ADDIS ABABA UNIVERSITYCOLLEGE OF HEALTH SCIENCES

SCHOOL OF GRADUATE STUDIESDEPARTMENT OF RADIOLOGY

CROSS SECTIONAL STUDY ON PATTERNS OF VARIATION IN HEPATICVASCULATURE IN PATIENTS ENROOLED TO RADIOLOGY DEPARTMENT AND EVALUATED BY COMPUTED TOMOGRAPHY AT TIKUR ANBESSA SPECIALIZED HOSPITAL, ADDIS ABABA UNIVERSITY, ADDIS ABABA, ETHIOPIA

FROM JUNE2018- SEPTEMBER 2018

INVESTIGATOR: DR. KALE’AB TESFAYE (MD, RADIOLOGY RESIDENT)

A THESIS SUBMITTED TO DEPARTMENT OF RADIOLOGY, COLLEGE OF HEALTH SCIENCE, ADDIS ABABA UNIVERSITYFOR PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR POST-GRADUATE PROGRAMME COMPLETION.

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CROSS SECTIONAL STUDY ON PATTERNS OF VARIATION IN HEPATIC VASCULATURE IN PATIENTS ENROOLED TO RADIOLOGY DEPARTMENT AND EVALUATED BY COMPUTED TOMOGRAPHY AT TIKUR ANBESSA SPECIALIZED HOSPITAL, ADDIS ABABA UNIVERSITY, ADDIS ABABA, ETHIOPIA FROM JUNE 2018- SEPTEMBER 2018.

Investigator; Kaleab Tesfaye(MD, Radiology resident)

Advisor: Tesfaye Kebede, MD, Associate Professor of Radiology, AAU

College of Health Sciences, TASH, Department of Radiology,

AA, Ethiopia.

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I take this opportunity to sincerely express my gratitude to my colleagues and friends.

Finally, I would like to forward my appreciation to my families and my wife Bethel Getachew for their tremendous help to materialize this study

Table of Contents

List of Tables

List of Figures

Acronym

CA	celiac artery
CHA	common hepatic artery
CTA	computed tomography angiography
DSA	Digital Subtraction Angiography
GDA	gastroduodenal artery
LGA	left gastric artery
LHA	left hepatic artery
PHA	proper hepatic artery
rCHA	replaced common hepatic artery
RHA	right hepatic artery
rRHA	replaced right hepatic artery
SMA	superior mesenteric artery

Summary

Background

Hepatic Artery, on the basis of intrahepatic branching patterns of blood supply and biliary drainage, liver creates 8 segmentations: anterior and posterior segments in right lobe, whereas medial and lateral segments in left lobe. Each segment is again subdivided into upper and lower segments[1]. The usual arterial supply of liver is common hepatic artery arising from celiac trunk, accounting for 25-75% of cases. The patterns of arterial supply are not constant. In variant patterns, it receives arterial flow through branches coming from superior mesenteric artery, left gastric artery, or, rarely from other arterial trunks[2].

Portal vein, the normal anatomy of portal vein is defined as a division of main portal vein into two branches left portal vein and right portal vein. Left portal vein supplying segments I, II, III and IV. The right portal vein is dividing secondarily into two branches- right medial (anterior) sectoral division supplying segments V & VIII and right lateral (posterior) sectoral division supplying segments VI & VII.[1] Variations are frequent and they account for 20-35% of the population.

Objective: This study is designed to evaluate the patterns of variation in hepatic vasculature on patients presented to radiology department and had computed tomography of the abdomen at tikuranbesa specialized hospital.

Method:Hospital based retrospectivecross-sectional study was conducted on 878 patients who underwent an abdominal CT at TASH andpatterns of variation in hepatic vasculature was evaluated in a period of 3 months from June 2018 to September.2018.

Data was collected by evaluating abdominal CT scans from PACS (Medweb). The data was checked for clarity and completeness. Computerized data analysis was conducted by using SPSS version 20.0 software

Result: Total of 878 (N = 878) patients were included in the study out of which 537 patients had a post contrast CT and 341 patients had a triphasic scan

Hepatic arterial anatomy was evaluated in those patients who had a triphasic abdominal CT, out of which 299 (87.7%) had a normal classic anatomy and 42(13.3%) cases had a variant anatomy.

Normal Portal vein anatomy was seen in 717 patients (79.94%) out of 878 patients. Trifurcation (Type I) variation was seen in 77 (8.8%) of the cases. Right posterior vein as first branch of MPV (Type II) variation was seen in 66 (7.5%) of the cases. Type III variation seen in 14 (1.6%) cases, type IV seen in 1 (0.1%) case and 3 cases had other types of variation which are not included in the variant, in which 2 patients had an absent Left Portal vein and 1 case had a division of the main portal vein into segment VI, segment VII, right anterior portal vein, and left portal vein as a "quadfurcation".

1. Introduction

1.1. Back ground

1.2. Statement of the problem and Significance of study

Hepatic Artery

On the basis of intrahepatic branching patterns of blood supply and biliary drainage, liver creates 8 segmentations: anterior and posterior segments in right lobe, whereas medial and lateral segments in left lobe. Each segment is again subdivided into upper and lower segments[1]. Theusual arterial supply of liver is common hepatic artery arising from celiac trunk, accounting for 25-75% of cases. The patterns of arterial supply are not constant. In variant patterns, the hepatic lobes may receive arterial flow through branches coming from superior mesenteric artery (SMA), left gastric artery (LGA), the aorta or, rarely from other arterial trunks[2]

The hepatic arteries provide 25% of blood supply and about 50% of oxygen supply to the liver[3]. The anatomy of hepatic artery is of great importance in hepatobiliarysurgery, especially in cholecystectomy, partial hepatectomy and liver transplantation. Variations in segmental arteries of the liver should be known to surgeons specialized in hepato-biliary-pancreatic area and radiologists during their intervention procedures like chemoembolisation[2]

When the hepatic artery arises from a source other than the terminal end of the Celiac Trunk, it is considered as an aberrant hepatic artery. These aberrant hepatic arteries are of two types: replaced and accessory. A replaced hepatic artery is a substitute for the normal hepatic artery which is absent. An accessory hepatic artery appears in addition to one that is normally present[4,5]. Michels stated that there are no accessoryhepatic arteries since each hepatic artery is an end artery with a selective distribution to a definite area of the liver and therefore cannot be sacrificed without resultant necrosis of liver tissue[6]. Injury to the RHA is more common in presence of aberrant arterialanatomy. These variations contribute to occurrence of potential problems during surgery leading to significant morbidity and even mortality. Adequate knowledge of normal andvariant hepatic arterial anatomy is crucial for hepatobiliarysurgery and liver transplantation. The aim of this cross-sectional, observational, quantitative, and descriptive studywas to record the normal and variant anatomy of the HA and to contribute to the existing knowledge.

Table 1Michels[21] and Hiatt [22] classifications for variations found in hepatic arterial anatomy

Hepatic arterial anatomy	classification Michels	classification Hiatt
Normal anatomy	Type I	Type I
LHA branch LGA	Type II	Type II
RHA branch SMA	Type III	Type III
Type I and II association	Type IV	Type IV
LHA accessory LGA	Type V	Type II
RHA accessory SMA	Type VI	Type III
LHA accessory LGA + RHA accessory SMA	Type VII	Type IV
LHA accessory LGA+ RHA branch SMA	Type VIII	Type IV
CHA branch SMA	Type IX	Type V
RHA and LHA branch LGA	Type X	------
CHA aorta branch	--------	Type V

"------"= liver variation not present in the corresponding classifcation column. RHA=right hepatic artery; LHA=left hepatic artery; SMA=superior mesenteric artery; LGA = left gastric artery; CHA=common hepatic artery

Portal vein

- *Normal Portal Anatomy*

  The portal vein arises from the confluence of the superior mesenteric, inferior mesenteric and splenic vein posterior to the neck of the pancreas. The normal anatomy of portal vein is defined as a division of main portal veinin the liver hilum into into two branches: left portal vein branch (LPV) and right portal vein branch (RPV). Any deviation from this anatomy is considered an anatomical variants[7-9]. LPV courses medially to the umbilical fissure, supplies segments II, III and IV and provides also a caudate branch. RPV subsequently divides in an anterior branch (RAPV), feeding segments V and VIII, and a posterior branch (RPPV), feeding segments VI e VII (Figure 1). Normal anatomy is encountered in 65 to 80% in the studies using multidetector CT. Variations are frequent and they account for 20-35% of the population.

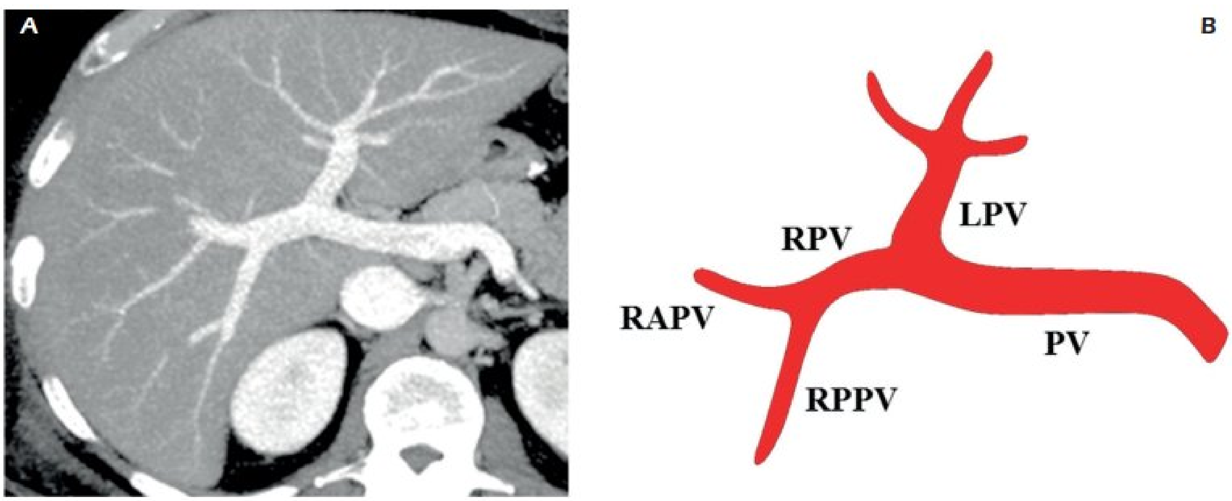

Figure 1. Normal portal anatomy. ***A,*** Contrast-enhanced CT on portal venous phase - axial MIP reconstruction. The portal trunk divides into a left and a right portal vein that subsequently divides in an anterior branch feeding segments V and VIII and a posterior branch feeding segments VI and VII. ***B,*** PV: portal vein; LPV: left portal vein; RPV: right portal vein; RAPV: right anterior portal vein; RPPV: right posterior portal vein.

- *Portal Vein Variants*

  Portal vein variants are quite frequent and easy to recognize with 3D reconstructions of CT or MR images, with a reported incidence of 27 and 35%.

  These variations have a considerable impact on liver surgery and radiological interventional procedures and should be precisely described; in particular, a reliable preoperative imaging of vascular anatomy is mandatory relating to recent developments in liver surgery, with living donor transplantation or complex hepatectomy[7], and in interventional radiology with portal vein embolization. Portal vein variants are associated with a significantly higher number of biliary anatomic variations, in particular the presence of portal vein variants increases the risk of bile duct hilar anatomical variation.

- *Most literature'sdescribe four main types of portal vein variants:*

  Type 1: *is the so called "portal vein trifurcation"with a reported occurrence of 9-11%, where*

  main portal vein divides into three branches: left portal vein (LPV), right anterior portal vein (RAPV), and right posterior portal vein (RPPV) (Figure 2).

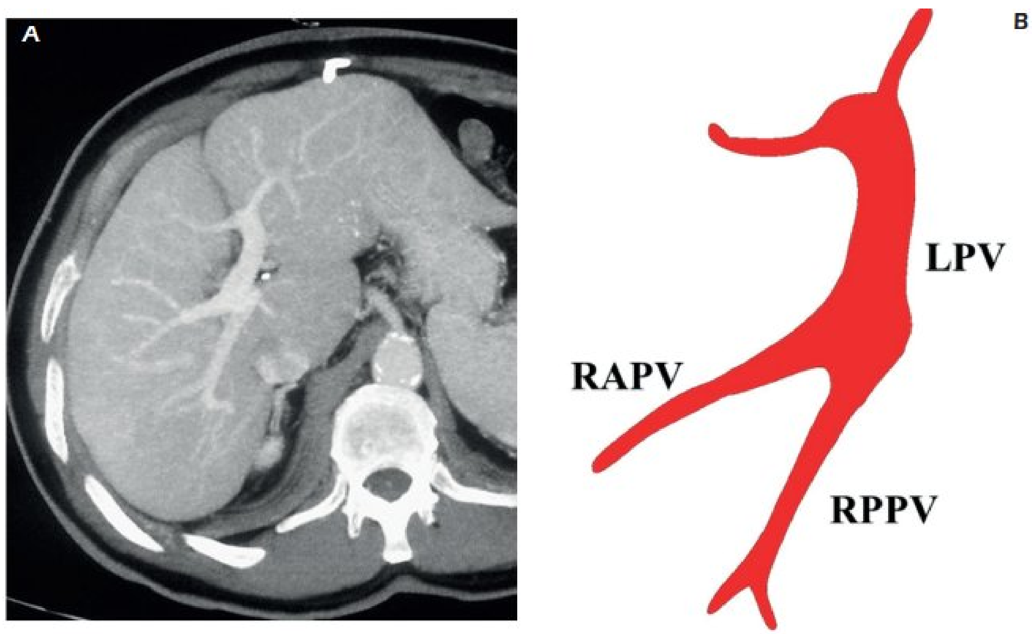

Figure 2. Portal vein variants – type 1: portal vein trifurcation. ***A,*** Contrast-enhanced CT on portal venous phase – axial MIP reconstruction. The main portal vein divides into three branches: the left portal vein, the right anterior portal vein, and the right posterior portal vein. ***B,*** LPV: left portal vein; RAPV: right anterior portal vein; RPPV: right posterior portal vein.

Type 2*: right posterior portal vein (RPPV) originates as the first branch of portal vein (PV), with a reported occurrence of 9.7-23% (Figure 3).*

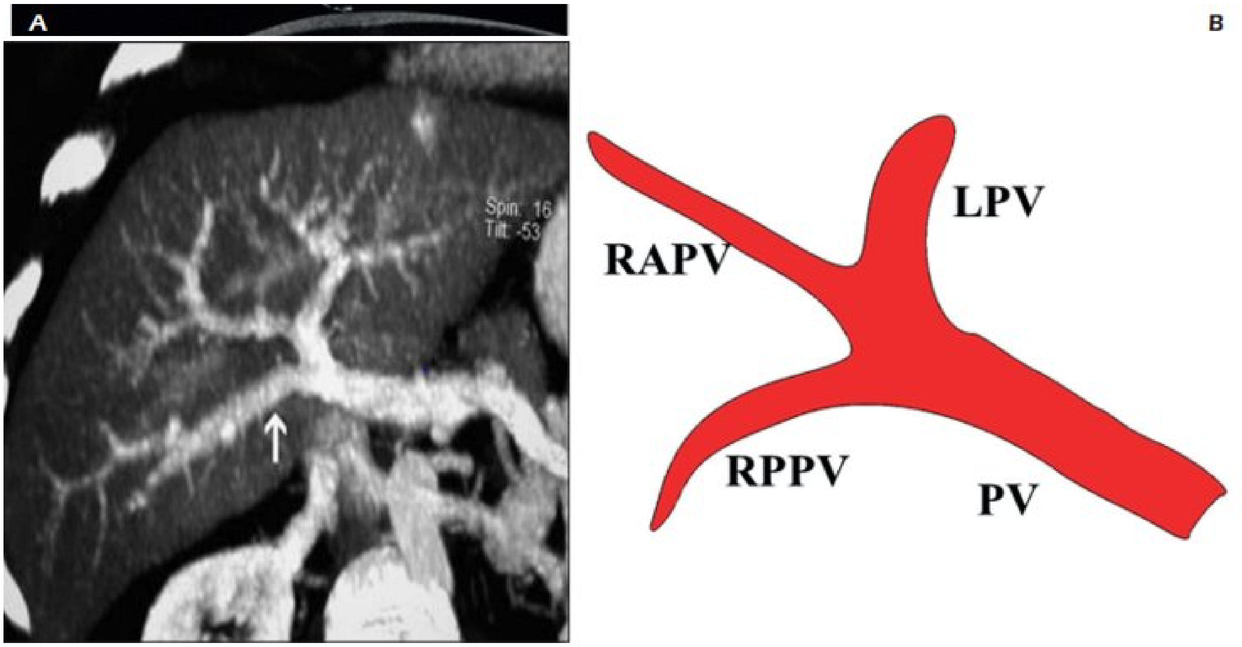

Figure 3. Portal vein variants – type 2. ***A,*** Contrast-enhanced MRI on portal venous phase - coronal MIP reconstruction. The right posterior portal vein originates as the first branch of the portal vein. ***B,*** PV: portal vein; RPPV: right posterior portal vein; RAPV: right anterior portal vein; LPV: left portal vein.

Type 3: *right anterior portal vein (RAPV) originates from the left portal vein (LPV) (Figure 4).*

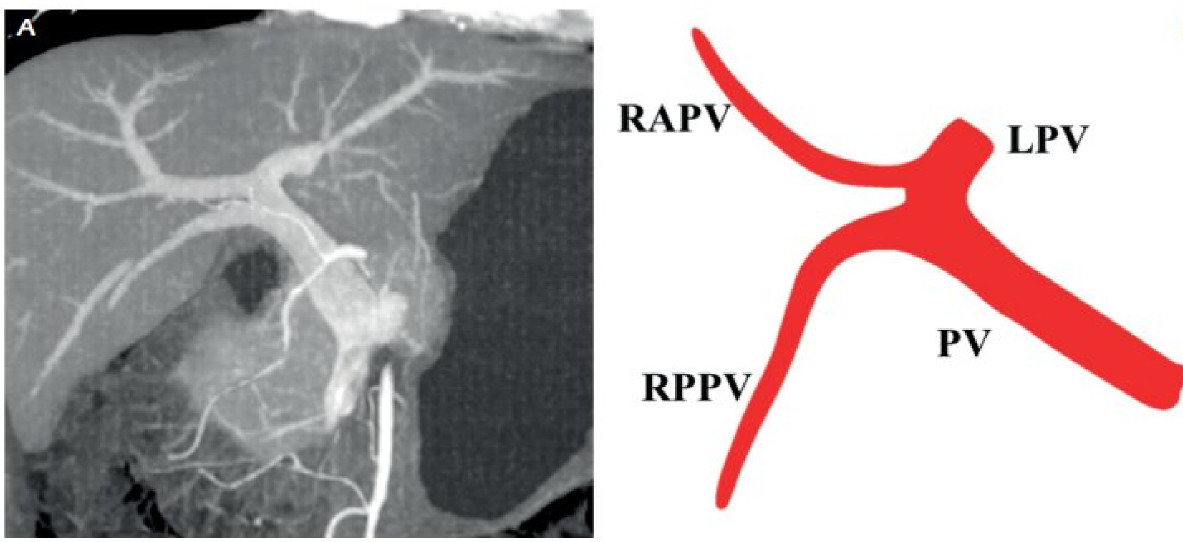

Figure 4. Portal vein variants – type 3. ***A,*** Contrast-enhanced CT on portal venous phase - coronal MIP reconstruction. The right anterior portal vein originates from the left portal vein. ***B,*** PV: portal vein; RPPV: right posterior portal vein; LPV: left portal vein; RAPV: right anterior portal vein.

- Type 4: *this portal vein variant is less common(< 2%) and is characterized by the absence of portal vein bifurcation (the portal vein gives only a single right portal branch in the* *liver hilum) and by the presence of a large vein coming from segment VIII and entering the distal segment of the left portal vein(Figure 5)*[8,10,11,12].

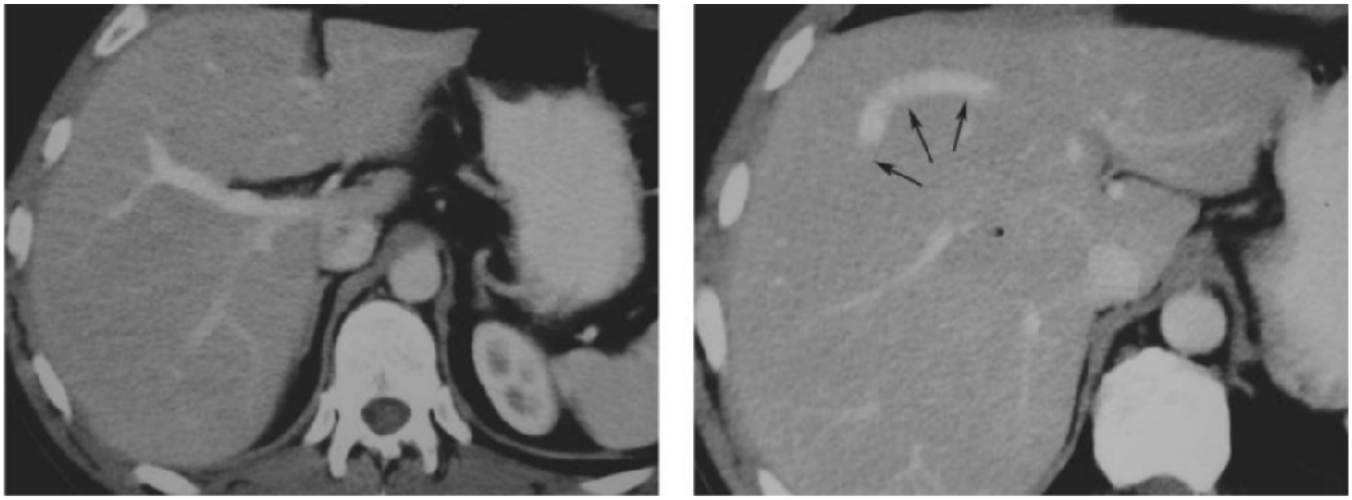

Figure 5. Absence of left portal vein. On a computed tomography (CT) image passing by the liver hilum the left portal vein is not visible. On a CT slice passing by segment VIII a large vein (arrows) is seen running parallel to the liver capsule and going from segment VIII to segment IV

The advent of most conservative method of liver surgery has necessitated the knowledge of intrahepatic branching pattern of portal vein, which has consequently assured a new vista in the hepatic resection. The variations must be diagnosed before hepatectomy, partial or total liver transplantations and also before complex interventional procedure such as portal vein embolization.

The awareness of variations will help to prevent complications like hemorrhage, difficult anastomosis in the recipient, ischemia in the graft and allograft failure. The variation of portal vein is one of the important selection criteria of donor because isolation of the portal vein branches is not possible during partial hepatectomy.

Hepatocellular carcinoma has a trabecular structure and vascularity is a prominent feature and these lesions frequently invade the branches of portal vein and occasionally hepatic vein. Venous spread or extension of tumor from small branches of the portal system in a retrograde fashion into larger branches and eventually into the main portal vein.[13]

Prior knowledge of normal portal venous anatomy and any variation in its branching pattern will also help for correct interpretation during radiological study. The purpose of this study is to review the normal and variant portal venous anatomy and their implication in liver surgery and preoperative portal vein embolization.

2. Literature review

Hepatic Artery

- The liver has 8 hepatic segments according to Couinaud's description which are numbered as segment 1,2,3,4,5,6,7 and 8 in a clockwise direction, starting with caudate lobe segment(1 by portal pedicles. Due to variable persistence of elements of embryologic blood supply, numerous anatomical variations are there in hepatic arterial system. In embryo, there are three hepatic arteries: right hepatic artery, middle hepatic artery and left hepatic artery. The right and left hepatic arteries disappear and middle hepatic artery becomes hepatic artery proper in adult. The wide spectrum of variation in hepatic arterial anatomy makes preoperative planning and intraoperative imaging in liver transplantation and other hepatic surgeries essential[14].
- Knowledge of hepatic vascular anatomy is of great importance for the surgeon to perform abdominal intervention[16]. It is known that changes present at diﬀerent stages of embryonic development lead to large variations in vasculature. In liver transplantation, in particular, detailed knowledge of the graft anatomy is essential to achieve its full arterialization and must be precisely identified at the time of organ captation[17,18,19]. Thus, the classic vascular anatomy will serve as a guide to understanding the vascular supply and graft drainage[19]. In cases of anatomical variations, the hepatic lobes can receive blood supply from other vessels, as accessories, occurring in addition to the normal blood supply, or as a substitutive way, representing the only primary lobe arterial supply[20]. Multiple anatomical variants were classified into 10 categories by Michels in 1966, in a study of 200 dissections, which is a reference to the present day for most studies[18,16]. This classification was modified by Hiatt in 19945, which, unlike Michels, did not make distinction between ancillary or hepatic arterial substitute structures, organizing it into six

categories. Hiatt classifcation[22] is simpler and frequently applied when the analysis is performed using angiographic studies, since it is considered difficult to distinguish between angiographically ancillary substitute or vascular structures[23]. In our study, both classifications will be used.

- Zagyapan et al analyzed 152 liver transplantation donors through digital angiography, finding 37,5% of anatomic variations of the hepatic artery[19]. Hiatt et al.[22] in a series of 1000 patients who underwent liver transplantation, found 24.3% of hepatic changes. In a series of 1200 cases, Kobayashi et al. identified normal hepatic arterial anatomy in 77.2%, and 22.8% of anatomic variations[16].
- However, as anatomical variations may occur due to genetic aberrations in the embryonic period, no detailed classification can cover all types[16]. Rare anomalies not covered in Michels and Hiatt classifications were observed in 14 patients (2.92%), following a pattern of major studies. Koops et al[25]. intheir series revealed frequency of 1.8% rare presentations and non-classified; meanwhile, Ugurel et al showed frequency of 3% of these forms in their paper. It is believed that the existence of rare variants shows that the embryological development of the branches of the aorta can be influenced by many factors, and is a complex process[23]. Among these variations, the hepatomesenteric trunk, common hepatic artery and superior mesenteric artery originated from the aorta into a common trunk, and the common hepatic artery from the left gastric artery, are variants found rarely between abdominal vascular anomalies and also rarely reportedin the literature. Chen et al.[24] reported these variations in their series with a prevalence of 1.5-0.7%, respectively. In this series, these changes were found in 1.04 to 0.2%.
- In Ethiopia, there is lack of published data, which described Hepatic arterial anatomical variations. In one study done on 2001, in which they investigated 110 postmortem and cadaveric subjects and found that; the right hepatic artery took origin from the proper hepatic artery (66.3%), the common hepatic artery (18.2%), the superior mesenteric artery (8.2%) or the celiac trunk (7.3%). Ten cases of accessory right hepatic artery originating from the superior mesenteric artery (7 cases), gastroduodenal artery (2 cases) or the left hepatic artery (1 case) were observed. The origin of the left hepatic artery included the proper hepatic artery (71.8%), the common hepatic artery (16.4%), the celiac trunk (10.9%) and the splenic artery (0.9%). The 14 cases of accessory left hepatic

arteries originated from the common hepatic artery (5 cases), right hepatic artery (3 cases), gastroduodenal artery (2 cases) or the celiac trunk (4 cases). An extrahepatic branch to the quadrate lobe of the liver, also known as the middle hepatic artery, was observed in 47.3% arising mainly from the right or left hepatic arteries (20% each), the superior mesenteric artery (2.7%) and from the gastroduodenal artery (4.6%)[26].

- The precise knowledge of the most common and rare variations that produce di□erent technical difficulties, or challenges, is essential to surgeons and interventional radiologists in order to avoid damage and vascular surgical complications[24,23].

Portal Vein

- Prior knowledge of normal portal venous anatomy and any variation in its branching pattern will help for correct interpretation during radiological study. Intrahepatic portal vein anatomy was described many years ago on cadaveric liver dissection and with corrosion casts of explanted liver.[27] Modern imaging techniques such as multislice computed tomography (CT) or magnetic resonance imaging (MRI) now allow for three-dimensional (3D) reformation of the entire liver vascular structures, and offers an interactive platform for surgeons and interventional radiologists to decide preoperatively the best treatment options.[11,12,28].The most common variant is the so called ‘‘portal vein trifurcation’’ where the main portal vein divides into three branches as described in the introduction. (type 1, Fig.2). The second most common variant is a right posterior portal vein originating as the first branch of the portal vein (type 2, Fig 3). These two variants account for the majority of main portal vein variation. Their relative incidence varies from study to study and the reported incidence of these variants increases with the use of the most recent imaging modalities. In older reports, the incidence was ranged between 0.09 and 24%.[29-31] The use of 3D reconstruction obtained fromthin axial CT images seems the most efficient technique with reported incidences of 27 and 35%[11,12,32]
- In the study of Atasoy and colleagues, type 2 was twice more frequent than type 1[11](23.5 and 9.5%, respectively). In the study of Covey and colleagues, the reported incidence of type 1 and 2 were respectively 9 and 13%.[32] In another recent study including 1384

patients, trifurcation was slightly more frequent than early origin of the right posterior branch of the portal vein (11.1 and 9.7%, respectively)[12].

- Less common portal vein variations have been described but their incidence has not been found to behigher than 2%.[11,12]The variants include quadrification in which the portal vein divides into a left portal branch and three separate right portal branches and a more complex variant is the so-called ‘‘absence of portal vein bifurcation’’[12] as described in the introduction as type 4. In the latter case, the portal vein gives only a single right portal branch in the liver hilum, the origin of the left portal branch being absent. A large portal branch coming from segment VIII crosses segments VIII and VI and ends in the umbilical portion of the portal vein and then supplies a small segment of left portal branch that gives the segments II, III, and IV branches (Fig. 5).
- In addition to variations of the main portal vein, there are other important variations in the anatomy of the division of right portal branches.[34] The division of right portal branches has been assessed in the Japanese literature with the use of Takayasu classification.[35] The knowledge of these variants has not been extensively disseminated because of its limited impact on most surgical and interventional procedures. However, the development of more limited anatomic resections suchas those in cirrhotic patients requires precise knowledge of the anatomic situation before surgery. Recently, an extensive study focused on this point. These authors observed that the typical division of the right portal branch (i.e., two main branches)[34]is encountered in 70% of cases. This division gives two branches for segments V and VIII (anterior right liver) and two separate branches for segments VI and VII (posterior right liver). The most common variant (seen in 20% of cases) is the absence of definite right posterior branches but the immediate bifurcation in two branches for segments VI and VII. A further variation concerns the origin of the segment V branch originating fromthe right posterior portal vein or directly from the right portalvein. Another important anatomic variation is the presence of segmental portal branches passing throughthe mid plane of the liver separating, theoretically, the left and the right liver. This was found in 4% of cases[12]and this concerns only segments IV and VIII fed by branches coming from the contralateral side.

3. Objectives

3.1. General objective

- To assess the patterns of hepatic vasculature variants

3.2. Specific objectives

- To assess the incidence of hepatic artery variants
- To assess the incidence of portal vein variants
- To identify the common anatomic variants of hepatic artery
- To identify the common anatomic variants of portal vein

4. METHODS AND MATERIALS

4.1 Study area and period

The study was conducted at TASH, College of health science, Addis Ababa University, Addis Ababa, Ethiopia. TASH, located in the nation's capital Addis Ababa, is a largest referral as well as a main teaching hospital. The hospital provides a tertiary level referral treatment with over 900 beds and is open 24hrs for emergency services. The study was conducted from June,2018-September, 2018 G.C.

4.2 Study design

A retrospectivecross-sectional studywas employed.

4.3 Population

4.3.1 Source population

The source population was all patients who had abdominal CT during the study period.

4.3.2 Study population

This is a cross-sectional study which includesa total number of 1003patients that were referred to the Radiology Department – Tikuranbessa Hospital to do either triphasic CT (which includes arterial phase) for liver assessment or Post contrast CT(which include only Portal venous) during the period from June,2018-September, 2018 G.C.

4.3.3 Inclusion and exclusion criteria

4.3.3.1 Inclusion criteria

- All patients evaluated with abdominal CT

4.3.3.2 Exclusion criteria

- Patients who had hepatic tumors or abdominal tumorsthat distorted the intrahepatic venous and arterial anatomy
- Patients who had a partial hepatic resection,
- Patients who had poor enhancement of the intrahepatic venous and arterial structures due to different reasons
- Patients who had a non-contrast low dose abdominal CT

4.4 Sampling technique and sample size

All patients with abdominal CT that has fulfilled the Inclusion criteria during the study period was included in the study.

4.5 Data collection plan

Data was collected using structured questionnaire from Picture Archive Communication System (MedWeb). Patients imagewas reviewed and patterns of Hepatic arteries wasevaluated from triphasic study and Portal venous anatomy was evaluated from all Post contrast and triphasic studies. The CT reports was reviewed and findings recorded in the questionnaires.

4.6 Data quality control

In order to evaluate the clarity of the findings, difficultimages werereevaluated together with radiology resident friends and some more difficult cases with my advisor

4.7 Data analysis and interpretation

The data was checked for clarity and completeness. Data was analyzed using nonparametric statistical methods with the help of SPSS version 20 software package. Then summarization and comparison of data was done.

4.8 Ethical considerations

In order to respect patient's bill of right, regulation of the hospital where the study was conducted, ethical considerations was taken in to account. Any piece of information was kept confidential by keeping anonymity of the study subjects.

4.9 Limitations

- Poorly timed arterial phase studies at Triphasic scan
- Minimal administration of IV contrast which lead to poor enhancement of the intrahepatic vessels
- Since there was no angiographic study, triphasic scan was used to depict the hepatic arterial anatomy and, in most cases, using the "3D MPR with maximum intensity projection (MIP)" was needed which is not working In Medweb software sodownloading each image was mandatory which was time consuming
- Because it's a cross sectional study it's difficult to identify risk factor

4.10 Plan of disseminating study finding

After the formal preparation of the final report the copy of the report was Submitted for evaluation, and possible future publication.

5. Result

I retrospectively reviewed 1003 abdominal multidetector CT (MDCT) examinations performed in our institute between June 2018 and September 2018. I excluded patients who had undergone previous liver resections (3 patients) and patients with large central tumors obscuring the hepatic vascular anatomy (29 patients) and patients who have a thrombosed vessel (18 patients) and those patients who had a low dose non-contrast abdominal CT and whose images were of poor quality, mainly because of insufficient portal venous opacification and motion artifact (75 patients).

So, finally a total of 878 (N = 878) patients were included in the study out of which 537 patients had a post contrast CT and 341 patients had a triphasic scan. This study group comprised 487 (55.5%) females and 391 male (44.5%) patients. Mean age of the patients was 42.37± 18.7 (mean±standard deviation).

Hepatic artery

Hepatic arterial anatomy was evaluated in those patients who had a triphasic abdominal CT (341 cases) out of which 299 (87.7%) had a normal classic anatomy and 42(13.3%) cases had a variant anatomy. The most common hepatic anatomic variant was Michels type V seen in 15 cases (4.4%) followed by type III and Type II with 3.2% and 2.1%. 3 cases (0.9%) had a variant anatomy which is not included in Michels classification that is "Replaced CHA arising directly from aorta".

Table 2 Number and Percentage of Hepatic arterial anatomy in our study

Type	Description	Percentage	No. of Patients
I	Classic anatomy	87.7	299
II	Replaced LHA arising from LGA	2.1	7
III	Replaced RHA arising from SMA	3.2	11
IV	Replaced LHA and replaced RHA	0	0

V	Accessory LHA arising from LGA	4.4	15
VI	Accessory RHA arising from SMA	0.3	1
VII	Accessory LHA and accessory RHA	0	0
VIII	Replaced LHA and accessory RHA or accessory LHA and replaced RHA	0.6	2
IX	Replaced CHA arising from SMA	0.9	3
X	Replaced CHA arising from LGA	0	0
XI	Any variant not included in Michels' classification	0.9	3
Total:		100	341

Portal Vein

Normal anatomy was seen in 717 patients (79.94%) out of 878 patients. Trifurcation (Type I) variation was seen in 77 (8.8%) of the cases. Right posterior vein as first branch of MPV (Type II) variation was seen in 66 (7.5%) of the cases. Type III variation seen in 14 (1.6%) cases, type IV seen in 1 (0.1%) case and 3 cases had other types of variation which are not included in the variant, in which 2 patients had an absent Left Portal vein and 1 case had a division of the main portal vein into segment VI, segment VII, right anterior portal vein, and left portal vein as a "quadrifurcation"

Table 3 Frequency and percentage of Portal venous anatomy

	Frequency	**Percent**
Normal PV anatomy in which MPV divides into LPV and RPV; then RPV divides into RAPV and RPPV	717	81.7
Variant Anatomy	161	18.3
Total	878	100

Table 4 Frequency and Percentage of portal venous specific variants

Variant Types	**Frequency**	**Percent**
Type 1	77	8.8
Type 2	66	7.5
Type 3	14	1.6
Type 4	1	0.1
Not classified	3	0.3
Total	161	100

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6 DISCUSSION

Hepatic Artery

Knowledge of hepatic vascular anatomy is of great importance for the surgeon to perform abdominal intervention[16]. It is known that changes present at different stages of embryonic development lead to large variations in vasculature. In liver transplantation, in particular, detailed knowledge of the graft anatomy is essential to achieve its full arterialization and must be precisely identified at the time of organ captation[17,18,19]

Thus, the classic vascular anatomy will serve as a guide to understanding the vascular supply and graft drainage[19]. In cases of anatomical variations, the hepatic lobes can receive blood supply from other vessels, as accessories, occurring in addition to the normal blood supply, or as a substitutive way, representing the only primary lobe arterial supply[20].

Multiple anatomical variants were classified into 10 categories by Michels[21] in 1966, in a study of 200 dissections, which is a reference to the present day for most studies[4,6]. This classification was modified by Hiatt in 19945, which, unlike Michels[21], did not make distinction between ancillary or hepatic arterial substitute structures, organizing it into six categories. Hiatt classifcation[22] is simpler and frequently applied when the analysis is performed using angiographic studies, since it is considered difficult to distinguish between angiographically ancillary substitute or vascular structures[23]. In this study, Michels classifications were used.

According to the literature, the prevalence of anatomical variations ranges from 20-50%[18]. Zagyapan et al.[19] analyzed 152 liver transplantation donors through digital angiography, finding 37.5% of anatomic variations of the hepatic artery[19]. Hiatt et al.[22] in a series of 1000 patients who underwent liver transplantation, found 24.3% of hepatic changes[21]. In a series of 1200 cases, Kobayashi et al.[16]identified normal hepatic arterial anatomy in 77.2%, and 22.8% of anatomic variations[16]. In this study, 299 patients (87.6%) had normal anatomy (Type I) and 42 patients (12.3%) had a variant anatomy, being this percentage the lowest prevalence among studies but a relatively comparable study done by Fonseca-netoetal In a 13-year retrospective study done on 479 liver transplantations in 2017 found 416 patients (86.8%) had normal anatomy (Type I) and 63 patients (13.15%) some sort of variation.

The most common arterial variation noted in Michel's and other studies like Hiatt et al.[22] Rafael Lopez-Andujar et.al, 2007[36] and Saba et al. 2011[37]was Type III (which was origin of replaced (aberrant) HA from superior mesenteric artery), Type II (presence of replaced(aberrant) LHA originating from LGA) & Type VI (accessory right hepatic artery arising from superior mesenteric artery) respectively (table no5.). In the present study, the most commonly observed variation was Type V pattern which was origin of accessory LHA from LGA (4.4% livers). In comparison to other studies and Michel's classification, the present study showed a different arterial pattern (Type V) to be more common but this study is similar with Covey et al, 2002[38] and C. Löschneretal 2014[39], a Germany study on Hepatic Arterial Supply in 1297 CT-Angiographies found that type V is the most common variant anatomy 10% and 8.8% respectively.

According to Michels classification, the most frequent change according to the literature is the type III present in 6-15.5% of cases [23]. It stands out as the most important because it has the potential to affect surgical procedures being indispensable in its identifcation[18]. This variation was seen as a second frequent in this sample, present in 3.2% of cases. followed by Type II (2.1%).

However, as anatomical variations may occur due to genetic aberrations in the embryonic period, no detailed classification can cover all types[16]. In our present study Rare anomalies not covered in Michelsclassifications were observed in 3 patients (0.9%). Koops et al.[25] in their series revealed frequency of 1.8% rare presentations and non-classified; meanwhile, Ugurel et al.[23] showed frequency of 3% of these forms in their paper. It is believed that the existence of rare variants shows that the embryological development of the branches of the aorta can be influenced by many factors, and is a complex process[23].

Table 5 Comparisons of percentage of Hepatic arterial anatomy with other studies

	Michels N = 200 autopsy	Rafael et.al. N=1081 Transplanted liver	Löschner C et al n=1297 CT-angio	Koops et al n=604 angio	Saba et al. N = 1629 CT-angio	Covey et al. n = 600 angio	Our Study N=341 Triphasic
TYPE I	55%	70%	72.2%	79.1%	61.4%	61.3 %	87.7
TYPE II	10%	9.70%	4.2%	2.5%	7.5%	3.8	2.1
TYPE III	11%	7.80%	6.4%	8.6%	10.6%	8.7	3.2
TYPE IV	1%	3.10%	1.5%	1.0%	1.3%	0.5	0
TYPE V	8%	3.90%	8.8%	0.5%	6.7%	10.7	4.4
TYPE VI	7%	0.60%	1.5%	3.3%	6.9%	1.5	0.3
TYPE VII	1%	0.60%	0.5%	0.2%	0.7%	1.0	0
TYPE VIII	2%	0.30%	0.8%	0.2%	1.9%	3.0	0.6
TYPE IX	2.50%	2.50%	2.0%	2.8%	1.6%	2.0	0.9
TYPE X	0.50%	0%	0%	0%	0.3%	0%	0
other	0%	1.5%	2.0%	1.8%	1.1%	1.1%	0.9

Portal Vein

Identification of branching patterns of the PV isan important part of the planning of liver resection(to ensure that portal perfusion to the remnant liveris not inadvertently compromised), liver transplantation (to enable appropriate graft selection so that complex portal venous anastomoses that might compromise the graft or a residual portion of the liver in a living donor can be avoided) and percutaneous interventional procedures (to allow safe, effective completion)[40].

Normally in Type I, at the hilum, PV divides into right and left branches. The right branch divides into RPPV and RAPV. The RPPV supplies segments VI and VII. The RAPV supplies segments V and VIII. The LPV goes medially and supplies segment II, III, IV and also gives a branch to the caudate lobe. Embryologically, the PV is formed in the second month of gestation by selective involution of the vitelline veins, which have multiple bridging anastomoses anterior and posterior to the duodenum. Normally, the stem of the portal vein is formed by left vitelline vein and posterior anastomosis; the left branch is formed by a part of left vitelline vein and cranial anterior anastomosis and finally the right branch is formed by part of the right vitelline vein. Any deviation in this normal obliterative process results in variations in branching of the portal vein[41,42]

The variant anatomy of the portal vein is found in 18.3% in our study. The variant anatomy of PV has the prevalence ranging from 12%, as observed by Saylisoy et al.2005[43], to 49%, as observed by Munguti et al. 2013[44]. Munguti studied 100 livers from adult black Kenyan population, and on dissection found the PV in 49% of African population. Maheshwari 2011[45] conducted the same study on Indian population and observed variant anatomy in 18% population.The difference could be due to racial or geographical reasons. All other studies were radiological. The values in the present study are comparable to other studies.

The most common variation in this study is Type I (trifurcation of PV) in 8.8% of cases. The prevalence of Type I PV variation ranges from 6%, as observed by Saylisoy et al.2005[43], to 19%, as observed by Erby et al.2003[29]. In the present study, Type I PV variation is observed in 8.8%, which is comparable to other studies. Trifurcation of the PV was observed as the most common variant in accordance with previous studies (Erbay et al.,2003[29];Gallego et al.,2002[46]; Kamel et al.,2001[47]; Koc et al.,2007[12]; Maheshwari, 2011[45]; Sureka et al., 2015[48])

The prevalence of Type II PV variation ranges from 7.5% as observed by Kamel et al.2001[47] to 23.5% as observed by Atasoy and Ozurek, 2006[11]. In the present study, the prevalence of type II PV variation is 7.5%. Type II is the most common variant in the previous studies (Atasoy and Ozurek,2006[11]; Covey et al., 2004[32]; Munguti et al.,2013[44]; Sureka et al.,2015[48]). In the present study, type II is the second common variant.

Type III variant which is RAPV arising from LPV seen in 0.9% in Akgul et al.,2002[49]. In our study 1.6% of this variation is seen.

Some authors have reported uncommon PV variants like quadrification (Koc et al., 2007)[12] of the portal vein into segment VI branch, RAPV, RPPV and LPV in 0.2% of cases which is relatively comparable with our study which is 0.11%. Kouadio et al. 2011[50] reported absence of PV bifurcation in a case report in an asymptomatic 39-year female on CT also koc etal,2007 [12] reported 0.1 % of absence of PV bifurcation. In our study this variation was seen in 0.22%. Congenital absence of PV known as Abernethy malformation is reported in some studies (Northrup et al., 2002)[51] but which is not seen in our study.

7. Conclusion

It was concluded that Detailed knowledge of hepatic arterial and PV anatomic variations can be detected on triphasic and postcontrast CT. Awarenessof this variations is important in surgical resection and transplantation. PV variations are also important in percutaneous interventional procedures.

Preoperative or intraoperative lack of awareness can result in injury, and their knowledge can reduce the incidence of complications. Therefore, clinically important Hepatic arterial and PV anatomic variants should be reported on CT

8. Annex

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