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Branching pattern of the portal vein in Indian population

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SUMMARY

Thorough knowledge of the variation of intrahepatic course of the portal vein is essential for preoperative assessment of various hepatic surgeries like hepatectomy and live donor liver transplant. This study aims to determine the variation in the branching pattern of the portal vein in South Indian population. The branching pattern of the portal vein was studied by 3D reconstruction of 100 contrast-enhanced computed tomography images and in 15 formalin fixed livers using modified luminal casting technique.

Radiologically, the normal portal vein anatomy was seen in 89%. The most common variation was trifurcation of portal vein (5%). A rare anomaly was noted in one case where the left portal vein gave a branch to segment VII. Using the modified luminal casting technique all the 15 specimens displayed Type I portal vein anatomy. The most common variation in the intrahepatic branching pattern observed was the right posterior segmental division supplying segment VIII. A rare left portal vein variation, in which it gave branches to segments V and VIII was noted. In this study, variations in the segmental supply of the portal vein were observed, which have not been studied in detail previously in the Indian population. Variations on the left portal vein are infrequent. A prior knowledge of such variations will help the interventional radiologists to reduce misinterpretations and subsequent misdiagnosis and guide the hepatobiliary surgeon in minimizing iatrogenic complications.

Key words: Portal vein to caudate lobe – Segment VIII – Segment V – Segment IV – Left branch of portal vein

INTRODUCTION

With the growing popularity of complex hepatobiliary surgical and interventional procedures including trisegmentectomy, portal vein embolization and transjugular intrahepatic portosystemic shunts (TIPS), preoperative assessment of the portal vein system and the detection of portal vein variants are increasingly relevant (Cheng et al., 1997; Kishi et al., 2010). The normal portal vein anatomy occurs in 90% of cases (Kishi et al., 2010).The portal vein begins at the level of the second lumbar vertebra and is formed by the union of the superior mesenteric and splenic veins posterior to the neck of the pancreas. It divides at the hilum of the liver into the left and right portal branches. The left portal vein is often of smaller calibre. It has horizontal and vertical portions, supplies segments II, III, and IV and gives off a caudate lobe branch. The right portal vein divides into the right anterior sector trunk, which in turn divides into segment V and segment VIII branches, and the right posterior sector trunk, which supplies segments VI and VII

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(Blumgart et al., 2000).

Various authors have studied the branching pattern of the portal vein and classified them accordingly. The classification of the branching pattern of the portal vein in current literature is as follows (Gunasekaran et al., 2017):

Type 1 -The main portal vein bifurcates into right and left portal vein trunks. The right portal vein further bifurcates into an anterior branch supplying liver segments V and VIII and a posterior branch supplying segments VI and VII.

Type 2 - The main portal vein trifurcates into a left portal vein, a right anterior portal vein supplying liver segments V and VIII, and a right posterior portal vein supplying liver segments VI and VII at the same craniocaudal level.

Type 3 - Early branching of the right posterior portal vein. The first branch arising from the main portal vein is the right posterior segmental branch supplying liver segments VI and VII. Beyond this early branch, the left portal vein supplying the left hepatic lobe and the right anterior portal vein supplying liver segments V and VIII bifurcate at the same level.

Type 4 - The right portal vein bifurcates into two vessels – one larger vessel supplying liver segments V, VI, and VIII and a smaller vessel supplying liver segment VII only – beyond the left portal vein origin from the main portal vein.

Type 5 - The right portal vein bifurcates into two vessels – one supplying liver segment VI only and another branch supplying liver segments V, VII, and VIII – beyond the left portal vein origin from the main portal vein.

Though there are a few studies available regarding the intrahepatic branching pattern of the hepatobiliary system in other populations, there is no data available for Indian population. The present study aims to determine the variation in the branching pattern of the portal vein in Indian population by 3D reconstruction of computed tomography (CECT) in South Indian population and to determine the variation in the intrahepatic branching pattern of portal vein by modified corrosion casting technique.

MATERIALS AND METHODS

Ethical approval was obtained from the Institutional Review Board, Christian Medical College, Vellore.

Radiological study

One hundred 3D reconstructed CECT images of the abdomen were used for this study. These images were obtained from 52 males and 48 females, their age ranging from 8 years to 86 years, who underwent CECT for various pathologies that included malignancies (urothelial, periampullary, ovarian and breast), benign masses and abdominal pain, but devoid of any pathology in the liver. The scanner used was Multidetector 64 slice GE Discovery 750 HD, Milwaukee, WI, USA. CT images were obtained at 0.625mm and reconstructed into 2.5mm thick slices. Enhancement was achieved by intravenous bolus administration of 80mlof a non-ionic contrast medium (Iopamidol/ Iohexol) at a speed of 3 mL/s. 3D reconstruction of the portal vein was done on the GE workstation. All post processing images were created on CT workstation (AW server) and the branching pattern of the portal vein was studied. The data obtained was statistically analysed with software STATA V.13.1. Fisher's exact test was done to find out whether there was any gender difference in the branching pattern of the portal vein.

Modified luminal casting technique

Fifteen formalin fixed livers without any major gross anomaly was chosen for the study. They were washed in running water overnight and were kept in an anticoagulant, sodium tri-citrate bath for 5-6 hrs. Again the livers were flushed with running tap water through the lumen of blood vessels in the porta hepatis. The portal vein was identified in the porta hepatis and a canula was inserted and then tied with thread. Then the BOSS FLEXSIL GP (Silicone Sealant) was injected into the portal vein using the silicon gun and then clamped using artery clamp. After the injection of the chemical was completed, the specimens were kept in a freezer overnight (4ºC). The following day the specimens were shifted to a bowl filled with diluted HCL and kept for 3-7 days. Dissection was carried out using the finger fracture technique for tracing the portal vein. The forceps was used to tease away the liver parenchyma and other vascular structures to expose the portal vein. The portal vein trunk was identified and its branching pattern was noticed and recorded by drawing the line diagram.

RESULTS

Branching pattern of the portal vein by radiological study

Table 1 shows the frequency of the variations of

Fig 1a. 3D reconstruction of the normal portal vein bifurcating into the left and right branches. Dashed arrow - main portal vein; curved arrow - left branch of portal vein; solid arrow - right branch of portal vein.

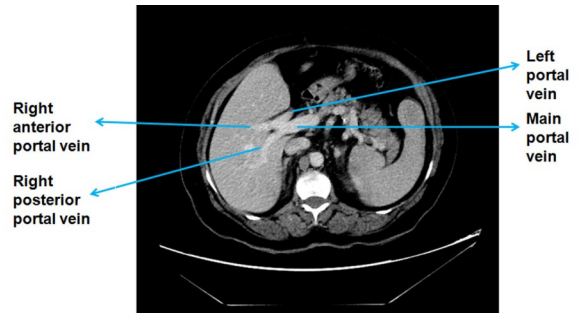

Fig 1b. Main portal vein trifurcates into right anterior portal vein, right posterior portal vein and left portal vein.

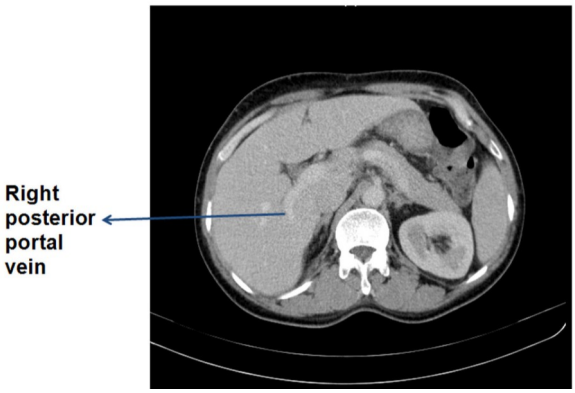

Fig 1c. Separate origin of right posterior portal vein from the main portal vein.

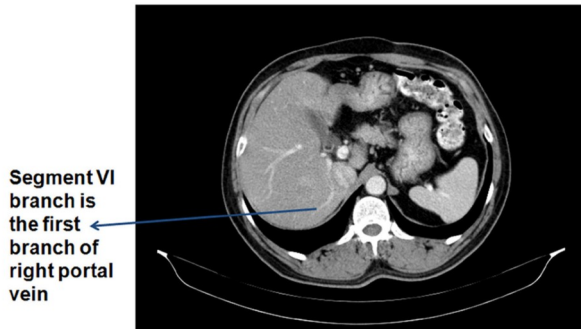

Fig 1d. Segment VI branch arises as the first branch of right portal vein (Type 5).

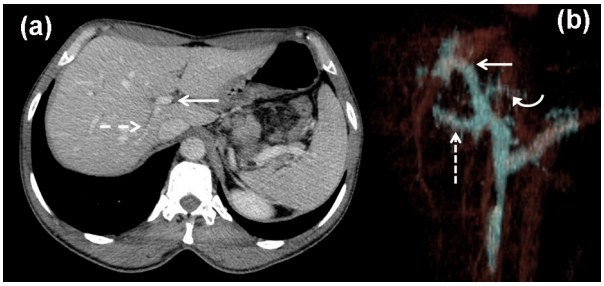

Fig 1e. S(a) CT axial sections of the abdomen and (b) 3D reconstruction, showing a branch to segment VII of the liver arising from the left portal vein. (a) Dashed arrow - branch to segment VII; solid arrow - left branch of portal vein; (b) solid arrow - left branch of portal vein; dashed arrow - right branch of portal vein; curved arrow - branch to segment VII.

the portal vein in the radiological study. The normal anatomy of the portal vein was observed in 89% subjects (Fig. 1a), while the remaining showed variant branching pattern. The most common variation encountered in the present study was Type 2, where there was trifurcation of the portal vein into a right anterior portal vein, a right posterior portal vein and a left portal vein (Fig. 1b) followed by Type 3 pattern (separate origin of right posterior portal vein from main portal vein, then common trunk which divides into right anterior portal vein and left portal vein, Fig. 1c). Type 5 variation (segment VI branch was first branch of the right portal vein) was observed in one case (Fig. 1d). In addition, in another case, a branch to segment VII arose from left portal vein (Fig. 1e). There was no gender difference in the branching pattern of the portal vein (Table 1).

Intrahepatic branching pattern of portal vein by modified corrosion cast technique

Table 2 shows variations in the portal vein branching pattern studied by the modified luminal casting technique. All the 15 specimens displayed Type I portal vein anatomy, in which the main portal vein was divided into the right and left portal veins. The right portal vein further divided into a right anterior and a right posterior segmental divisions. The left portal vein divided into horizontal

Table 1. Branching pattern of portal vein by radiological study (n=100)

S.No	Branching pattern	Description	Male	Female	Total %	P value
1	Type 1	Conventional anatomy	42	47	89	
2	Type 2	Trifurcation	3	2	5	
3	Type 3	Separate origin of RPPV from MPV first, then common trunk of RAPV and LPV which divides	1	3	4	
4	Type 4	Segment VII branch is first branch of RPV	0	0	0	0.757
5	Type 5	Segment VI branch is first branch of RPV	0	1	1	
6		Separate branch to segment VII from LPV	0	1	1	

p value <0.05 is significant

RPPV - right posterior portal vein, MPV - main portal vein, RAPV - right anterior portal vein, RPV - right portal vein, LPV - left portal vein

Table 2. Variation in the branching pattern of portal vein by luminal casting (n=15)

		Number	Percentage
Conventional Type I, where the main portal vein dividing into the right and left portal vein		15	100
Branch to Caudate lobe	From left portal vein alone	5	33.33
	At the bifurcation of the main portal vein alone	4	26.33
	From both the right and left portal vein	3	20
	Both from left portal vein and the bifurcation of main portal vein	3	20
Right anterior sectoral division (RASD)	Early segmentation of RASD supplying segment VIII	3	20
	Supplying segment VII	3	20
	Supplying segment VI	1	6.6
	RASD superior division giving a branch to segment V	1	6.6
	Supplying IVa and IVb with absence of branch to segment V	1	6.6
	Supplying V and VII and left portal vein supplying V and VIII	1	6.6
Right posterior sectoral division (RPSD)	RPSD supplying segment VIII	7	46.6
	Early segmentation RPSD supplying segment VI	1	6.6
	RPSD supplying V and VIII and branch to segment V also supplies segment VI	1	6.6
Left vein variation		1	6.6

Fig 2. Line diagrams showing the branching patterns of the portal vein.

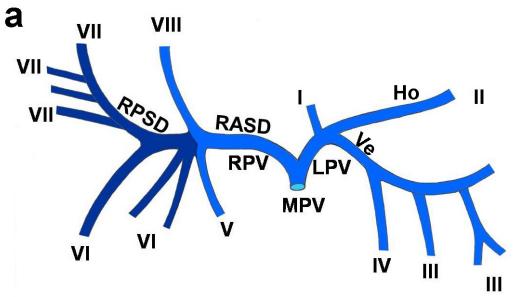

Fig 2a. Main portal vein (MPV) divides into right portal vein (RPV) and left portal vein (LPV). RPV further divides into right anterior segmental division (RASD) and right posterior segmental division (RPSD). LPV further divides into horizontal (Ho) and vertical (Ve) branches. LPV gives a branch to segment 1 (caudate lobe).

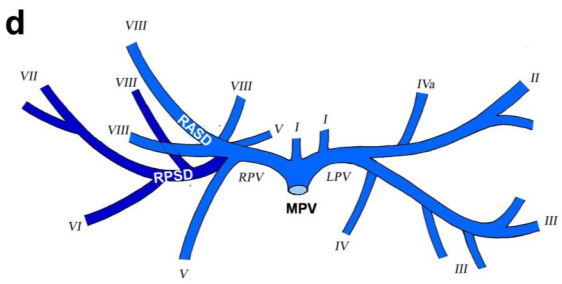

Fig 2d. Segment I receives branches both from left portal vein (LPV) and the point of bifurcation of the main portal vein (MPV). Note the right posterior segmental division (RPSD) supplies segment VIII. RPV – right portal vein; RASD – right anterior segmental division.

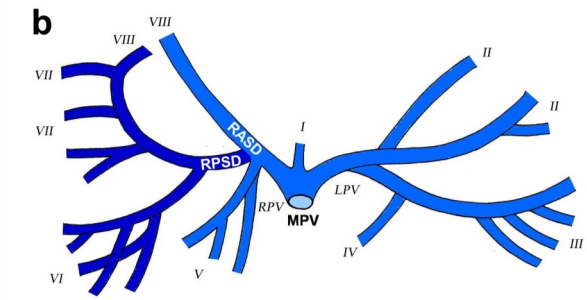

Fig 2b. Caudate lobe or segment I receives its branch from the point of bifurcation of the main portal vein (MPV). Note that the right posterior segmental division (RPSD) supplies segment VIII. RPV – right portal vein; LPV – left portal vein; RASD – right anterior segmental division.

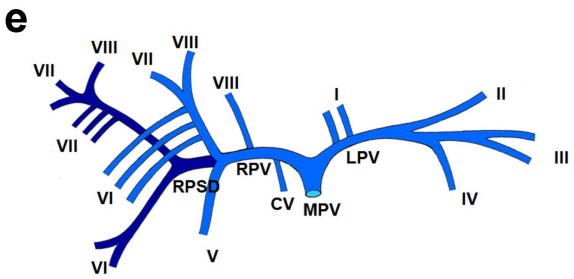

Fig 2e. Right portal vein (RPV) gives off a cystic branch (CV). Early segmentation of RPV supplying segment VIII. Right anterior segmental division (RASD) supplies segments VI and VII. Right posterior segmental division (RPSD) supplies segment VIII. Left portal vein (LPV) gives branches to segment I (caudate lobe).

and vertical branches (Figs. 2a, 3a).

The caudate lobe received its portal supply either from the left portal vein alone (33.3%) (Figs. 2a, 3b) or from the point of bifurcation of the main portal vein alone (26.6%) (Figs. 2b, 3c). In the rest, it had dual supply from both the right and left portal

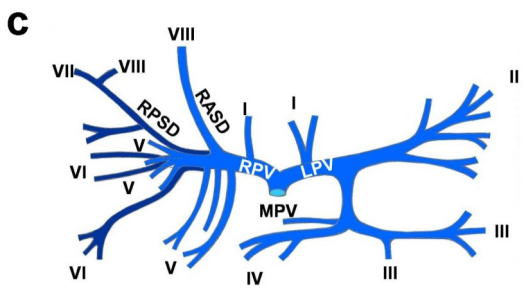

Fig 2c. Caudate lobe or segment I receives branches both from the right portal vein (RPV) and from left portal vein (LPV). Right posterior segmental division (RPSD) supplies segment VIII. MVP – main portal vein; RASD – right anterior segmental division.

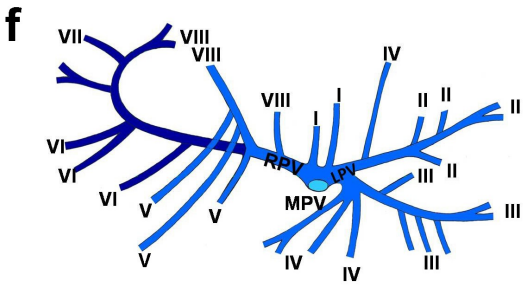

Fig 2f. Early segmentation of right portal vein (RPV) which supplies segment VIII. Right anterior segmental division (RASD) supplies segments V and VIII. Note the superior branch of RASD supplies segment V. RPSD - right posterior segmental division

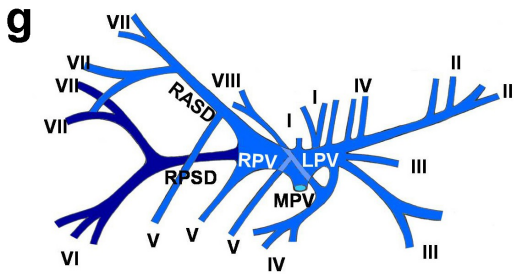

Fig 2g. Right anterior segmental division (RASD) supplies segments V and VII. Left portal vein (LPV) supplying segments V and VIII. Segment I (caudate lobe) gets multiple branches from left portal vein and also from the point of bifurcation of main portal vein (MPV). RPV – right portal vein; RSPD- right posterior segmental division.

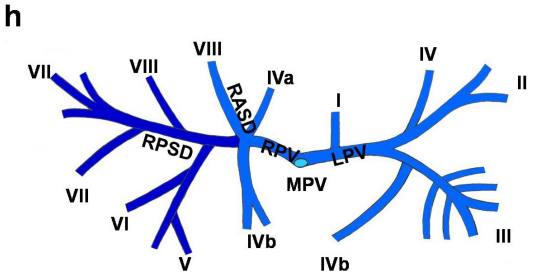

Fig 2h. Right anterior segmental division (RASD) supplies segments IV and VIII. Right posterior segmental division (RPSD) supplies segments V, VI, VII and VIII. MPV – main portal vein; RPV – right portal vein; LPV - left portal vein.

veins (20%) (Figs. 2c, 3d) or from the point of bifurcation and left portal vein (20%) (Fig. 2d).

In most specimens segment VIII received portal blood supply from the right anterior sectoral division. In 3 cases, early segmentation of right anterior sectoral division that supplied segment VIII was noted (Fig. 2e,). In addition, segment VIII also got its portal supply from right posterior sectoral division in 7 cases (Figs. 2f, 3e). A rare variation was seen in that the segment VIII did not receive its supply from the right portal vein, but the vertical portion of the left portal vein in addition to its supply to the segments III and IV, gave off branches to segments V and VIII (Fig. 2g).

In most of the specimens, segments VI and VII received portal blood supply from the right posterior sectoral division. In 3 specimens, segment VII received its portal blood also from right anterior sectoral division (Fig. 2.e.) and in two specimens, segment VI from right anterior sectoral division (Fig. 2.e).

Segment V was supplied by right anterior sectoral division in most of the specimens. In 2 specimens, it also received its portal blood supply from right posterior sectoral division (Fig. 2h). In one

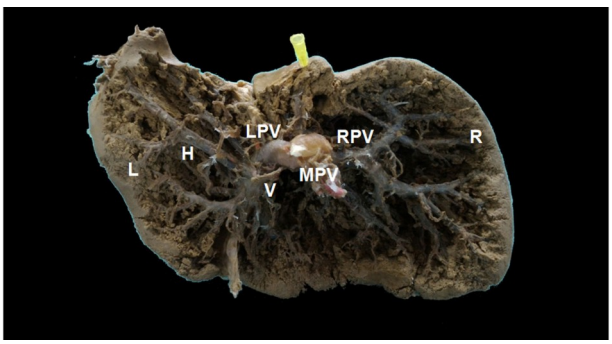

Fig 3a. Main portal vein (MPV) dividing into right portal vein (RPV) and left portal vein (LPV). LPV further divides into horizontal (H) and vertical (V) portions.

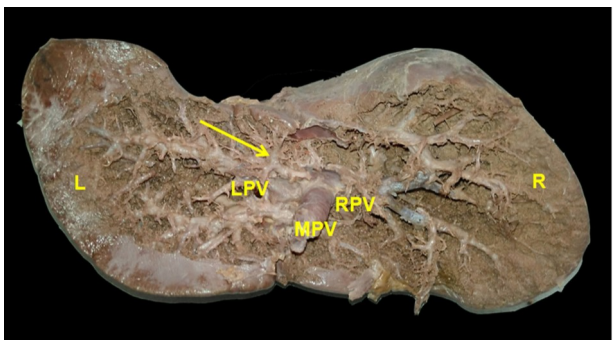

Fig 3b. Arrow indicates portal branch to caudate lobe from the left portal vein (LPV). MPV – main portal vein; RPV – right portal vein; R – right lobe of the liver; L – left lobe of the liver.

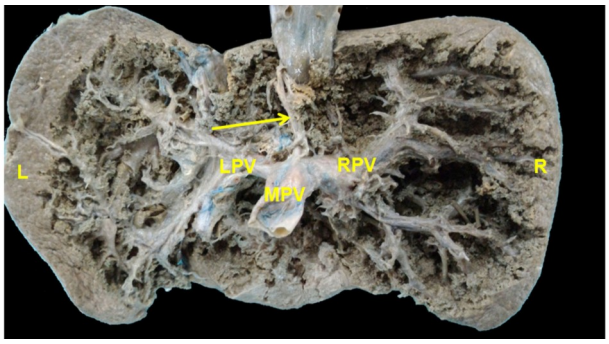

Fig 3c. Arrow indicates portal branch to caudate lobe from the point of bifurcation from the main portal vein (MPV). RPV – right portal vein; LPV – left portal vein; R – right lobe of the liver; L – left lobe of the liver.

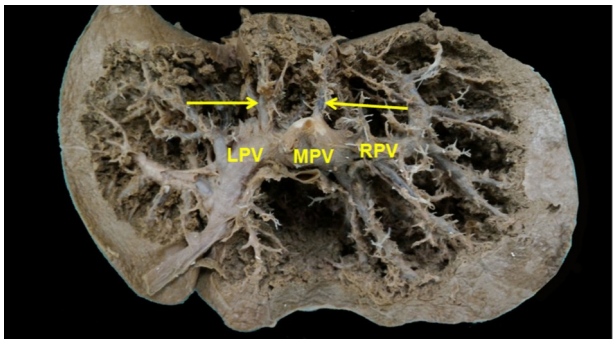

Fig 3d. Arrows indicate portal branches to caudate lobe from the left portal vein (LPV) and right portal vein (RPV). MPV – main portal vein.

Table 3. Comparison between present study and other studies showing variations in morphological feature of liver.

Portal vein branching pattern	Gunasekaran & Gaba n=100 (in %)	Covey et. al. n=200 (in %)	Koc et al. n=1384 (in %)	Sureka et al. n=967 (in %)	Kishi et al. n=361 (in %)	Takeishi et al. n=407 (in %)	Current study n=100 (in %)
Type 1	67	65	75	80	91	89	89
Type 2	10	9	11	7	6	6.1	5
Type 3	6	13	10	5	-	4.7	4
Type 4	1	1	0.5	3	-	-	-
Type 5	8	6	2	1	-	-	1
Miscellaneous	8	6	1.5	4	2.2	49	1

case, it received its portal blood supply from left portal vein in addition to right anterior sectoral division and right portal vein (Fig. 2g).

In all the 15 specimens, the left portal vein supplied segments II, III and IV. In one specimen, the segment IV, in addition to its branches from the left portal vein, also received branches from a right anterior sectoral division.

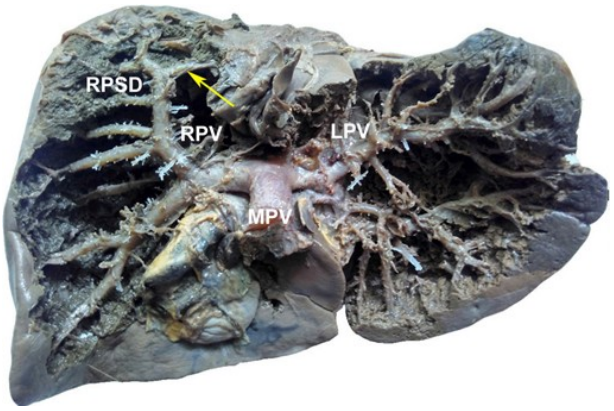

Fig 3e. Arrow indicates right posterior segmental division (RPSD) giving a branch to segment VIII. MPV – main portal vein; RPV – right portal vein; LPV – left portal vein.

DISCUSSION

In live donor liver transplant (LDLT), careful manipulation of the vasculobiliary system is critical to avoid injury to the portal vein in the residual liver and/or the graft. For TIPS, which has been employed for the treatment of portal hypertension, the right portal vein is commonly accessed (Kishi et al., 2010; Macdonald et al., 2005; Schroeder et al., 2002; Uchida et al., 2010). Prompt identification of anatomical anomalies can help the surgeon to determine whether cancer located at the portahepatis is operable or not (Hiraoki et al., 2009). Therefore, thorough knowledge of the variation of intrahepatic course of portal vein is essential.

Variation in portal anatomy was reported by various authors. Guler et al. (2013) reported that 12.6% donors have portal vein variations. Macdonald et al. (2005) reported portal venous anomalies in 18%, Kishi et al. (2010) in 9%, Takeishi et al. (2015) in 11%, Koç et al. (2007) in 27.4% and Sureka et al. (2015) in 20%.

Table 3 shows the comparison of branching pattern of the portal vein of various studies with the current radiological study. Of the portal vein anatomy described, the conventional Type 1, in which the main portal vein divides into right and left portal vein, was the most commonly encountered branching pattern in previous studies. In the current radiological study, conventional type I branch-

ing pattern was seen in 89% of the population. Specimens prepared by luminal casting showed that all 15 specimens had conventional type I branching pattern.

In the current study, trifurcation of the portal vein is the second most common type and was seen in 5% by radiological study which is in accordance with previous studies. Kishi et al. (2010) reported trifurcation in 6% of the cases, Takeishi et al. (2015) in 6.1%, Koc et al. (2007) in 11.1%, Sureka et al. (2015) in 6.83%, Covey et al. (2004) in 9% and Gunasekaran and Gaba (2017) in 10%.

Type 3 branching pattern in which there was a separate origin of the right posterior portal vein had a separate origin from the main portal vein, which was reported by Takeishi et al. (2015) in 4.7%, Koc et al. (2007) in 9.7%, Sureka et al. (2015) in 4.9%, Covey et al. (2004) in 13% and Gunasekaran and Gaba (2017) in 6%, and in the present radiological study in 4%. In the luminal casting study early segmentation of right posterior segmental division was seen in one specimen (6.6%). Though many authors have reported that Type 2 variation is the most common type, Atasoy and Ozyurek (2006) reported that Type 3 was more commonly occurred than Type 2 in their study. The differentiation between type 2 and type 3 was made according to the shape of the gap between the right anterior portal vein and the right posterior portal vein. If the gap was triangular, the anatomy was classified as type 2; if the gap was rectangular, as Type 3 (Hwang et al., 2004).

In addition, variations like right posterior sectoral division supplying segments IV, V VIII were noted in this study. Right posterior sectoral division supplying segment VIII was seen in 46.6%.

Type 4 variation in which a portal vein branch to segment VII arises as the first branch of the right portal vein was reported by Sureka in 2.69% (Sureka et al., 2015). This anomaly was not encountered in the present radiological study.

Type 5 variation in which a portal branch to segment VI arises as the first branch of right portal vein has been reported by Gunasekaran and Gaba (2017) in 8%, Covey et al. (2004) in 6%, Koc et al. (2007) in 2%, Sureka et al. (2015) in 1%, and 1% in the present radiological study.

In addition to this, in the current radiological study a separate branch arising from the left portal vein supplying segment VII was also noted. There is only one case report describing such anomaly (Cheluvashetty et al., 2017). In the luminal casting study, other variations of the right anterior sectoral division were also noted, like early segmentation of the right anterior segmental division supplying segment VIII, and gave branches to segments VI and VII and to segment IV.

The conventional Type 1 portal vein anatomy is most suitable for donation, as only one anastomosis is required between the donor and recipient portal veins (Vohra et al., 2014). Atosoy and Ozyurek (2006) reported that differentiation between type 2 and type 3 anatomy is important during surgeries. They have mentioned that donors with Type 2 anatomy are of better advantage, because a single portal lumen can be obtained from the right anterior portal vein and the right posterior portal vein due to their close approximation. But Type 3 anatomy makes surgery more complicated, because two transections of the right anterior portal vein and the right posterior portal vein are needed, resulting in two portal lumens in the right lobe graft.

Though variation of the left portal vein anomalies are rare, in the luminal casting study a rare variation in one specimen was encountered, where the branch to segment IV also supplied segment V and VIII. Such an anomaly is very rare and has been earlier reported by only a few authors. Koc et al. (2007) in their study on 1384 patients reported segment VIII being supplied by the left portal vein in 0.8% and segment V supplied both by the right and left portal vein in 0.1%. Atosoy and Ozyurek (2006) also reported such a variation in which segment VIII being supplied by the left portal vein in their radiological study. Guiney et al. (2003) have reported that dominant portal venous supply of the right liver segments originating from the left portal vein is a relative contraindication to right lobe harvesting.

It should be also noted that there was no gender difference in the branching pattern of the portal vein.

The caudate lobe of the liver is considered as a separate segment and is designated as segment I. It is anatomically distinct from the right and left lobes. Caudate lobe resection is one of the most demanding procedures among hepatic resection, owing to its deep and complex location and its proximity to major vessels (Pillai et al., 2013). Knowledge of vascular anatomy of the caudate lobe is vital in preventing and controlling haemorrhage. Kogure et al. (2000) observed that the number of branches supplying the caudate lobe varied from one to six. Gosavi et al. (2016) observed presence of up to 5 branches from extra hepatic part of portal vein for caudate lobe in 93.02% livers. The presence of a single branch to caudate lobe was observed by Ortale and Keiralla (2004) in 37.5%, Munguti et al. (2014) in 25.8%, Gosavi et al. (2016) in 18.6% cases, while in the present study single branch to caudate lobe was seen in 53.3%. Ortale and Keiralla (2004) observed two or three branches in 62.5% cases, Kogure et al. (2000) in 32.5%, Munguti et al. (2014) observed two branches in 48.5% and three branches in 19.7%.

Lopez-Andújar et al. (2007) observed that the portal vein branches to the caudate lobe came predominantly from the left branch of the portal vein, but it may also arise from the right branch of the portal vein or at the portal vein bifurcation. Go-

savi et al. (2016) reported that a majority of the branches (62.11%) supplying the caudate lobe were originating from the left portal vein, 26.09% from the point of bifurcation and 11.8% from the right portal vein. The finding in the current study is in accordance with the previous studies. The branch to the caudate lobe, when single, arose either from the left portal vein (33.33%) or from the point of bifurcation (26.33%). When dual veins supplying the caudate lobe it arose both from right and left portal veins in 20% or from left portal vein and at the point of bifurcation (20%).

Interestingly, while the right portal vein showed substantial anatomic variation, the left portal vein anomalies were less frequently encountered. Though variation of the left portal vein anomalies are rare in the luminal casting study, in one specimen segment IV also received its portal blood supply from RAPV in addition being supplied by left portal vein. Atosoy and Ozyurek (2006) have reported that dominant portal venous supply of segment IV from the right portal vein may contraindicate right lobectomy in liver transplantation candidates.

In summary, the radiological study showed that the normal conventional type was seen in 89%, and the most common variation was the trifurcation of portal vein, which is in accordance with the previous studies. In addition, in this study segment VII supplied by the left portal vein was noted in 6.6%. The luminal casting technique showed that variations were present in the intrahepatic branching pattern. The caudate lobe received branches from the left portal vein, from the point of bifurcation of the main portal vein into the right and left portal vein, from both the right and left portal vein and also from the left portal vein and bifurcation of main portal vein. There was early segmentation of the right portal vein, right anterior division, right posterior division. Knowledge regarding the vascular anatomy and their variation will help the radiologist, surgeons to minimize the iatrogenic complications during various surgical procedure involving the hepatobiliary system.

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