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Hepatic arterial variations detected at multidetector computer tomography angiography in the Romanian population

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Background: *Our purpose was to determine the prevalence of normal hepatic vascularization and variations of the hepatic arteries using multidetector computed tomography (MDCT) angiography. These variants should be known before any surgery of the abdomen; however, there are not many studies on large groups of patients using high-specialized imaging.*

Materials and methods: *This study was carried out on 4192 patients. We performed MDCT angiography on each patient and had a specialized team observe the images.*

Results: *Using Michels' classification, the normal anatomy (type I) was present in 3392 (80.91%) cases, while abnormal hepatic arteries were observed in 800 (19.08%) cases. The variations were distributed as follows: type II in 40 (0.95%) cases, type III in 442 (10.54%) cases, type IV in 13 (0.31%) cases, type V in 285 (6.79%) cases, type VI in 12 (0.28%) cases, type VII in 3 (0.07%) cases, type VIII in 108 (2.57%) cases, type IX in 6 (0.14%) cases and type X in one case (0.02%). One hundred seventy (4.05%) unclassified cases were observed. Using Hiatt's classification, the variations were: type II in 325 (7.75%) cases, type III in 454 (10.83%) cases, type IV in 124 (2.95%) cases, type V in 6 cases (0.14%) and type VI in 69 (1.64%) cases. One hundred two (2.43%) unclassified cases were observed.*

Conclusions: *We observed well-known variations of the hepatic arterial pattern and also found a large number of rare, unclassified cases.* (Folia Morphol 2024; 83, 2: 354–359)

Keywords: hepatic patterns, anatomical variations, multidetector computed tomography angiography, aberrant artery

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INTRODUCTION

Comprehensive knowledge of the morphological variations of hepatic vascularization plays a very important role in hepatic transplantation, resection and tumour embolization. For the last decades, anatomists as well as radiologists and surgeons have tried to decide on a standardization of the normal anatomy of the abdominal aorta (AA), coeliac trunk (CT) and their variations. Standard hepatic arterial anatomy does occur in most cases (50–80%), but still, the remaining cases account for a higher percentage than it was believed in the past and these cases are sometimes overlooked [9].

A high number of complications, including vascular damage, can be avoided if we use specialized imaging before surgeries or liver donation. Because there are significant percentages of hepatic artery variations observed in different nationalities worldwide, we can safely say that the presurgical study and knowledge of these variations can give us useful information beforehand [14]. Three-dimensional imaging and multiplanar reconstruction may give us insight into standard anatomy and variants.

Haller was the first one to define and describe the CT and its branching pattern in the year 1756. Since then, this aspect has been considered standard anatomy and is commonly present within study lots with a prevalence that varies between 72.29% and 90.78% [8, 15]. Nowadays the most common classifications which are being used for the description of the CT and its variants are the ones reported by Morita [13] and Michels [12].

Morita proposed in 1935 five types of the CT: type I is normal coeliac trunk, type II is hepatogastric trunk, type III is gastrosplenic trunk, type IV is hepatogastric trunk, and type V is the absence of the coeliac trunk [13]. Michels defined the hepatic arterial patterns and their variations using 200 cadavers and identified 10 different types of hepatic arterial anatomy [14]. His classification [12] and subsequently the revised Hiatt classification [7] defined the anatomical variations of the hepatic arterial system.

Multidetector computer tomography (MDCT) angiography is an accurate paraclinical investigation which can be very reliable in detecting normal and abnormal hepatic anatomy. MDCT uses faster volume imaging of the entire liver and can deliver thinner slices in high spacial resolution [11].

Our main goal was to determine the standard and abnormal arterial pattern of the liver on a large sized study group using the gold-standard investigation, MDCT angiography. Additionally, we wanted to emphasize that some variations that were previously thought to be extremely rare are nowadays, with the help of the radiological investigations, more common and that there are still many variations yet to be defined and included in the classifications

MATERIALS AND METHODS

We have taken into consideration 4315 patients from Timisoara, Romania who were referred to undergo MDCT angiography for various symptomatology. The exclusion criteria applied were: tumours affecting the upper abdominal region, complete occlusion of CT and motion artifacts/suboptimal contrast images. One hundred twenty-two cases were excluded and, consequently, MDCT angiographies of a total number of 4192 patients were included in the study from August 2015 to December 2021. The patients were between 18 to 93 years old and belonged to the Romanian population. Ethical clearance was obtained from the Ethics Committee of "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania (protocol code 26/2019).

The device that has been used for the radiological investigation was the 64-row scanner MDCT Angiography machine. The MDCT radiological examination was performed with a tube voltage of 120 kVp and a reference tube current of 110 mAs. The scanning has been done in a craniocaudal direction, while the images were displayed in axial, coronal and sagittal planes with 5 mm-thick slices.

Angiography was performed by injecting 120 mL of iodinated contrast medium at the rate of 4 mL/s through an 18–20 Gauge cannula in an antecubital vein using a standard dual-head computer tomograph power injector, followed by a fixed saline chase of 50 mL at the same flow rate.

In this study, we used Multiplanar Reformation (MPR), Maximum Intensity Projection (MIP), Volume Rendering Techniques (VRT) and SSD (Shaded Surface Display) for visualization and post-process images of vascular components in the upper abdominal region. Beforehand, we performed reconstruction of the images at 0.625 mm.

We used Microsoft Office Excel 2007 in order to gather all of the cases, while for data correlation and distribution determination, we used IBM SPSS Statistics Version 29.

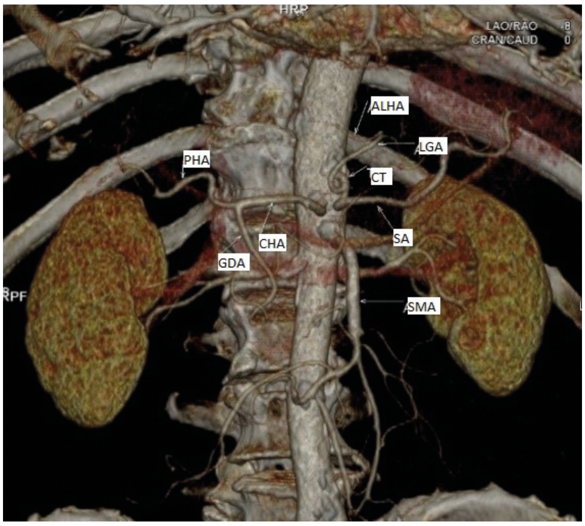

Figure 1. MDCT angiography, coronal view of AA and CT. MDCT angiography, anterior incidence. Male patient, 68 years old. Accessory left hepatic artery originating from the left gastric artery. SMA — superior mesenteric artery; SA — splenic artery; aLHA — accessory left hepatic artery; LGA — left gastric artery; CHA — common hepatic artery; CT — coeliac trunk; GDA — gastroduodenal artery; PHA — proper hepatic artery.

Table 1. Distribution by age of left aberrant hepatic arteries

Study group	Nr.	L min.	L Max.	AM	Me	SD	SE
Entire group	326	22	91	65.58	66	10.89	0.60
Male group	234	22	88	64.30	65	10.67	0.70
Female group	92	40	91	68.84	68	10.82	1.13

Nr. — number of subjects ; L min. — minimum limit; L max. — maximum limit; AM — arithmetic mean; Me — median; SD — standard deviation; SE — standard error.

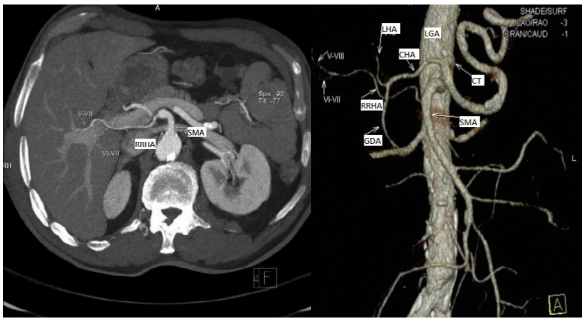

Figure 2. MDCT angiography. **A.** Axial view; **B.** Coronal view. Replaced right hepatic artery originating in the superior mesenteric artery. Female patient, 83 years old. RRHA — replaced right hepatic artery; SMA — superior mesenteric artery; LHA — left hepatic artery; LGA — left gastric artery; CHA — common hepatic artery; CT — coeliac trunk; GDA — gastroduodenal artery.

Table 2. Prevalence of the origin of right aberrant hepatic arteries

Aberrant hepatic artery/origin	Nr.	Percent [%]
aRHA	14	2.52
SMA	12	2.16
CT	2	0.36
RRHA	540	97.47
SMA	442	79.78
CT	55	9.92
AA	12	2.16
CHA	15	2.7
H-S TR	3	0.54
SMA + CT	2	0.36
LGA	1	0.18
SA	2	0.36
IPDA	3	0.54
LGA-SA-GDA TR	4	0.72
GDA-SA TR	1	0.14
TOTAL	554	100

ARHA — accessory right hepatic artery; SMA — superior mesenteric artery; CT — coeliac trunk; RRHA — replaced right hepatic artery; AA — abdominal aorta; CHA — common hepatic artery; LGA — left gastric artery; SA — splenic artery; IPDA — inferior pancreaticoduodenal artery.

RESULTS

Our study revealed a standard anatomical pattern of the hepatic arteries in 3392 (80.91%) of all cases. We observed 800 cases with variants of the hepatic arteries, out of which 724 cases showed variants of the left and right hepatic arteries and the remaining 76 cases presented replaced common hepatic arteries (RCHA).

We highlighted a number of 326 cases with aberrant left hepatic arteries (ALHAs), out of which a number of 286 (87.730%) cases presented ALHA and a number of 40 (12.270%) cases presented RLHA. The vast majority of the left aberrant hepatic arteries (99.69%) had their origin in LGA (Fig. 1), while one case of ALHA originated at AA level (0.307%). 314 cases (96.31%) were cases described by Michels in his classification. A percentage of 3.68% (12 cases) were new cases not classified by Michels. The study revealed a higher occurrence of left aberrant hepatic arteries in males (71.779%) than in females (28.221%). The mean age of this group was 65.58 years (Table 1).

In 554 cases we observed right aberrant hepatic arteries, 14 cases (2.527%) were ARHAs and a number of 540 (97.47%) were replaced right hepatic arteries (RRHAs). The majority of the right aberrant hepatic arteries (81.949%; 454/554 cases) had their origin in SMA (Fig. 2); the second source of origin was the CT (10.229%; 57/554 cases). Seven further levels of origin for RRHA were also highlighted (Table 2), accounting for 18.18% of cases. 449 cases (81.04%) fell within the types described by Michels, while 18.95% (105 cases) were new cases not classified by Michels.

Table 3. Distribution by age of right aberrant hepatic arteries

Study group	Nr.	L min.	L Max.	AM	Me	SD	SE
Group of right aberrant hepatic arteries	554	18	91	66.42	66	10.47	0.44
Male group	398	29	91	65.22	65	10.13	0.51
Female group	156	18	91	69.48	70.5	10.73	0.86

Nr. — number of subjects ; L min. — minimum limit; L max. — maximum limit; AM — arithmetic mean; Me — median; SD — standard deviation; SE — standard error.

Figure 3. MDCT Angiography. coronal view. RCHA originating from AA in association with RRHA originating from SA and a gastro-splenic Trunk. Male, 68 years old. RRHA — replaced right hepatic artery; SMA — superior mesenteric artery; LHA — left hepatic artery; CHA — common hepatic artery; GDA — gastroduodenal artery; SA — splenic artery; AA — abdominal aorta; GS trunk — gastro-splenic trunk.

The vast majority (71.841%, 398/554 cases) were males and 28.159% (156/554 cases) were females. The mean age of this group was 66.42 years (Table 3).

Out of the 800 total cases with hepatic arteries variants, we observed a group of 76 cases (9.5%) with RCHA.

The study of their origin revealed three distinct morphological types: (i) AA (90.78%) (Fig. 3); (ii) SMA (7.89%) and (iii) LGA(1.31%). Within the group, 71.05% of cases were male and 28.94% of cases were female. The average age of the group was 66.49 years (Table 4).

Of the 800 cases with variations of hepatic arteries, 124 cases (15.5%) involved the association of right and left aberrant hepatic arteries. The following types associations were observed: ARHA-RLHA, 3 cases (2.41%), ARHA-ALHA, 3 cases (2.41%), RRHA-ALHA, 105 cases (84.67%), RRHA-RLHA, 13 cases (10.48%).

Table 4. Distribution by age of cases with RCHA in the total group, in the male group and in the female group

Study group	Nr.	L min.	L Max.	AM	Me	SD	SE
Group with RCHA	76	19	93	66.49	67.5	12.08	1.39
Male cases	54	19	86	64.91	65.0	12.23	1.66
Female cases	22	40	93	70.36	72.5	11.03	2.35

Nr. — number of subjects ; L min. — minimum limit; L max. — maximum limit; AM — arithmetic mean; Me — median; SD — standard deviation; SE — standard error.

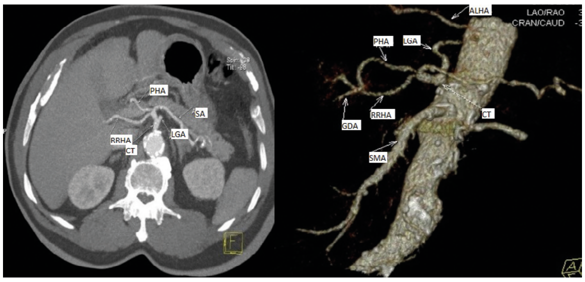

Figure 4. MDCT angiography. (1) axial view. (2) coronal view. Association of accessory left hepatic artery and replaced right hepatic artery. Male patient, 77 years old. RRHA — replaced right hepatic artery; SMA — superior mesenteric artery; SA — splenic artery; PHA — proper hepatic artery; LGA — left gastric artery; CHA — common hepatic artery; CT — coeliac trunk; GDA — gastroduodenal artery; aLHA — accessory left hepatic artery.

According to Michels' classification, normal hepatic vascularization (type I) was present in 80.91% of cases, while variants of the hepatic arterial patterns were observed in the remaining 19.08% of cases. The variations were distributed as it follows: type II was observed in 40 cases (0.95%), type III in 442 cases (10.54%), type IV in 13 cases (0.31%), type V in 285 cases (6.79%), type VI in 12 cases (0.28%), type VII in 3 cases (0.07%), type VIII in 108 cases (2.57%), type IX in 6 cases (0.14%) and, lastly, type X in 1 case (0.02%). We also found other variants of unclassified cases in our study. Following Hiat's classification, the variants were distributed as it follows: type II was observed in 325 cases (7.75%), type III in 454 cases (10.83%), type IV in 124 cases (2.95%), type V in 6 cases (0.14%), type VI in 69 cases (1.64%). We also found several other unclassified cases.

DISCUSSION

Taking into consideration studies on hepatic anatomy using angiographic imaging, we can discuss differences and similarities between our study and other studies from the specialized literature. A comparative analysis of Michels' study [12], Fonseca-Neto [5], Gümüs [6], and Coco [4] revealed the highest prevalence out of the aberrant hepatic arteries of the right replaced hepatic artery, with a variation range of the prevalence of RRHA from the total cases of hepatic arteries studied between 5.63–15%. Thangarajah [18] discovered type V of Michels' classification, the presence of left accessory hepatic artery, as the most common abnormality (8.5% of all cases), followed by Type III (8%) and Type II (6%). In the study of Choi, ARHAs and ALHAs were highlighted in 15.63% and 16.32% of the patients, respectively. Both an ARHA and an ALHA were found in 4.53% of patients [3]. Chen highlighted 0.7% of cases with Michels type IV [2], as well as Zaki [20], Koops [9] and the well-known study of Michels (each one 1%) [12].

Types VII, VIII, IX and X are rarely described in the specialized literature, whereas in our study type VIII of Michels classification showed a higher percentage than usual, accounting for 108 cases (2.57%). Compared to studies found in the literature discussing the association of left and right aberrant hepatic arteries, the present study found the association of RRHA--ALHA as the most common association between two aberrant hepatic arteries (type VIII Michels). Michels reported a higher percentage of type VII (2%) [12].

Zimmitti et al. [21] emphasized the presence of RCHA with a variation range between 0.4–4.5%. Sureka et al. reported this origin in 0.33% of cases [17], Zaki et al. in 0.4% [20] and Chen et al. in 0.5% of cases [2]. Yang observed 2.34% of cases presented RCHA originating from SMA [19].

Song found [16] 183 patients with RCHAs with the following site of origin: (1) LGA (0.16%), (2) SMA (3%), and (3) AA (0.4%).

Thangarajah et al. [18] found 3 cases of RCHA with origin in SMA (1.5%), and one case originating from LGA (0.5%). According to Hiatt [7], 1.5% showed RCHA with an origin at SMA level, while 0.2% of cases showed RCHA with origin in the abdominal aorta. In Hiatt's classification type III was the most common out of the hepatic arterial variants and was present in 10.6% of cases, while the second most common variation was type II with a percentage of 9.7% of cases. Malviya et al. [10] found 3.64% cases with type III according to Hiatt, after which type II was found in 1.82% of cases.

Compared to some studies that used MDCT angiography, cadaveric studies could show higher rates of these hepatic artery variations because in radiological investigations, the usage of contrast agents may lead to insufficiency of opacification in extremely thin vessels [1].

The main strengths of this study are, undoubtedly, the large scale study group, as well as our findings: 4.05% of cases were new variants, not mentioned by Michels and 2.43% of cases not mentioned in Hiatt's classification. In addition to that, we observed type VII, VII, IX, X by Michels' classification, which are rare variants described in the specialized literature. Taking into account all associations between variants of left and right hepatic arteries, our study surprisingly provided a very large number of RRHA-ALHA and ARHA-RLHA, unlike many others above mentioned large studies.

CONCLUSIONS

This study offers an overview of the variations of hepatic arteries present in the Romanian population. Our results shows know hepatic arterial variations, but also highlights the presence of unclassified variants of the hepatic arteries.

ARTICLE INFORMATION AND DECLARATIONS

Conflict of interest: The authors have no conflict of interest to disclose.

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