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Original Research Article

AN EVALUATION OF VARIATIONS OF THE RIGHT HEPATIC ARTERY USING MULTI DETECTOR COMPUTED TOMOGRAPHY (MDCT)

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ABSTRACT

Background: The study on the variations of the hepatic artery dates back to 1917 when Lipshutz B reported the variations of celiac artery and its branches. These variations result from the persistence and/or abnormal regression of parts of primitive arterial system. Owing to the greater variability of the right intrahepatic vascular anatomy, resections extensively involving the right hepatic lobe rely heavily on preoperative assessment of origin and branching pattern of right hepatic artery (RHA).

Aim: The present study was intended to provide numerical parameters of the frequency of occurrence of the right hepatic artery variations in a given study population.

Materials and Methods: The present study was conducted using Multi detector computed tomography (MDCT) angiography images of 200 patients, in the department of Radiodiagnosis and imaging, Kasturba medical college, Manipal, India. MDCT arterial phase images of abdominal aorta done for various clinical indications routinely were evaluated to describe the origin and branching pattern of the RHA. Presence of an accessory RHA was documented.

Results: Variations in the origin of the RHA were encountered in 26 cases (13%) out of which, 16 were male patients and 10 were female patients. RHA arose from the superior mesenteric artery (SMA) in 19 cases (9.5%), directly from the coeliac trunk in one case (0.5%) and aorta in one case (0.5%). Accessory RHA arising from the SMA was seen in 5 cases (2.5%).

Conclusion: A detailed knowledge of the hepatic angioarchitecture is considered a prerequisite for planning and conducting uncomplicated biliary tract operations, liver transplants, chemo-embolization of a liver neoplasm, as well as other procedures performed in this region. Hepatic arterial anatomy must be defined precisely to ensure optimal donor hepatectomy and graft revascularization.

KEY WORDS: Right hepatic artery, Variations, MDCT, Right hepatic lobe resection, Accessory hepatic arteries.

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INTRODUCTION

Liver is a highly vascular structure, where two distinct afferent circulatory systems coexist. Approximately 70% of its total blood flow is derived from the portal vein, responsible for the functional circulation of the liver and the rest 30% from the hepatic arteries, for its nutritional demand [1]. Common hepatic artery (CHA), a branch of coeliac trunk (CT) continues as proper hepatic artery (PHA) distal to the origin of gastroduodenal artery (GDA). Right hepatic artery (RHA), arises as a larger branch of PHA, turns laterally and enters the liver via the right intersegmental fissure passing in between the bile duct and the portal vein. Within the liver or extrahepatically in the porta, it divides into anterior and posterior branches.

The variations are seen as the developmental changes of the primitive ventral splanchnic arteries which may be due to abnormal disappearance of an arterial segment that should normally persist or persistence of an arterial segment that should normally disappear or both [2]. Hepatobiliary surgeries like liver transplantation, tumor resection, therapeutic chemoembolisation and laparoscopic cholecystectomy have increased enormously in recent years. Owing to the greater variability of the right intrahepatic vascular anatomy, resections extensively involving the right hepatic lobe rely profoundly on preoperative assessment of the liver using diagnostic imaging to detect vascular and biliary anatomic variants [3].

MDCT angiograms of abdominal aorta are conventional angiogram-like images and 3D reconstruction of CT angiography provides a highly graphic and easily understood depiction of the angio-architecture. Due to these advancements in imaging technology, newer studies on hepatic arterial variations in different population and subjects are reporting many rare anomalies which were not seen previously. Hence the surgeon can expect any number and combinations of variations. The present study is intended to evaluate and describe the prevalence of various types of variations of right hepatic artery.

MATERIALS AND METHODS

The present study was conducted using MDCT angiography images of 200 patients which included 128 male and 72 female subjects aged between 18 to 80 years. It was a prospective study which was done using MDCT arterial phase images of abdominal aorta done for various clinical indications. The study setting included the department of Radio diagnosis and imaging, Kasturba hospital, Manipal for the data collection and image analysis. Literature search and documentation were done in the department of Anatomy, Kasturba medical college, Manipal. Ethical committee approval was obtained prior to the study.

Inclusion Criteria: Patients without any remarkable liver lesions were included in the study as malignant lesions may show neovascularity and interfere with interpretation of normal arterial anatomy. Patients having images with clear arterial contrast demonstrating intrahepatic segmental branches were included in the study.

Exclusion criteria: Patients with hepatic trauma and having hepatic tumor or abscess were excluded.

The scans were performed on 64 row Philips Brilliance MDCT scanner using triple phase protocols. The patients were scanned in supine position and sections were taken from the level of diaphragm to iliac crest. 100 ml of non-ionic iodinated contrast agent (ULTRAVIST injection 370mg/ml, Bayer Healthcare, Berlin, Germany) was injected at a flow rate of 5ml/s by using a power injector (MEDRAD's Stellant Injection systems, USA) followed by 40-50 ml saline chaser to flush the contrast agent. 5mm thickness sections were acquired in a single breath hold using 0.64 x 0.625mm detector collimation, 120 KV tube voltage, 300mAS tube current, with a pitch 1.142 and reconstruction interval of 0.6mm. Images were further reconstructed into 1mm thin slices to enable exquisite visualization of main trunk branches as well as the smaller segmental branches. MDCT data sets were processed on EBW or Portal 4.5 version workstation with facilities for multiplanar reformatting (MPR), maximum intensity projection (MIP) and volume rendering. Images thus obtained were evaluated and interpreted with the help of radiologist. Arterial phase images were acquired on Philips brilliance software. Reformation of the source images of the arterial phase scans were done to produce high quality MIP (maximum intensity projection) images to visualize smaller branches. Multiplanar reformatted images were created from the retrospectively reconstructed axial images derived from the projection data in both sagittal and coronal planes. Volume rendering technique was employed subjectively to produce three dimensional pictures for optimal visualization of the hepatic artery. Unwanted structures like bones were removed by post processing bone removal tool and resulting images were projected at appropriate angles for correct interpretation.

Observations were made concerning the origin and branching pattern of the CHA, RHA and LHA. However, to highlight the importance of right hepatic arterial morphology, only the variations of RHA are discussed in this paper. Presence of accessory RHA was also documented. Lengths of the replaced RHAs were measured.

RESULTS

The standard textbook description of the origin and branching pattern of the right hepatic artery was observed in 174 cases (87%). Deviation from the classical description was considered as variation.

Variations in the origin of the RHA were encountered in 26 cases (13%) out of which, 16 were male patients and 10 were female patients, which are discussed below.

(a)The RHA arose from the superior mesenteric artery (SMA) as a replaced vessel in 19 cases (9.5%). In most of such cases, the proper hepatic artery (PHA) continued as the left hepatic artery (LHA) **(Fig. 1a and 1b)**. In one case amongst these the common hepatic artery (CHA) trifurcated into the LHA, gastroduodenal artery (GDA) and segment IV artery. Two cases among them showed PHA bifurcating into LHA and segment IV artery. In another case the CA itself was replaced to the SMA. The average length of the replaced RHA measured 6.7±0.84cms.

In five cases (2.5%), the RHA branched off from SMA as an accessory artery **(Fig. 2).**

(b) In one case RHA directly started off from the coeliac axis (CA) where the CHA divided into LHA and GDA **(Fig. 3).**

(c)Presence of replaced RHA arising directly from the aorta in between the emergence of CA and SMA was observed in one case **(Fig.4a and 4b).**

Fig. 1: (a) coronal and (b) 3D reconstructed volume rendered MIP CT angiograms demonstrating replaced RHA arising from the SMA and the CHA dividing into the LHA and the GDA.

Fig.1a

Fig.1b

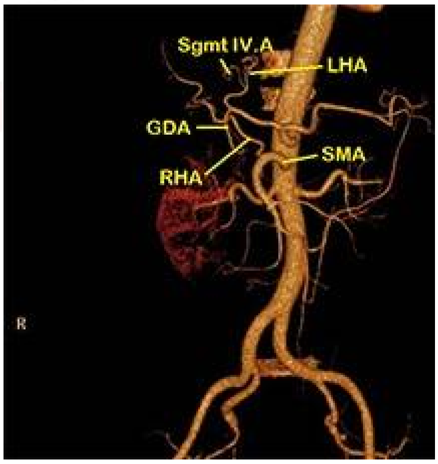


Fig. 2: MIP CT angiograms of abdominal aorta showing axial view of accessory RHA from the SMA.

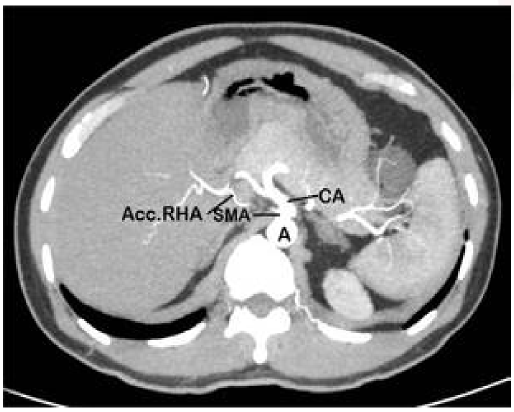


Fig. 3: MIP image from the CT angiographic data demonstrating the coronal view of the replaced RHA arising directly from the CA.

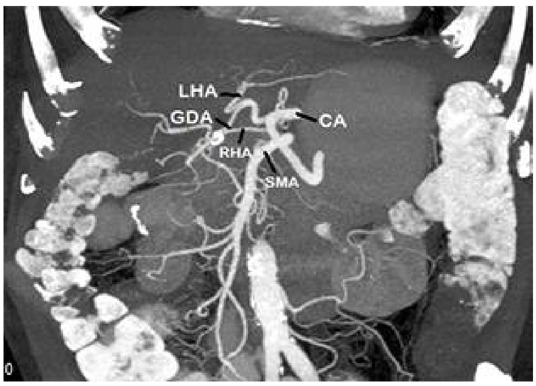


Fig. 4: MDCT angiographic data showing the MIP coronal (a) and 3D reconstructed (b) images of direct origin of the RHA from the aorta.

Fig.4a

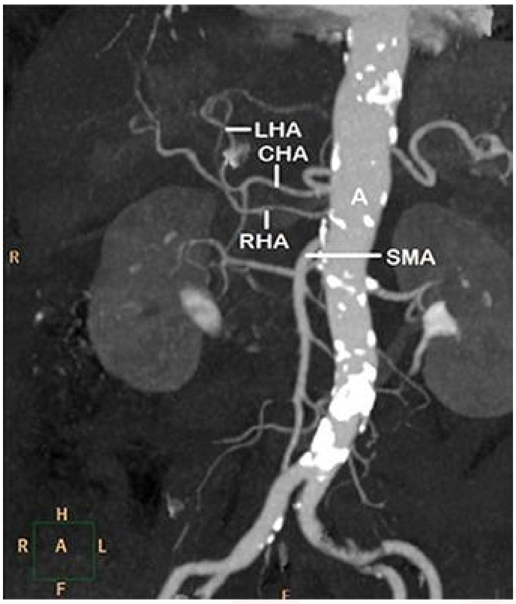
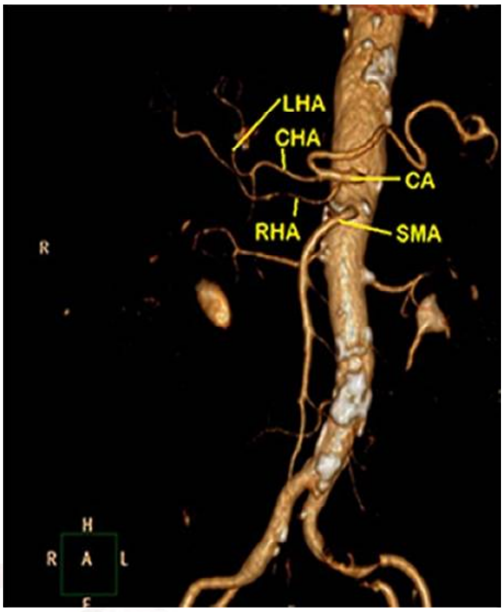


Fig.4b



DISCUSSION

Developments in the liver transplantation procedure using living donor or split liver emerged as a lifesaving boon for patients with irreversible end stage liver damage, in the context of scarcity of cadaver livers. Extremely complex techniques involved in these procedures demands the exact knowledge of hepatic vascular architecture to plan and execute best surgical approach.

The review of existing literature suggests that the standard hepatic arterial anatomy occurs only in approximately 50% of the study population, though most of the variations of the other 50% have little surgical significance [4]. The variation of the hepatic artery has been studied extensively using cadavers, livers harvested for transplantation as well as angiographic techniques used for preoperative donor evaluation.

Michel defined ten basic anatomical variations of the hepatic artery which have served as a benchmark for all subsequent studies in this field. The normal description of hepatic artery architecture was classified as type I by him, was observed in 55% of his study population. Stemmler B J et al.,[5] and Prabhasavat et al.,[6] observed type I anatomy in 81% and 84% of cases respectively which indicates that the incidence of variation among them were comparatively less. In contrast to that, McDonald et al., [7] and Ugurel et al., [8] observed type I anatomy in 56% and 52% of cases respectively, which is consistent with that of Michels' findings. In the present study the normal hepatic arterial anatomy categorized under type I of Michel classification was noticed in 64.5% of cases.

The variant RHA may be 'replaced'(R), substituting the normal artery or 'accessory'(A), meaning that they add on to the normal arterial supply but still represents the primary arterial supply to the liver [1]. These arteries are 'accessory' only in the origin and name because, functionally they are indispensable to the arterial blood supply of liver. Healy et al used corrosion casts of hepatic arteries to show that accessory hepatic arteries have specific distribution within the liver and are solely responsible for their areas of vascularization [9].

Table 1 shows the variations of RHA, as observed in various studies. RHA arising from the SMA as a replaced artery was described under type III variety by Michel which was the most common variation encountered and was seen in 11% of their study population. Similar observations were made by McDonald et al., [7] in 20.5%, Prabhasavat et al., [6] in 6% and Ugurel et al., [8] in 17% of their study population. In the present study also the type III was the most common variant observed in 8.5% of cases. Stemmler et al., [5] observed it as the second common variation in 6.3% of cases among their study population.

Table 1: Variations of the RHA as observed in various case study series.

Author	Type of study	Total no. of cases	Variant RHA – branching off the				
			SMA	GDA	CA	Aorta	Others
Jones (2001)[20]	Graft liver	180	32	10	-	3	RGA - 3
Covey et al., (2002) [4]	DSA	600	73(R) 11(A)	1	16	7	Rt. Inf. Phrenic A-2 LGA-1
Sahani D et al., (2002) [11]	MDCT	42	5(R) 3(A)	-	-	-	Splenic A - 1
Bertevello (2002)[21]	Graft liver	60	15	-	4	-	-
Lee et al., (2003) [13]	MDCT	102	3(R) 1(A)	4	3	-	Dorsal pancreatic A - 1
Rawat K S (2006) [10]	MDCT	125	18(R) 4(A)	3	1	-	Early division - 1
Yoshida et al., (2008) [17]	MDCT	52	7	1	-	-	CHA – 1
Prabhasavat (2008) [6]	MDCT	200	12	-	-	-	LGA – 1, CHA – 3(A)
Ugurel P et al., (2010) [8]	MDCT	100	17(R) 1(A)	-	-	1	Middle colic A - 1
Bhardwaj N (2010) [12]	Cadaver liver	60	5 (R) 1(A)	2	3	-	CHA - 12
Present study (2013)	MDCT	**200**	**17(R) 4 (A)**	**-**	**1**	**1**	**-**

Variant origin of RHA from the SMA was also observed by Rawat et al., [10] in 14.4%, Sahani et al., [11] in 12%, Bharadwaj et al., [12] in 8.3% and Lee et al., [13] in 3% of their study population. They also observed the presence of accessory RHA from the SMA in 3.2%, 7%, 1.6% and 1% of cases respectively. RHA branching off the SMA as an accessory artery was found in 2% of our study population.

Such variations of RHA require extra surgical steps in both the donor and the recipient in the context of living related liver transplantation [14]. Replaced RHA from the SMA, runs posterior to the main portal vein in the portocaval space and classically ascends posterolateral to the common bile duct [15].

As the right lobe of the liver during the early stages of development is supplied by a branch from the SMA, such fetal vessels may persist in the adults as accessory or replaced RHA from the SMA. Several studies have reported the most common variant origin of the RHA is from the SMA with an incidence of 10.6%-18% in various subject groups [16].

Nevertheless, the RHA can arise from different sources. Most frequent source of the variant RHA reported till date, apart from the SMA was the GDA as observed by Lee et al., [13] in 4 cases, Rawat et al., [10] in 3 cases and Yoshida et al., [17] in one case of their study population. However such a variation was not encountered in the present study. Less commonly the RHA could arise directly from the CA as mentioned in the previous reports. Lee et al., [13] and Bhardwaj et al., [12] observed it in 3 cases each and Rawat et al., [10] in one case. In the present study, the RHA was seen to arise directly from the CA in one case. The RHA arising directly from the aorta was reported by Ugurel et al., [8] which is concurrent with the finding in our study. Very rarely the RHA can arise from the splenic artery [11], dorsal pancreatic artery [13], LGA [6] or even from the middle colic artery [8].

As per the surgical perspective, the RHA arising directly from the aorta can be more easily damaged during arterial reconstruction in the setting of liver transplantation compared to those originating from the SMA or GDA [18]. However, in case of replaced RHA from the SMA, chances of post-operative hepatic artery thrombosis were less as they would be longer and larger [19].

CONCLUSION

A detailed knowledge of the hepatic angioarchitecture is considered a prerequisite for planning and conducting uncomplicated biliary tract operations, liver transplants, chemoembolization of a liver neoplasm, as well as other procedures performed in this region. Hepatic arterial anatomy must be defined precisely to ensure optimal donor hepatectomy and graft revascularization. Present study encountered variations of RHA more or less in a similar pattern as described in the previous literatures. We found the most common variation being the RHA arising from SMA. Rare variations such as RHA arising directly from the aorta and CA were also encountered. The present study was intended to provide numerical parameters of the frequency of occurrence of the right hepatic artery variations in a given study population.

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ABBREVIATIONS

MDCT – Multidetector computed tomography
RHA – Right hepatic artery
LHA – Left hepatic artery
CHA – Common hepatic artery
PHA – Proper hepatic artery
CT/CA – Coeliac trunk/Coeliac axis
GDA – Gastroduodenal artery
SMA – Superior mesenteric artery
LGA – Left gastric artery
DSA – Digital subtraction angiography
Rt. Inf. Prenic A – Right Inferior Phrenic artery
RGA – Right Gastric artery
(R) – replaced artery
(A) – accessory artery

Conflicts of Interests: None

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