ORIGINAL RESEARCH

Branching pattern of the hepatic artery and portal vein of liver in human cadavers at Mewar region of Rajasthan and its clinical implications

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ABSTRACT

Background: liver is the biggest organ, is situated in the upper right region of the belly, extending into the middle and a tiny part of the upper left area. Couinaud's classification identifies eight distinct functional regions (I to VIII) within the liver. The split is based on how the portal vein system and the hepatic veins are distributed throughout the body.This study emphasises the anatomical arrangement of the hepatic artery and portal vein within the liver. Additionally, we discovered variations in the segmental supply, a topic that has received limited attention in prior studies of the Indian population.

Purpose: This inquiry was conducted with the purpose of determining the gross anatomical differences of the liver as well as the consequences these variances have for clinical and surgical procedures.

Methods: We examined the hepatic artery and portal vein's branching pattern using two methodologies:

1. "Luminal casting (modified)
2. Radiological study"

A total of 20 liver specimens were utilised for luminal casting, with 10 specimens dedicated to studying the branching pattern of the hepatic artery and the other 10 specimens focused on examining the branching pattern of the portal vein.A total of 80 contrast-enhanced computed tomography (CECT) images were utilised for the radiological examination.Therefore, a sample size of 100 was utilised for each group.The acquired results were subsequently organised into a table.

Statistical Analysis: Utilising the most recent version of SPSS, the appropriate statistical test was carried out.

Results: Furthermore, the Indian population has rarely undergone detailed examination of the variations in segmental supply.Both the branching patterns of the portal vein and the hepatic artery are very uncommon to exhibit variations on the left side of the body. The branching pattern of the portal vein and the hepatic artery did not exhibit any noticeable differences regardless of the gender of the individual.

Keywords: Liver, morphological variations, hepatic artery, portal veins

Introduction

The liver, the largest organ in the abdomen, is located in the right hypochondrium, epigastrium, and a little amount of the left hypochondrium.Taking into consideration the peritoneal and ligamentous attachments that are located on the surface. [(1)]There are four lobes that make up the liver: the right, the left, the caudate, and the quadrate lobes.In the anterior region, the falciform ligament serves as a barrier between the right and left lobes of the liver. In the inferior region, the fissures for the ligamentum venosum and the ligamentum teres serve as a barrier between the two lobes.Cantlie's line is a functional anatomical structure that separates the liver into left and right lobes. In addition to being situated on the surface of the diaphragm, it is situated between the fossa for the gall bladder and the inferior vena cava. That is the central vein of the liver.It is the hepatic artery, the portal vein, and the bile duct that make up the hilum of the liver.The blood supply and biliary

outflow in the liver follow a branching pattern, which originates from the lobes and subsequently divides to produce the liver's segments or sectors.Couinaud's classification identifies eight distinct functional regions (I to VIII) within the liver.The split is based on the distribution of the portal venous system and the hepatic veins. (2)

There have been prior reports of variations in the hepatic artery and portal vein's extra-hepatic branching pattern. The right gastro-duodenal, right gastric, and right hepatic arteries emerge from the celiac trunk and are derived from the common hepatic artery. "The right, left, and middle hepatic arteries", which feed the liver's right, left, and quadrate lobes, respectively, are produced from the appropriate hepatic artery. Michael has categorised extrahepatic arterial variations into ten distinct kinds.(3)

Materials and Methods

With institutional review board ethical approval, the research was carried out at the anatomy and radiology departments of Pacific Medical College & Hospital, Udaipur. The hepatic artery and portal vein branching patterns, as well as the overall structural changes of the liver, were examined in this observational research.

Branching pattern of the hepatic artery and portal vein

Sample size determination: With 6% accuracy and a 95% confidence range, the sample size was determined as the total of 100 numbers taken into consideration the prevalence of hepatic artery changes, or 25%.

The following formula is used to sampling

$N = 4pq/d^2$

Where,

"N is the number of samplesp is the prevalenced is the precision."

Two methods were used to examine the hepatic artery and portal vein's branching patterns:

1. Luminal casting (modified)
2. Radiological study

Twenty liver specimens were utilised for luminal casting; ten were used for the "branching pattern of the portal vein and ten for the hepatic artery". Each of the 80 CECT pictures was utilised for the radiological research. As a result, 100 samples in total were chosen for each.

Procedure

Only the liver specimens free of significant gross deformities were selected. After that, the liver treated with formalin was cleaned overnight under running water. After that, the liver was maintained for five to six hours in a bath containing sodium tri-citrate, an anticoagulant. "Once again, the liver was cleaned with flowing water and by syringing water into the porta hepatis' blood vessel lumen".

The branching pattern of the hepatic artery was examined using Souda Foam, which is made of polymethylene polyphenylisocyanate.

Glass sealant, or silicon, was utilised to cast the specimens for the portal vein. The same procedures that were used to cast structures using Souda Foam and inject silicon material were used here. Wearing an apron, a facemask, goggles, and gloves is an example of the mandatory safety measures that were performed throughout the procedure.

The finger fracture method was used during dissection to trace the vascular systems. The liver parenchyma was peeled away with the forceps to reveal the arteries. "The hepatic artery and portal vein trunks" were recognised, and their division pattern was observed. Drawing the line diagram allowed for the recording of the branching pattern.

Radiological study

For this investigation, "one hundred 3D reconstructed contrast-enhanced CT (CECT) images" were employed. The ages of the subjects in these photos varied from 8 to 86 years old, with 47 men and 53 women. CECT images were acquired using (GE-Discovery, USA) at 2.5 mm thick slices.

Statistical Analysis

The most recent version of STATA software was used to statistically analyse the data, and Fisher's exact test was used to determine if "the branching patterns of the portal vein and hepatic artery differed based on gender".

Results

Hepatic artery branching pattern

Extrahepatic branching pattern

In one hundred individuals, a radiological investigation was carried out utilising CECT to assess the extra-hepatic branching pattern of the hepatic artery. In the present research, 73% of the patients had normal anatomy, whereas the other 27% had abnormal anatomy. (8)

The coeliac trunk gave rise to the common hepatic artery, which in turn released the correct hepatic artery. "The right and left hepatic arteries split out from the normal hepatic artery". The study observed that in 3% of cases, the common hepatic artery originated from the superior mesenteric artery; in 15% of cases, the right hepatic artery was replaced; in 5 cases, the left gastric artery was the source of the accessory left hepatic artery; and in 1 case, the right hepatic artery split off from the common hepatic artery just beyond its origin. Of the observed changes, the gender difference in the variance in the branching pattern was modest, and the substituted right hepatic artery had a greater occurrence (Table 1).

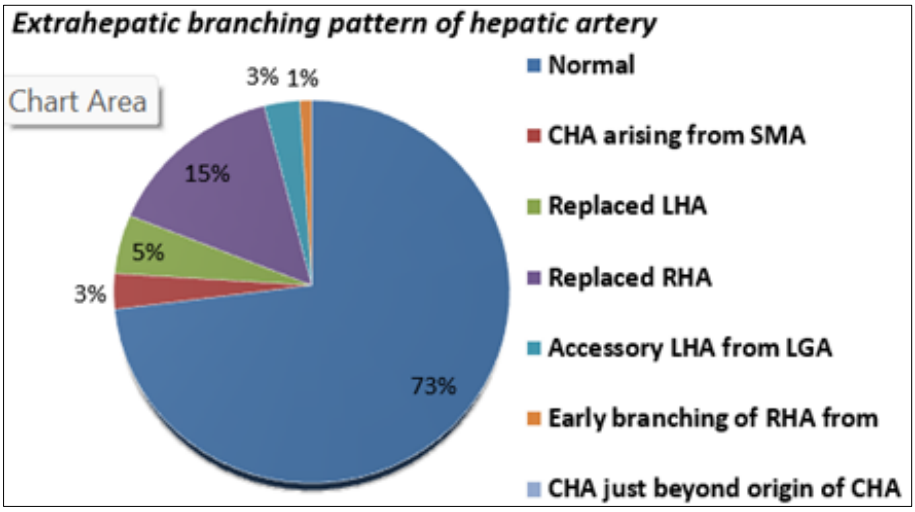

Fig 1:FOR Extrahepatic branching pattern of hepatic artery

Table 1: Extrahepatic branching pattern of hepatic artery (n=100)

S.No.	"Branching pattern"	Female (n=53) N (%)	Male (n=47) N %	Total in %	P value
1.	Normal	37 (69.81)	36 (76.59)	73	0.529
2.	CHA arising from SMA	1(1.88)	2(4.25)	3	
3.	Replaced LHA	4 (7.54)	1 (2.12)	5	
4.	Replaced RHA	8 (15.09)	7(14.89)	15	
5	Accessory LHA from LGA	2 (3.77)	1(2.12)	3	
6	The first branching of RHA from CHA, which occurred shortly past the formation of CHA	1 (1.88)	(0)	1	

p value <0.05 is significant

"CHA-Common hepatic artery; SMA-Superior mesenteric artery; LHA - Left hepatic artery; RHA - Right hepatic artery; LGA - Left gastric artery"

Intrahepatic branching pattern

The pattern of the hepatic artery was investigated in 10 liver tissues that had been embalmed with formalin. The Sauda Foam and a modified luminal cast technique were used for this investigation. The pattern of branching of the "hepatic artery" in 10 different livers? In this examination, there were five specimens that had normal anatomy, which is fifty percent of the total. Further the regular "hepatic artery", the "right and left hepatic arteries" are also separated from it. Two portions of the right hepatic artery, the anterior and posterior segments, separated from one another. The left hepatic artery was responsible for supplying blood to segments II, III, and IV. "The right hepatic artery gave rise to both the cystic artery and the artery that supplies the caudate lobe." The differences in the origins of the quadrate lobe, caudate lobe, and cystic artery are shown in Table 2.[5]

Three (30%) of the specimens had different origins for the cystic artery: one specimen had it come from the right anterior division, one from the right posterior division, and one from the left hepatic artery.

In six samples, the caudate lobe was supplied with blood via the "right hepatic artery". (7) Of these, the arteries to the "caudate lobe" derived after the right posterior division in 2 (20%) of the specimens, the right anterior division in 2 (20%) of the specimens, and the right hepatic artery in 1 specimen gave rise to two branches before "dividing into the right anterior and right posterior divisions. The caudate lobe artery in one instance branched out at the correct hepatic artery's bifurcation. The caudate lobe artery originated from the left hepatic artery in one instance (10%)".

In the majority of instances, the left hepatic artery supplied blood to the quadrate lobe. Three specimens showed differences "in the artery supply to the quadrate lobe. In one specimen, the right hepatic artery provided a branch to the quadrate lobe", accounting for 10% of the cases. Additionally, another specimen showed a branch connecting to "the right anterior division of the right hepatic artery".The hepatic artery proper in a third specimen exhibited division into the left, right, and middle hepatic arteries. Notably, "the middle hepatic artery provided a branch to the quadrate lobe in this particular case".

Pattern of segmental branching

In two instances, the right posterior division provided Segment V, in addition to the segment given by the right anterior division. In three cases, the right posterior division provided Segment VIII. In first

case, the "right hepatic artery" had both greater and lower divisions.Segments VII and VIII originated as of top divide, whilst V and VI segments derived from the lower division.In another instance, the posterior right division was divided at an early stage, leading to the formation of branches that connect to "segments V, VII, and VIII.The branch responsible for supplying segment VIII also generated a branch that fed the caudate lobe, whereas the right posterior branch continued to give segments VI and VIII."

Segment VI was consistently furnished by the right posterior division in all 10 cases.

Moreover, section VI received blood supply from an initial division of the right hepatic artery. In one instance, the right anterior division provided Segment VII together with the quadrate lobe; in other specimens, the right posterior division supplied Segment VII.

In conclusion, the hepatic artery's branching pattern variance is as follows:

The artery to the caudate lobe and the cystic artery originated from the right hepatic artery. Additionally, in one specimen, the right hepatic artery underwent early segmentation, resulting in a branch to segment VI. In another specimen, it provides a branch to segment IV.

"Segments II, III, and IV are typically fed by the left hepatic artery". Furthermore, it resulted in the formation of a caudate lobe artery and a cystic artery in a single specimen.

In addition to feeding segments V and VIII, the right anterior division gave birth to the caudate lobe artery in three specimens, In one specimen, the cystic artery, the artery to segment VI, and early segmentation supplying segment IV were seen.

"In one specimen, the right posterior division supplied segments VI and VII, along with the cystic artery. In two specimens, it also provided a branch to segment VIII, and in one specimen, a branch to the caudate lobe. Additionally, in two specimens, a branch to segment V was seen".

Portal vein's Branching pattern

The pattern of branching of portal vein's was examined using the modified corrosion cast method on ten formalin-embalmed liver tissues and CECT on one hundred participants. The occurrence of the "portal vein" alterations in the "radiological investigation" is shown in Table 3. Seven percent of the participants had the portal vein's regular structure visible, while the other subjects had branching pattern differences. This pattern, in which the left and right portal veins split out from the primary portal vein. "Type 2, with the portal vein split into the right anterior, right posterior, and left portal veins," was the most prevalent variety seen. 5% of cases showed this variance. In five instances, the Type 3 pattern was seen, characterised by the right posterior portal vein originating separately from the main portal vein, followed by a shared trunk that divides into the left and right anterior portal veins. An instance of this phenomenon is the type 5 variation, characterised by the segment VI branch serving as the primary branch of the right portal vein."In another case, the left portal vein originated the branch leading to segment VII." Types 2 and 3 were the most prevalent differences among those observed (Chart 2). The portal vein's branching pattern did not alter based on gender (Table 2).

Table 2: Radiological analysis of the portal vein's branching pattern (n=100)

S. No	" Branching pattern "	Description	Male	Female	Total in %	P value
1	Type 1	Conventional anatomy	41	46	87	0.563
2	Type 2	Trifurcation	1	4	5	
3	Type 3	"Separate origin of RPPV from MPV first, then common trunk of RAPV and LPV which divides"	3	3	5	
4	Type 4	"Segment VII branch is first branch of RPV"	1	0	1	
5	Type 5	"Segment VI branch is first branch of RPV"	1	1	2	
6		"Separate branch to segment VII from LPV"	0	0	0	

"p value <0.05 is significant"

"Right anterior portal vein (RAPV), main portal vein (MPV), and right posterior portal vein (RPPV)".

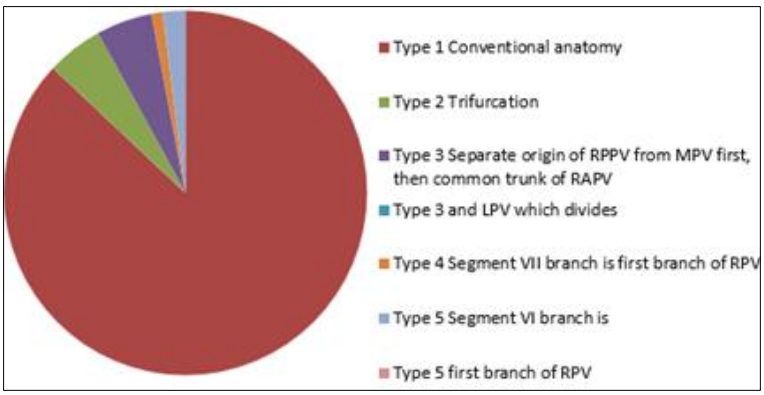

Fig 2: For branching pattern of portal vein by radiological study

The "portal vein's branching pattern" was investigated using a modified luminal casting method. Variations in its branching pattern are seen in Table 3. All 10 specimens showed "Type I portal vein architecture, where the primary portal vein is divided by the right and left portal veins. There are two segmental divisions of the right portal vein: the right anterior and the right posterior. The left portal vein split into branches that were vertical and horizontal".

The portal branch supplying the caudate lobe originated from different locations: also after the bifurcation of the" main portal vein" into the right and left branches in two specimens (20%); solely from the left portal vein in three specimens (30%); from both branches in one additional specimen (10%); "where the main portal vein and left portal vein split into four branches in four more specimens (80%)."In 9 specimens, the caudate lobe had a solitary branch that came either from the left portal vein or the point of bifurcation.In the remaining cases, it was provided by either two or more veins. The primary source of portal blood flow to segment VIII is mostly derived from the "right anterior sectoral division". Two cases were noted where the right anterior sectoral division, "responsible for supplying segment VIII, exhibited early segmentation.In addition, the right posterior sectoral division supplied the portal for segment VIII in seven cases.An atypical variation occurred where the vertical portion of the left portal vein provided blood supply to segments V and VIII, in addition to segments III and IV.Consequently, segment VIII did not get its supply from the appropriate portal vein".

In most cases, the right posterior sectoral division provided portal blood supplies to Segments VI and VII. However, in two specimens, Segment VII also Obtained portal blood from the right anterior sectoral division.Segment VI of a particular specimen obtained portal blood specifically from the right anterior sectoral division.

In the majority of the cases, the right anterior sectoral division supplied Segment V. In one instance, the right posterior sectoral division supplied the portal blood supply as well. In one instance, it got blood from both portal vein for its portal blood supply.

Segments I, III, and IV were fed by the left portal vein in every case. In one example, the segment IV acquired branches from "the right anterior sectoral division in addition to the left portal vein"

Discussion

Table 5 compares "the branching pattern of the portal vein in different studies with the current radiological investigation", illustrating how their findings and the current study compare. The most frequent branching pattern seen in prior research was the traditional Type 1, which describes the architecture of"the portal vein" and shows how the primary portal vein splits into the Portal veins on the right and left sides 87% of the population in the present radiological investigation had a standard type I branching pattern. Luminal casting specimens revealed that every one of the ten specimens displayed a typical type I branching pattern.

Table 3: Comparative analysis of the current study and previous research reveals discrepancies in the morphological characteristics of the liver

"Portal vein branching pattern	Guna sekaran & Gaba n=100, %	Covey *et al.*,n=200, %	Koc*et al.*,n=1334, %	Sureka *et al.*, n=967, %	Kishi al., Na=361, %	Takeishi *et al.*, n=407,%	Current study n=100, %
Type1	67	65	75	80	91	89	87
Type 2	10	9	11	7	6	6.1	5
Type 3	6	13	10	5	-	4.7	5
Type 4	I	1	0.5	3	-	-	1
Type 5	8	6	2	1	-	-	2
Miscellaneous	8	6	1.5	4	2.2	49	-

One of the most prevalent types of portal vein divisions is a three-branch configuration. Trifurcation was recorded in 6% of instances by Kishi *et al.*, 6.1% by Takeishi *et al.*, 11.1% by Koc *et al*., 6.83% by Sureka *et al.*, 9% by Covey *et al*., and 10% by Gunasekaran and Gaba. Trifurcation was seen in 5% of cases with radiological examination in the present research.

Takeishi *et al.* reported "a type 3 branching pattern where the right posterior portal vein had a separate origin from the main portal vein in 4.7% of cases. Koc reported this pattern in 9.7% of cases, Sureka *et al.* in 4.9% of cases, Covey *et al*. in 13% of cases, and Gunasekaran and Gaba in 6% of cases. In the present radiological study, this pattern was observed in 5% of cases.One specimen in the luminal casting research showed early segmentation of the right posterior segmental division. Furthermore, it was observed that one specimen had modifications, such as a right posterior sectoral division that supplied segments IV, V, and VIII.A right posterior sectoral division supplying segment VIII was seen in 46.6% of cases".

Sureka described a Type 4 variant where the branch of the portal vein that supplies segment VII develops as the first branch of the right portal vein, occurring in 2.69% of cases.This abnormality was observed in a single specimen during the current radiological investigation.

Gunasekaran and Gaba described a type 5 variant where the initial branch of the right portal vein is the segment VI branch, which was found in 8% of cases. Covey *et al*. found this variation in 6% of cases, Koc *et al*. in 2% of cases, Sureka *et al*. in 1% of cases (61), and 1% in the current radiological investigation.

Furthermore, the ongoing radiological examination revealed the presence of an independent branch originating from the left portal vein, which supplies section VII.This abnormality has not been before documented.Additionally, the luminal casting investigation observed many additional polymorphisms of the right anterior sectoral division.The mentioned structures consist of the first division of the right anterior segment, which supplies "segment VIII and provides branches to segments VI and VII, as well as segment IV".

"Left portal vein anomalies are rare, however a luminal casting study identified a variation in one sample where the branch supplying segment IV also supplied segment V and VIII.This anomaly is quite rare and has previously been recorded by a solitary author.Koc *et al.* conducted a study on 1384 people and discovered that segment VIII received blood supply from the left portal vein in 0.8% of instances." Additionally, they observed that segment V received blood supply from both the right and left portal veins in 0.1% of cases.

Familiarity with the vascular architecture and its variations can assist radiologists and surgeons in reducing iatrogenic consequences during surgical procedures involving the hepatobiliary system.

In conclusion,

This research included the examination of "the branching pattern of the hepatic artery and portal vein inside the liver". Previously, there has been little research on the detailed study of variations in the segmental supply in the Indian population. "The occurrence of changes on the left side is rare in both the branching patterns of the hepatic artery and the portal vein.There was no discernible disparity in the branching pattern of either the hepatic artery or the portal vein based on gender. "Familiarity with these variables may enable the interventional radiologist to decrease or prevent misinterpretations and consequent misdiagnosis, as well as assist the hepatobiliary surgeons in minimising iatrogenic consequences." Additionally, it would enable the surgeons to achieve enhanced and effective postoperative results".

Limitations

The samples used in this investigation have stored in formol for around 8 years. However, there is a concern regarding the openness of the channels inside the structure that has to be injected, since a majority of the capillaries are obstructed by blood clots. Fresh specimens are recommended for luminal plastination purposes.Our investigation on the segmental supply of the liver was hindered by the insufficient sample size for luminal casting due to restricted availability.

Future Scope

To investigate the spread of the biliary system throughout the liver using luminal cast method and radiographic examination.

The hepatic veins' branching pattern can be used to identify the liver segments as described by Couinaud's classification of liver anatomy.

For a precise pre-operative diagnosis, it is critical to take these factors into account. The surgeon can use this information to better plan surgeries on the liver's caudate lobe. When analysing CT images at or below the porta hepatis, the papillary process of the caudate lobe could potentially cause problems".A thorough understanding of the many types of mistakes might help prevent them while analyzing CT images by considering the physical anatomy of the caudate lobe.

Ethical Clearance: Taken from ethical committee at tertiary care centre at Udaipur where study was done.

Source of Funding: Self

Conflict of Interest: Nil

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