

## A CORROSION CAST STUDY OF RAMIFICATION PATTERN OF PORTAL VEIN IN RIGHT LOBE OF HUMAN LIVER

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### ABSTRACT

**Objectives:** The aim of the study was to know the intrahepatic ramification pattern of portal vein in right lobe of liver & its variations.

**Methods:** 25 human fresh livers were obtained after autopsy and studied by corrosion cast method. Polymeric granules of butyl butyrate were dissolved in acetone and 20% homogenous solution was made. Solution was injected into portal vein and the injected liver was placed in 10 % formal saline for 24 hours at room temperature (20°C) for polymerization of infused butyl butyrate solution. Maceration of liver tissue achieved by whole-organ immersion in 1.8 N KOH solution at 68°C for 24 hrs. Each cast thus obtained was preserved in glycerin and details were studied.

**Results:** The length of the right portal vein varies 0.5 to 1.8 cm (1.2 cm). The right portal vein bifurcated into second order branches - right anterior portal vein (RAPV) & right posterior portal vein (RPPV) in 87 % of the cases, while trifurcated in rest of 13 % of cases. The angle between the anterior and posterior division ranged from 58°-95°. Anterio-superior (P<sub>8</sub>) branch shown three type of ramification - Bifurcation type (72 %), P<sub>8</sub>- one pedicle type (8 %) and P<sub>8</sub>- trifurcation type (20%). Anterio-inferior (P<sub>5</sub> max ) branch shown the three type of ramification pattern - P<sub>5</sub>-common type (72 %), P<sub>5</sub>- P<sub>8</sub> anterior type (28 %) but P<sub>5</sub>- P<sub>8</sub> posterior type was not observed. Right Posterior Portal Vein has shown three types of ramification pattern - Type I-Fan shaped (64%), Type II (28 %) & Type III-Trifurcation type (8%).

**Conclusions:** The findings of present study on hepatic vasculature have immense importance in the field of hepato-biliary surgeries like hepatic resection, segmentectomy and liver transplantation.

**KEY WORDS:** Liver, Corrosion cast, Portal vein, Ramification, Right lobe.

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DOI: 10.16965/ijar.2014.551

**Web site:** International Journal of Anatomy and Research  
ISSN 2321-4287  
www.ijmhr.org/ijar.htm

Received: 30 Nov 2014

Peer Review: 30 Nov 2014 Published (O):31 Dec 2014

Accepted: 13 Dec 2014 Published (P):31 Dec 2014

### INTRODUCTION

Liver is the largest viscera in human body & it is essential for life, since it carries out most of metabolic function necessary for homeostasis, digestion and immunity. Recently its vascular anatomy has gained even greater significance

due to faster development in the field of hepatic surgery such as hepatic resection, segmentectomy & split hepatic grafting for liver transplantation. All these procedures require detail knowledge of intrahepatic vascular anatomy with most common variations associated with

it. Many authors [1-5] proposed liver segmental division but the division proposed by Couinaud (1954)[1] was widely recognized. According to Couinaud (1954)[1] the liver is divided into right & left lobes, lobe into sectors & sectors further into segments based on third order ramification of portal vein and its drainage. He reported that portal vein branching appears first during the embryonic development, while arterio-biliary branching follows the portal vein distribution. Also portal segmentation was much simpler than the arterio-biliary and portal vein duplication of the first-order branches found in 23.5% of livers, while arterio-biliary duplication of first-order branches is found in 50% , hence to study the portal vein ramification yields better anatomical study of liver. Couinaud (1954) [1] described eight segments. The right lobe of liver divided into -

Anterio-inferior (Segment V)

Anterio-superior (Segment VIII)

Posterior-inferior (Segment VI)

Posterior-superior (Segment VII).

All these drained by right branch of hepatic vein situated in right fissure.

Left lobe of liver divided into -

Segment II (left lateral)

Segment III (left paramedian)

Segment IV (left paramedian)

All these drained by left branch of hepatic vein lying in left fissure.

Caudate lobe : segment I – drained by middle hepatic vein.

Each of these segments has its independent hepatic venous drainage and third order branch of portal veins, with minimal anastomosis & a few variations, makes its surgical resection possible. These segments form the basis of hepatic resection as defined in the various hepatic surgeries like hepatectomy, segmentectomy & liver transplantation.

## METHODS

The aim of the study was to know the intrahepatic ramification pattern of portal vein in right lobe of liver & its variations. In the present study, 25 human cadaver livers obtained after autopsy in

S. N Medical College, Agra during 2005 to 2008.

The liver specimen was removed en-bloc along with the portion of inferior vena cava & all structures at porta hepatis remained intact. The specimen was thoroughly washed in running tap water with gentle pressure to squeeze out any residual blood or clots present in portal vein or hepatic vein. The portal vein was then cannulated with glass canulae with latex tubing on other end and the liver gently perfused with physiologic saline to flush the organ. After suture-ligation of identified leaks, drainage of the saline solution done. Cases with hepatic trauma, gross liver pathology or signs of decomposition were excluded from the study.

**Preparation of cast material:** 20 grams of Butyl butyrate granules were mixed with 100 ml acetone & continuously stirred to make thick homogenous solution of 20 % Butyl butyrate.

**Infusion of cast material:** Butyl butyrate solution was injected at a constant pressure into the portal vein until increase in resistance felt due to increase in pressure within the vessel & solution could be felt on surface of liver. On average, 70 – 90 ml colored solution was required for right lobe. There after the cannula was clamped with suture placed earlier or with artery forceps. After infusion, the injected liver was placed in 10 % Formal saline for 24 hours at room temperature (20°C) for polymerization of infused butyl butyrate solution.

**Corrosion of Parenchyma:** Maceration of liver tissue achieved by whole-organ immersion in 1.8 N KOH solution at 68°C for 24 hrs. After 24 hours when total maceration of whole parenchyma occur, the soften parenchyma was removed thoroughly by washing with slow running water and the cast thus obtained cleaned to remove any residual organic material with fine probe & fine forceps. The casts were then photographed & the observations were noted.

## RESULTS AND DISCUSSION

In all 25 cases, there was single portal vein found. The two type of pattern was observed in portal vein ramification (first order branch) -

i. Bifurcation type - The main trunk was divided into two branches right portal vein & left portal

vein in 23 of 25 cases (92%). It was observed as the commonest type by the other authors also. [6-11]

ii. Trifurcation type - The main trunk of portal vein was divided into three branches – right anterior portal vein (RAPV), right posterior portal vein (RPPV) & left portal vein. It was observed in 2 of 25 cases (8%) in present study while observed by Yamane [7] in 12% cases & by Ortale [10] in 22.2% cases. In such cases, during right hepatectomy, both RAPV & RPPV should be ligated separately, as one of these branches can be mistaken for the right portal vein. If one of these remained un-ligated, severe hemorrhage can result. Type III (RPPV as first branch & RAPV & LPV as common trunk) were not found in any of the case of our study as it was seen by Yamane [7] in (8% of the cases). (Table – 1) Quadrification & other rare variation were not observed in the present study.

The length of the right portal vein ranged from 0.5 to 1.8 cm in the present study. The length of the anterior branch of right portal vein (RAPV) varied from 0.5- 2.5 cm and the length of the posterior branch of right portal vein (RPPV) varies from 1.0 – 2.4 cm. The lengths of these second order branches were studied by very few scientist & these were new observed findings of the present study. (Table-2)

The angle between RPV & LPV i.e. portal angle have the range from 90 °– 170 °. It was stated that the RPV & LPV had obtuse angle in most of the cases. The angle between Right portal branch & main portal trunk varies from 100 °– 170 ° while the angle between LPV & the main trunk was from 80 °– 130 °. These observations concluded that RPV was more in the line of main portal trunk. The angle between the RAPV & RPPV has range from 58°-95 °. In 7 of the 25 cases ( 28 %) it has valve more than 90° while it was more than 90° in 20 % of all the cases as observed by Arora [11] . (Table-3)

The ramification pattern of right portal vein as follows:

In the present study, in 20 of total 23 cases (87%), the right portal vein bifurcated into right anterior portal vein (RAPV) & right posterior portal vein (RPPV). While in remaining 3 of 23 cases (13%) trifurcation type pattern was

observed in which the right portal vein was divided into three branches -right anterior-superior vein ( $P_8$ ), right anterior-inferior vein ( $P_5$ ) & right posterior portal vein (RPPV). This finding was also observed by Gupta (1977)[6] (Table-4). In 2 of 25 cases PRV was absent as RAPV & RPPV directly originated from main portal vein (trifurcation type) in this study.

The right anterior portal vein usually ran, forming a gentle curve, toward the superior direction to become the antero-superior portal vein occupying the superior region of the anterior – medial segment of right lobe of liver (Segment VIII). Superiorly, right anterior portal vein continued as antero-superior branch to Segment VIII and known as  $P_8$  branch of RAPV. According to Yamane (1988)[7] the Right anterior portal vein before reaching to segment VIII, has diverged into various branches running toward antero- inferior direction to supply the antero-inferior segment (segment V). The diameters & numbers of branches diverging from the right anterior portal vein into segment V & their ramification sites were variable. The antero-inferior branch having maximum diameter was given the name  $P_{5 \max}$  branch of RAPV. The variation of ramification of right anterior portal vein (RAPV) as followed:

**Ramification of antero-superior ( $P_8$ ) branch from RAPV:** There were three type of ramification seen:

I. Bifurcation type : In 18 of 25 cases (72 %), the right anterior portal vein while running toward the superior direction split into two major branches for antero-superior segment , these branches were named as  $P_8$  – anterior branch &  $P_8$  – posterior branch (bifurcation type).

II.  $P_8$  - one pedicle type : in the present study, in 2 of 25 cases(8%), single trunk ( $P_8$  - one pedicle type) to the anterior superior segment of segment VIII was there as the continuation of right anterior portal vein.

III.  $P_8$  – trifurcation type: In 5 of 25 cases(20%) , the RAPV ( $P_8$  – trifurcation type) trifurcated to give three branches in antero- superior direction for the segment VIII.

Yamane [7] found the bifurcation pattern commonest (84 %) while Ortale [10] observed it in (83 %). This was contrary to the finding

observed by Arora [11] who has observed the bifurcation pattern only in 40% of the cases. The present findings were more close to the Yamane & Ortale[7,10] ( Table – 5)

**Ramification of Anterio-inferior ( $P_5$  max ) branch from RAPV:** There were two type of ramification of anterio-inferior ( $P_5$  max) branch seen:

i.  $P_5$  common type: The type in which  $P_5$  max branch ramified on the proximal side of the major portal vein of segment VIII . it was observed in 18 of 25 cases (72 %).

ii.  $P_5 - P_8$  anterior type:  $P_5$  max branch ramified from  $P_8$  anterior portal vein was observed in 7 of 25 cases (28%).  $P_5 - P_8$  posterior type was not observed in the present study. (Table -5)

**Ramification of Right Posterior Portal Vein (RPPV):** RPPV originated from RPV or directly from portal trunk. It ramified into number of the branches to supply postero- superior (segment VII) & postero- inferior (segment VI) segment. The number of the branches varies from 1 to 4. Three types of ramification pattern were observed:

i. Fan shaped: It was the most common type of ramification pattern observed. The right posterior portal vein ran toward the posterior-superior direction as a continuous trunk while ramifying into several small branches like the ribs of the fan on a plane almost parallel to the posterior aspect of the liver. Usually the first branch was given in inferior direction to the segment VI & remaining trunk divided into superior & inferior major branches for postero-superior ( $P_7$ ) & postero – inferior( $P_6$ ) . This pattern was observed in 16 of 25 cases (64%).

ii. Bifurcation type : The right posterior portal vein ran toward the posterior- superior direction & soon divided into postero- superior ( $P_7$ ) & postero – inferior( $P_6$ ) branches. It was observed in 7 of 25 cases (28 %).

iii. Trifurcation type: the right posterior portal vein divided into three branches postero-superior ( $P_7$ ), postero – inferior( $P_6$ ) & an intermediate branch which soon divided into superior & inferior branches. It was observed in 2 of 25 cases (8%). Comparative observations are shown in the table – 6.

**Table 1:** Portal vein Ramification.

| Ramification Pattern |              | Authors      |               |                |              |               |
|----------------------|--------------|--------------|---------------|----------------|--------------|---------------|
| Types                |              | Gupta - 1977 | Yamane - 1988 | Ortale - 2000  | Arora - 2003 | Present Study |
| I                    | Bifurcation  | 88%          | 20/25 - 80%   | 28/36 - 77.80% | 15/15 - 100% | 23/25 - 92%   |
| II                   | Trifurcation | 12%          | 03/25-12%     | 06/36-22.20%   | nil          | 02/25 - 8%    |
| III                  | Type III     | nil          | 02/25-8%      | nil            | nil          | nil           |

**Table 2:** Length of Right Portal Vein (RPV).

| Branch | Authors      |              |               |              |             |
|--------|--------------|--------------|---------------|--------------|-------------|
|        | Gupta - 1977 | Ralph - 1989 | Mishra - 1998 | Arora - 2003 | Present     |
| RPV    | 0.5-2.0 cm   | 0.5-1.0 cm.  | 1.0-2.6 cm.   | 1.3-2.3 cm.  | 1.0-1.8 cm. |

**Table 3:** Portal & Others Angles Between Different Branches.

| Angles                                     | Authors        |              |              |               |
|--|----------------|--------------|--------------|---------------|
|  | Hjortso - 1953 | Ralph - 1989 | Arora - 2003 | Present Study |
| i. Portal angle (Angle between RPV & LPV)  | 90°-100 °      | 90°-180 °    | 80°-160 °    | 90°-170 °     |
| ii. Angle between RPV & main portal trunk  | -              | -            | 110°-170°    | 110°-170°     |
| iii. Angle between LPV & main portal trunk | -              | -            | 90°-140°     | 80°-130°      |
| iv. Angle between RAPV & RPPV              | -              | -            | -            | 58°- 95 °     |

**Table 4:** Right portal vein (RPV) Ramification.

| Ramification Pattern |              | Authors      |               |               |              |               |
|----------------------|--------------|--------------|---------------|---------------|--------------|---------------|
| Types                |              | Gupta - 1977 | Yamane - 1988 | Ortale - 2000 | Arora - 2003 | Present Study |
| I                    | Bifurcation  | 88%          | 100%          | 100%          | 100%         | 87%           |
| II                   | Trifurcation | 12%          | -             |               | -            | 13%           |

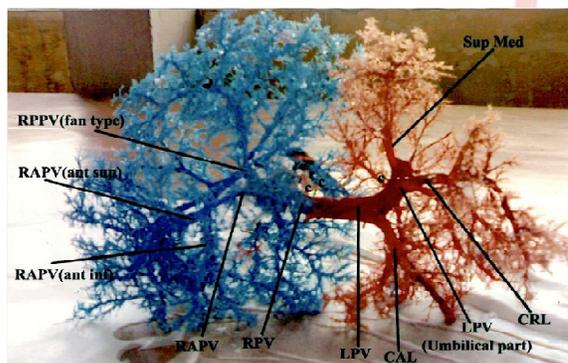
**Table 5:** Right anterior portal vein (RAPV).

| Ramification Pattern  |   | Authors      |               |               |              |               |
|---|---|--------------|---------------|---------------|--------------|---------------|
| Types   |   | Gupta - 1977 | Yamane - 1988 | Ortale - 2000 | Arora - 2003 | Present Study |
| <b>Ramification pattern of Anterio-superior branch (P<sub>8</sub>)</b>          |   |              |               |               |              |               |
| i.  | One pedicle (major P <sub>8</sub> )               | -            | 02/25- 8%     | 05/36 - 14%   | 60%          | 02/25 - 8%    |
| ii.   | Bifurcation type                                  | -            | 21/25 -84%    | 30/36 -83%    | 40%          | 18/25 -72%    |
| iii.  | Trifurcation type                                 | -            | 2/25 -8%      | 1/36 -2.8%    | NA           | 5/25 -20%     |
| <b>Ramification pattern of Anterioinferior branch (P<sub>5</sub>) from RAPV</b> |   |              |               |               |              |               |
| i.  | P <sub>5</sub> max from common P <sub>8</sub>     | -            | 13/25 -52%    | 19/36 -52.8%  | 80%          | 18/25 -72%    |
| ii.   | P <sub>5</sub> max -P <sub>8</sub> anterior type  | -            | 10/25 -40%    | 16/36 -44.4%  | 20%          | 7/25 -28%     |
| iii.  | P <sub>5</sub> max -P <sub>8</sub> posterior type | -            | 2/25 -8%      | nil           | nil          | nil           |

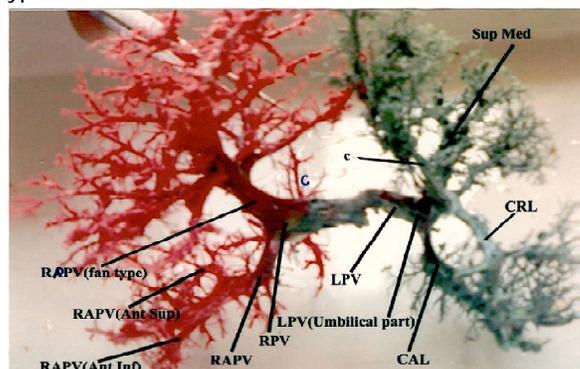
**Table 6:** Right posterior portal vein (RPPV).

| Ramification Pattern |   | Authors     |              |              |             |               |
|----------------------|---|-------------|--------------|--------------|-------------|---------------|
| Types                |   | Gupta -1977 | Yamane -1988 | Ortale -2000 | Arora -2003 | Present Study |
| I                    | Fan type  | nil         | 13/25 -52%   | 16/36 -44.4% | NA          | 16/25 -64%    |
| II                   | Bifurcation (P <sub>7</sub> ) & (P <sub>6</sub> ) | 100%        | 09/25 -36%   | 16/36 -44.4% | NA          | 7/25 -28%     |
| II                   | Trifurcation type                                 | nil         | 3/25 -12%    | 4/36 -11.2%  | NA          | 02/25 -8%     |

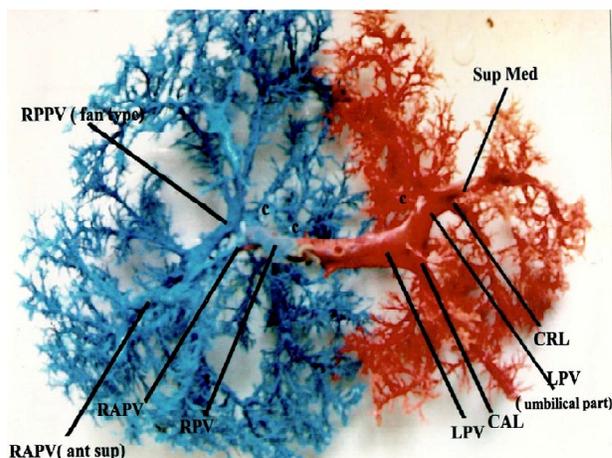
**Fig. 1:** Corrosion cast of intrahepatic ramification pattern of portal vein; blue color – right lobe of liver & red color – left lobe of liver. Portal vein bifurcated into RPV & LPV; RPV bifurcated into RAPV & RPPV. RAPV showing bifurcation into anterio-superior (P<sub>8</sub>) & anterio-inferior (P<sub>5</sub> max common type); RPPV showing Fan type ramification.



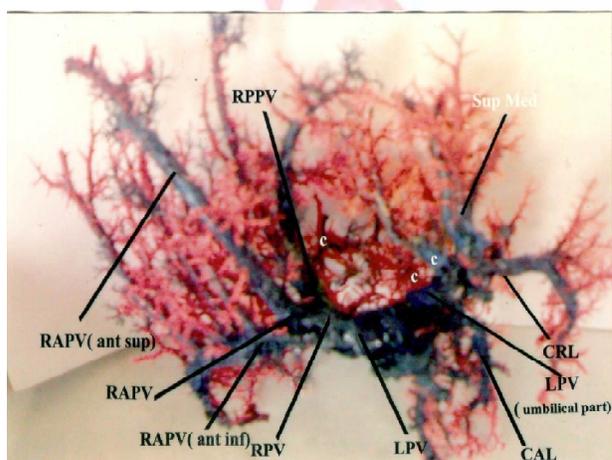
**Fig. 2:** Corrosion cast of intrahepatic ramification pattern of portal vein; red color – right lobe of liver & black color – left lobe of liver. Portal vein bifurcated into RPV & LPV; RPV bifurcated into RAPV & RPPV. RAPV showing bifurcation into anterio-superior (P<sub>8</sub>) & anterio-inferior (P<sub>5</sub> max common type); RPPV showing Fan type ramification.



**Fig. 3:** Corrosion cast of intrahepatic ramification pattern of portal vein; blue color – right lobe of liver & red color – left lobe of liver. RPV bifurcated into RAPV & RPPV. RAPV showing bifurcation into antero-superior ( $P_8$ ) & anterior-inferior ( $P_{5\max}$  common type); RPPV showing Fan type ramification.



**Fig. 4:** Corrosion cast of intrahepatic ramification pattern of portal vein; red color – right lobe & left lobe of liver. RPV bifurcated into RAPV & RPPV. RAPV showing bifurcation into antero-superior ( $P_8$ ) & anterior-inferior ( $P_{5\max}$  common type); RPPV showing bifurcation type ramification.



## CONCLUSION

The present study was directed to know the intrahepatic ramification pattern of portal vein & its variations. The detail of ramification up to third order branches of portal vein was studied in different hepatic segments which was

observed in very few Indian studies. Application of these detail variations in the ramification pattern of portal vein with the advancement in surgical technique involved in hepatic resection & liver transplantation will revolutionize the entire approach in the management of liver disorders.

**Conflicts of Interests: None**

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### How to cite this article:

Rajput AS, Kumari S, Mishra GP. A CORROSION CAST STUDY OF RAMIFICATION PATTERN OF PORTAL VEIN IN RIGHT LOBE OF HUMAN LIVER. *Int J Anat Res* 2014;2(4):791-796.

**DOI:** 10.16965/ijar.2014.551