73% of cases [36]). We found that the prevalence of the HSMT in association with the independent origin of LGA from AA was higher in studies conducted through radio-imagistic procedures than with anatomical dissection (0.829% and 0.068% of cases, respectively). The same aspect was highlighted for the other anatomical variations taken in the study. Clearly, radio-imaging examinations are more sensitive than those performed by anatomical dissection are. On this casuistry, there have not been explicitly highlighted situations in which from LGA to arises other arterial elements.

Table 1 – *Incidence of CT, CMT, absence of the CT as a morphological entity and HSMT in association with the independent origin of LGA from AA as reported in large case series, using anatomical dissection and radioimagistic procedures*

Author	Year	Method of examination	Number	CT [%]	CMT [%]	CHA + LGA + SA + SMA [%]	HSMT + LGA [%]	Other association [%]
Eaton [31]	1917	Anatomical dissection	206	90.8				9.2
Lipshutz [32]	1917	Anatomical dissection	83	73.5	2.4			24.1
Adachi [33]	1928	Anatomical dissection	252	86.7	2.38		**1.19**	9.83
Shoumura *et al.* [34]	1991	Anatomical dissection	450	90.6	1.1		**0.4**	7.9
Iezzi *et al.* [15]	2008	Radioimagistic procedures	524	72.14		0.57	**0.38**	26.91
Chen *et al.* [10]	2009	Anatomical dissection	974	89.83	0.72		**0.72**	8.73
Song *et al.* [16]	2010	Radioimagistic procedures	5002	89.1		1	**0.68**	9.22
Ugurel *et al.* [17]	2010	Radioimagistic procedures	100	89		1	**1**	9
Wang *et al.* [35]	2014	Radioimagistic procedures	1500	89.8	1.53	0.2	**1.73**	6.73
Osman & Abdrabou [36]	2016	Radioimagistic procedures	1000	90.5	0.6	1		7.9
Marco-Clement *et al.* [37]	2016	Anatomical dissection	43	86				14
Marco-Clement *et al.* [37]	2016	Radioimagistic procedures	596	90.8				9.2
Iacob [38]	2018	Radioimagistic procedures	5442	90.81	0.42	0.33	**0.13**	8.31
Total			16 172	89.321	0.445	0.247	**0.897**	9.09
Anatomical dissection			2008	11.044	0.124	0	**0.068**	2.01
Radioimagistic procedures			14 164	78.277	0.321	0.247	**0.829**	7.08

CT: Celiac trunk; CMT: Celiacomesenteric trunk; HSMT: Hepato-spleno-mesenteric trunk; LGA: Left gastric artery; AA: Abdominal aorta; CHA: Common hepatic artery; SA: Splenic artery; SMA: Superior mesenteric artery.

Some cases reports highlight the origin of other arteries from LGA associated with the presence of a HSMT. Hirai *et al.* [39] show one gastro-phrenic trunk with an external diameter of 3.4 mm at origin, and a length of 10.5 mm; this trunk it divided into the IPAT and the LGA. Matusz *et al.* [6] described a common stem origin of LGA, RIPA and LIPA with a length of 2.5 mm; from the distal end of this common stem arises the LGA, with an endoluminal diameter at origin of 2.8 mm; laterally (right and left) arose the RIPA and LIPA, with an endoluminal diameter at origin of 1 mm.

On 7058 cases over six studies, Matusz *et al.* [6] estimated the prevalence of the LGA originating directly from the AA is 5.32%. In this study, the authors highlight the origin of LGA from AA, with five branching pattern types of the CT and SMA: (*i*) absence of the CT (0.13% of cases); (*ii*) spleno-mesenteric trunk (SMT) in association with the independent origin of the CHA (0.13% of cases); (*iii*) HST in association with the independent origin of the SMA (4.34% of cases); (*iv*) hepatomesenteric trunk (HMT) in association with the independent origin of the SA (0.17%); (*v*) HSMT (0.67% of cases).

A comparative morphological analysis of the HSMT components reveals significant morphological differences between the cases reported in literature and its own case; cases described by Sridhar Varma *et al.* [2], Hemanth *et al.* [14], Matusz *et al.* [6] have the proximal component (HSMT) (14.2–20 mm) more developed than the distal one (HST) (10.3–15.8 mm) compared to its own case where the proximal component (HSMT) has a length of only 4 mm and the distal one (HSM) of 22.3 mm.

Analyzing the prevalence of IPAT origin at the level of major arterial sources on a total of 4306 cases from 12 studies (Table 2) highlighted the AA prevalence in 15.7% of cases, the CT in 12.43% of cases and LGA in 0.18% of cases.

Table 2 – *Incidence of variants in origin of IPAT as reported in large case series, using different methodologies*

Author	Year	Method of examination	Number	All IPAT [%]	AA IPAT [%]	CT IPAT [%]	LGA IPAT [%]	Other IPAT [%]
Adachi [33]	1928	Anatomical dissection	74	24.32 /18	14.86 / 11	8.11 / 6	**1.35 / 1**	
Pick & Anson [40]	1940	Anatomical dissection	200+4*	31.5 / 63	18.5 / 37	13 / 26		
Greig *et al.* [41]	1951	Anatomical dissection	425	18.08 / 132	10.4 / 77	7.26 / 52	**0.42 / 3**	
Kahn [42]	1967	Radioimagistic procedures	50	26 / 13	26 / 13			
Piao *et al.* [43]	1998	Anatomical dissection	68	8.42 / 10	5.06 / 6	3.36 / 4		
Loukas *et al.* [44]	2005	Anatomical dissection	300	42 / 34	31 / 22	11 / 12		
Basile *et al.* [45]	2008	Radioimagistic procedures	200	37 / 74	21 / 42	16 / 32		
Ozbűlbűl *et al.* [46]	2011	Radioimagistic procedures	92	36.96 / 34	17.39 / 16	19.57 / 18		
Gürses *et al.* [47]	2015	Anatomical dissection	26	34.61 / 9	15.38 / 4	19.23 / 5		
Aslaner *et al.* [19]	2017	Radioimagistic procedures	1000	29.5 / 295	16.4 / 164	12.6 / 126	**0.1 / 1**	0.4
Kara *et al.* [48]	2018	Radioimagistic procedures	1023	25.9 / 265	11.44 / 117	13.59 / 139	**0.29 / 3**	0.58
Bergman *et al.* [49]	2019	Anatomical dissection	848	33.3 / 282	19.7 / 167	13.6 / 115		
Total			**4306+4***	28.54 / 1229	15.7 / 676	12.43 / 535	**8 / 0.18**	0.23
Anatomical dissection			**1941+4***	12.73 / 548	7.53 / 324	5.11 / 220	0.09 / 4	0
Radioimagistic procedures			**2365**	15.81 / 681	8.17 / 352	7.32 / 315	0.09 / 4	0.23

*Double arteries of equal caliber on four left sides (Pick & Anson, 1940 [40]). AA: Abdominal aorta; CT: Celiac trunk; LGA: Left gastric artery; IPAT: Inferior phrenic artery trunk.

Transcatheter arterial chemoembolization (TACE) is a good alternative to hepatic surgery to treat the cases with unresectable hepatocellular carcinoma (HCC) [50]. HCC received numerous extrahepatic collateral vessels even under the conditions of a normal blood supply of the liver arteries [6].

In a study of 3179 patients with HCC, Kim *et al.* [50] have been highlighted 2104 extrahepatic collateral routes which will vascularize intraparenchymatous hepatic tumor, grouped into 13 vascular structures, which in the order of the frequencies of the vessels observed were: (*i*) RIPA; (*ii*) omental branch; (*iii*) suprarenal artery; (*iv*) intercostal and subcostal artery; (*v*) cystic artery; (*vi*) LIPA; (*vii*) right internal thoracic artery; (*viii*) renal or renal capsular artery; (*ix*) branch of SMA; (*x*) LGA; (*xi*) right gastric artery; (*xii*) left internal thoracic artery; (*xiii*) lumbar artery.

Both the origin level and the diameter and length of the arterial trunk in the IPAT are of great importance in the successful execution of chemoembolization procedures. The situation in which RIPA, LIPA or IPAT originated in AA represents a favorable situation for successful the arterial catheterization. The origin of these arteries at the level CT, LGA, and RAs are factors that can complicate the good execution of the chemoembolization process. Of the three types of IPAs, RIPA, LIPA and IPAT, the most unfavorable situation to achieve chemoembolization is IPAT. Matusz *et al.* [6] consider it a diameter of IPAs less than 1 mm is a disfavoring factor for chemoembolization.

In our case, with the presence of an IPAT arising from LGA originated independently from the AA, we highlighted four unfavorable factors for making TACE: (*i*) the independent origin of LHA on the anterior face of AA, which has an angle of 90°; (*ii*) origin of IPAT from the LGA cavity at 18.6 mm from its aortic origin; (*iii*) the IPAT trunk has a length of only 2.4 mm, achieving a 90° top face of the LGA; (*iv*) early bifurcation of LIPA (1 cm). The endoluminal diameters of LGA, IPAT, RIPA and LIPA are permissible for good TACE performance: 4.2 mm, 2.6 mm, 2.3 mm and 1.7 mm, respectively.

CHA from CT divides usually in the HAP, and GDA. PHA irrigates the liver by the gives right and left hepatic arteries in 52–79% of cases [26]. The anatomical variations of the hepatic arteries were described and classified in various anatomical and imagistic studies. An internationally recognized classification evaluated the main variations of the vascular system of the liver was elaborated by Michels in 1966 [29], following the analysis of 200 anatomical pieces, which allowed the description of 10 morphological types: (*i*) normal anatomy with HAP from the CHA and bifurcates into the RHA and LHA; (*ii*) replaced LHA from the LGA; (*iii*) RRHA from the SMA; (*iv*) co-existence of replaced LHA from the LGA and RRHA from the SMA; (*v*) ALHA from the LGA; (*vi*) ARHA from the SMA; (*vii*) ALHA from the LGA and ARHA from the SMA; (*viii*) RRHA from the SMA and ALHA from the LGA or, reverse of this, ARHA from the SMA with a replaced LHA from the LGA; (*ix*) CHA from the SMA; (*x*) CHA from the LGA. Studied the variations of extrahepatic arterial anatomy in 1000 donor livers, Hiatt *et al.* (1994) reduce the 10 types described by Michels and present six types: Type 1 – modal pattern, the CHA arose from the CT to form the GDA and HAP; the HAP divided distally into right and left branches; Type 2 – replaced LHA or ALHA originated from the LHA; Type 3 – RRHA or ARHA originated from the SMA; Type 4 – double-replaced pattern, the RHA arose from the SMA, and the LHA arose from the LGA; Type 5 – CHA originated from the SMA; Type 6 – CHA originated direct from the AA.

On 20 634 cases over 24 studies, we estimated the prevalence of the ALHA originated from LGA (Type V in Michels classification) (Table 3) of 3.25%, with a variation between 0.2% [15] and 10% [17]. The difference between prevalence of the ALHA and replaced LHA from LGA is very small namely of 3.25% and 3.14% of cases, respectively. On Michels' case [29], values and prevalence difference of the ALHA and replaced LHA from LGA was much larger (8% and 10% of cases, respectively).

Table 3 – *Incidence of hepatic artery variation according to Michels' classification as reported in large case series, using various procedures*

Michels Type			***I***	***II***	***III***	***IV***	***V***	***VI***	***VII***	***VIII***	***IX***	***X***	***Other****
Authors	**Year**	**Number**	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***	***[%]***
Michels [29]	1966	200	55	10	11	1	**8**	7	1	2	4.5	0.5	
Iezzi *et al.* [15]	2008	524	72.1	5.9	9.3	0	**0.2**	0	0	0	3.6	0	8.7
Ugurel *et al.* [17]	2010	100	52	11	17	1	**10**	1	1	1	2	0	4
Osman & Abdrabou [36]	2016	1285	72.4	3	12.5	0	**5.2**	1.1	0.6	1	2.3	0	0.1
Noussios *et al.** [51]	2017	18 810	81.56	2.96	3.77	0.87	**3.15**	1.64	0.2	0.35	1.3	0.03	4.17
Total	*Number*	**20 634**	16 624	648	923	166	671	335	47	81	298	6	835
	%	**100**	**80.57**	**3.14**	**4.47**	**0.81**	**3.25**	**1.62**	**0.23**	**0.39**	**1.44**	**0.03**	**4.05**

*Reviewing 20 studies in the literature; **"Not otherwise described" in the literature.

According with Shinohara *et al.* [52], in gastric cancer, the most frequently encountered lymph nodes metastases are placed around the LGA. During curative surgical procedure, the resection of all the elements of the lesser omentum, including *en bloc* dissection of the lymph nodes is associated with ligation and division of LGA at its origin. The case of the presence of an ALHA originated from LGA, the surgical procedure imposes ligation and division of the ALHA; this procedure requires immediate left hepatic lobectomy (segments II and III) or arterial reconstruction.

Apart from the ALHA originated in the LGA (which are the majority) in the literature, ALHA has been described as originating in: AA [53], CT [54, 55], CHA [53, 54], RHA [54], GDA [53, 54], SA [53].

In our case, from the LGA has its origin both ALHA and IPAT. In the case of surgical treatment of gastric cancer, ligation and division of LGA at its origin will affect major also the vascularization of the liver lateral left division (segment II and III), due to LGA's origin of ALHA, but also diaphragm vascularization due to IPAT origin in LGA. Left liver resection (segments II and III) or liver revascularization on the one hand, and aortic reimplantation of the IPAT, on the other hand are absolutely necessary.

Conclusions

The authors presented in this paper an extremely rare case in which the presence of a HSMT is associated with an ALHA and an IPAT of RIPA and LIPA originated from LGA arising independently from the AA, highlighted by MDCT angiography. All these vascular anatomical variations can be explained by considering the embryological development. Knowledge of the variations in the CT branches is important for anatomists, interventional radiologists, and surgeons. Knowledge of the anatomical variations in origin and distribution of IPAT and ALHA is important for planning and performing TACE.

Conflict of interests

The authors declare that they have no conflict of interests.

Authors' contribution

Laura-Andreea Bolintineanu and Adina-Nadia Costea contributed equally to this work.

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