ANATOMICAL VARIATIONS OF CELIAC TRUNK AND HEPATIC ARTERIAL SYSTEM USING MULTI DETECTOR COMPUTED TOMOGRAPHIC ANGIOGRAPHY

BY

ENAM UL HAQ

A dissertation submitted in fulfillment of the requirement for the degree of Master of Medical Sciences

Kulliyyah of Medicine
International Islamic University Malaysia

NOVEMBER 2018

ABSTRACT

Variation in celiac trunk (CT) and hepatic arterial system (HAS) is common and has relevance in preoperative planning to reduce the risk of accidental vascular injuries during surgical and radiological intervention. The objectives of the study were to measure the prevalence of CT and HAS variations and describe different types of variations using multi-detector computed tomographic angiography (MDCTA) in a study population in Hospital Tengku Ampuan Afzan (HTAA), Kuantan, Pahang, Malaysia. A cross sectional study was conducted. Computed tomographic angiography (CTA) images were retrieved from July till December 2017. Images were reconstructed in three dimensional (3D) format using workstation and reviewed for the normal and anatomical variations of both the CT and HAS. Variations of the CT were classified according to Uflacker's classification and of the HAS were classified according to Michel's and Hiatt's classification. A total of 100 patients were selected, from which 15 were excluded. The results were calculated using IBM SPSS statistic version 22. Mean age was 58 years and male/female percentage was 66/34. Anatomical variation of the CT was found in 38 cases (44.7%). The most common variation was the celiac-phrenic trunk in 14 cases (16.5%) followed by celiac-colic trunk in 10 cases (11.8%). However, 22 cases (25.8%) displayed variations that were not described in Uflacker's classification. These variations include celiac-phrenic trunk, coexistence of inferior phrenic artery (IPA) with other Uflacker's variations, Buhler arc, and accessory hepatic artery from celiac trunk and coexistence of celiac-colic trunk with gastro-splenic trunk or hepato-splenic trunk in one case each. In addition, anatomical variation in the HAS was found in 25 cases (29.4%). The most common variation in HAS was 8 cases (9.4%) depicted (Michel's type Ⅴ). Accurate knowledge and identification of anatomical variations in CT and HAS which can be found in one third of the patients, is crucial before undergoing any surgical or invasive imaging procedure. This can help surgeons and interventional radiologists to prevent accidental vascular injuries and perform a safe procedure.

خلاصة البحث

انه لمن الشائع وجود تباين تشريحي للجذع البطني (CT) وكذلك للنظام الشرياني الكلوى (HAS)؛ ولتقليل خطر الإصابات اثناء الجراحة فإن معرفة هذا التباين ذو أهميه قصوى قبل القيام بأي عمليه جراحية أو عند القيام بمداخلة إشعاعية. وتهدف هذه الدراسة الى قياس مدى انتشار تباين الشرايين بواسطة الحاسوب للتصوير المقطعى (CT), وتهدف كذلك إلى وصف مختلف أنواع التباين التشريحي باستخدام المكشاف التعددي لتصوير الشرايين (MDCTA) لقاطني كوانتان والخاضعين لعملية تصوير الشرايين فى مستشفى تنكو أمبوان أفزان (HTAA) كوانتان بولاية باهانج, ماليزيا. وقد قمنا بدراسة مقطعية استيعابية لصور الخاضعين للتصوير المقطعي للشرايين في الفترة من ديسمبر حتى يوليو من عام 2017. وقد استخدمنا المكشاف التعددي لتصوير الأشعة لإعادة بناء صور ثلاثية الأبعاد تُظهر التباين التشريحي للجذع البطني وللنظام الشرياني الكلوي. و وجدنا تباين الجذع البطني لتصنيف أُفلاكر؛ أما نظام الشريان الكلوي فوافق تصنيف مايكل وحيات، وحُسبت نتائج البحث باستعمال برنامج آي بي ام الإحصائي اصدار 22. و تم اختيار 100 مريض كعدد اجمالى حيث استُثْنِي منهم 15 حالة، وكان متوسط أعمار الحالات المستخدمة 58 حيث كانت نسبة الذكور إلى الإناث 66:34. أظهرت النتائج نسبة تباين تشريحي للجذع البطني في 38 حالة (44.7%). كان أكثر التباين شيوعاً في الجذع البطني الحجابي بنسبة 16.5% (14 حالة)، ويليه الجذع القولوني بنسبة 11.8% (10 حالة). وقد أظهر البحث كذلك تباينات في 22 حالة (25.8%) لم يذكرها تصنيف أُفلاكر في وجود الجذع البطني الحجابي في نفس الوقت مع الشريان الحجابي السفلي بالإضافة لوجود تباينات أُفلاكر وبوهلر. أما بالنسبة للتباين التشريحي للنظام الشرياني الكلوي فقد أظهرت نتائج البحث وجود تباين في 25 حالة (29.4%). فكانت أكثر التباينات شيوعاً في النظام الشرياني الكلوي في 8 حالات (9.4%) حيث كانت متوافقة مع نموذج مايكل. إن التعرف الدقيق على تباينات الجذع البطني وللنظام الشرياني الكلوي هو في غاية الأهمية قُبيل إجراء أي عملية جراحية أو تصوير اقتحامي للأوعية الدموية فتساعد هذه المعرفة في تجنب أي اصابات عرضية للأوعية الدموية والقيام بإجراء جراحي آمن.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Medical Sciences.

…………………………………..
Emad Mohamad Nafie
Supervisor

…………………………………..
Radhiana Hassan
Co-Supervisor

…………………………………..
Saad Mohammed Abdulrazzaq
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Medical Sciences.

…………………………………..
Zunariah Buyong
Internal Examiner

This dissertation was submitted to the Department of Basic Medical Sciences and is accepted as a fulfillment of the requirement for the degree of Master of Medical Sciences.

…………………………………..
Mohammed Imad Al-Deen Mustafa Mahmud
Head, Department of Basic Medical Sciences

This dissertation was submitted to the Kulliyyah of Medicine and is accepted as a fulfillment of the requirement for the degree of Master of Medical Sciences.

…………………………………..
Azmi Md Nor
Dean, Kulliyyah of Medicine

DECLARATION

I hereby declare that this dissertation is the result of my own investigation, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Enam Ul Haq

Signature…………………. Date …..................

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

ANATOMICAL VARIATIONS OF CELIAC TRUNK AND HEPATIC ARTERIAL SYSTEM USING MULTIDETECTOR COMPUTED TOMOGRAPHIC ANGIOGRAPHY

I declare that the copyright holder of this dissertation is jointly owned by the student and IIUM.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below.

1. Any material contained in or derived from this unpublished research may be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieval system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Enam Ul Haq

……..…………………… ………………………..

Signature Date

This dissertation is dedicated to my parents and family for their unconditional love and support.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Beneficent, the Most Merciful. All praise and thanks to Allah, the creator of all. I thank Allah for His continuing blessing; I am able to achieve this work only because of Allah's mercy and grace.

First of all, I would like to express my deepest thanks to my beloved wife and my son and daughters; my heartfelt gratitude goes to them. I would not be able to complete this dissertation without their prayers, encouragement, patience, support, helpful suggestions and their significance contributions.

I would also like to express my profound gratitude to my father for his endless love, persistent invaluable support and help and for his trust in my ability; and to my mother for her unconditional love and care. I acknowledge, with my debt of thanks, to my dear brothers and all family members for their loving care and encouragement. I would also like to express my special thanks to my beloved family-in-law, for their love and understanding.

I am also sincerely thankful to my supervisor, and co-supervisors. It is my pleasure to express my sincere thanks to Assoc. Prof. Dr. Emad Mohamad Nafie, for his constant and unconditional help, valuable advice, and his constant and unfailing support and valuable guidance in the preparation of this dissertation and to Assoc. Prof. Dr. Radhiana Hassan for her help and guidance in each step of data collection, reconstruction of the images and her kindness and timely support and encouragement throughout the study; and I would also like to thank Assistant Prof. Dr. Saad Mohamed, for his help and guidance throughout the research, particularly in the writing phase and publication.

In addition, Department of Basic Medical Sciences, Kulliyyah of Medicine, the International Islamic University Malaysia; Department of Radiology and Department of Diagnostic Imaging HTAA; Department of Radiology in IIUM Medical Center are all gratefully acknowledged.

Finally, I am deeply thankful to the Ministry of Higher Education (MOHE) Afghanistan to provide me the scholarship and financial support through Higher Education Development Project (HEDP) to fulfill my dreams and achieve my Master Degree. I also wish to express my gratitude to Postgraduate Office (KOM, IIUM). Last, but not least, I wish to thank my colleagues, my friends, and all those who helped and guided me during my stay here.

Once again, I glorify Allah for His endless mercy on us of which is enabling me to successfully round off the efforts of writing this dissertation.

Alhamdulillah

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS / SYMBOLS

%	Percentage
+	Plus
-	Minus
=	Equal to
<	Less than
>	More than
±	Plus minus
(	Left parenthesis
)	Right parenthesis
,	Comma
.	Full stop
:	Colon
;	Semicolon
a-HA	Accessory hepatic artery
a-LHA	Accessory left hepatic artery
a-RHA	Accessory right hepatic artery
CC	Celiac-colic trunk
CHA	Common hepatic artery
CM	Celiac-mesenteric artery
CP	Celiac-phrenic trunk
CT	Computed tomography
CT	Celiac trunk
CTA	Computed tomographic angiography

DSA	Digital subtraction angiography
GDA	Gastro-duodenal artery
GS	Gastro-splenic trunk
HAS	Hepatic arterial system
HG	Hepato-gastric trunk
HGS	Hepato-gastro-splenic trunk
HM	Hepato-mesenteric trunk
HS	Hepato-splenic trunk
HSM	Hepato-spleno-mesenteric trunk
HTAA	Hospital Tengku Ampuan Afzan
IPA	Inferior phrenic artery
LGA	Left gastric artery
MDCTA	Multi-detector computed tomographic angiography
PHA	Proper hepatic artery
RGA	Right gastric artery
RIS	Radiology information system
r-LHA	Replaced left hepatic artery
r-RHA	Replaced right hepatic artery
SMA	Superior mesenteric artery
SP	Splenic artery

CHAPTER ONE

INTRODUCTION

1.1 RESEARCH BACKGROUND

Foregut which is the cranial part of the developing gastro-intestinal tube includes the abdominal oesophagus, the stomach, the duodenum proximal to the opening of the bile duct, the liver and pancreas and lastly the biliary apparatus. They are supplied by the first visceral branch of the abdominal aorta called the celiac trunk (CT). The spleen is also supplied by the CT, hence it is considered as part of the foregut.

According to Grey's anatomy, the CT is the first ventral branch which arises just below the aortic opening of diaphragm between the lower border of 12^{th} thoracic and the upper border of 1^{st} lumbar vertebra. Its length is 1.5-2 cm and proceeds forwards and slightly right above the pancreas and splenic vein. It divides into three branches, the left gastric artery (LGA), the common hepatic artery (CHA) and the splenic artery (SP), as shown in Figure 1.1.

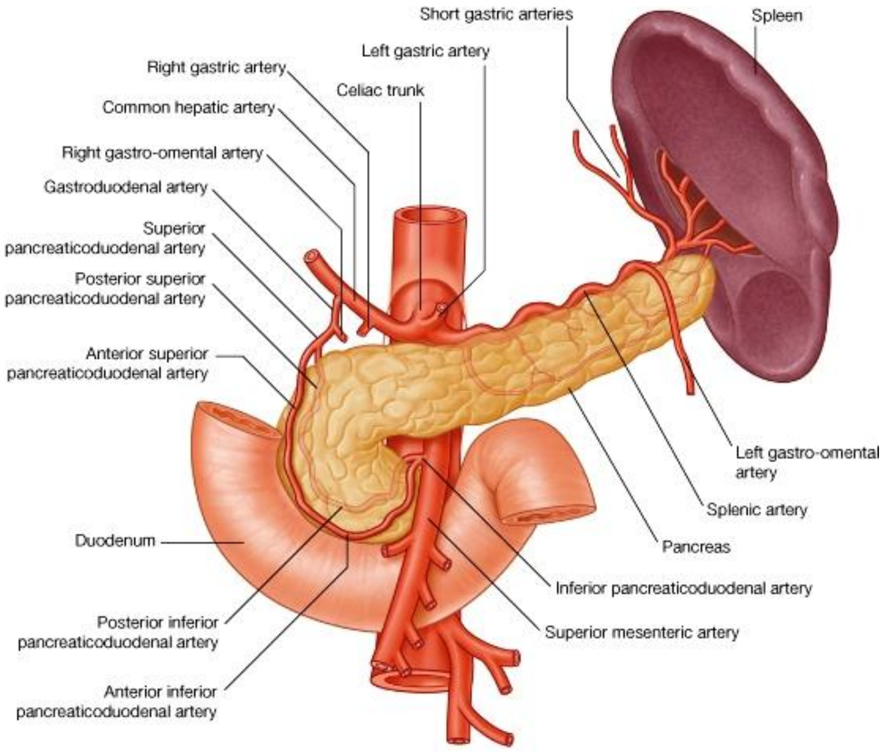

Figure 1.1 Normal trifurcation of CT. (Drake, Vogl, & Mitchell, 2009; Standring et al., 2005)

The CT may also give off one of the right or left or both inferior phrenic arteries. It is also possible that superior mesenteric artery (SMA) may have common origin with the CT, or one or more superior mesenteric branches may originate from the CT.

Anteriorly CT is related to omental bursa and celiac plexus of nerves surrounding the trunk. Right laterally, it is related to right celiac ganglion, right crus of diaphragm and caudate lobe of the liver. Left laterally, it is related to left celiac ganglion, left curs of diaphragm and cardiac end of the stomach, and inferiorly it is related to the pancreas and splenic vein. Suspensory muscle of duodenum may encircle the CT (Drake et al., 2009; Standring et al., 2005).

LGA is one of the 3 main branches of CT. It is the smallest branch of CT which supplies both the distal esophagus and the stomach. It arises between the origin of the CT from aorta and its terminal bifurcation. The LGA divides into branches for the anterior wall of the stomach and into a posterior branch that anastomosis with the right gastric artery (RGA) in the region of the angular incisor. The LGA gives off branches such as esophageal, cardiac and branches for the upper part of the stomach.

The most common variation of the LGA is an origin from left hepatic artery (LHA). It may also originate from the CHA or right hepatic artery (RHA). Other variations include a common origin of the LGA with the CHA, an accessory or replaced LHA (r-LHA) associated with LGA, which are so important during surgical mobilization of the upper stomach.

Hepatic artery is medium in size among left gastric and splenic arteries but in fetal life it is the largest celiac branch. Firstly, it passes forward and right below the epiploic foramen to the upper aspect of the superior part of the duodenum. Then, crossing the portal vein and ascends between two layers of the lesser omentum to the porta hepatis, where it divides into left and right branches. Right branch goes posterior to the common hepatic duct.

Hepatic artery may be subdivided into two parts. The first one is CHA, starts from the CT and ends at the origin of the gastro-duodenal artery (GDA). The second one is Proper hepatic artery (PHA) starts from the point where GDA arises and continues to its bifurcation. The branches of CHA are including GDA, RGA and PHA, which then subdivided into right and left hepatic arteries, as shown in Figure 1.2, (Standring, 2015; Standring et al., 2005).

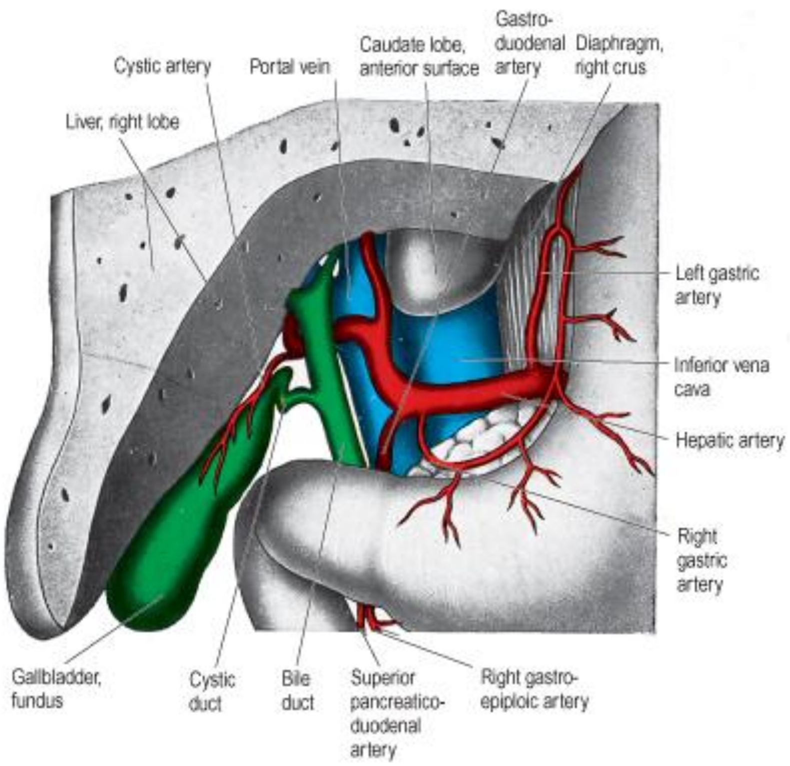

Figure 1.2 Normal pattern of HAS

SP is the largest branch of the CT and is tortuous, accompanied by a straight splenic vein. It ascends to the left behind the stomach and omental bursa along the superior border of the pancreas, running anterior to the left suprarenal and left kidney and enters splenorenal ligament. Near the splenic hilum it gives off three main branches to pancreas and stomach. Thereafter, it enters into the splenic hilum and further divides into 4 to 5 segmental branches which enter its hilum. Its branches are including short gastric artery, posterior gastric artery, left gastro-epiploic artery and segmental branches (Drake et al., 2009; Standring, 2015; Standring et al., 2005).

Anatomical variations of blood vessels are usually interesting from embryological standpoint and significantly important from clinical or surgical point of view. Vascular anomalies usually do not cause any problem, but they might be problematic in patients during interventional angiography or any surgical procedure (Selvaraj & SUNDARAmURTHI, 2015).

According to Tandler hypothesis regarding the morphogenesis of the CT and SMA, the primitive fetal blood supply is with double aortas which provide blood supply to the abdominal organs both ventrally and dorsally (Walker, 2009). By the embryonic remolding, most of this double vascular supply regresses but some parts of this double blood supply persist, which accounts for anatomical variation of mesenteric circulation, as described in Figure 1.3, (Chen, Yano, Emura, & Shoumura, 2009; Walker, 2009).

A series of vitelline arteries arise from the fused, paired dorsal aortas in the fetus which are connected by a ventral anastomotic channel. During fetal remolding, CT, SMA and inferior mesenteric artery are formed from the persisted three vetelline segments (Chen et al., 2009; Guiney et al., 2003; Healey Jr, Schroy, & Sorensen, 1953) and the remaining segments disappear before birth. If a part of this ventral anastomosis does not regress or the vitelline segments persist abnormally, consequently anatomical variation occurs (Iezzi, Cotroneo, Giancristofaro, Santoro, & Storto, 2008; Kaufman & Lee, 2013; McNulty, Hickey, Khosa, O'Brien, & O'Callaghan, 2001).

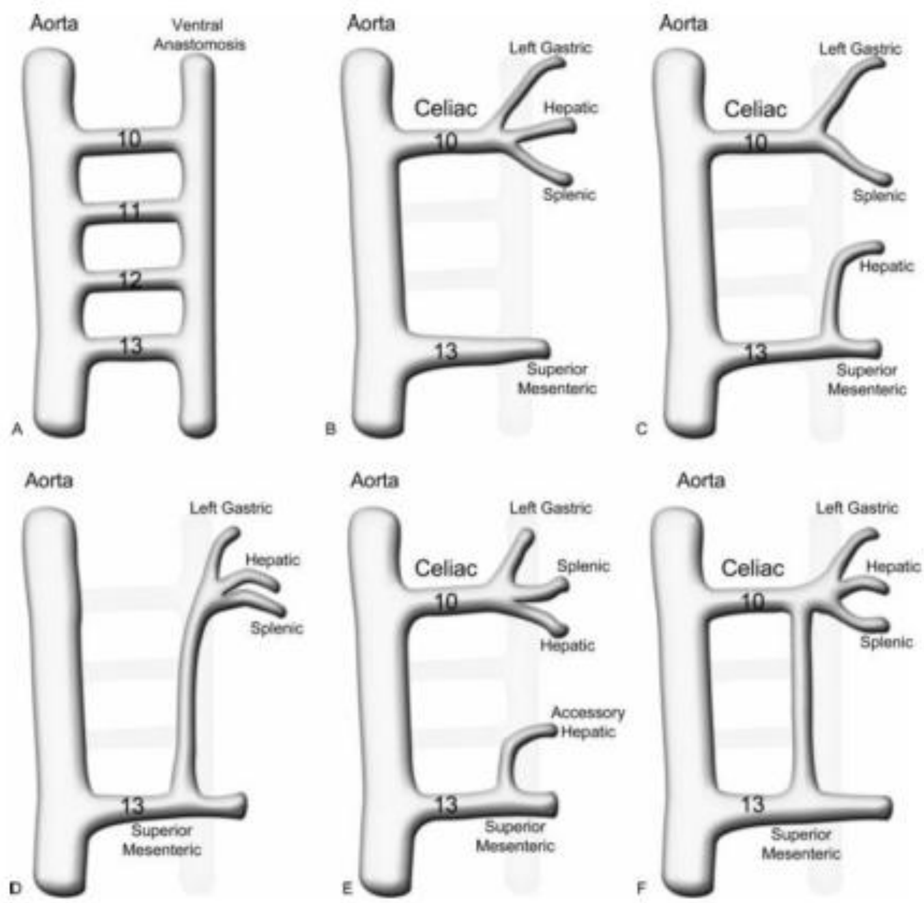

Figure 1.3 Normal and variant embryological development in celiaco-mesenteric vasculatures (A) the initial splanchnic arteries, the 10th to 13th roots connect the aorta and a primitive ventral anastomosis. (B) Usually the 11th and 12th roots and most of the ventral anastomosis regress, the remaining 10th root represents the CT and the 13th represents the SMA. (C) When the ventral anastomosis regresses incompletely, resulting to form the HM, where the HA arises from the SMA. (D) The 10th to 12th roots degenerate and a large portion of the ventral anastomosis keep on connecting the CT to the SMA. This makes a CM. (E) When a part of ventral anastomosis fails to regress, a partially replaced or accessory HA happens as same as a completely replaced HA occurs. (F) Buhler arc occurs when the ventral anastomosis persists along with the regression of the 11th and 12th roots, connecting the celiac and SMA (Walker, 2009).

CT is the largest branch of the abdominal aorta since it supplies all the supra-mesocolic organs. From the embryological stand point, CT represents the roots or the proximal ends of the vitelline arteries near the 7th cervical segment but subsequently in 17 mm stage it is moved caudally to the 12th thoracic vertebra. According to Peen Kopf (Longo & Reynolds, 2016), the definitive stem of the CT is visible as early as 5 mm stage of embryo. The CT which arising with two or three roots, these roots originate to form single root. Then with only one root, the origin of the artery wanders 10 segments caudally, so that in the 14 mm stage it is already at the level of 9^{th} thoracic segment. The branches of CT are visible as early as 10 mm embryo (Longo & Reynolds, 2016).

Formation of CM has been explained by Tandler (1904) on the following basis: In 4-17mm stage of embryo, omphalo-mesenteric artery arises by 4 roots (10-13 ventral segments), which are unified by a ventral longitudinal anastomosis moving down parallel to aorta. In general, the middle two roots (11 and 12) along with the larger part of this ventral longitudinal anastomosis disappear (Longo & Reynolds, 2016). As the result, the first root represents the CT and the last root represents the SMA. If the roots, which should have given origin to the CT, undergo regression, while the ventral longitudinal anastomosis persists, a CM is formed. Normally 3 main branches of the CT arise in series successively from the cranial end of the longitudinal anastomosis, these accounting for the fact that the LGA arises proximal to the origin of the CHA and the SA.

In case if, the ventral anastomosis is interrupted between left gastric and splenic, (that is the 1^{st} and last roots persists along with greater part of the longitudinal anastomosis) then the LGA will arise separately from the aorta, SA and CHA arise from SMA as CM. In short, all the branches of the CT as well as the accessory hepatic artery (aHA) originate from the persistent part of the ventral longitudinal anastomosis between the roots of the primitive arteries. (Longo & Reynolds, 2016).

During fetal life, initially the liver is bulky comparing to the gut which is very small; therefore the hepatic arteries are predominant. Later on, the size of the liver proportionally decreases while the gut equally increases, and the 3 main hepatic embryonic arteries are united in the porta hepatis and some of them may regress and the enteric arteries expand. If the right or left embryonic hepatic arteries do not regress completely, the right or left aberrant hepatic arteries result, as illustrated in Figure 1.4 (Couinaud, 1989).

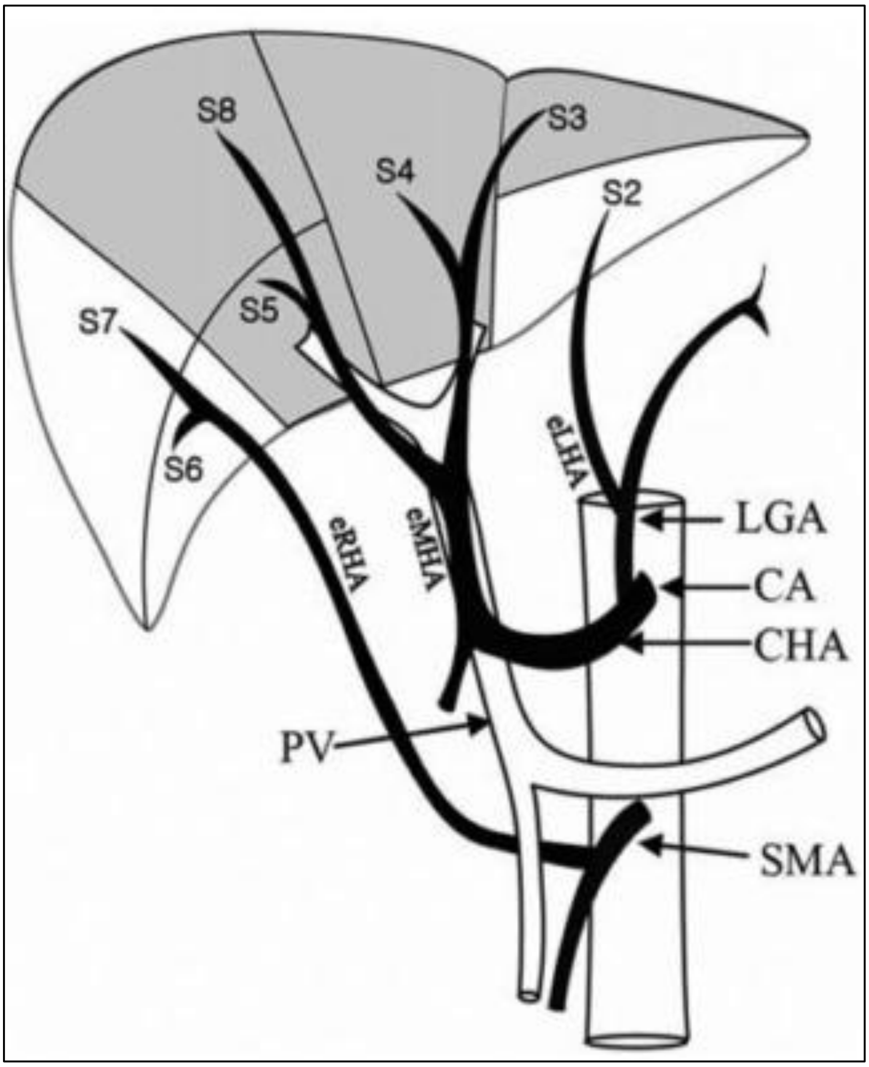

Figure 1.4 In embryonic stage of hepatic formation, there are 3 lobes of liver with its own embryonic artery: the lateral segment (S2) by embryonic LHA, the medial and anterior segment (S3, S4, S5, S8) by embryonic middle HA, and the posterior segment (S6, S7) by the embryonic RHA (Couinaud, 1989).

Tandler in 1904 proposed a hypothesis about the embryological development of the CT and SMA (Tandler, 1904). In early human embryonic life, four splanchnic arteries originating from the dorsal aorta and they are connected to ventral longitudinal anastomosis. These primitive splanchnic arteries are initially paired vessels. By embryological developmental process, they convert into four unpaired arteries connected to the ventral longitudinal anastomosis.

Thereafter, the longitudinal anastomosis disappears between the CT and SMA. The first tree roots unite and form the CT where the fourth one remains as the SMA and gradually travels caudally. The persistence and/or abnormal regression in any part of this primitive arterial system account for different types of anatomical variations of the CT and SMA.

1.2 ANATOMICAL VARIATIONS AND ITS CLINICAL IMPORTANCE

The anatomical variations of the CT and its branches are due to developmental changes in the ventral splanchnic arteries. The arterial variations like other anatomical variation cannot be ignored during operative procedures in the upper abdomen. It is of great importance for surgeons and radiologists to be aware of the variation in the CT and HAS during surgical and radiological procedures in upper abdomen (Chen et al., 2009; Drake et al., 2009).

1.3 SIGNIFICANCE OF THE RESEARCH

The identification of anatomical variations in CT and HAS becomes increasingly important for surgeons, with the increment in the number of laparoscopic procedures, oncological surgical interventions and organ transplantations before planning upper abdominal surgical procedures, to prevent vascular injuries during operation and