Original Article

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Hepatic Artery and Portal Vein Variations using Contrast Enhanced Computed Tomography Abdominal Angiography

Radiology Section

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ABSTRACT

Introduction: Normal hepatic vascular anatomy and its variants carry considerable importance during liver transplants, laparoscopic surgeries, penetrating abdominal trauma, and radiological abdominal interventions. The occurrence of iatrogenic hepatic vascular injury increases in case of atypical anatomy and variations.

Aim: To determine the prevalence of common hepatic artery and portal vein variants by using Multidetector Computed Tomography (MDCT).

Materials and Methods: This is a hospital based retrospective study done in Sri Mankula Vinayagar Medical College and Hospital, Puducherry, India, between July 2019 and July 2020. The Contrast Enhanced Computed Tomography (CECT) abdominal angiography of 350 patients was taken for the study. The MDCT abdominal angiography was performed using 16 slice PHILIPS MX16 CT scanner with intravenous administration of non ionic iodinated contrast, having iodine content of 300 mg/mL at the dosage of 1.5 mL/kg body weight, using automated pressure injector at a rate of 3.5 mL/sec. Arterial phase and portal venous phase images were obtained at 25 and 55 seconds respectively. The hepatic artery anatomical types were classified according to Michel's classification and the portal vein according to Covey AM et al., classification. Data obtained was entered in EPI INFO version 7.2.1.0 and analysed using Statistical Package for the Social Sciences (SPSS) software version 24.0.

Results: Hepatic artery proper (right and left hepatic arteries arising from common hepatic artery) (Type I) was seen in 222 (63.4%) of cases. The most common variant was replaced Left Hepatic Artery (LHA) from the left gastric artery (Type II) with a prevalence of 46 (13.1%). A normal portal vein branching pattern (Type I) was seen in 201 (57.4%) of cases. The most common variation was trifurcation (Type II) with a prevalence of 68 (19.4%).

Conclusion: Knowledge about normal hepatic artery, portal vein, and its variants is important in hepatic interventions and CT angiography is the modality of choice for evaluating the vascular anatomy.

Keywords: Classification, Laparoscopic surgeries, Michel's classification, Multidetecter computed tomography

INTRODUCTION

Liver has a dual blood supply. The hepatic artery and the portal vein are the major vascular supply to the liver. Portal vein contributes the majority of the blood flow to the liver (75%) followed by the hepatic artery (25%) [1]. The hepatic artery has right and left divisions which are branches of the common hepatic artery which in turn is a branch of the celiac artery. Superior mesenteric and splenic veins join together to form portal vein behind the neck of the pancreas, which in turn bifurcates into the right and left portal vein, to the corresponding lobes of the liver [1]. The clinical significance of hepatic artery variations has been an area of interest and research since 1756 when Haller was the first to describe the celiac axis variations [2]. Later in 1955, Michel came up with a classification scheme for describing hepatic artery anatomic variations based on the results from dissecting 200 cadavers [2].

Knowledge about normal hepatic artery and portal vein variants carries considerable importance during liver transplants, laparoscopic surgeries, penetrating abdominal trauma, and radiological abdominal interventions. The frequency of iatrogenic hepatic vascular injury increases in the event of aberrant anatomy and variants [3]. Though Digital Subtraction Angiography (DSA) is the gold standard procedure for evaluating blood vessels, MDCT is frequently used as a problem solving tool, due to its less invasive nature and excellent image quality. The prevalence of normal (73.8%) and aberrant hepatic arteries (26.2%) among the Egyptians differs, when compared to other ethnic groups [3]. The purpose of this study is to determine the comprehensive spectrum and prevalence of hepatic artery and portal vein variations with the help of MDCT.

MATERIALS AND METHODS

This hospital based retrospective study was carried out in the Department of Radiodiagnosis, Sri Manakula Vinayagar Medical College and Hospital, Puducherry, India. After obtaining clearance from the Institute's Ethics Committee (EC/40/2020), 350 cases who were referred to the Department of Radiodiagnosis for CECT abdomen between July 2019 and July 2020 were analysed from August 2020 to December 2020.

Inclusion criteria: Patients of all ages and both sexes were included in the study.

Exclusion criteria: Patients who underwent major hepatic resection surgery and any pathologies involving the hepatic vasculature were excluded from the study.

Imaging Technique

Abdominal angiography was performed using 16 slice Philips MX16 CT machine with intravenous administration of non ionic iodinated contrast (Iohexol) having Iodine content of 300 mg/mL at 1.5 mL/kg body weight using automated pressure injector at a rate of 3.5 mL/sec. Arterial phase and portal venous phase images were obtained at 25 and 55 seconds. Images were obtained in axial sections which were reconstructed with 0.625 mm slice thickness and reformatted into coronal and sagittal planes. A 3D multiplanar reconstruction, volume rendering, and maximal intensity projection were used to map the hepatic artery and portal vein variants using system software. After acquiring the images, the hepatic artery type was classified according to Michel's classification and the Portal vein according to Covey AM et al., classification [4,5].

STATISTICAL ANALYSIS

Data obtained was entered in EPI INFO version 7.2.1.0 and statistical analysis was performed using SPSS software version 24.0. The results were obtained and frequencies of variants were calculated and tabulated.

RESULTS

The total number of patients included in the study was 350, which includes 180 females and 170 males. The median age of participants was 50 years, with ages ranging from 15-90 years [Table/Fig-1].

Age group (years)	No of patients
15-30	32
31-45	106
46-60	126
61-75	74
≥76	12
Total	350

[Table/Fig-1]: Age distribution among study participants.

Hepatic artery variations: The hepatic artery variations were defined and analysed according to Michel's classification. Out of 10 types described by Michel, seven variations were seen in this study [Table/Fig-2]. The normal hepatic artery anatomy was seen in 222 (63.4%) patients. Variants of hepatic artery were seen in 128 (36.6%) patients [Table/Fig-3]. The LHA originated from the hepatic artery proper in 222 (63.4%) patients and replaced origin of LHA from the left gastric artery (Type II) was found in 46 (13.1%) patients. Accessory LHA (Type V) was found in 15 (4.2%) cases. Replaced origin of Right Hepatic Artery (RHA) (Type III) from the superior mesenteric artery was seen in 26 (7.4%) of the cases. In 4 (1.1%) of cases, we observed replaced RHA with accessory LHA (Type VIII). The entire hepatic artery was seen arising from Superior Mesenteric Artery (SMA) in 6 (1.7%) of cases. Type VI, VII, and X variations were not observed in our study. Six of the cases could not be classified under Michel's classification, which is found to be minor variations of the coeliac artery where the common hepatic trunk arises directly from the abdominal aorta [Table/Fig-4].

Types	Description	No of cases (n=350)	Percentage (%)
I	Right and left hepatic arteries arise from the common hepatic artery	222	63.4
II	Replaced Left Hepatic Artery (LHA) from the left gastric artery	46	13.1
III	Replaced Right Hepatic Artery (RHA) from the superior mesenteric artery	26	7.4
IV	Replaced right and left hepatic arteries	25	7.1
V	Accessory LHA from the left gastric artery	15	4.2
VI	Accessory RHA from the superior mesenteric artery	0	0
VII	Accessory right and left hepatic arteries	0	0
VIII	Replaced RHA and accessory LHA or replaced LHA and accessory RHA	4	1.1
IX	Entire hepatic trunk arises from the superior mesenteric artery	6	1.7
X	Entire hepatic trunk arises from the left gastric artery	0	0
Miscellaneous	Not described otherwise	6	1.7

[Table/Fig-2]: Hepatic artery variations according to Michel's classification.

Portal vein variation: The portal vein branching patterns were defined and analysed according to Covey AM et al., classification [Table/Fig-5]. The normal portal vein (Type I) branching pattern was seen in 201 (57.4%) cases. Variants in portal vein branching patterns were seen in 149 (42.6%) cases [Table/Fig-6]. In, Trifurcation (Type II) is the most common variation accounting for 68 (19.4%) cases followed by Type III where the right posterior portal vein comes as the first branch of the main portal vein. In 27 (7.7%) cases, the segment VI branch arises as a separate branch from the right portal vein and in 15 (4.3%) cases the right portal vein gives a separate branch to segment VII. In 8 (2.3%) cases, variations of portal vein branching patterns were noted, which was not described under Covey AM et al., classification system [Table/Fig-7].

Hepatic artery	No. of Cases	Percentage (%)
Normal anatomy	222	63.4
Variants	128	36.6
Total	350	100

[Table/Fig-3]: Hepatic artery variants.

Hepatic arteries not described under Michel's classification	No. of Cases (n=6)	Percentage (%)
The LHA is a direct branch from the abdominal aorta and replaced the RHA from the superior mesenteric artery	1	0.3
Replaced LHA from left gastric artery and RHA from CHA both arise separately from the aorta	1	0.3
Accessory LHA from left gastric artery and right and LHA from CHA	1	0.3
Common hepatic trunk from the abdominal aorta	3	0.8

[Table/Fig-4]: Variations of hepatic arteries in this study.
CHA: Common hepatic artery

Types	Description	No. of Patients (n=350)	Percentage (%)
I	Standard anatomy	201	57.4
II	Trifurcation	68	19.4
III	Right Posterior portal vein as the first branch of main portal vein	31	8.9
IV	Segment VII branch as a separate branch of right portal vein	15	4.3
V	Segment VI branch as a separate branch of right portal vein	27	7.7
Others	Not described in classification	8	2.3

[Table/Fig-5]: Portal vein variation according to Covey AM et al., classification.

Portal Vein	No. of Cases (n=350)	Percentage (%)
Normal anatomy	201	57.4
Variants	149	42.6
Total	350	100

[Table/Fig-6]: Portal vein variants.

Portal vein variant not described under Covey AM et al.,	No of cases (n=8)	Frequency %
Segment V supplied by left portal vein branch	3	0.87
Segment V supplied by both right and left portal vein branches	2	0.57
Right anterior portal vein a branch of left portal vein	1	0.29
Single portal vein with segmental arteries	2	0.57

[Table/Fig-7]: Variations in this study

DISCUSSION

Due to recent advances, the complexity of liver interventions by both surgeons and interventional radiologists has increased. Anatomical variations of hepatic artery and portal vein play an important role in evaluation before liver resection, liver transplant, and interventional procedures like transhepatic portal vein embolisation, transhepatic intraparenchymal portosystemic shunts, and intra-arterial chemoembolisation.

Although DSA is the gold standard in studying the vascular system, it is invasive and expensive [3]. The various non invasive imaging modalities available for the evaluation of the hepatic artery and portal veins are doppler ultrasonography, computed tomography, and magnetic resonance. Ultrasound is user dependent and has poor value in delineating subtle variations of the hepatic artery and portal veins. Magnetic resonance has the advantage of the absence of ionising radiation and improved tissue contrast, however, due to its longer acquisition times, increased susceptibility, and motion-related artifacts, it is not the preferred non invasive imaging modality for studying hepatic artery and portal vein variations. The MDCT is preferred non invasive modality for imaging the hepatic artery and portal vein variations due to its shorter acquisition time and 3D reconstruction capabilities. Because of the complex anatomy, multiplanar reconstruction, curved reconstruction, and volume, rendered 3D images are needed for the visualization of arterial branches [6]. The disadvantages of MDCT include ionising radiation, nephrotoxicity of iodinated contrast material, and lack of qualitative flow information.

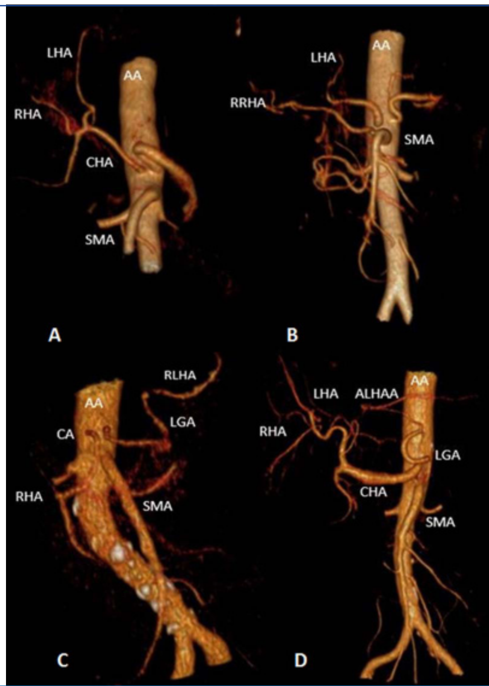
Hepatic artery: The hepatic artery supplies 12-49% of the liver's blood supply. Normally, it arises from the coeliac artery and runs superiorly and to the left side of the common hepatic duct, where it divides into right and left hepatic arteries to supply right and left hepatic lobes, respectively [5]. Hepatic artery branches developing from other than the coeliac trunk is termed as an aberrant hepatic artery that can be accessory or replaced. The most common type of variation was the origin of the RHA from SMA and the next common variation was the origin of the LHA from the left gastric artery [7]. Hepatic artery anatomy and its variations have many classification systems [Table/Fig-8]. The variant anatomy was found to be less in our study (36.6%) when compared to Michel's study (45%) [4]. A similar result was exhibited in a study conducted by Covey AM et al., [8]. The most common variant reported in the literature is type III (6-15%) followed by type II (2.5-10%) [3,9]. In this study, Michel's 10 type classification system was followed, because it was most widely accepted and gives the best anatomical approach. Our study showed a higher percentage of normal variants (63.4%) compared to Michel's study (55%). Similar results were reported by Covey AM et al., and Daly JM et al., [8,10]. In this study, a slightly higher prevalence of type II (13.1%) followed by type III (7.4%) was found. Replaced RHA and LHA was found in 7.1% population in our study, which has slightly higher prevalence compared Michel's NA, Covey AM et al., and Daly JM et al., [4,8,10]. Accessory LHA from left gastric artery has a prevalence of 4.2% in our study, which was in accordance with the study (3.5%) conducted by Daly JM et al., [10]. In Michel's type VIII; the left lobe of liver receives dual supply both from hepatic artery proper and accessory hepatic artery from the left gastric artery, which has a prevalence of 1.1% which is consistent with Michel's NA and Covey AM et al., [4,8]. A rare variant with a prevalence of 0.8%, where the common hepatic trunk arises directly from the splenic artery (Michel's Type IV). In this study, the unclassified variants show a frequency of 1.7%, where the hepatic artery arises as a direct branch from the celiac trunk which is reported in Sureka B et al., 2013 and Chen CY et al., 1998 reported such variant in 0.5% and 0.33% [2,11]. In this study, types VI, VII, and X were not observed [Table/Fig-9,10].

Michel's type II and III variants have longer replaced right or left hepatic arteries which were suitable during liver transplants for surgeons to perform a safer anastomosis [3]. Improper mapping of hepatic arterial variation during liver transplant leads to damage to the vessel and subsequent liver ischaemia [12].

Portal vein: The portal vein carries as much as 80% blood from the digestive tract, the spleen, pancreas, and gall bladder into the liver. At hepatic hilum, it is divided into the left portal vein that supplies segment II, III and IV and right portal vein which again divided into anterior and posterior division which supplies segment V, VI, VII and VIII [13]. Portal vein develops during the second to third month of gestation from two vitelline veins. The main stem develops from

Hepatic artery branching pattern	Current study (n=350), %	Michel's NA et al., 1966 [4] (n=200), %	Daly JM, 1984 [10] (n=200), %	Chen CY et al., 1998 [11] (n=321), %	Covey AM et al., 2004 [8] (n=600), %
Type I	63.4	55	76	80.3	61.3
Type II	13.1	10	4	7.8	3.8
Type III	7.4	11	6	5.2	8.7
Type IV	7.1	1	0	0.7	0.5
Type V	4.2	8	3.5	1.3	10.7
Type VI	0	7	4	1.5	1.5
Type VII	0	1	0	0.5	1
Type VIII	1.1	2	0	0	3
Type IX	1.7	4.5	2	1.6	2
Type X	0	0.5	0	0	0
Not otherwise described	1.7	0	6	1.1	7.5

[Table/Fig-8]: Hepatic artery branching pattern frequencies [3,9-11].



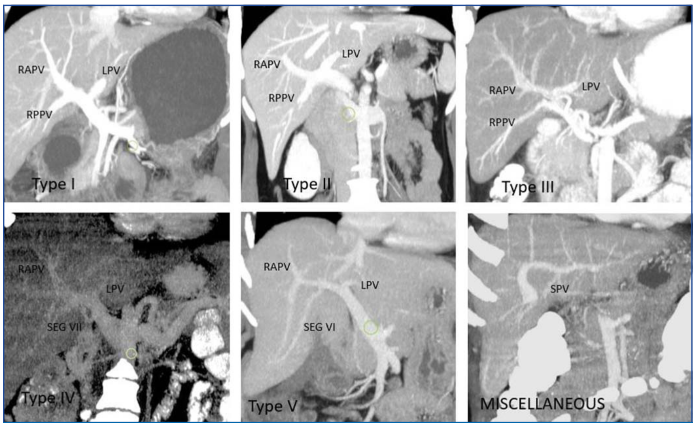
[Table/Fig-9]: Volume rendered images of variants of hepatic arteries in this study. A. Common hepatic artery (CHA) arises from aorta, B. Left hepatic artery from the aorta with a replaced Right Hepatic Artery (RHA) from the splenic artery, C. Replaced Left hepatic artery from left gastric artery and RHA from CHA both arises separately from the aorta, D. Accessory left hepatic artery from left gastric artery and right and left hepatic artery from CHA.

[Table/Fig-10]: Maximum intensity projection showing types of Hepatic artery variations according to Michel's classification.
CHA: Common Hepatic artery, RHA: Right hepatic artery, LHA: Left hepatic artery, SA: Superior mesenteric artery, LGA: Left gastric artery, RRHA: Replaced right hepatic artery, RLHA: Replaced left hepatic artery, and ARHA: Accessory right hepatic artery

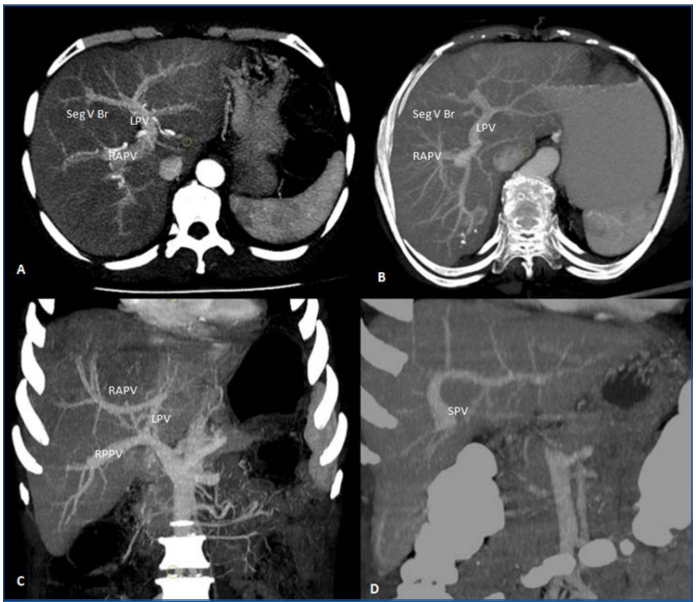
the left vitelline vein and its dorsal anastomosis, the left branch from the left vitelline and cranioventral anastomosis, and the right branch from the right vitelline vein. Any deviation from this normal anastomosis will result in variations [5]. As the frequency of hepatic interventional procedures and complex hepatic surgeries increases in modern medicine such as hepatic trisegmentectomy, portal vein embolisation, Transjugular Intrahepatic Portosystemic Shunts (TIPS), and Selective Internal Radiation Therapy (SIRT), the precise anatomical mapping of the portal vein and knowledge about its variant anatomy plays crucial importance to avoid any postprocedural complications. We followed Covey AM et al., classification system to categories portal vein variants [Table/Fig-11-13].

Portal vein branching pattern	Current study (n=350), %	Covey AM et al., [5] (n=200), %	Sureka B et al., [15] (n=967), %
1	57.4	65	80
2	19.4	9	7
3	8.9	13	5
4	4.3	1	3
5	7.7	6	1
Miscellaneous	2.2	6	4

[Table/Fig-11]: Portal vein branching pattern frequencies [5,15].



[Table/Fig-12]: Maximum Intensity projection images showing types of portal vein variations according to Covey AM et al., classification. RAPV: Right anterior portal vein, RPPV: Right posterior portal vein, LPV: Left portal vein, SEG VI: Segment VI branch, SEG VII: Segment VII branch and SPV: Single portal vein.



[Table/Fig-13]: Maximum intensity projection images showing portal vein variations in this study. A. Segment V branch arising from left portal vein, B. Segment V branch arising from both right anterior portal vein and left portal vein, C. Right anterior portal vein, a branch of left portal vein, and D. Single portal vein giving segmental branch to all segments of liver.

In our study, there was a higher percentage of normal variant (57.4%) observed, which is in accordance with Covey AM et al., [5]. Carnerio et al., found the typical branching of main portal vein in 65% of individuals [7]. When compared to literature, Type III followed by Type II is the most common variant [14]. In this study, there is a slight preponderance of type II (trifurcation) which accounts for 19.4% followed by type III (right posterior portal vein as the first branch). This was seen in accordance with the study done by Sureka B et al., who found trifurcation (Type II) anomaly in 66 (6.83%) of cases and right posterior vein as first branch of main PV (Type III) anomaly was seen in 48 (4.96%) of their cases [15]. Type IV and type V variants are being rare which occur at a frequency of 4.3% and 7.7%, respectively. In this study, unclassified or miscellaneous variants were observed such as segment V supplied by right and left portal vein branches, segment V supplied by both right and left portal vein branches, right anterior portal vein arising from left portal vein, and single portal vein with segmental arteries which are described by Stagno A et al., and Sureka B et al., [13,15].

The hepatic artery and portal vein have many variant anatomical branching patterns and origins. These variant anatomies were best described by Michel's classification (hepatic artery) and Covey's classification (portal vein). According to Michel's classification, the hepatic artery was divided into ten types. Few miscellaneous types, which were not classified under Michel's classification were found in this study, where LHA is a direct branch of the aorta. Likewise, Covey's system of portal vein classification has five types and few miscellaneous types, which we found in our study.

Limitation(s)

One potential limitation of our study would be the relatively smaller sample size and lack of DSA correlation.

CONCLUSION(S)

The CT Angiography is a valuable tool to study the vascular anatomy of the upper abdomen. Because of its shorter image acquisition time and multiplanar reconstruction capability, hepatic artery branches will be seen with better resolution. Likewise, axial oblique Multiplanar Reformation (MPR) and Maximum Intensity Projection (MIP) techniques will be better for studying portal vein branching patterns. Knowledge about variant hepatic artery and portal vein anatomy helps in aiding hepatobiliary surgeons and interventional radiologists during hepatic interventions. Preprocedural assessment of hepatic and portal vein variants would be useful in presurgical planning reducing mortality and morbidity.

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