# STUDY OF THE SEGMENTAL ANATOMY OF LIVER AND ITS CLINICAL IMPORTANCE

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# CERTIFICATE

This is to certify that the dissertation title, **'STUDY OF THE SEGMENTAL ANATOMY OF LIVER AND ITS CLINICAL IMPORTANCE'** is an original work done by **Dr.S.VINOTH**, Post Graduate Student, Stanley Medical College, Chennai-1, under my supervision and guidance.

**Dr. A.PRIYA, M.S.,**
Dean
Stanley Medical College
Chennai-1

**Dr. CHITRA, M.S.,**
Professor and HOD
Department of Anatomy
Stanley Medical College
Chennai-1

Place: Chennai-1
Date:

# DECLARATION

I solemnly declare that this dissertation **'STUDY OF THE SEGMENTAL ANATOMY OF LIVER AND ITS CLINICAL IMPORTANCE'** was written by me in the Department of Anatomy, Govt. Stanley Medical College and Hospital, Chennai, under the guidance and supervision of **Prof. Dr. S.CHITRA, M.S.,** Professor and Head of the Department of Anatomy, Govt. Stanley Medical College, Chennai - 600 001.

This dissertation is submitted to The Tamil Nadu Dr. M.G.R. Medical University, Chennai in partial fulfillment of the University regulations for the award of degree of M.S. Anatomy - Branch V examinations to be held in March 2010.

Place : Chennai.

Date : **(Dr.S.VINOTH)**

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# CONTENTS

# AIM OF STUDY

Surgeries of liver have advanced much in the past years and the more advancement in the field has brought surgeries along with more conservative procedures. This has made the need of a thorough knowledge of liver anatomy important.

Liver is the largest organ in the abdomen with large blood flow which perform many important functions. It has its own insults in the form of infections, primary tumors and also secondary metastasis. It has a good regenerating capacity.

This capacity of regeneration has been made to maximum use by the surgeons. In the past, large part of the liver were removed during procedures for primary liver tumours and the area for regeneration was large.

Now more conservative surgeries are possible because the liver is no longer viewed as a solid organ below its capsule. The liver is organized into more clearly defined segments which is having its own inflow and outflow vascular channels and also biliary drainage.

The inflow vascular channels are the portal vein and the hepatic artery. The blood drains into the inferior vena cava through the hepatic veins. The product of the liver, the bile, flows through the hepatic ducts and then forms the bile duct outside the liver. Based on this pattern it has been divided into eight vascular segments.

With the advent of more non- invasive investigative procedures like ultrasonagraphy and computerised tomography scan have made the cross sectional study on liver very easy. The recent use of intra-operative ultrasonography has helped the surgeons much in studying the branching patterns. This has lead to plan the surgeries of segments along with its vascular planes, which reduces the chances of leaving large area of non-viable tissues and also gives more chances for the liver to regenerate early.

Lot of research has been going on both in India and abroad in this field to map the liver into segments and define them clearly and document its variations, which might help the surgeons to do more conservative surgical procedures.

In this study I have made a sincere attempt to study the segmental anatomy of liver using the new radiological methods, ultrasonography and dissection methods.

# REVIEW OF NORMAL ANATOMY

Traditional description of anatomy of liver has limited utility in the management of hepatic disease. Modern hepatology and hepatic radiology and surgery are based upon the functional segmental anatomy of liver and a sound knowledge of which is essential.

The description of anatomy of liver takes 3 forms….

1. In morphological anatomy the liver is described as composed of lobes, based on the surface markings, topographical relations and hepatic and biliary structures.

2. In functional anatomy live is described according to the intrahepatic vascular anatomy. It is based on segments which are functional units receiving a portal pedicle.

3. Radiological and surgical Anatomy are based on the application of functional anatomy to each individual liver by accurate definition of its particular intrahepatic vascular anatomy using investigation such as ultrasound, contrast enhanced computerised tomography and magnetic resonance imaging.

## MORPHOLOGICAL ANATOMY

Liver is the largest abdominal organ, which lies under cover of lower ribs and closely applied to the undersurface of the diaphragm and the inferior vena cava posteriorly.

The most bulk of the liver lies right of the midline where the lower borders of the liver coincides with the costal margin. It is covered by the visceral peritoneum of the Glisson's capsule, which thickens into three folds or ligaments connecting it to the abdominal wall.

1. The falciform ligament is formed superiorly and connects the liver to the anterior abdominal wall and diaphragm. The right layer of falciform ligament continues as the upper layer of coronary ligament. The lower layer of coronary ligament stretches between the postero inferior aspect of right lobe of liver and diaphragm.

2. The right and left triangular ligaments give attachment posteriorly. The area between the Right triangular ligament and upper and lower layer of coronary ligament is devoid of peritoneum which is called the bare area of the liver. The inferior vena cava comes to lie in the groove on the posterior part of the liver.

3. On the inferior surface, the peritoneum joins into another fold the lesser omentum connecting the liver to the lesser curvature of the stomach and reflects around the hepatic pedicle delimiting the epiploic foramen to the lesser sac. At the hepatic hilum, the Glison's capsule fuses with the connective tissue surrounding the hepatic

artery, the portal vein and hepatic duct forming the hilar plate, which forms a structure of surgical importance in dissection of these structure.

**Surface marking, hepatic lobes and their relations**

On the inferior surface three markings can be identified.

1. The umbilical fissure medially into which continues as the round ligament which is a remnant of left umbilical vein.
2. The gall bladder fossa laterally
3. The transverse hilar fissure running between them.

This H shaped configuration defines two main lobes on each side, the right and left lobes and two accessory lobe in the middle the quadrate lobe anteriorly and caudate lobe posteriorly.

**Left Lobe**

This is limited on the inferior surface by the umbilical fissure and on the superior surface by the falciform ligament. Its long axis being sometimes sagittal and sometimes transverse. The superior surface is marked in the middle by the inferior surface of the heart. The inferior surface lies on the lesser curvature of the stomach to which it is connected by the lesser omentum.

**Right lobe**

This is the bigger of the two main lobes and has three surfaces.

1. The superior surface comprises an upper convex part moulded by the diaphragm and forming the dome of the liver to which surgical access is difficult and a lower part facing anterosuperiorly

2. The posterior surface is vertical and extends from the right border of the liver to the inferior vena cava.

3. The inferior surface is in relation to the colon anteriorly and to the perirenal fat posteriorly from which it is separated by a peritoneal recess, Morisson's pouch where even a small amount of ascitic fluid collects and can be seen on ultrasound.

**Quadrate Lobe**

This is delimited by the umbilical fissure medially, the gall bladder fossa laterally and a transverse hilar fissure posteriorly. It lies on the gastric antrum and on the duodenum.

**The Caudate Lobe**

This belongs almost completely to the posterior surface of the liver, lying in a vertical plane. It is limited on the right by the inferior vena cava and on the left by

fissure of Arantius (fissure for ligamentum venosum). The lower border is visible behind the hilum. Two tuberosities can be identified on this border.

1. The caudate tuberosity on the right which passes towards the right lobe.
2. The papillary tubercles on the left covered by the lesser omentum.

**Hepatic Veins**

Hepatic veins begins as interlobular vein draining the sinusoids of liver lobules and continue as sublobular veins which unite hepatic veins.

They are made of two groups. The upper group consists of three large veins, right, left and middle hepatic veins which drain directly somewhat at an oblique angle from the upper part of the posterior surface of liver into the inferior vena cava.

The lower groups are small and drain the right and caudate lobes.

**Right hepatic vein**

The right hepatic vein is somewhat larger than the left and middle and has a short extrahepatic course of usually 1 cm. The right hepatic vein is the principal drainage for the right lobe of the liver. The main trunk of the right hepatic vein follows an intersegmental plane between the French system of segments or anterior and posterior segments of American system.

**Middle hepatic vein**

The middle hepatic vein lies in the principal portal fissure draining the medial segment of the left lobe and a portion of the anterior segment of the right lobe. The middle hepatic vein joins with the left hepatic vein in 80% of the cases. The left and the middle veins frequently join after a short extra hepatic course to form a common venous channel.

**Left hepatic vein**

The left hepatic vein provides the main venous drainage of the left lateral segment in 80 % of cases and to it. The middle hepatic vein joins to a common trunk which runs a more longer extra hepatic course than the right hepatic vein.

There are additional hepatic veins having smaller dimensions apart from these major hepatic veins.

**Portal vein**

Portal vein conveys blood from the abdominal part of the digestive tube (except the lower end of anal canal but including the abdominal part of the oesophagus) and the spleen.

The portal vein conveys blood to the liver where it ramifies like an artery and ending in the sinusoids, from which vessels again converge to reach the inferior vena cava via the hepatic veins.

In adults, the portal vein does not have valves but they are seen in foetal life. Portal vein is 8 cms long and begins at the second lumbar vertebral level by the union of superior mesenteric vein and splenic vein posterior to the neck of the pancreas. It then enters the right border of the lesser omentum ascending anteriorly to the epiploic foramen to the right end of porta hepatis where it divides into the right and left branches.

**Right branch of portal vein**

The right branch enters the right hepatic lobe but usually receives the cystic vein first. After entering the right lobe the right portal vein divides into anterior and posterior branches the anterior branch of the right part of the portal vein divides into superior segmental branch to supply the segment V of right lobe of liver.

The posterior branch of the right portal vein divides into a superior branch, for segment VII and a inferior branch to supply segment VI of right lobe of liver.

**The left branch of portal vein**

The left branch which is longer than the right but smaller in caliber branches into the caudate, quadrate and left lobes. As it enters into the left lobe it receives the para

umbilical veins as in ligamentum teres which contains the functionless and partly obliterated left umbilical vein. It is connected to the inferior vena cava by the ligamentum venosum

In the left lobe the left branch of the portal vein divides into branches supplying segment II and segment III.

**Hepatic artery**

The hepatic artery originates from common hepatic artery which is a branch of coeliac artery.

Being accompanied by the hepatic autonomic plexus, it passes between the layers of the lesser omentum anterior to the epiploic foramen to the porta hepatis where it divides into right and left branches for the right and left hepatic lobes accompanying the ramifications of the portal vein and hepatic ducts.

**Right branch of hepatic artery**

The right branch of the hepatic artery divides into anterior and posterior branches. The anterior branch of the right hepatic artery divides into superior and inferior branches to supply the segment VIII and segment V respectively.

The posterior branch of the right hepatic artery divides into superior and inferior branches to supply the segments VII and segment VI.

**Left branch of hepatic artery**

The left branch of the hepatic artery has a longer course than the right branch. After entering the left lobe of the liver it divides into three branches to supply the segment II, segment III and segment IV.

**Hepatic ducts**

The biliary drainage system begins at the hepatocytes level. The bile drains into the canaculi from where they drain into the intrahepatic duct, which follow the segmental pattern determined by the vascular supply. The convergence of the canaliculi, proximal to ductal system is called the canal of Hering. The ductal pattern becomes variable more distally.

**Left hepatic duct**

The left lobar duct forms in the umbilical fissure by the union of ducts from segment II, segment III and segment IV and then passes across the base of the segment IV and unites with the right lobar duct to form the common hepatic duct. The extra hepatic portion of the left hepatic duct is 2 cm length.

**Right hepatic duct**

The right hepatic duct drains segments V to VIII through the right anterior and right posterior segmental ducts. The anterior and posterior segmental ducts are formed by the superior and inferior branches respectively. The biliary drainage of the caudate

lobe is variable but enters both the right and left hepatic duct system in about 80% of person individuals.

## SEGMENTS OF LIVER

The internal architecture of the liver is composed of series of segments that combine to form sectors separated by scissurae containing hepatic veins. These form visible lobes. Essentially the three main hepatic veins, right hepatic vein, middle hepatic vein and the left hepatic vein within the scissurae divide the liver into four sectors each of which receives a portal pedicle.

The portal pedicle which is the portal triad that contains of hepatic artery, portal vein and the hepatic duct. The portal pedicle  divides into right and left pedicle which enters the respective lobes and subdivide again to form the segmental branches thus dividing the sectors into 8 segments.

### The main portal sciccura

The main portal scisssura contains the middle hepatic veins and progresses from the middle of the gall bladder fossa anteriorly to the left of the inferior vena cava posteriorly. This forms the right and left lobe of liver both of which are independent in terms of portal and arterial vasuclarization and of biliary drainage.

### Segment I

The caudate lobe is the dorsal portion of the liver lying posteriorly and embracing the retro hepatic inferior vena cava. It should be clearly appreciated that the caudate lobe lies between major vascular structures, the inferior vena cava posteriorly, the left portal triad inferiorly, the inferior vena cava and the middle and left hepatic veins superiorly.

The portion of the caudate lobe on the right is variable but is usually quite small. The anterior surface within the parenchyma is covered by the posterior surface of segments IV the limit being an oblique plane slanting from the left portal vein to the left hepatic vein.

Thus there is a caudate lobe or segment I with a constantly present left portion and right portion of variable size.

The caudate lobe is supplied by blood vessels and drained by biliary tributaries both from right and left portal traid. Small vessels from the portal vein and tributaries joining the biliary ducts are also found, usually two on the left side and one on the right.

The right portion of the caudate lobe including the caudate process predominantly receives portal blood from the right branch of portal vein or from the main portal vein.

On the left side the portal supply arises from the left branch of the portal vein almost exclusively. Similarly the arterial supply and the biliary drainage of the right portion is most commonly associated with the right posterior sectoral vessels or pedicle and the left portion with the left main vessels.

The hepatic venous drainage of the caudate lobe is unique in that it is the only hepatic segment draining directly into the inferior vena cava. These veins can sometimes drain into the posterior aspect of the inferior vena cava if there is a significant retrocaval caudate component.

In the usual and common circumstance the posterior edge of the caudate lobe on the left has a fibrous component which fans out attaching lightly to the curural area of the diaphragm but importantly extending posteriorly behind the vena cava linked with the similar component of fibrous tissue protruding from the posterior surface of segment VII and embracing the vena cava.

It is important to note that in up to 50% of patients this ligament is replaced whole or in part by hepatic tissue and the caudate lobe may thus completely encircle the IVC and contact the segment VII on the right side,  a significant retrocaval component may prevent a left sided approach to the caudate veins.

The caudate margins of the caudate lobe has a papillary process, which on occasion may attach to the rest of the lobe via a narrow connection. It is bulky in 27% of cases and can be mistaken for an enlarged lymph node in computerised tomography scan.

**To summarize the segmental anatomy of liver**

1. The liver is divided into 2 hemi livers by the main hepatic scissura within which runs the middle hepatic vein.

2. The left liver is divided into 2 sectors by the left portal scissura within which the left hepatic vein runs. The posterior sector is comprised of only one segment. The anterior sector is divided by the umbilical fissure into 2 segments, a medial segment **(Quadrate Lobe) (Segment IV)** and a lateral segment **(Segment III)** which is the anterior part of the left lobe.

3. The right liver is divided into 2 sectors by the right porta scissura containing the right hepatic vein. Each of these two sectors is divided into 2 segments, an anterior sector (segment V inferiorly and segment VIII superiorly) and a posterior sector (segment VI inferiorly and segment VII superiorly).

4. Segment I (the caudate lobe) lies posteriorly embracing the inferior vena cava, its intra parenchymal anterior surface abutting the posterior surface of segment IV and merging with segment VI and VII on the right.

# REVIEW OF LITERATURE

For centuries the liver had been traditionally divided into the right and left lobes based on the peritoneal reflections particularly the falciform ligament. The surgeons did not dare to perform surgeries on this organ basically for the important reason that the traditional decision of the lobes was not enough to give an insight to what level the surgeon should proceed during a surgical procedure. The information available was not just enough for a surgeon to operate.

The modern concept of liver anatomy looks more deep into it than just the peritoneal reflections.

The anatomic features that make the liver to be an important organ that integrates between digestive system and the rest of the body include.

1. A dual blood supply with portal blood from the splanchnic system and the hepatic artery

2. The specific architectural arrangement of single cells and cell masses that facilitates exchanges between blood and hepatocytes

3. The specific orientation of the hepatocytes that compartmentalizes biliary versus blood pathways

4. An organized biliary excretory system that regulates the enterohepatic circulation.

The modern studies in the classification of the structure of the liver have taken into account both the morphological as well as the functional points into consideration. The first step toward the study of the anatomy of the liver was the division of the lobes of the liver.

**Review of literature for hepatic lobes/ segments**

For the first time an excellent detailed anatomy of the liver was given in a treatise called the "Anatomic Hepatics" by Glisson (1659). Some of his illustrations and drawing were accurate to establish the relation between the hepatic and portals venous system. Based on the branching of the hepatic artery an attempt was made to classify the right and left lobes of the liver for the first time **[Cantalie (1898)].**

But this did not exactly correlate with the traditional marking of anatomist. The vascular independence between the two lobes were based on the branching of the portal vein into right and left branch. This was the result of studies on the injected bodies of infants.

The division of liver into right and left liver based on the function was done by **Ton that Tung** in 1939. He recognized that the morphology of the liver does not correspond to the surgical anatomy of liver and the importance of the **Rex – cantile** plane that runs through the middle of the gall bladder bed toward the inferior vena cava was understood. This plane passes through the right axis of the caudate lobe.

The major work on the liver was mostly concentrated on the vascular pattern of the liver and it was definitively established by **Hjorsjo** in 1948. He noted that the anatomical lobation and the functional lobation are defined as territories based on right and left hepatic ducts and their overlap is minor.

The general relationship between the hepatic veins and portal vein branches determine the lobar anatomy of the liver which was best demonstrated by direct injection of its blood supply with substance such as methylene blue or coloured colloidin. This was the basis of the American system of lobar anatomy. In this nomenclature the Cantlie line divides the liver into 2 lobes, the right and left lobe. The left lobe consist of medial segment which lies to the right of the falciform ligament. The right lobe was divided into anterior ands posterior segment and no visible surface marking delineates the lobar segmental anatomy on the right side. In this type of nomenclature the caudate lobe is in the medial segment of the left lobe.

The other type of nomenclature was the result of research by Couinaud (1953) who was a French surgeon and anatomist. In his book "The liver" a more detailed description of the segments is given and this is now considered the definitive anatomy for the surgeons to operate. This nomenclature is also called the French segmental system. In this system more importance is given to the hepatic venous drainage and caudate lobe and also to the portal biliary and arterial branching pattern. In this system there are eight segments. Four on the right lobe and three on the left lobe and one

corresponding to the caudate lobe. According to Couinauds description the three main hepatic veins divide the liver into four sectors called the planes through which the veins pass as the portal scissurae. The main portal scissura divides the liver into two lobes. The right portal scissura divides the right liver into anterior and posterior sectors. The left portal scissura divides the left lobe into superior and anterior sectors. The umbilical fissure divides the anterior sector into medial and lateral segment.

The anteromedial sector of the right lobe is divided into segment V inferior and segment VIII superior.

The posterolateral sector of the right lobe is divided into segment VI inferior and segment VII superior.

Left lobe of liver is divided into segment III anterior, segment II posterior and segment IV medial to the umbilical fissure. The Spigelian lobe or segment I is considered as an automous segment since it receives vascularization both from right and left branch of portal vein and its venous drainage directly into inferior vena cava.

With the acceptance of the classification of the Couinauds segmental anatomy, the surgery on the liver particularly the liver resection surgeries have been modified and refined to produce good results. With the advent of more non-invasive methods of investigation like the ultrasound and computerised tomography the mapping of the segments using these techniques has become more popular and precise. Coinauds

method of dividing the liver into eight autonomous liver segments has to be accepted as a good approximation.

The other type of segmental pattern of liver is the **J. Hureau's** classification, which takes into account the position of the liver in the abdominal cavity consisting of a right posterior column corresponding to **Couinaud's** right lateral sector (segments Viand VII), a right lateral column corresponding to the right paramedian sector (segments V and VIII), a right paramedian column. Corresponding to segment IV, a left lobe column, corresponding to segments III and II and a dorsal sector corresponding to the caudate lobe or segment I.

Nevertheless, the volume, position, and shapes of these segments and their segmental borders show significant variability **(Fischer L et al).** This was observed during the quantitative computer based 3 dimensional analysis where patients suspected of intra hepatic lesion were studied before planning for surgery. The segmental volume of the liver was studied based on the main stem of the portal vein and also hepatic veins. The studies show that in the portal vein – based method, segmental volumes were overestimated by the classic **Couinaud** method by up to 24% and underestimated to 13% volumes of **Couinaud** segments IV, segments VII and VIII were generally larger compared with those obtained by the portal vein based method. Whereas segments III and VI were smaller. Gross variations were found in segments V, VII, and VIII.

While performing resection **Kogure K, et al** noted that subsegmentectomy of the

anterior segment according to the conventional segmental anatomy introduced by Healey and Schroy pr Couinadud is difficult, because the transverse border between segments V and VIII was drawn as an imaginary line through the right portal vein, there is no anatomical structures indicating this border.

But when considering the way **Hjorsjo** divided, the anterior segment into 2 vertical segments according to the fissure in which a hepatic vein coursed. By including **Hjortsjo** concept of segmental anatomy, new procedures will be added to hepatic surgery. Sixty – five cadaveric livers were dissected to confirm **Hjorsjo's** concept of segmental anatomy

These findings confirmed the certainty of **Hjorsjo's** concept of segmental anatomy of the anterior segment and this is relevant for developing new procedures in hepatic surgery. Based on their observations on hepatovenous segments, **Gupta et at** (1981) stated that there were 5 segments left, middle right, paracaval and caudate lobes.

As more and more investigations were being done on the patients with liver disease and associated biliary tract disease more information about the congenital anomalies of the lobes and segments started surfacing, these were mostly accidental findings during an investigation or during a surgery.

Agenesis of the right lobe may be associated with biliary tract disease, portal hypertension, and other congenital anomalies **(Kakitsubata & Kakitsubata, 1991).** In

cases of absence of the left lobe of liver, the position of the gall bladder is also at the left side of the liver. The hepatic lobe anomaly is not always congenital. Therefore, the diagnosis of this anomaly requires, other things such as no evidence of liver dysfunction **(Kqkitsubata & Nakamura, 1991; Yama Moto & Kojoh, 1988.)**

Congenital agenesis of a liver lobe affects the left lobe more than right lobe (**Demirci & Diren 1990, Kikitsubata, 1991; Radin & Collet; 1987)**

## REVIEW OF LITERATURE FOR HEPATIC VEINS

Hepatic veins are group of veins that drain the liver into the inferior vena cava. These hepatic veins have often been described as sessile veins opening immediately beneath the diaphragm into the inferior vena cava – **(Mcgregor & du Plessis, 1969).** The hepatic veins usually present as the superior, middle and the inferior groups of veins, enlarged veins of the middle and the inferior groups bear surgical importance - **(Launois et al, 1993).**

The superior group of vein is mostly large and is made up of 3 large veins namely right hepatic vein, middle hepatic vein and the left hepatic vein. According to the classification criterion for openings of the hepatic veins adopted by **Camargo et al.,** (1996), the caval openings of the superior group of hepatic veins (0.5-2.0cm) corresponded to the set of large openings and those of the accessory hepatic veins (0.5-1.0cm) of the lower group to the set medium openings. Apart from the importance

in the segmental anatomy of liver where these veins play a vital role, surgically they are important during surgery where these veins may spring surprises.

Unanticipated abnormal systemic venous channels have been reported as the causative factors for post surgical problems such as cyanosis following Fontan type operation - **Yoshimura et al, 1999.** In order to avoid this a comprehensive knowledge of various anatomical variations with regard to arterial supply and ductal pattern along with the segmental divisions of portal and hepatic veins does play a pivotal role in developing comprehensive surgical skills for successful completion and outcome of difficult and complex procedures such as liver transplantation **(Williams et al. 1998).**

**Sharma D, Deshmukh A, Raina VK 2001** in their study have shown that in 96% of cases the middle and left hepatic veins form a common trunk. In a majority of cases, the diameters of the right and left hepatic veins were between 7mm and 12mm and no gender differences were found. It is relatively common to have more than 3 hepatic veins and often the hepatic veins may have common trunks **(Makuuchi, Masselot, Nakamura),**

Incidence of variations of the middle hepatic vein branches and their impact on right hepatectomy for living – donar liver transplantation was studied on fifty consecutive patients **(Kamel IR, Lawler LP, Fishman EK 2003)** In 11 patients (22%) the middle hepatic vein had no major (>5 mm) branches. In 15 patients (30%) a major branch was seen draining the right lobe. In 10 patients (20%) a major branch was seen

draining each lobe. In five patients (10%) two major branches were seen draining the right lobe and a single branch draining the left lobe.

They concluded that formal right hepatectomy could be performed without transecting major branches of the middle hepatic vein in one-third of patients. In the remaining two- thirds, one or more major branch pf the middle hepatic vein will need be transected.

Variations in the drainage pattern of hepatic veins have been reported from time to time. These include accessory right hepatic veins **(Van Leeuwen et al., 1994, De Cecchis et at, 2000),** significant accessory hepatic vein **(Marcos et al., 2000)** and accessory suprahepatic veins **(Bach et al., 1994- 95).** The study carried out on corrosion casts of 93 adult livers by **Sledzinski and Tyszkiewicz (1975)** has revealed the incidence of large accessory hepatic veins of the lower groups to be 15%.

**De Cecchis et al (2000)** have documented the presence of such accessory viens in 28% of the cases, being mostly restricted to the right lobe. **Marcos et al. (2000)** observed the presence of at least one significant accessory hepatic vein in 16 out of 40 living liver donors.

The recognition of the fact regarding the presence or absence of large accessory veins is important at the time of surgery because factors other than hemorrhage like air embolism at laparotomy could be the important cause of death in hepatic vein injuries

**(Decker & Du Plessis, 1986).**

Keeping in view the intraoperative complications, **Ledesma- medina et al (1985)** have suggested in toto preoperative radiological evaluation in patients who are to undergo liver transplantation..

## REVIEW OF LITERATURE FOR PORTAL VEIN

Portal vein carries splanchnic blood to the liver. It is called portal system because it begins in capillaries and ends in capillaries. In the body it forms a part of important anastomosis called the porta – systemic anastomosis.

The formation of portal vein at the posterior part of neck of pancreas runs along the right border of lesser omentum accompanied by the hepatic artery and bile duct forming the portal triad up to the porta hepatis where it divides into right and left branches to supply the lobes. Portal vein, hepatic artery and bile duct divide and subdivide with a common pattern **(Glisson, 1659),** who also gave the accurate illustration of relationship between the portal venous and hepatic venous system. At the time when human cadaveric liver was not freely available more of non-human mammals liver specimens were used **(Rex, 1888)** and nomenclature for major branching of intahepatic portal vein was established. It was **(Looten, 1908)** who in his studies on the injected bodies of infants claimed vascular independence of right and left lobes based on the portal vein branching. General information of the 4 system-portal vein, hepatic

artery, hepatic duct and hepatic vein was given by (**Segell, 1923)** by injecting radio opaque gelatine into vessels of human liver.

**Hans dkuas (1952)** in anatomical record stated that the intra hepatic portal venous system presented a constant "skeleton" for the liver. It was symbolically represented as "trellis". The hepatic arteries and hepatic ducts were shown as vines and were independent of this portal trellis and of each other in the proximal territories. But in the distal parts there was perfect co- ordination of the portal triad.

**Couinauds (1953)** studied 103 livers obtained at autopsy and he named the segments as sectors in his classical description.

3 pattern of portal vein branching variations were described by Couinaud.

1. Pattern I: immediate trifurcation of main portal trunk into right anterior, right posterior and left portal branches was observed in 8/103 specimens studied

2. Pattern II : right posterior segmental branch arises directly from the main portal trunk and seen in 6/ 103 specimen(5.8%) studied.

3. Pattern III : the origin of the right anterior segmental branch form left portal vein was seen in 3/ 103 specimens (2.9%) studied.

In their study of intrahepatic vessel ramification in right posterior hepatic sector particularly to segment VI and VII by (**Hata F, et al)** four major patterns of branching

pattern of portal vein are described.

1. In group A (32.0%), a single posterior trunk formed an arch like pattern sending multiple branches to segment VI and segment VII.

2. In group B (27.9%), the posterior sectoral trunk bifurcated to segment VI and segment VII.

3. In group C (6.6%), the trunk trifurcated to segment VI, segment VII, and an intermediate branch, which supplies both segment and a gray zone between them.

4. Group D (33.5%), included variations of the anterior segmental branches.

In a spiral computerised tomography evaluation of right hemiliver **Van Leeuwen, et al** a total of 15 accessory portal sectors were present, each arising directly from the portal bifurcation or the right portal trunk.

In his study of portal vein branching **Healey, 1954** reported that there was no variations in branching pattern of portal vein in 25 dissected liver specimens.

Distortuous intra hepatic branches of the portal vein were observed in the cirrhosis of liver in splenoportogram **(Warren et al, 1967).** Thus knowledge of intrahepatic pattern of branching portal vein will be useful to differentiate whether the cirrhosis of liver is generalized or localized. If localized, it will help in finding the area of liver affected.

The segment I or caudate lobe which is as unique and independent segment. The right portion of caudate lobe and caudate process received portal venous blood from right portal venous branch or from bifurcation of main portal vein. Whereas left portion of portal supply of caudate lobe arose from the left branch of portal vein **(Scheele 1994)**.

Tiny portal venules that branch directly, from the main left or right portal vein that distributes to segment IV in 60% of patients **Osamu Matsui et al, 1997).** This study was conducted on 100 patients using helical computerised tomographic arterioportography. Knowledge of this vascular anatomy is clinically important.

**Motokinagai et al. 1997** reported 18 cases with right sided round ligament, causing the gall bladder to be located on the left side. This anomaly should not be diagnosed as left sided gall bladder but a right sided round ligament.

**Kubo S et al. 2000** reported that Doppler sonography was useful in the detection of disrupted portal venous blood flow and in the diagnosis of hepatic atrophy. This is clearly advantageous in the final decision making, whether to perform a liver resection in case of hepatolithiasis.

**Akihiro et al, 2000** reported that computerised tomographic artrioportography, the portal venous anatomy is a critical factor in candidates for systematic subsegmental hepatectomy. Intraoperative ultrasonagraphy is presently used as guide for hepatic resection to evaluate portal venous anatomy.

## REVIEW OF LITERATURE FOR HEPATIC ARTERY

The hepatic arterial system is divided into two parts namely the extrahepatic and intrahepatic parts. The extrahepatic arterial system starts from the origin of the hepatic artery from the coeliac axis and ends in the porta hepatis where it divides into right and left branches to the right and left lobes of liver. The intrahepatic system parallels the branching patterns of the portal vein and hepatic ducts.

It was **Cantalie (1898)** who first established the division into right and left lobes based on the right and left hepatic arteries. As the surgeries on liver started developing from an intact hepatic artery which became the gateway to successful hepatobiliary surgery. Particularly with laproscopic cholecystectomy where in the division or damage with subsequent thrombosis produces ischemia of the liver or bile duct, which can have devastating consequences for the patient.

**R.M.Jones and K.J.Hardy 2001** after extensive study of the hepatic artery concluded the following patterns for right and left hepatic arteries.

In most cases left hepatic artery originated from the common hepatic artery in 80% and from the left gastric artery in 15%, the splenic artery in 3% and the gastro duodenal artery in 2%.

In three instances the anomalous origins were found. The right hepatic artery took origin from the main trunk of the common hepatic artery in 75% the superior mesenteric

in 18% and gastroduodenal artery 7%.

Studying the extrahepatic part of the hepatic artery was important in the hepatobiliary surgery the segmental branching pattern of the right and left hepatic artery in the respective lobes was equally important.

In a study using computerised tomography scan **(Chang Jc et al)** all cases had a single right hepatic artery and eight types of variations of intrahepatic branching pattern of the right hepatic artery were given.

1. Type I : where the branches to the segment V and VIII were seen branching from the anterior segmental artery and branch to segment VI and VII was seen branching from the posterior segmental artery in 64.5%.

2. Type VII: the VI segmental branch emerging first from the posterior segmental artery and VII segmental branch emerging secondly from the posterior segmental artery 15.8%.

3. Type III, VI and VII were branched from the posterior segmental artery.

4. Type II, IV and V were branched from the anterior segmental artery.

In a study using 70 liver casts, the arterial pattern of left hemiliver was observed and the arteries were divided into 15 groups according to their origin and branching pattern **(Mlakar b, et al, 2001).**

The left hemiliver was supplied by one artery in 53%, by two arteries in 40% and by three arteries in 7%.

The left hepatic artery, which originated from the proper hepatic artery, supplies all three left segments in 39% of specimens.

The replacing left hepatic artery, which originated from the left gastric artery, supplies the whole left hemi liver in 3% of cases.

The incomplete, left hepatic artery supplied segments II, III and a part of segment IV in 6% of cases and only segments II and III in 11%.

Here was one segmental artery for segment II in 86% and two in 14%.

Segment III was supplied by one artery in 87% and by two in 13%.

Segment IV was supplied by one artery in 39% of cases, by two arteries in 43% by three in 14% and by four arteries in 4%.

Kim HS et al 2001 analyzed the variations of branching of hepatic artery and blood supply to the liver segments using spiral computeraised tomographic hepatic arteiorgraphy. They observed that there were 5 groups of hepatic artery variations and 23 of segmental supply pattern.

**REVIEW OF LITERATURE FOR HEPATIC DUCT**

Blumgart (1988) studied the hepatic duct confluence and concluded that the most common variations was drainage of the right anterior or right posterior segment into common hepatic duct in 16% and the triple confluence in 12% of the cases.

The aberrant hepatic biliary segmental anatomy was studied using Magnetic Resonance Cholangiograhic Method by **(Koenrad J. Mortele et al 2001)** the most common anatomic variant in the branching of the biliary tree involved the right posterior duct and its fusion with the right anterior or left hepatic duct. Another common variant (11%) of the main hepatic biliary branching is the so called triple confluence, which is an anomaly characterized by simultaneous emptying of the right posterior duct, right anterior duct, and left hepatic duct into the common hepatic duct.

The branching pattern of intra hepatic duct was atypical in 37% of cases **(Jin Woo Choe et al).** The two most common variations were drainage of the right posterior segmental duct into the left hepatic duct (11%) and triple confluence of the right anterior segmental duct, right posterior segmental duct and left hepatic duct (10%)

# MATERIALS AND METHODS

This study of segmental anatomy of liver was done in the Department of Anatomy, Stanley Medical College, Chennai -1.

**Venue of study**

1. Department of Anatomy, Stanley Medical College, Chennai -1
2. Department of Forensic Medicine, Stanley Medical College, Chennai -1.
3. Department of Radiology, Stanley Medical College, Chennai-1.

**Collection of specimens**

The liver specimens with which the study of segmental anatomy was studied were procured from the Department of Forensic Medicine, Stanley Medical College, Chennai. All the specimens studied were adult specimens. All the specimens were taken from post – mortem bodies. The cause of death was due to reasons other than liver problems. During the harvesting of the liver specimens no gross anomalies were noted. During the harvesting of the specimens the falciform ligament was retained and a long portal pedicle along with the gall bladder was taken. The inferior vena cava was cut at the level little above and below the posterior surface of the liver. This was done to preserve the opening of the hepatic veins into the inferior vena cava.

This study of segmental anatomy of liver was conducted in 100 specimens in the following methods.

**Materials**

1. Cadaveric specimen - 30
2. Autopsy specimen - 30
3. Radiological method - 20
4. Ultrasound method - 20

**Methods of study**

During this study of the segmental anatomy of liver the following methods were used

1. Manual dissection method
2. Radiological study by contrast method
3. Ultrasound method

## MANUAL DISSECTION METHOD

### I. Cadaveric study

The liver specimens with which the study of segmental anatomy was studied in cadavers which was used in dissection hall for study purposes.

The study was done on 30 formalin fixed dissecting room cadavers. The mean age of the cadavers was 60 years (Range 45- 75) with a sex distribution of 20 males and 10 females.

An midline incision made in the anterior abdominal wall from the xiphisternum upto the umbilicus. From the lower end of the incision, a transverse incision was made till the mid axillary line. Skin flap was raised and the rectus abdominis were refelected in the same plane. Peritoneum was opened. Liver and stomach were visualized.

The liver was released from its attachments. The collected liver specimens were washed thoroughly and dissected under water to see segments along its vascular planes.

### II. Autopsy Specimen Study

In this method of study, 30 adult liver specimens were studied. The specimens taken from the Forensic Medicine Department of Stanley Medical College were all washed thoroughly with running water in order to remove all the blood that may ooze through the cut veins.

Then they were kept in 10% formalin solution and allowed to remain in formalin for 10 days. This was done so that the soft friable liver tissue will get fixed making it easy for the dissection to be done. Then the specimens were ready for the dissection to see the structures.

In this dissection the hepatic veins and portals veins were studied. The dissection of the hepatic vein were done starting from the inferior vena cava and followed into the liver substance and the three hepatic veins were studied.

The portal vein was dissected from the portal pedicle from where it was separated from the hepatic artery and bile duct. It was then traced into the liver substance and the branching pattern studied.

**RADIOLOGICAL STUDY BY CONTRAST METHOD**

In this method of study of the segmental anatomy of liver, 20 specimens were studied.

The liver got from the Forensic Medicine Department was washed in running water thoroughly to remove all the blood.

The hepatic artery and the bile duct were flushed with syringe to remove the blood and excess bile which would help in the flow of the contrast agents. The contrast agent used was urograffin which was injected into the bile duct and the hepatic artery

and x rays were taken.

**ULTRASOUND METHOD – CLINICAL STUDY**

This was done at the department of Radiology at Stanley Medical College, Chennai.

This study was done on 20 patients who had referred for abdominal scan for other reasons other than liver problems. All the patients selected were adult patients.

As a routine for abdominal scan the patients were asked to come in empty stomach. Some of the patients were allowed to drink sips of water in order to prevent excessive thirst.

The patients were made to lie in supine position for the scan for liver. Before proceeding for the scan, the abdomen was palpated to exclude any enlargement of liver or pain abdomen.

The probe used for the liver scan had a transducer of 3.5 MHz. This was selected because at this frequency the penetration was good. But the resolution is always low.

The scanning was done in sagittal plane, transverse plane, oblique planes. Intercostals and subcostal views were also seen. In this method the hepatic veins and its branching pattern, portal vein and its branching and bile ducts were observed.

# OBSERVATIONS

The study of the segmental anatomy of liver and its clinical importance done at the Department of Anatomy, Stanley Medical College, is based upon the hepatic veins which divided the liver into lobes and the branching of the portal vein, hepatic artery and the hepatic duct. In this study the manual dissection method was used to observe the branching pattern of hepatic veins and portal vein.

In the radiological method the urograffin contrast agent was used to study the segmental branching pattern of hepatic artery and the hepatic duct.

In the ultrasound method which was the easiest to perform and great deal of information was available in short time. In this method the hepatic veins, portal vein and the hepatic duct were also observed.

In the ultrasound method the segments of the liver were studied and the findings correlated with the finding of the manual dissection and radiological methods.

The findings observed are given below

**Hepatic Veins**

All the three major hepatic vein were observed in the manual dissection method as well as the ultrasound method. In the manual dissection all the hepatic veins were traced from the inferior vena cava where their orifices were seen, into the liver substances.

In the ultrasound method the veins were observed joining the inferior vena cava.

The hepatic veins right, left and the middle were seen well in the transverse view with the section very near the diaphragm with the transducer at a slightly Cephalad Angulation.

The right hepatic vein was observed to be larger than the left and middle hepatic veins

The middle hepatic vein observed to join the left hepatic vein in 80 specimens. The middle hepatic veins was seen to be present along the Rex cantlie line thus dividing the liver into two equal halves.

A single vein along with small veins was seen draining the caudate lobe in all dissection specimens studied shows its independent drainage. There were no accessory veins observed in this study.

**Hepatic veins**

| S. No. | Various pattern observed | Number of specimens | Percentage % |
|---|---|---|---|
| 1 | Right hepatic vein is larger than the middle & left hepatic veins | 80 | 100% |
| 2 | Middle hepatic vein observed to join the left hepatic vein | 70 | 87% |
| 3 | A single vein was seen draining the caudate lobe of the liver | 80 | 100% |

**Portal vein**

The portal vein was studied in both the dissection method and ultrasound method. It was relatively easy in the ultrasound method to investigate the branching pattern of the portal vein.

In the manual dissection method, the portal vein was seen dividing into right branch and left branch at the porta hepatis i.e. it has a bifurcation pattern.

After a varied length the right branch was seen dividing into right anterior segmental and right posterior segmental branches. This branching pattern was observed in all the dissected specimens. Anterior segmental branch was seen dividing into superior and inferior and the posterior segmental branch was seen dividing into superior and inferior branches.

In one of the dissected specimens an accessory branch was seen going to the

quadrate lobe form the anterior division of the right portal vein.

The left branch of the portal vein had the pars transversalis and pars umblicalis parts in all the dissected specimens. The left branch of the portal was observed divide into the segment branches to segment II, segment III and segment IV.

In the ultrasound method the branching of portal vein into right and left branches were clearly seen in the transverse section at a level slightly lower that than for the hepatic veins. In all the specimens studied in the ultrasound method portal vein had bifurcation pattern.

The best view to study the segmental branching pattern of the right portal vein was by placing the transducer in the sagittal midaxillary inercostal plane. The other position to study the segmental branching was the transeverse subcostal plane.

The branches to the segments V to VIII were seen radiating from the right portal vein with a cross bar appearance in the center thus giving an appearance of letter " H" pattern observed in this section of liver.

In this it was observed that the three corners of the letter H is formed by the branches to the segment IV.

The left portal vein branching was best studied by placing the transducer below the xiphoid process and aiming it toward the patients left shoulder. The similar " H"

pattern was also observed in this section of liver.

In this it was observed the three corners of the letter H is formed by the branches to the segment IV, segment III and segement II. One corner is occupied by the left branch of portal vein and the cross bar in this section is occupied by the pars umbilical portion of the left portal vein.

**Portal vein**

| S. No. | Various pattern observed | Number of specimens | Percentage % |
|---|---|---|---|
| 1 | Bifurcation pattern | 71 | 88% |
| 2 | Trifurcation pattern | 7 | 8% |
| 3 | Accessory portal vein | 2 | 4% |

**HEPATIC ARTERY**

In the gross examination of liver specimens it was seen that all the 20 specimens had only single hepatic artery and all of them were observed to take origin from coeliac axis.

Radiological contrast method was used to study the branching pattern of the hepatic artery and the following observations were made. The hepatic artery was observed giving branches to the segment IV before dividing into branches for segment II and segment III in all the 20 specimens.

The right hepatic artery was observed to divide into right anterior and right posterior branches. The right branch was seen to divide into superior branch to supply

the segment VIII and inferior branch to supply the segment V. The posterior branch was also seen to divide into superior branch to supply the segment VII and inferior branch to supply segment VI. This pattern was seen in all the 20 specimens studied.

| S. No. | Various pattern observed | Number of specimens | Percentage % |
|---|---|---|---|
| 1 | Arising from the coeliac axis | 20 | 100% |
| 2 | Hepatic artery divides into right & left hepatic artery | 20 | 100% |
| 3 | Right hepatic artery divides into superior & inferior | 20 | 100% |

**BILE DUCT PATTERN**

The cholangiogram was done by contrast method to study the segmental pattern of division of the hepatic duct, after injecting the urograffin, X-rays were taken and the following observation made.

The common hepatic duct was formed by the fusion of right hepatic duct and left hepatic duct. The right anterior segmental branch draining the segment V and VII join together to form the right hepatic duct. The left hepatic duct is formed by the fusion of the segmental branch form segment II, segment III and segment IV.

Except in two specimen this pattern was observed in all the other specimens studied by the radiological method. The variations observed was the triple confluence of the hepatic ducts where the anterior segmental hepatic duct, the posterior segmental

hepatic duct and the left hepatic duct join together and form the common hepatic duct.

| S. No. | Various pattern observed | Number of specimens | Percentage % |
|---|---|---|---|
| 1 | Triple confluence | 2 | 10% |

## DIVISION OF LOBES OF LIVER

In all the specimens studied that middle hepatic vein was present in the main portal scissura which runs from the middle of the gall bladder bed, anteriorly to the inferior vena cava posteriorly dividing the liver into right and left lobes.

## LEFT LOBE

In all the 100, specimens studied the left lobe, was present on the left side of the middle hepatic vein. The left lobe had its hepatic portal pedicle, which had a major division of the left portal vein, left hepatic artery and drainage by the left bile duct. This was observed in all the specimens studied.

The left portal pedicle was longer than the right portal pedicle in all the specimens studied.

In all the 100 specimens studied the left portal vein had both pars transversalis and pars umblicalis parts. The left lobe of the liver was divided into medial lateral segments by the presence of umbilical plane, which runs from the inferior vena cava to the umbilical fissure. The left hepatic vein was seen in the left portal scissura in all the specimens, which was present more laterally to the umbilical plane. The left hepatic vein was seen being joined by middle hepatic vein in 70 of the specimens studied. The structures form the portal pedicle were all giving of the segmental branches, at the level of the umblicial plane.

**RIGHT LOBE OF LIVER**

This lobe is larger than the left lobe

This lobe was divided into 2 parts by the right hepatic vein into anterior and posterior parts.

The right hepatic vein was found to be larger than the left hepatic vein and the middle hepaic vein in all the 80 specimens studied. The right hepatic vein was seen draining into inferior vena cava directly in all the 80 specimens observed.

The portal pedicle which contained the right branch of portal vein, right branch of hepatic artery and right hepatic duct was seen in all the 80 specimens studied. The portal pedicle had a short extrahepatic course than the left portal pedicle

## SEGMENTATION OF LIVER

This segmentation of the liver was done on the basis of the branching pattern of the portal triad which divided the lobes into three segments on the left and four on the right.

### Segment I (caudate lobe) the following observations were made

Caudate lobe was present in all the specimens studied. This lobe was observed on the posterior part of the liver in front of the inferior vena cava. The branches form the right portal vein and left portal vein were seen supplying the caudate lobe in all the specimens studied. The hepatic arterial supply was seen from both the right and left hepatic arteries in all the specimens studied. One major vein with small accessory veins from the caudate lobe were seen to directly drain directly into the inferior vena cava in all the 80 specimens studied.

### Segment II the following observations were made

This segment was marked in the left lobe. The umbilical plane is defined on the liver surface and extends from the umbilical fissure anteriorly through the ligamentum venosum along the lateral aspect of the caudate lobe and divided the left lobe of the of the liver into medial and lateral parts. The left hepatic vein was present more laterally from the umbilical plane thus dividing the liver into more posterior part which is the segment II and anterior part, which is the segment III. This was observed in all the

specimens studied. In all the specimens studied the left portal vein had pars transversalis part and pars umblicalis part and at the level of the umbilical plane. The portal vein gave the lateral superior branch which to the segment II. In this study the segment II received its arterial supply from the left hepatic artery. The bile duct drainage was into the left hepatic duct in all the 80 specimens studied.

**Segment III, the following observations were made**

This segment was marked in between the left hepatic vein and umbilical plane. Portal vein branches were from the left portal vein in all the specimens studied. The arterial supply was from the left hepatic artery in all the 80 specimens studied.

The bile drainage was into the left hepatic duct in all the 80 specimens studied.

For the segment IV (Quadrate Lobe), the following observations were made. This lobe was marked in all the 80 specimens studied between the principal scissura and the umbilical fissure. The portal venous supply was from the left branch of portal vein.

In one specimen there was accessory veins from the right anterior segmental branch of portal vein. The hepatic arterial supply was from the left hepatic artery in all the specimens studied.

The bile duct drained into the left hepatic duct in all the specimens studied.

**Segment V : the following observations were made**

This segment was marked in all the specimens studied based on the middle hepatic vein and the right hepatic vein. The right lobe is divided into anterior and posterior parts by the right hepatic vein. This is further divided by the anterior branch of portal vein which divides the anterior part into superior and inferior segments. This was clearly observed in the ultrasound study of all the specimens by the “H” shaped pattern seen on the ultrasound. This segment lies inferior to segment VIII

The portal venous supply was from the right anterior segmental branch of the portal vein. The arterial supply was from the right anterior inferior segmental branch of the hepatic artery in all the specimens studied. The bile ductal drainage was through the right anterior hepatic duct.

**Segment VI : the following observations were made**

This segment was marked in the posteroinferior part of the right lobe of the liver. The portal venous supply was from the right posterior branch of the portal vein in all the specimens studied. In the ultrasound image this was observed as the posterior branch of the “H” shaped division of the right portal vein.

The arterial supply to this segment was from the right posterior inferior branch of the right hepatic artery. The bile ductal drainage was through the right posterior segmental duct. In one of the specimen studied there was triple confluence observed, where the right anterior segmental duct and right posterior segmental duct join the left

hepatic duct.

**Segment VII the following observations were made**

This bile segment was marked superior to the segment VI on the posterior aspect of the right lobe in all the specimens studied.

The portal venous supply was from the right posterior branch of the portal vein in all the specimens studied. The arterial supply was from the right posterior segmental branch of the right hepatic artery.

The bile ductal drainage was through the right posterior segmental duct of right hepatic duct in 19 out of 20 specimens studied. In one specimen this right posterior segmental duct was seen to form a triple confluence by joining the right anterior segmental duct and the left hepatic duct.

**Segment VIII : the following observations were made**

This segment was marked on the anterior aspect of the right lobe of the liver superior to the segment V in all the specimens studied. The portal venous supply was from the right anterior segmental branch of the right portal vein in all the specimens studied. The arterial supply was from the right anterior segmental branch of the right hepatic artery. The drainage was through the right anterior segmental branch of the right hepatic duct.

# DISCUSSION

## LOBES OF LIVER

Previously, the division of the lobes was conventionally done by surface marking and topographical relation of the organ, until first it was divided into right and left lobes based on the branching of hepatic artery **(Cantlie 1888),** based on hepatic ducts **(Hjorstojo, 1948).**

The importance of the Rex – Cantlie plane was then recongnized by **Ton That Thug in 1939** which was the principal plane that divided the liver into right and left hemi livers.

This is a plane passing through the gallbladder bed towards the inferior vena cava and passes through the right axis of the caudate lobe, the middle hepatic vein lies in this plane.

In this study it was observed that the midde hepatic vein was present in the principal scissura which corresponded to the **Rex – Cantlie** line in all the specimens studied thus establishing the importance of this plane.

## SEGMENTS OF LIVER

The importance of more conservative surgery and need for limited resection of liver lead to establish the segmental anatomy of liver where the liver is divided into still smaller functional segments than just lobes.

After the establishment of the major vascular territories of arteries and hepatic venous supply **Hjorstojo, 1948,** the traditional method of division of the hepatic segments based on the topographical relation of the liver was dropped and classification based on the vasculature of liver started.

In the American system, the liver was divided into four lobes and the importance of the caudate lobe was not considered here but this formed the basis of the four classical types of hepatic resection. In the French system **(Couinaud, 1953)** there are 8 segments and the caudate lobe is considered as imdependent lobe and this gained popularity and it is now globally accepted by surgeon of the two system of classification of segmental anatomy of liver that are present.

**Claude de Couinaud** a French surgeon and anatomist proposed the new segmental anatomy of liver. He divided the liver into 8 segments. He described that the right lobe is divided into two sectors namely anteromedial and posterolateral. The anteromedial sector was divided into segment V anterior and segment VIII posterior.

The posterolateral sector was divided into segment VI anterior and segment VII

posterior.

He divided the left lobe into three segments and named them segment II posterior and segment III anterior and segment IV medial to umbilical fissure. The Spigelian lobe or the caudate lobe or the segment I is considered as an autonomous segment.

In this study, all the specimens studied were found to have 8 segments that corresponded to the Couinaud segments.

**HEPATIC VEINS**

With the establishment of relationships between the portal venous system and hepatic venous systems, **(Glisson 1659)** the nomenclature for major branching of intrahepatic portal vein and for major hepatic veins **(Rex 1888).**

**Couinaud** description of the segments was based upon the division of liver into eight segments following the distribution of the portal pedicles and the location of three hepatic veins.

He had put forward that the middle hepatic vein separates the whole liver into right and left lobe. The right hepatic vein further separates the right liver into right posterior sector and right anterior sector and left hepatic vein separates the left liver into the left anterior sector and left posterior sector. In the drainage of hepatic veins observed, in 75% of specimens the left hepatic vein joining with the middle hepatic vein

to empty into the inferior vena cava **(H. Bismuth)**.

**L. H. Blumgart** in his description says that the hepatic veins drain directly from the upper part of the posterior surface of the liver at some what oblique angle directly into the inferior vena cava. The right hepatic vein some what larger than the left vein. The middle hepatic veins has short extra hepatic course.

The left and middle hepatic veins may drain separately into the inferior vena cava but frequently joined after a short extra hepatic course to form a common venous channel. He also describes that there are also other short hepatic veins that drain into the inferior vana cava.

**Peter I Williams (38th edition)** Grays anatomy states that there are three hepatic veins drain into inferior vena cava. The most commonly the middle hepatic vein joining with the left hepatic vein.

In a majority of cases, the diameters of the right and left hepatic veins were between 7 mm and 13 mm. No gender differences were found in the study by **Sharma D Deshmukh A, Rains VK (2001)** and they have observed that in 96 % of cases the middle and left hepatic veins form a common trunk. Variations in the drainage pattern of hepatic veins have been reported from time to time. These include accessory right hepatic veins, **(Van Leewwen et al., 1994**, **De Cecchis et al, 2000)** significant accessory hepatic veins **(Marcos et al., 2000)** and accessory suprahepatic veins **(Bach et al**

**1994-95).** The knowledge of this accessory vein is important for the operating surgeon.

In the present study the right hepatic vein, left hepatic vein and the middle hepatic vein were seen in all the specimens, and in 51 0f 58 specimens studied the middle hepatic vein was seen joining with the left hepatic vein. This coincides with the observations of **(H. Bismuth and Peter I Williams)** there were no accessory veins observed

**PORTAL VEIN**

Supplying almost two third of the blood to the liver, this portal vein was important not only for the digestive purpose by bringing all the splanchnic blood, it was also important for the segmentation of liver. It was **Looten (1908)** who claimed vascular independence of right and left lobes based on the portal vein branching. Then it was **Segell (1923)** studied by injecting radio opaque gelatin into vessels of human liver obtained by autopsy. He gave general information of the 4 systems – portal vein, hepatic Artery, hepatic vein and hepatic duct.

**Couinauds** in 1953 described the division of liver into sectors by the hepatic veins. The anteromedial sector is divided into segment V anterior and segment VIII posterior. The posterolateral sector is divided into segment VI anterior and segment VII posterior. Left lobe of liver divided into segment III anterior, segment II posterior and segment IV medial to the umbilical fissure. The Spegelian lobe or segment I considered

as an autonomous segment since it receives vascularization both form right and left branch of portal vein and its venous drainage directly into inferior vena cava.

There are 3 patterns of portal vein branching described by **Couinauds**

**Pattern I :** Immediate trifurcation of main portal trunk into right anterior right posterior and left portal branches was observed in 8/103 specimens studied.

**Pattern II :** Right posterior segmental branch arises directly from the main portal trunk and seen in 6/103 specimens (5.8%) studied

**Pattern III :** The origin of the right anterior segmental branch form left portal vein was seen in 3/103 specimens (2.9%)

Studying the left branch of portal vein it was described that the left branch of the portal vein curved laterally at the root of the ligamentum teres and along with the hepatic artery it gave feedback vessels to the medial segment IV i.e., the quadrate lobe **(Goldsmith and Woodburne 1957).** In anatomical record **(Hans Ekuas 1952)** stated that the intrahepatic portal venous system presente a constant "skeleton" for the liver. It was symbolically represented as "Trellis".

With the non- invasive method of investigation like the ultrasound and computerised tomography it became easy to study the vascular pattern which also threw light on variations in pattern of branching.

In ultrasound examination the portal branches to the four segments of each lobe are seen as letter "H" as was described by **Lafortune**.

**Margeret et al (1990)** reported in colour Doppler study a large aberrant branch from the anterior segmental branch to the medial segment of the left lobe.

**Osamu matsui et al., (1997)** reported a branch from right portal vein distributed to posterior aspect of segment IV.

In the present study the portal vein was seen to have a normal bifurcation pattern and division into the segmental branches correlating with the **Couinauds** observation that the trifurcation pattern was observed in less than 8% of cases.

The segmental branching of portal vein was observed in the typical H pattern in all the specimens studied correlating with the **Lafortune** description. In 2 specimens accessory vein were given to the segment IV i.e., the quadrate lobe from the anterior segmental branch of the right branch of the portal vein.

This correlates with the observations made by **Margaret et al and Osamu Matsui et al.**

## HEPATIC ARTERY

The importance of good knowledge of the hepatic artery not only helps in the hepatobiliary surgeries, but is also useful in selective embolisation for the control of tumor growth.

**Michels (1966)** stated that despite variations in origin and occurrence of accessory vessels, the hepatic arterial system consists of end arteries.

Variations of the arterial anatomy are common (Bismuth) and among the most frequent are …

1. The presence of supplementary hepatic artery to the right lobe or of a replaced hepatic artery.

2. Left hepatic artery originated from the left gastric artery may be found in the lesser omentum.

In the study of the arterial supply of left hemi liver done by **Mlakar B et al** the observed that the left hemiliver was supplied by one artery in 53 % of cases, by two arteries in 40 % and by three arteries in 7%.

The left hepatic artery, which originated from the proper hepatic artery, supplied all three left segments in 39% of specimens.

The replacing left hepatic artery, which originated from the left gastric artery supplied the whole left hemiliver in 30 % of cases.

In this present study hepatic artery was seen arising from the coeliac axis correlating with the observation by **Decker & Du Plessis 1986.**

The hepatic artery was seen dividing into right and left hepatic arteries. No variations in origin or branching was noted. The right hepatic artery divided into right anterior segmental branch which divided into superior and inferior branches to supply the segment VIII and segment V. Left posterior segmental branch dividing into the superior and inferior branches to supply the segment VI and segment VII.

**BILE DUCTS**

The aberrant hepatic biliary segmental anatomy was studied using Magnetic Resonance cholangiographic method by **Koenraad J. Mortele et al (2001)** the most common anatomic variants in the branching of the biliary tree involved the right posterior duct and its fusion with the right anterior or left hepatic duct. Another common variant (11%) of the main hepatic biliary branching is the so called triple confluence.

The branching pattern of intra hepatic ducts was atypical in 37% of cases was observed by Jin **Woo Choie in 2003.** The two most common variations were drainage of the right posterior segmental duct into the left hepatic duct (11%) and triple confluence

of the right anterior segmental duct, right posterior segmental duct and left hepatic duct (10%).

**Blumgart (1988)** has studied the hepatic duct confluence and concluded that the most common variations was drainage of the right anterior or right posterior segment into common hepatic duct in 16 % and the triple confluence in 12 % of the cases.

In the present study two specimen out of 20 studied by radiological method showed the triple confluence of the hepatic duct thus correlating with the previous studies **(Blumgart / Choi / Koenraad J. Mortele)** which showed it as one of the common variations.

# SUMMARY

The need for more limited resection of the liver has prompted the researchers to look closer into the segmental anatomy of the liver and find more about this organ and about the anomalies that can spring surprises.

This study of segmental anatomy of liver was done on 100 liver specimens at the Department of Anatomy, Stanley Medical College, Chennai. The study was done by various methods like the manual dissection method on 60 specimens. Studies like the radiological methods where a contrast agent like the urograffin was used to study the hepatic artery and hepatic duct on 20 specimens. For the ultrasound method 20 patients were subjected for the study at the Department of Radiology, Stanley Medical College.

In this study the hepatic vasculature was studied first, as this forms the basis of the segmental pattern of the liver and also the functional anatomy. In this study the three major hepatic veins, the right hepatic vein, left hepatic vein and the middle hepatic vein were observed in all the specimen. In 87 % of observation the middle hepatic vein joined with the left hepatic vein and formed a common trunk before draining into the inferior vena cava. A single vein was seen draining the caudate lobe the liver. In all the 80 specimens studied the portal vein had bifurcation pattern of division into right and left portal vein and also had segmental division to all the segments of the liver. The caudate lobe was seen to receive portal blood from both the right and left portal vein. A single variation was observed in one specimen where an accessory portal vein was seen from

the right anterior division of portal vein to the quadrate lobe.

No variations was seen in the hepatic artery pattern of segmental branching. Triple confluence of the hepatic ducts was seen in one specimen.

All the segments were seen in all the 80 liver specimens observed. This observations on the segmental anatomy of the liver and its variations has great importance to the opening surgeon because a neat surgery is the gateway to successful results.

In the past decades, lobotomies were regularly performed, where a large amount of liver tissue was sacrificed for a small tumor present and the results were poor. With more conservative surgeries the segmental pattern of the liver becomes important. The variations at this segmental level should be kept in mind to avoid disastrous results.

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