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PhD THESIS

**MORPHOLOGICAL VARIABILITY OF ABERRANT HEPATIC
ARTERIES (REPLACED AND ACCESSORY) STUDIED USING
MDCT ANGIOGRAPHY**

– A B S T R A C T –

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Knowledge of morphological parameters of aberrant hepatic arteries has always played an important role in hepatic transplantation, resection, tumour embolisation and in extrahepatic abdominal surgeries involving the main organs, such as the stomach, pancreas or gall bladder. Even in the case of interventional radiology, preprocedural computer tomography evaluation of the celiac axis and hepatic arterial anatomy can help one perform and interpret different types of variations. Considering that the entire medical community has made important steps towards digitalizing technical support and imaging, even the surgical procedures, it is of great importance to help prevent any complications during surgery, in order to avoid physical or financial damage.

This thesis entitled 'Morphological variability of aberrant hepatic arteries (replaced and accessory) studied using MDCT angiography' is a morphological, observational, comparative and retrospective study that is extended on a large period of time, 6 years and 5 months (from 01.08.2015 to 31.12.2021) in a highly-specialized medical imaging centre ('Neuromed' Timisoara) using 64-slice MDCT angiography (SOMATOM Sensation, Siemens Medical Solutions, Forchheim, Germany).

From a total of 4315 consecutive adult patients which were considered at the beginning of the study, after taking into consideration the exclusion criteria, we remained in the present study with a number of 4192 cases who underwent 64-slice MDCT angiography. Out of these cases we discovered a number of 800 patients who presented variations of aberrant hepatic arteries and included them in this study. We found 326 cases with left aberrant hepatic arteries (ALHA and RLHA), 554 cases with right aberrant hepatic arteries (ARHA and RRHA), 124 cases with the association of a left aberrant hepatic artery with a right aberrant hepatic artery and 76 cases with replaced common hepatic artery (anatomic variation in the absence of the common hepatic artery originating from the celiac trunk). We used the MDCT angiographic examination for each of the case, which required a thorough anamnesis of the patients to exclude any previous allergic reaction and to acknowledge the history of the patient, as well as the collection of blood for paraclinical investigations.

Each patient was monitored during the imaging procedure and then the images were analyzed and reconstructed by a radiologist and an anatomist. Imaging determinations were assigned to the lots described above according to morphometric and morphological parameters.

The main purpose of this thesis is the evaluation of morphology data (origin, trajectory and distribution) and morphometrics of aberrant hepatic arteries, left and right, replaced or accessory. The objectives of the study were to obtain data and develop a systematic review regarding replaced hepatic arteries and accessory hepatic arteries with the help of their morphological parameters obtained during MDCT imaging. We discovered a number of 800 cases with aberrant hepatic arteries (replaced and accessory) and we subcategorized them in

left aberrant hepatic arteries, right aberrant hepatic arteries, the association of left aberrant hepatic arteries and right aberrant hepatic arteries and replaced common hepatic arteries .

We were able to categorize these 800 cases into 4 study lots in order to better understand the parameters above mentioned:

- The first lot consisting of 200 patients (100 female and 100 male) on which we determined the morphological standard of the celiac trunk and we analyzed the morphological parameters
- The second lot on which we performed the analysis of vascular micrometry and morphometry, as well as the analysis and description of the morphological variability of the left aberrant hepatic arteries (accessory and/or replaced) - 326 cases (from the total of 800 cases with aberrant hepatic arteries) which were studied with the help of MDCT angiography on a series of 4315 cases during a long period of time, 6 years and 5 months (from 01.08.2015 to 31.12.2021)
- The third lot on which we analyzed vascular micrometry and morphometry, as well as described the morphological variability of the right aberrant hepatic arteries (accessory and/or replaced) - 554 cases (from the total of 800 cases with aberrant hepatic arteries) which were studied with the help of MDCT angiography on a series of 4315 cases during a long period of time, 6 years and 5 months (from 01.08.2015 to 31.12.2021)
- The fourth lot-we performed the analysis of vasculare micrometry and morphometrics of replaced hepatic common hepatic arteries (described as the origin of common hepatic artery trunk being situated outside of the classical anatomical composition of celiac trunk) on a number of 76 cases.

During this study we analyzed the following parameters: sex and age, the prevalence of morphological subtypes of aberrant hepatic arteries in each one of the study lots, the association of other vascular abnormalities in the study groups, the association of different subtypes of aberrant hepatic arteries, endoluminal diametre at the origin of the arteries studied, the distance between the origin of aberrant hepatic arteries and the origin of source arterial trunk, the length of aberrant hepatic arteries, the hepatic parenchyma vascularization, as well as the association between aberrant hepatic arteries and celiac trunk abnormalities found in these cases.

Analyzing the first lot, the control group, our purpose was to obtain a morphological standard of the celiac trunk and for that we analyzed the morphological parameters of 200 cases (100 male cases and 100 female cases), patients without a surgical history at the level of the supramesocolic floor of the abdominal cavity. A percentage of 75.50% out of the total cases

have presented bifurcated celiac trunk, while a percentage of 24.50% of the total cases have presented trifurcated celiac trunk. The vertebral level of CT at its origin in relation to the vertebral and discal elements have shown that in the male study group the highest percentage was 32%, while in the female control group most of the cases had the level of origin of the celiac trunk set at the superior third of L1 vertebra, with a percentage of 30%. The diameter at the origin of the celiac trunk for the entire control group had a mean value of 0.70 cm and the length of the celiac trunk for the entire control group varies between 0.64 cm and 4.03 cm, with a mean value of 2.15 cm. In terms of the localization and relation of proper hepatic artery we have found two types of trajectories: (i) proper hepatic artery anterior to the main portal vein (P-P) and (ii) proper hepatic artery posterior to the main portal vein (S-P).

The second lot is composed of the patients that were discovered with left aberrant hepatic arteries (RLHA and ALHA) on which we analyzed the parameters previously mentioned. Out of the 800 cases we have studied, we found 326 cases with one (or both) of the two types of left aberrant hepatic arteries. We separated the cases in four groups depending on their association with other variants of aberrant arteries: one group of left aberrant hepatic arteries (ALHA and RLHA) not associated with the presence of other hepatic vascular variations (57,362%); one group of double aberrant hepatic arteries (37,116%), one group of left aberrant hepatic arteries (ALHA and RLHA) associated with a replaced common hepatic artery (4,602%) and one group of double aberrant hepatic arteries associated with replaced common hepatic artery (0.920%). Discussing age and sex, a percentage of 71,779% were male and 28,221% were female, while the mean age of the group with cases of left aberrant hepatic arteries was 65.58 years. Throughout the entire study material we highlighted a number of 326 cases with left aberrant hepatic arteries, of which a number of 286 (87,730%) presented ALHA and a number of 40 (12,270%) presented RLHA. Considering the aspect of the celiac trunk, the vast majority of cases with left aberrant hepatic arteries have a bifurcated CT (59,815%) or a trifurcated CT (23,393%), while the remaining 16.792% were other types of anatomical variations of the CT.

Most of the left aberrant hepatic arteries (99,693%) originated in LGA; only one case of ALHA originated in AA (0.307%) while all RLHAs originated in the LGA. The next parameter taken into consideration is the endoluminal diameter at the origin of left aberrant hepatic arteries, where we analyzed the values of the endoluminal diameter of the left aberrant hepatic arteries, in general on the 326 cases studied, and secondly, separately on ALHA and RLHA. In the whole group of left aberrant hepatic arteries, the average value of the endoluminal diameter at the origin was 0.26 cm, while for ALHA, the mean endoluminal diameter at the origin was 0.24 cm and for RLHA, the mean endoluminal diameter at the origin was 0.34 cm.

The 326 cases serve the hepatic segments II, III and IV in which case we can identify five types of associations: (i) segment II, (ii) segment III, (iii) segment II and IV, (iv) segments II-III, (v) segments II-III-IV.

Another parameter we analyzed was the endoluminal diameter at the origin of the left aberrant hepatic arteries, depending on their association with the right aberrant hepatic arteries. If the ALHAs were not associated with right aberrant hepatic arteries, the endoluminal diameter at the origin is 0.25 cm and in the case of an association between ALHA and right aberrant hepatic arteries the endoluminal diameter at the origin is 0,23 cm. Taking into consideration the same association, if the RLHAs were not associated with any vascular anomalies the endoluminal diameter at its origin had a mean diameter of 0.35 cm and if the RLHAs were associated with right hepatic aberrant arteries the endoluminal diameter at its origin had a mean value of 0.35 cm. Discussing the distance between the origin of the left aberrant hepatic arteries and the origin of the source arterial trunk, in the entire control group this distance had a mean value of 4.24 cm, while for ALHA it was 4.17 cm and for RLHA it was 4.79 cm. We found that the mean values of the distance between the origin of the left aberrant hepatic arteries and the origin of the source arterial trunk is the smallest (2.40 cm) if the artery supplying the third hepatic segment comes only from the left aberrant hepatic artery.

Within the group of left aberrant arteries a percentage of 96,319% fell within the classic types of aberrant hepatic artery variations described by Michels (types II, IV, V, VI, VII, VIIla and VIIlb). The remaining percentage of 3,681% were new cases not classified by Michels.

The next study lot included in the thesis was the one with 554 cases of right aberrant hepatic arteries (RRHA and ARHA), characterized by the origin of the right aberrant hepatic artery most commonly in the trunk of the SMA. Within this group a percentage of 71,841% were male cases and 28,159% were female cases. The mean age of the group with cases of right aberrant hepatic arteries was 66.42 years. Out of the 554 cases a number of 14 (2,527%) were ARHAs and a number of 540 (97,473%) were RRHAs. The vast majority of cases with right aberrant hepatic arteries have the CT with a bifurcation aspect (71,300%) or a trifurcation aspect (16,245%). A number of ten other types of anatomical variations of CT and SMA were also highlighted, which totaled 12,455% of cases.

In terms of the origin of right aberrant hepatic arteries, most of them (81,949%) originated in SMA; the second source of origin is the CT (10,229%). We also identified 9 other arterial sources for RRHA, which represent a percentage of 7.822% of the group of right aberrant hepatic arteries.

The next parameter which we analyzed was the endoluminal diameter of the right arteries at their origin. In the whole group of right aberrant hepatic arteries, the mean value of

the endoluminal diameter at their origin was 0.33 cm, for ARHA the mean endoluminal diameter was 0.30 cm and for RRHA the mean endoluminal diameter was 0.33 cm.

The 554 cases serve the hepatic segments V-VIII and help us describe five types of associations: (i) segment V, (ii) segments VI-VII, (iii) segments V-VI-VII, (iv) segments VI-VII-VIII, (v) segments V-VIII, the first four for ARHA, and the last for RRHA.

In the whole group of cases, the average value of the distance between the origin of the right aberrant hepatic arteries (ARHA and RRHA) and the origin of the source arterial trunk was 2,620 cm; meanwhile for ARHAs, the average value of this distance was 2,250 cm and for the group of cases with RRHA, the mean endoluminal diameter was 2.57 cm.

For the analysis of the relation between the trunk of the right aberrant hepatic arteries (ARHA and RRHA) we used the classification proposed by Iacob (in 2018), who separated them into five types, in which the right aberrant hepatic artery is placed in relation with the pancreatic parenchyma according to the following:

- type I - postero-lateral to the head of the pancreas (79.422% of the cases).
- type II - intrapancreatic (3,610% of the cases),
- type III - in the fossa of the superior mesenteric vein (9,567% of the cases),
- type IV - superior to pancreas and posterior to hepatic portal vein (6,498% of the cases),
- type V - supero-lateral to the head of the pancreas and posterior to the hepatic portal vein (0.903% of the cases).

Within this group a percentage of 81,047% fell within the classic types of variations of aberrant hepatic arteries described by Michels (types III, IV, VI, VII, VIIla and VIIlb) and 18,953% were new cases not classified by Michels.

Out of the entire study lot, 124 cases involved the association of right and left aberrant hepatic arteries (accessory and replaced) on which we studied the same parameters as for the study lots number 2 and 3. The 124 cases were separated in two other groups: (i) right and left aberrant hepatic arteries (accessory and replaced) not associated with the presence of other hepatic vascular variations (16,713%); (ii) double aberrant hepatic arteries) associated with replaced common hepatic arteries (originating outside the CT components) (17,647%). Overall, 4 types of right / left aberrant hepatic arterial associations were highlighted: (i) ARHA - RLHA-2,419%; (ii) ARHA - ALHA-2,419%; RRHA - ALHA- 84,678% and lastly RRHA - RLHA-10,484%.

Within the group of cases with the association of right and left aberrant hepatic arteries a percentage of 71.7979% were male and 28.222% female. The mean age of the group with cases of right and left aberrant hepatic arteries was 65.82 years. The vast majority of cases with

the association of right and left aberrant hepatic arteries have bifurcated CT (60,484%) and trifurcated appearance (16,936%). A number of other seven types of anatomical variations of CT and SMA were also highlighted, which amounted to 22,580% of cases.

Considering the segmental distribution of right and left aberrant hepatic arteries, in the group of right aberrant hepatic arteries a percentage of 4,839% belongs to ARHA and 95,161% belongs to the RRHA group. Most ARHAs are distributed through segmental branches, to hepatic segments VI and VII (right lateral division of the liver). RRHAs are distributed entirely to the hepatic segments V-VIII (medial and right lateral divisions). In the group of left aberrant hepatic arteries a percentage of 87,097% belongs to ALHA and 12,903% belongs to the RLHA group. The majority of ALHA (64,527%) are distributed through segmental branches, to hepatic segments II and III (left lateral division). RLHAs are distributed entirely to the hepatic segments II-III-IV (left lateral and medial divisions). The analysis of the association of the right and left aberrant hepatic arteries highlights 8 morphological aspects that supply the hepatic parenchyma. The most frequent association (67,711%) is represented by the presence of six segments (II, III, V, VI, VII, VIII), a situation in which only segment IV is served by arterial elements of the celiac axis.

Taking into consideration Michels classification, within this group a percentage of 89,516% fell within the classic types of variations of aberrant hepatic arteries described by Michels (types IV, VII, VIIla and VIIlb). A percentage of 10,484% (13/124 cases) were new cases not classified by Michels.

The last study lot, the patients with replaced common hepatic arteries, was formed by 76 cases. Within this group 71.052% were male and 28.948% were female. The average age of the group with cases of replaced CHA was 66.49 years, meanwhile the level of origin of the replaced CHA in the 76 cases revealed three distinct morphological types. In order of frequency, the origin of the replaced CHA was highlighted at the level of: (i) AA; (ii) SMA and (iii) LGA. In terms of the aspects of morphological variability of the celiac trunk and the superior mesenteric artery, we analyzed the presence of the replaced common hepatic arteries and the aspects previously mentioned. A number of 6 variational aspects were highlighted, which in descending order of frequency were: (I) - gastro-splenic trunk associated with the independent origin of replaced CHA from AA (68.420% of cases), (II) - CT absent as a morphological entity, with the independent origin of CHA, LGA and SA from AA (26.316% of cases), (III) - gastro-splenic-mesenteric trunk with independent origin of CHA in AA (1.316% of cases), (IV) - common trunk formed by LGA - GDA - SA, associated with the independent origin of replaced CHA from AA (1.316% of cases), (V) - gastro-phreno-splenic trunk associated with the independent origin of SMA from which originated the replaced CHA, with the presence of a complete inversus site

(1.316% of cases) and (VI) - gastro-splenic trunk associated with the origin of replaced CHA from LGA (1.316% of cases).

In the group with replaced CHA, we identified two distinct subgroups depending on the presence or absence of other morphological variations of the hepatic arteries. The first subgroup is represented by a number of 44 patients (replaced common hepatic arteries without the association of other aberrant hepatic arteries), in which five distinct types of associated vascular anatomical variations were highlighted. The second subgroup is represented by 32 cases (replaced common hepatic artery in association with other aberrant hepatic arteries (accessory or replaced, right or left), in which two distinct types of associated vascular anatomical variations were highlighted.

The second subgroup included cases with CHA and other forms of aberrant hepatic arteries: (i) RRHA; (ii) RRHA associated with ALHA; (iii) ALHA; (iv) RLHA. The 14 cases with RRHA originated in: CHA (in 50% of cases with RRHAs associated with replaced CHA); SMA (42.857% of cases with RRHAs associated with replaced CHA); SA (7.143% of cases with RRHA associated with replaced CHA). These 14 cases of RRHA were associated with the presence of 10 cases with gastro-splenic trunk (71.429%) and 4 cases of CT absent as a morphological entity (28.571%). The 3 cases of RRHA in association with ALHA originated in: SMA (in 66.677% of the cases with RRHA and ALHA associated with replaced CHA); CHA (33.333% of cases with RRHA and ALHA associated with replaced CHA). These 3 cases of RRHA and ALHA were associated with the presence of 3 cases with gastro-splenic trunk (100%). The 13 cases of ALHA originated in LGA (100% of cases). These 13 cases of ALHA were associated with the presence of 12 cases with gastro-splenic trunk (92.307%) and in one case with the presence of a CT absent as a morphological entity (with independent AA origin of: LGA, CHA and SA) (7.693%). The 2 cases of RLHA originated in LGA (100% of cases). These 2 cases of RLHA were associated with the presence of one case with gastro-splenic trunk (50%) and in one case with the presence of a CT absent as a morphological entity (with independent AA origin of: LGA, CHA and SA) (50%).

Considering segmental distribution of aberrant hepatic arteries associated with replaced common hepatic arteries, in all cases of RRHAs from the second subgroup the terminal portion of the artery is distributed to the right medial division and the right lateral division of the liver parenchyma - segments V - VIII. The 3 cases that present the association of RRHA with ALHA will distribute their terminal parts to the right medial, right lateral and left lateral divisions of the hepatic parenchyma - segments V - VIII and II - III. In 10 of the 13 cases with ALHA the terminal portion of the aberrant artery serves the left lateral division of the liver parenchyma - segments II - III. In 3 of the 13 cases with ALHA the terminal portion of the aberrant artery serves only the posterior half of the left lateral division of the hepatic perenchyma - segment II.

The trajectory of the replaced CHA trunk, between the aortic origin and the hepatic pedicle portion of HPV is variable and depends primarily on the level of origin of the replaced CHA and the type of morphological variability associated with replaced CHA. We analyzed the relationships of the trajectory of replaced CHA based on three morphological parameters: (i) the relationships with the pancreatic parenchyma; (ii) the level of the vascular trajectory according to the pancreatic parenchyma; (iii) the relationships with the HPV and SMV path. In the group of 76 cases of replaced CHA, the vast majority-97.37%-had extrapancreatic trajectory and only 2.63% had a transpancreatic trajectory. Within the group of cases with extrapancreatic trajectory, the analysis of the relations of the replaced CHA trunk with the pancreatic parenchyma highlights 3 morphological types of relations: (i) trajectory superior to the pancreatic parenchyma in 75.68% of cases, (ii) trajectory inferior to the pancreas parenchyma in 12.97% of cases, (iii) semicircular trajectory inferior to the pancreatic parenchyma (1.35%) in a case of total situs inversus. The discussion of the relations of the replaced CHA trajectory with the HPV and SMV trajectory leads to the description of 2 subtypes for each of the first two morphological types in the cases of replaced CHA with extrapancreatic pathway. Within the group of cases with transpancreatic trajectory (type IV), the analysis of the relationships of the replaced CHA trunk with the pancreatic parenchyma reveals 2 morphological subtypes of relationships according to the existing relations with: (i) the confluence of SMV with HPV (subtype IVa); (ii) SMV trunk (subtype IVb).

The discussions of this study refer to the following: (i) morphological parameters of left and right aberrant hepatic arteries (accessory and replaced) and replaced common hepatic artery, (ii) morphological variations of left and right aberrant hepatic arteries (accessory and replaced) and replaced common hepatic artery. By comparing our results and other data obtained in the last few years regarding aberrant hepatic arteries, we found important information regarding similarities between different countries in the world and between different types of investigations. Michels' classification and subsequently the revised Hiatt classification are most often used in the literature, but they also have their limitations. For this reason, it is particularly important to describe optimal criteria for the definition of aberrant hepatic arteries, taking into account both their origin and the anatomical pathway. Michels classified for the first time in 1955 the theoretical possibilities for presenting the varied typologies of hepatic arteries (common, right, left). Hiatt, relying on this first classification, further described a new variability of liver arteries. At the moment, medical researchers who are studying the vascularization at the abdominal level use these two classifications to describe standard or ambiguous morphologies.

This first factor included in the thesis represents the number of cases with left aberrant hepatic arteries (accessory and replaced) present, being characterized by the origin of the left

aberrant hepatic artery trunk at the level of the LGA trunk (with only one case having other origin). At the same time, the right aberrant hepatic arteries were taken into account in this study, most often originating in the SMA trunk. In this study, which was carried out on a number of 800 cases using MDCT angiography, 326 patients presented left aberrant hepatic arteries (RLHA and ALHA), and 554 were represented by right aberrant hepatic arteries (RRHA and ARHA). Covey et al. discovered on a number of 600 cases that 61.3% of the total had standard hepatic vascularization, 19.8% of the total presented left aberrant hepatic arteries and 14.8% of total presented right aberrant hepatic arteries; Michel's study found RLHA present in 7.5% of cases, RRHA in 10% of cases, ALHA in 10% of cases and ARHA in 5% of cases. According to Hiatt et al, out of a series of 1000 patients studied, 75.7% showed normal hepatic vascularization, while the remaining 24.3% showed anatomical variations. A few other studies were taken into consideration to study the differences and similarities between this study and them.

Comparing endoluminal diameter of aberrant hepatic arteries at their origin with results from other studies, although the methods of investigation were different, our study exposed almost the same mean value of endoluminal diameters. Iacob described the origin diameter of aberrant hepatic arteries in a specialized study on 500 cases. In the case of patients presenting left replaced hepatic arteries, the average diameter at the origin was 0.34 cm and in patients with left accessory hepatic arteries the endoluminal diameter at origin was 0.26 cm. In patients with right replaced hepatic arteries, the mean origin diameter was 0.34 cm and in patients with right accessory hepatic arteries, the endoluminal diameter of the origin had a mean value of 0.32 cm. Thus, similarities may be observed in terms of the endoluminal origin diameter of aberrant hepatic arteries in the present study compared to other data in the literature.

Discussing the origin of left and right aberrant hepatic arteries, in this study, 99.693% of the left accessory hepatic arteries originated in the left gastric artery and only one case was presented originating in the abdominal aorta. All 40 cases of replaced left hepatic arteries originated in the left gastric artery. By comparison with Zaki's study, it can be said that studying only the left aberrant hepatic arteries, most will originate in the left gastric artery. Out of the right aberrant hepatic arteries, most originate in the superior mesenteric artery (81.949%), the second source of origin being the celiac trunk (10.229%), the residual percentage of 7.82% being represented by the 9 sources of the arterial trunk for RRHA, of which 12 cases (2.16%) have their origin in the abdominal aorta.

The standard anatomy of hepatic vessels was initially described by Couinaud, dividing the hepatic parenchyma in the VIII segments to which the liver arteries branches are distributed. This standard of anatomy is also used nowadays. The knowledge of the variability of hepatic arteries and the presence of aberrant hepatic arteries is essential for planning surgical

interventions such as liver transplantation. Iacob discussed the distribution of aberrant hepatic arteries in the hepatic parenchyma and from the total of 400 right aberrant hepatic arteries and 188 left aberrant hepatic arteries they were distributed to the hepatic lobes as it follows: RRHA served in 100% cases the V-VIII segments, and ARHA vascularized segments VI-VII in 4 cases, segment V in 3 cases, segments V and VIII in 3 cases and segments VI, VII and VIII in 2 cases. Regarding the left aberrant hepatic arteries, RLHA vascularizes constantly in all cases segments II-IV (left hepatic parenchyma), and ALHA is distributed to segments II-III in 135 cases and to segment II in 20 cases. The current study analyzed 124 cases out of the total of 800 cases that presented the association of right and left aberrant hepatic arteries and observed their distribution in the liver segments. From the group of right aberrant hepatic arteries, the vast majority is represented by RRHA, and all these are distributed to liver segments V-VIII. In the case of ARHA, the vast majority serve the right lateral division of the liver (VI-VII segments), and in one case it is distributed through the branches of segments V, V-VII and VIII, respectively. From the group of left aberrant hepatic arteries, ALHA is being distributed through segmentary branches as it follows: 80 cases serve the hepatic segments II-III, 27 cases serve the liver segment II, and a single case serves the hepatic segment III. In the cases with RLHA, they are all supplying the hepatic segments II-III-IV. The analysis of the previously mentioned studies, including the present one, led to the conclusion that in the literature research describing hepatic vascularization of aberrant hepatic arteries is quite limited. But we can say, however, that the general variation range of parenchymal distribution is not very broad, and, in general, aberrant hepatic arteries, with few exceptions, lead to the constant vascularization of the same liver segments. Comparing the variability of the morphological aspect of CT (bifurcated or trifurcated) with Iacob's study, it turns out that the retrospective percentages are similar.

Variations of the celiac trunk are widely analyzed and discussed in different countries and were also taken into consideration in this study. We used Song's study which has been done on a very large group of patients as the point of reference and compared it to our results and other from the literature. The most common variation is described in his study by the hepato-splenic trunk (4.42% of the total cases). In the present study, on a group represented only by aberrant hepatic arteries, the hepato-splenic trunk was represented in a percentage of 5.828% in combination with left aberrant hepatic arteries and 4.33% in combination with right aberrant hepatic arteries. The following variation in terms of frequency in Song's study is represented by the hepato-mesenteric trunk and the gastro-splenic trunk with the presence of a percentage of 2.64%. In the study of Iacob, this variation is represented by 2.02% of cases. In the present study, this type is present in 2.146% of cases with associated left aberrant hepatic arteries and 0.180% of cases with right aberrant hepatic arteries, a percentage quite different from their usual prevalence in the groups studied in the specialized literature.

The third in frequency in the Song classification, with a percentage of 1.06% is the celiaco-mesenteric trunk. Guglielmo describes its presence between 0-2.41%, Sureka found it in 0.66% of cases and Iacob in 0.42% of cases. In this study, the celiaco-mesenteric trunk was found in 0.307% of cases associated with left aberrant hepatic arteries and in 0.903% of cases associated with right aberrant hepatic arteries.

The hepato-spleno-mesenteric trunk was described by Song with a frequency of 0.68% and by Thangarajah in 1% of the cases. Chen describes the presence of the hepato-splenomesenteric trunk in 0.7% of the cases, Iacob describes its presence in 0.12% of total cases, and Bergman describes the presence of this variation in 0.5 % of cases. The present study finds the hepato-spleno-mesenteric trunk in combination with right aberrant hepatic arteries in 0.180% of cases, and there was no such variation of the celiac trunk among the cases of left aberrant hepatic arteries.

The gastro-splenic trunk is placed next in Song's study, with a frequency of 0.22% of all cases, according to Sureka it was found in 0.83% of cases, in Iacob's study, it represented one of the most common variations of the celiac trunk (1.43%) and Torres et al described the gastro-splenic trunk with a variation of 4.1% of all cases. In the present study, the association between left aberrant hepatic arteries and the gastro-splenic trunk was found in 5.216% of the studied cases, and the association between right aberrant hepatic arteries and gastro-splenic trunk was described in 2.708% of cases. It can be observed that the frequency of this anatomical variation of the celiac trunk may vary depending on the authors and the studied group.

The celiac trunk absent as a morphological entity is found in Song's study as a rare anatomical variation (0.10%), while Iacob describes the presence of 18 cases (0.330%) with this anatomical variation. The present study found an absent CT as a morphological entity in 0.61% of cases associated with left aberrant hepatic arteries and in 0.722% of cases associated with right aberrant arteries, these percentages being present in the variation range of the type associated with the absence of CT in the specialty literature.

The tetrafurcated celiac trunk is a very rare anatomical variant. Iacob describes a number of 17 cases with tetrafurcated CT (0.312%), and in the present study we reported the prevalence of 0.616% of the total cases associated with the presence of left aberrant hepatic arteries and 1.444% of the total cases associated with the presence of right aberrant hepatic arteries.

The spleno-gastroduodenal trunk is being characterized by the two arterial elements-SA and GDA. Iacob describes the presence of a single case with splenogastroduodenal trunk (0.018% of total cases). In the present paper, in cases with left aberrant hepatic arteries, we found 3 cases with splenogastroduodenal trunk, these representing 0.923% of the total and a

number of 2 cases with this variation in the cases associated with right aberrant hepatic arteries, representing 0.361% of the total cases.

Of the anatomical variations of the celiac trunk, with a very low prevalence in the population, the following cases are also found in the present study: in the case of left aberrant hepatic arteries association - a trunk formed by the left gastric artery, splenic artery and gastroduodenal artery (LGA-SA-GDA Tr in 1.846% of cases), hepato-phreno-splenic trunk (HPS Tr in 0.308% of cases), and in the case of association with right aberrant hepatic arteries - trunk formed by the left gastric artery, splenic artery and gastroduodenal artery (LGA-SA-RGA in 1.264% of cases), hepato-splenic trunk, associated with spleno-mesenteric trunk (HS Tr, SM Tr in 0.361% of cases).

In the current study, of the 800 cases analyzed, 124 cases were highlighted having an association between right and left aberrant hepatic arteries (accessory and replaced), these being characterized by their origin outside the normal components of the celiac trunk. These were divided into two groups (1) association of the two variations without other hepatic vascular variations (16.71%) and (2) association of the two variations with replaced common hepatic arteries (17.64%). Studying the way of association between the abnormal variants of aberrant hepatic arteries, the following were highlighted: 3 cases of ARHA-RLHA association (2.41%), 3 cases of ARHA-ALHA association (2.41%), 105 cases of RRHA- ALHA association (84.67%) and 13 cases of RRHA-RLHA association (10.48%). Compared to studies found in the literature on 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).

This study presents 76 cases with replaced CHA, which were analyzed by their origin point. Depending on their origin and the order of frequency, they were divided into three categories: (1) the abdominal aorta, (2) superior mesenteric artery and (3) left gastric artery. In 69 of the cases with replaced CHA (8.625% of total cases), the origin was at the level of abdominal aorta. In 69 of the cases with replaced CHA (8.625% of total cases), the origin was at the level of abdominal aorta. The vertebral level of the origin in the 69 cases studied showed that most arterial trunks originate between the intervertebral disc T12/ L1 and 1/3 of the body, at the level of the first lumbar vertebra L1 (69.565% of cases). In 6 of the cases that presented replaced CHA, the highlighted origin was at SMA level (0.75% of total cases), and in one case with replaced CHA, the origin was at LGA (0.125% of total cases). It is easily noticed that in the present study the origin of replaced CHA in AA represents the vast majority, particularly compared to the data in the literature. Hiatt, out of the 800 cases studied, presented 9.5% with replaced CHA, while Zimmitti emphasized the presence of replaced CHA in the literature with a variation range between 0.4-4.5%. Winston describes variations in the origin of common hepatic

artery in 4% of the cases studied in this paper, of which 2% showed the origin of the common hepatic artery in the upper mesenteric artery, and 2% showed the origin of the common hepatic artery in the abdominal aorta. The study of Prakash et al presented the existence of a percentage of 86% of celiac trunk cases according to the standard. 14% of cases were divided into three categories: (1) LGA, CHA and SA arose separately from AA (4%), (2) LGA originated from AA, and the celiac trunk was bifurcated, giving rise to CHA and SA (4.8%), (3) CT bifurcated into CHA and LGA, while SA originated from AA.

Discussing the relation of common hepatic arteries with the pancreatic parenchyma, out of the 76 cases of replaced CHA, 97.37% had extrapancreatic pathway, while 2.63% had a transpancreatic pathway. Studying the cases with extrapancreatic pathway, there were highlighted 3 morphological relation types: (1) superior pathway from the pancreatic parenchyma (75.68%), (2) posterior pathway from the pancreatic parenchyma (12.97%) and (3) semicircular pathway inferior to the hepatic parenchyma in a case of total inversus situs (1.35%). HA et al analyzed the replaced common hepatic arteries with the origin in SMA and its pancreatic relations, defining the following morphological types: (1) the replaced common hepatic artery crossing the pancreas (transpancreatic pathway), posterior to the superior mesenteric vein, (2) replaced common hepatic artery does not cross the pancreas (extrapancreatic pathway) and is posterior to the trunk of the hepatic portal vein/ superior mesenteric vein and (3) the replaced common hepatic artery does not cross the pancreas (extrapancreatic pathway) and is situated anterior to the hepatic portal vein or is situated posterior to the superior mesenteric vein; meanwhile, in his study, Song et al highlighted, of all 176 cases presenting replaced CHA with origin in (1) the left gastric artery, (2) superior mesenteric artery or (3) the abdominal aorta, that the vast majority presented an extrapancreatic pathway (93.75%). Thus, in the case of patients with replaced CHA origin in LGA, all showed an extrapancreatic pathway, just like in patients with origin in AA. In patients with replaced CHA originating in SMA, 11 were highlighted with an intrapancreatic pathway.

In the end of the study we were able to reach the following conclusions regarding the left aberrant hepatic arteries: (i) the majority of cases (87.730%) were classified as ALHA, and RLHA was highlighted in a percentage of 12.270% of all; (ii) morphological variations of CT were studied in the group that presented left aberrant hepatic arteries, with the presence of 11 morphological types while the other nine types of anatomical variations were unclassified in Michels classification; (iii) in the ALHA group the vast majority originated in LGA (99.693%), only one case originating in AA (0.307%), while all RLHAs originate in the LGA. The conclusions regarding the right aberrant hepatic arteries we were able to find are that (i) the vast majority of cases were represented by RRHA, totaling a percentage of 97,473%, and ARHA cases represented 2,527%. Of the cases with right aberrant hepatic arteries, 75,090% did not

associate the presence of other hepatic vascular variations, 37,117% presented the association with left aberrant hepatic arteries, and 3,069% presented the association with replaced CHA; (ii) most of the cases with right aberrant hepatic arteries have bifurcated (71,300%) and trifurcated (16,245%) CT. Ten other types of anatomical variations of CT and SMA were also found; (iii) ARHA originates most frequently in SMA, the rest of the cases originating in CT, while RRHA originates most frequently in SMA, with lower frequency originating in CT, CHA, AA, LGA-SA-GDA trunk, H-S trunk, IPDa (0.542%), SMA + CT, SA and LGA. In the group studied with replaced common hepatic arteries, we obtained the following conclusions: (i) the level of origin of the replaced CHA distinguished three distinct types, with the vast majority (90,789%) of cases having arterial origin at the AA level, while the rest of the cases originated at the level of SMA (7,895%) and LGA (1,316%); (ii) the analysis of CT and SMA in the group of cases with replaced common hepatic arteries highlighted 6 morphological variational aspects (i) - gastro-splenic trunk associated with the independent origin of replaced CHA from AA (68,420%), (ii) CT absent as morphological entity, with independent origin of CHA, LGA and SA from AA (26.316%), (iii) gastro-splenic-mesenteric trunk with independent origin of CHA from AA (1.316%), (iv) trunk formed by LGA - GDA - SA, associated with the independent origin of the replaced CHA from AA (1,316%) gastro-splenic trunk associated with the origin of replaced CHA from LGA (1,316%); (iv) the vast majority (97.37%) had an extrapancreatic trajectory, and 2.63% had a transpancreatic trajectory.

The study of the presence of aberrant hepatic arteries and their parameters using MDCT angiography is important for the planning of surgeries of the supramesocolic space and the decrease of the frequency of iatrogenic lesions at this level. There have been reported multiple variations of the celiac trunk as well as the hepatic arteries, but there aren't many studies which have been done on large groups to describe the arteries mentioned above. Given these aspects, I believe that the aberrant hepatic arteries need greater attention provided by the academic research, because there is still a lack of information regarding morphology and morphometry of hepatic arterial variations. This study has been done in order to recognize and describe different types of variations of hepatic arteries and their relation with other arteries as well as with the liver and pancreas and had the purpose of avoiding a number of complications during organs donation or during liver surgeries by describing the aberrant arteries.