CT angiographic study of hepatic arteries variants in Iranian subjects

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SUMMARY

This retrospective study aimed to assess the anatomical variations of hepatic arteries (HAs) in Iranian subjects referred to the Baqiyatallah Hospital (Tehran, Iran) as a reference medical center. The presence of anatomical variations such as hepatic arteries (HA) is approved among different societies. Classification of common patterns and probable variants of HA seems necessary in preoperative precautions of hepatosurgeries. Multidetector computed tomography angiography scans were prepared from the patients referred to the Baqiyatallah Hospital from January 2019 to January 2020. Inclusion and exclusion criteria were assessed, and all patterns of hepatic arterial supply were evaluated in 240 cases based on Michels' classification of HA. Following the assessment of 240 patients, HA variants with aberrant origin (types of II-VIII) were detected in 55 cases (22.92%). Besides, no patients were reported as types of XI and X variants (n=0). Also, no relationship was found between the HA and gender. Detection of common patterns along with abnormal variations of HA variants is necessary for hepatosurgical procedures. We found that 22.92% of Iranian patients referred to the Baqiyatallah hospital represented HA variation which must be considered in hepatic surgeries.

Key words: Variation – Hepatic artery – Computed tomography – Abdominal angiography

INTRODUCTION

Different hepatic functions are affected by the liver perfusion arteries, including HA and portal vein, which supplies 25% and 75% of the liver, respectively. Due to the critical role of HA in the preservation of the vital status of the liver, these arteries should be considered in various hepatosurgery processes. The celiac trunk (CT), as an essential branch of the aortic artery is responsible for blood supply to the essential organs such as spleen, stomach, and liver. Three main branches are divided from CT, including left gastric artery (LGA), splenic artery (SA), and common hepatic artery (CHA). Finally, the CHA is divided into two main branches, right HA (RHA) and left HA (LHA), which are responsible for the blood supply to the right and left lobes of liver, respectively (León et al., 2021). These

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arterial branches of the liver are sometimes divided from other sources than CHA, which are considered HA variants. The importance of angiography examination and identification of these variants prior to surgery is necessary for safe hepatosurgeries.

According to concepts of anthropology, HA has different variants in each country. Systematic examination of HA variants was first performed by Michels on autopsies (1966). Michels introduced 10 types of classification of HA as an accepted criteria for other investigations (Michels, 1966). In 2021, Imam et al., after examination of anatomical variations of HA, concluded that despite the presence of unclassified variants of the hepatic artery in different communities, this study also requires further in-depth evaluation due to the different unclassified patterns and HA variations requires further examinations in other countries (Imam et al., 2021). The most common classification of normal and variant hepatic arteries is based on Michels' guidelines. Ten different types of HA have been reported originated from a gastric artery or even from the superior mesenteric artery (SMA). Also, in this type of classification, accessory hepatic arteries were found following corpus dissection (Imam et al., 2021).

Multidetector computed abdominal tomography angiography is a technique used to visualize arterial and venous vessels throughout the body. This imaging protocol is widely used in the study of HA branches and their variants (Zaki et al., 2020).

Since there is no comprehensive study examining the prevalence of HA in the Iranian population, we aimed to investigate the typical anatomical structure and variants of HA in Iranian patients referred to Baqiyatallah Hospital as a reference medical center, using Multidetector computed tomography abdominal angiography technique and based on Michels' criteria. The results of this study can determine the types and prevalence of HA variations in Iranian society for safer hepatosurgeries.

MATERIALS AND METHODS

Patients collection and inclusion/exclusion criteria

All adult patients (18-80 years) referred to the Baqiyatallah hospital (Tehran, Iran) with abdominal pathologies were selected for primary screening of HA patterns from January 2019 to January 2020. Baqiyatallah hospital, as a reference medical center for hepatogasteric pathologies, was considered for data collection. Following preparation of multidetector computed tomography (MDCT) angiography (SOMATOM Sensation 16, Siemens, Germany), low-quality images, dissatisfied patients with the experiment, and the individuals with previous experience of HA surgery were excluded. Finally, a total of 240 patients were entered into the study. All administrative protocols were applied under the supervision of the Research Committee of Baqiyatallah University of Medical Sciences (Ethics Code: IR.BMSU.REC.1399.395), and the patients' medical records also remained confidential and undisclosed.

Protocol of MDCT procedure

A topography scan was performed following patient preparation and basic routine arrangements from the diaphragmatic region to the pubic symphysis. Using the Timing Bolus technique, the time required for the contrast agent to reach the CT was calculated. The thickness of images was defined as 7mm, and other device settings were provided as follows; 120 KV and Mas 320. Appropriate volume (1cc/kg) of Visipaque 320 mg contrast medium using an injector (speed of 4-6 ml/s) was injected through the cubital vein. The obtained axial images were entered into the workstation, and sagittal, coronal, three dimensional (3D) reconstructions were provided (Kalra et al., 2008).

Image interpretation and Michels` classification

The prepared images were analyzed independently by two expert radiologists. Celiac axis anatomy was evaluated, including LGA, SA, and CHA. Also, SMA was assessed to detect possible variations of aberrant arteries. HA variations

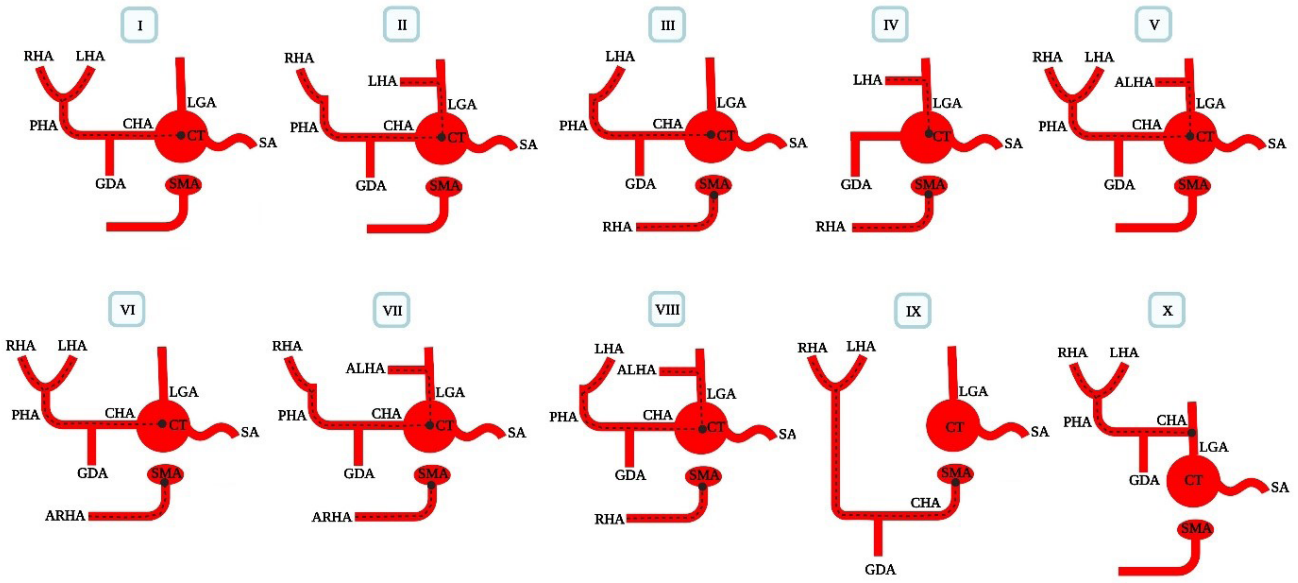

Fig. 1.- Ten patterns of hepatic artery variants according to the Michel`s classification. CT: celiac trunk, LGA: left gastric artery, SA: splenic artery, CHA: common hepatic artery, GDA: gastroduodenal artery, PHA: proper hepatic artery, RHA: right hepatic artery, and LHA: left hepatic artery.

were categorized for all images according to the Michels' guideline including: I. normal anatomy of HA, II. LHA originated from LGA, III. RHA originated from SMA, IV. LHA originated from LGA, and RHA originated from SMA, V. accessory left hepatic artery (ALHA) originated from LGA, VI. accessory right hepatic artery (ARHA) originated from SMA, VII. ALHA originated from LGA and ARHA originated from SMA, VIII. ALHA originated from LGA and RHA originated from SMA, IX. CHA originated from SMA. Finally, X. CHA originated from LGA (Fig. 1). The probable relationship between the prevalence of HA variations and male and female genders was evaluated and reported.

Statistical analysis

The statistical analysis among the prevalence of HA variation and gender was assessed using the Chi-squared χ^2 Test. Whole analyses were performed using SPSS™ software (v. 22, IBM Corporation NY, USA). The significant level was considered $p<0.05$.

RESULTS

Following consideration of inclusion/exclusion criteria, 240 (of 320 adult individuals) patients referred to the Baqiyatallah hospital were selected for CT, and it`s arterial branch variations. Demographic findings represented that the mean age of the patients was 45±3 years. Also, no significant ($p<0.05$) alteration was detected among the type of HA variants and the gender of patients (Table 1). All cases were found in the category of Michels` classification, and no new unclassified HA variations were detected.

In the field of assessment of origination of CHA, these types of variations were only found in IV, IX and X types. Respectively, no CHA was originated from CT (type IV), and also CHA was originated from SMA (type IX), and LGA (type X). In this study, no variants of CT and CHA were reported in types of IX and X. Besides, in our findings, 1.66% of cases had no CHA. In these cases, the RHA and LHA were originated from SMA and LGA, respectively (Table 1, Fig. 2).

According to the Michels' classification for assessment of RHA and ARHA variations, abnormal origination of RHA or the presence of ARHA were detected in variant types of III, IV, VI, VII, VIII, IX, and X. Totally, 8.32% of cases had abnormal origin of RHA and ARHA was detected in 7.07% of patients. In HA, the RHA variant of III (5.83%), IV (1.66%), and VIII (0.83%) were originated from SMA, while in types of VI (6.66%) and VII (0.41%), the presence of ARHA was detected (Table 1, Fig. 2).

Following assessment of LHA and ALHA, the aberrant origin of LHA was found derived from LGA in variation types of II (5%) and IV (1.66%).

Table 1. Frequency of types of hepatic artery variations according to the Michel`s classification. Data were presented in percentage. N=100. Type I: normal anatomy, type II: left hepatic artery from left gastric artery, type III: right hepatic artery from superior mesenteric artery, type IV: left hepatic artery from left gastric artery and right hepatic artery from superior mesenteric artery, type V: accessory left hepatic artery from left gastric artery, type VI: accessory right hepatic artery from superior mesenteric artery, type VII: accessory left hepatic artery from left gastric artery and accessory right hepatic artery from superior mesenteric artery, type VIII: accessory left hepatic artery from left gastric artery and right gastric artery from superior mesenteric artery, type IX: common hepatic artery from superior mesenteric artery, type X: common hepatic artery from left gastric artery.

Variant Types	I	II	III	IV	V	VI	VII	VIII	XI	X
Frequency (n/%)	185 77.08%	12 5%	14 5.83%	4 1.66%	6 2.5%	16 6.66%	1 0.41%	2 0.83%	0 0%	0 0%
Relationship with genders	p=0.32	p=0.18	p=0.09	p=0.17	p=0.07	p=0.09	p=0.08	p=0.20	p=0.31	p=0.14

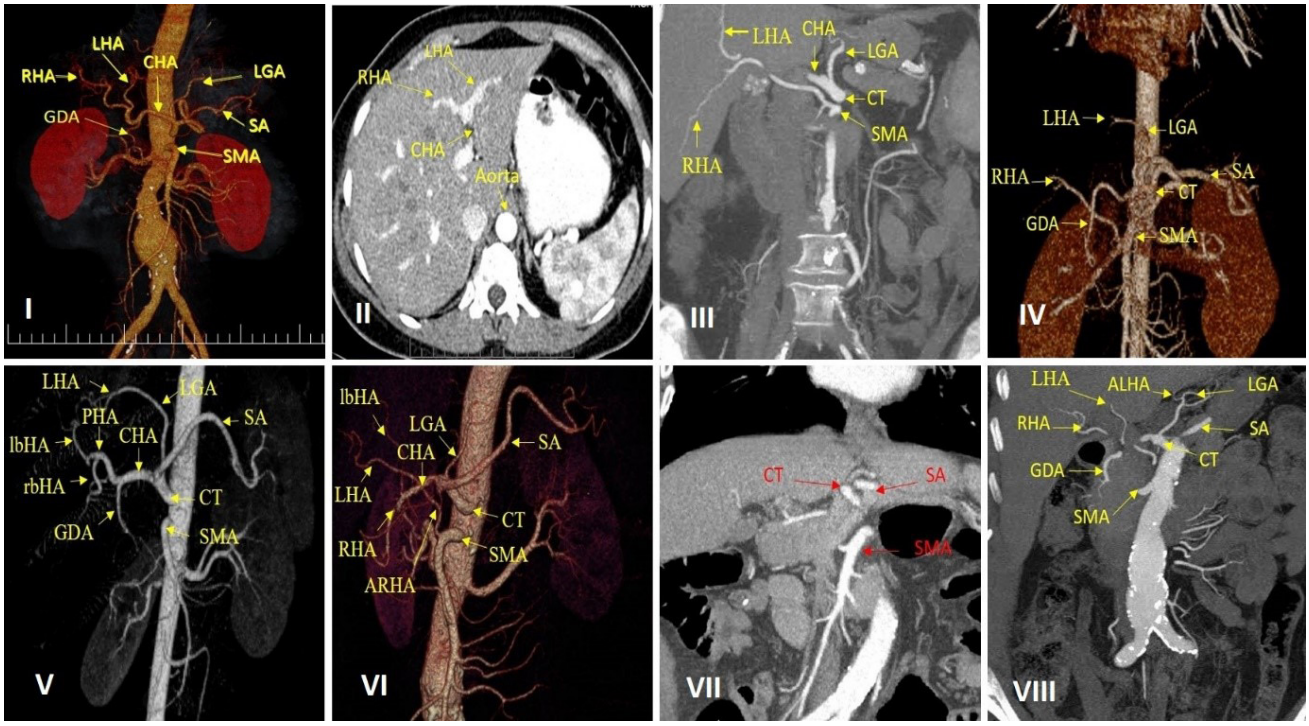

Fig. 2.- CT angiography images of hepatic artery variants in patients referred to Baqiyatallah hospital. CT: celiac trunk, LGA: left gastric artery, SA: splenic artery, CHA: common hepatic artery, GDA: gastroduodenal artery, PHA: proper hepatic artery, RHA: right hepatic artery, and LHA: left hepatic artery.

Also, no LHA was detected in type VII (0.41%). In types of V (2.5%), VII (0.41%), and VIII (0.83%), the left lode of the liver was also supplied by ALHA, as an additional artery originated from LGA. Totally, 6.66% of cases had an aberrant origin of LHA, and 2.91% had an extra artery for the left lobe of the liver in the form of ALHA (Table 1, Fig. 2).

DISCUSSION

According to the anatomical differences of HA among the countries and the need for determination of the prevalence of HA variants in Iranian society as one of the necessary arrangements for a safe hepatosurgery, we conducted an original retrospective study. Totally, we found that in 22.92% of the Iranian population, the HA is prone to variation, while 77.08% of individuals had a typical form of vascular pattern of HA. In a comprehensive investigation, Johnson coworkers assessed the prevalence of Hepatic artery anomalies in unselected patients undergoing computed tomography (CT) of the abdomen. 309 CT angiographic studies performed over 2 years were selected and assessed according to the Michels guideline. They found that 63.4% of individuals had conventional vascular anatomy, and the remaining represented variation in European countries (Johnson et al., 2013).

In this study, 1.66% of patients lacked the CHA branch. In these cases, the right and left hepatic arteries were derived from the SMA and LGA, respectively. Examination of DICOM images

showed that in the absence of RHA separated from CHA; this artery is probably originated from SMA. Besides, this artery is isolated from LGA in the absence of LHA originating from CHA. Parallel to our findings, Juszczak and coworkers assessed the unusual pattern of CT in 350 cases using MDCT images. As we found, they also reported the rare cases of variation in CT, especially the absence of CHA. They concluded that, although the absence of CHA is rare, it should be considered an essential issue in heapatosurgical procedures (Juszczak et al., 2021). Cankal et al. explicitly examined the variants of CT and HA in 200 patients using assessment of Multi-slice computed tomography images. CHA was found in 4% of cases in study of Cankal, which showed a significant difference in the frequency distribution of this variation in Turkish society compared to Iran; in our study population, no sample was found for type IX, but in Cankal`s study, 1.5% of the Turkish population represented CT with no CHA branch. In these cases, CHA was derived from the SMA (Cankal et al., 2021).

The RHA is one of the main clinical and surgical arteries due to its involvement in gallbladder blood supply, as well as the major part of the right lobe of liver (Mugunthan et al., 2016). In our findings, 8.32% of cases had an aberrant origin of RHA. In this cases, the blood supplies of right lobe and gallbladder were provided through SMA as an alternative blood supply. Mugunthan et al. assessed the probable variation of RHA in 60 adult cadavers (Mugunthan et al., 2016). Although in most cases, the typical origin of RHA was reported by Mugunthan, et al., but approximately in 13% of cadavers, the aberrant origin of RHA was found. Choi et al. (2021) in a comprehensive study on 5625 patients using computed tomography and digital subtraction angiographic images, evaluated the anatomic variations of hepatic arteries. They found the prevalence of aberrant RHA and LHA approximately 15%. Our study found this value as 8.32% and 6.66% for RHA and LHA, respectively. Finally, they reported that, if there was a variation in the hepatic artery (right or left), the accompanying variation in the other related hepatic artery is possible (Choi et al., 2021). In this study and based on Michels' guideline, the ARHA was originated from SMA in 7.07% of patients. In serval articles, this sub-arterial branch (ARHA) was derived from the GDA (Yamashita et al., 2015) or CHA (Polguj et al., 2010).

Another critical artery blood supply to the left lobe of the liver is LGA involved in hepatic artery reconstruction during liver transplantation (Yilmaz et al., 2021), esophagogastric, and gasterectomy (Shinohara et al., 2007). Our findings represented that 6.66% of all cases have aberrant origin of LHA. Also, we found that all cases of aberrant LHA were derived from LGA. In a meta-analysis study in 2020, the global prevalence of LHA was estimated 13.52%, in comparison with 6.66 in our study for the Iranian population (Cirocchi et al., 2020). Futara and coworkers analyzed HA variations on Ethiopians 110 postmortem cadavers comprehensively. Considerably, there was no LHA variation originating from LGA in Ethiopian populations, whereas in the same population, this artery was isolated from other arterial branches such as SA, CHA, and CT (Futara et al., 2001). Besides, in Iranian population in the present study, LHA was only originated from LGA.

It would be worth mentioning that the highest percentage of HA variations was observed in type VI, indicating that an extra branch of ARHA was originated from SMA. Besides, a lower percentage of HA variation was found in the XI and X types.

We also found no considerable relationship between the prevalence of HA variants and gender. Fatih Cankal and coworkers evaluated the prevalence of CT, HA, and their collateral branches using Multi-Slice Computed Tomography. They found no considerable differences among the prevalence of HA variants and genders in the turkey population (Cankal et al., 2021). This concept was also considered by Farghadani et al. in the field of assessment of anatomical variation of the celiac axis and its arterial branches using multidetector computed tomography angiography technique. As we found no considerable changes, they also stated the non-significant association among the male or female genders and the prevalence of CT variants (Farghadani et al., 2016).

CONCLUSION

The results of this novel study showed that most people of the Iranian society have a liver with a typical arterial pattern. Interventional radiologists and hepatobiliary surgeons practicing in Iran must be cognizant of these differences in order to minimize morbidity and mortality during invasive procedures. It is recommended that this research protocol be conducted in other communities as well in order to reach a global conclusion in this regard.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All assessments were conducted in accordance with ethical principles and under the supervision of the University's Ethics Committee (Ethic NO: BMSU.REC.1399.395).

REFERENCES

CANKAL F, KAYA M, GUNER MA (2021) Evaluation of celiac trunk, hepatic artery variations, and their collateral arteries by multi-slice computed tomography. *Sisli Etfal Hastanesi tip bulteni*, 55(2): 217-223.

CHOI TW, CHUNG JW, KIM HC, LEE M, CHOI JW, JAE HJ, HUR S (2021) Anatomic variations of the hepatic artery in 5625 patients. *Radiol Cardiothoracic Imag*, 3(4): e210007.

CIROCCHI R, D'ANDREA V, AMATO B, RENZI C, HENRY BM, TOMASZEWSKI KA, RANDOLPH J (2020) Aberrant left hepatic arteries arising from left gastric arteries and their clinical importance. *Surgeon*, 18(2): 100-112.

FARGHADANI M, MOMENI M, HEKMATNIA A, MOMENI F, BARADARAN MAHDAVI MM (2016) Anatomical variation of celiac axis, superior mesenteric artery, and hepatic artery: Evaluation with multidetector computed tomography angiography. *J Res Med Sci*, 21: 129-129.

FUTARA G, ALI A, KINFU Y (2001) Variations of the hepatic and cystic arteries among Ethiopians. *Ethiopian Med J*, 39(2): 133-142.

IMAM A, KARATAS C, MECIT N, AFAK K, YILDIRIMOGLU T, KALAYOGLU M, KANMAZ T (2021) Anatomical variations of the hepatic artery: a closer view of rare unclassified variants. *Folia Morphol*, doi: 10.5603/FM.a2021.0024. Online ahead of print.

JOHNSON PB, CAWICH SO, ROBERTS P, SHAH S, GARDNER MT, GORDON-STRACHAN G, PEARCE NW (2013) Variants of hepatic arterial supply in a Caribbean population: A computed tomography based study. *Clinic Radiol*, 68(8): 823-827.

JUSZCZAK A, CZYŻOWSKI J, MAZUREK A, WALOCHA JA, PASTERNAK A (2021) Unusual variations in the branching pattern of the coeliac trunk and their clinical significance. *Folia Morphol*, 80(2): 283-289.

KALRA MK, SAINI S, RUBIN GD (2008) *MDCT: from protocols to practice*: Springer Science & Business Media.

LEÓN RAE, AGUIRRE GB, CORONADO VT, SÁNCHEZ DA, NAVA MCI, ZAMUDIO MD, PINEDA-MARTINEZ D (2021). Variations of the celiac trunk in Mexican population by MDCT angiography. *Eur J Anat*, 25(1): 57-64.

MICHELS NA (1966) Newer anatomy of the liver and its variant blood supply and collateral circulation. *Am J Surg*, 112(3): 337-347.

MUGUNTHAN N, KANNAN R, JEBAKANI CF, ANBALAGAN J (2016) Variations in the origin and course of right hepatic artery and its surgical significance. *J Clin Diagnos Res*, 10(9): AC01-AC04.

POLGUJ M, GABRYNIAK T, TOPOL M (2010) The right accessory hepatic artery; a case report and review of the literature. *Surg Radiol Anat*, 32(2): 175-179.

SHINOHARA T, OHYAMA S, MUTO T, YANAGA K, YAMAGUCHI T (2007) The significance of the aberrant left hepatic artery arising from the left gastric artery at curative gastrectomy for gastric cancer. *Eur J Surg Oncol*, 33(8): 967-971.

YAMASHITA K, HASHIMOTO D, ITOYAMA R, OKABE H, CHIKAMOTO A, BEPPU T, BABA H (2015) Accessory right hepatic artery branched from gastroduodenal artery. *Surg Case Rep*, 1(1): 90.

YILMAZ S, AKBULUT S, KUTLUTURK K, USTA S, KOC C, AYDIN C, BASKIRAN A (2021) Using the recipient's left gastric artery for hepatic artery reconstruction in living donor liver transplantation. *Liver Transplant*, 27(6): 923-927.

ZAKI S, ABDELMAKSOUD A, KHALED B, KADER IA (2020) Anatomical variations of hepatic artery using the multidetector computed tomography angiography. *Folia Morphol*, 79(2): 247-254.