

Study of the normal anatomy and variations of portal vein in North Indian population: a MDCT study

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SUMMARY

Knowledge of the anatomy of the portal vein and its variations is important for performing surgical interventions, transplantation and other interventional procedures of the liver. While planning for adult right lobe liver transplantation, preoperative examination of potential donors can be carried out by use of multidetector computed tomography (MDCT). The study was conducted on randomly selected one hundred North Indian patients who were routinely coming for CT abdomen in the department of Radio-Diagnosis at a tertiary care centre in North India. The analysis of MDCT abdomen was done for branching patterns of PV and was classified as described by Covey et al. (2004).

Portal vein (PV) variations were identified in 29 out of 100 patients. The prevalence of PV variations in male and female were 27.5% and 30% respectively. Trifurcation (Type II) was the most common variant present in 12% cases. The next common variant (Type IV) was observed in 7% cases, in which Segment VII branch was a separate branch of the right portal vein. Type III i.e. left portal vein was arising after origin of right anterior portal vein (5%) and Type V (segment VI branch as separate branch of right portal vein) was detected in 5% cases each. Preoperative or intraoperative lack of awareness of PV variations can result in injury, and their knowledge can reduce the incidence of complications. So, clinically

important PV variants should be reported on CT.

Key words: Portal vein – Variations – MDCT – Liver – Transplantation

INTRODUCTION

The liver is the largest abdominal organ and it occupies most of the right hypochondrium, epigastrium and extends into the left hypochondrium as far as the left midclavicular line (Standring, 2009). The portal vein (PV) conveys blood from the abdominal part of the alimentary tract, the gall bladder, the pancreas, the spleen and conveys it to the liver. In the liver, it ramifies like an artery and ends at sinusoids. PV provides about three fourths of blood supply to the liver. This vein has a maximum diameter of 13 mm and is 5-8 cm in length (Meyers et al., 1990). Normal portal blood flow in human beings is about 1000-1200 ml/min. The portal vein contributes 40ml/min or 72% of total oxygen supply to the liver (Covey et al., 2004; Burroughs, 2011; Manjunatha et al., 2012). In the US, 6000 liver transplants are performed annually. In the last 10 years, there is a steady increase in the number of patients undergoing liver transplants in the UK. A similar trend is observed in China, Canada and India (Sureka et al., 2015). As there is severe shortage of cadaveric livers, living donor liver transplantation is being performed by transplantation surgeons. Now the healthy adults can donate portions of their livers to compatible recipi-

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ents who are suffering from end-stage liver disease most commonly caused by hepatitis C. A left lobe lateral segment graft cannot meet the metabolic demand of larger adult recipients as in paediatric transplantation. In adults, living right lobe liver transplantation is performed, and the removal of the right lobe of the liver should not endanger the vascular supply or metabolic function of the remaining left lobe. So, preoperative imaging plays an important role in patient selection and surgical planning. Preoperative imaging provides a vascular map, essential for the surgery (Kamel et al., 2001). Variations in the PV are frequent and occur in 20-35% of the population. A complete understanding of the surgical anatomy of the liver is essential for any surgeon operating on liver and biliary tract, either by open surgery or by laparoscopy, and other diagnostic or therapeutic percutaneous intrahepatic interventions (Bismuth et al., 2009). The detailed anatomical knowledge of the hepatic vein, the portal vein, the hepatic artery and the biliary anatomy is of clinical and radiological significance in dealing with portal vein embolization, liver resection, liver transplant, trans-jugular intrahepatic portosystemic shunt and other complex procedures (Sureka et al., 2015).

Multidetector computed tomography (MDCT) is a form of computed tomography (CT) technology in which the two-dimensional detector array permits CT scanners to acquire multiple slices or sections simultaneously, and to greatly increase the speed of CT image acquisition. Advent of MDCT has resulted in the development of high resolution CT applications such as CT angiography and CT colonoscopy.

Previously, studies have been done on cadavers by dissection or by injecting dyes, but nowadays MDCT is the gold standard technique for visualizing the vascular anatomy of the liver in living subjects. In MDCT, multiple slices or sections can be acquired at a higher rate, and the speed of CT image acquisition can be greatly increased. Very few studies have been performed on living subjects by MDCT technique in India. The purpose of this study was to review the normal and variant portal venous anatomy and its implication in liver surgery and preoperative portal vein embolization.

MATERIALS AND METHODS

The study was conducted on randomly selected one hundred North Indian patients who were routinely coming for CT abdomen in the department of Radio-Diagnosis at a tertiary care centre in North India. Adult patients of both sexes with no liver pathology on MDCT were included in the study. Patients with liver resection, hepatic mass, cirrhosis and portal hypertension distorting architecture of veins were excluded. The study was performed on 64 slice MDCT G.E. (general electronics) Light Speed VCT Xte machine after ingestion of 750 ml

of water as negative contrast agent or oral contrast agent. 80-100ml of non-ionic contrast was given at rate of 2.8 ml/sec followed by 30 ml of normal saline flush at the same rate. The scans were taken after 60 seconds of start of I/V contrast. The anatomy was initially seen on axial scans. Oblique, Coronal, Sagittal thin slice MPR (Multi Planner Reformatted) and MIP (Maximum Intensity Projection) images were also examined for the better delineation of segmental PV branches, and 3D-reconstruction had an added advantage in the delineation of PV anatomy. Patterns of PV anatomy was classified as described by Covey et al. (2004).

After completion of study, the observations were tabulated and analysed using Epi-info version 7.0. Chi-square test was used for the evaluation of prevalence of PV variations in males and females. P < 0.05 was accepted as statistically significant.

RESULTS

The patient group included 60 females and 40 males with mean age 47.96 ± 16.39 years. In our study PV variations were detected in 29 (29%) patients out of which 62% were female and 38% were male. (Table 1)

The patterns of portal vein branching observed are:

Type I (71%): main portal vein divides into right

Table 1. Gender-wise distribution of portal vein variations.

Type	Female	Male	Total
I	42	29	71
II	7	5	12
III	3	2	5
IV	5	2	7
V	3	2	5
total	60	40	100

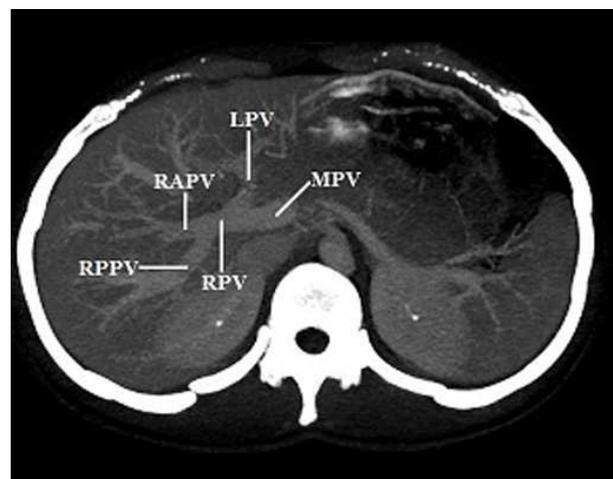


Fig. 1. Axial oblique MIP image of 22-year-old male with type I PV anatomy showing MPV dividing into RPV and LPV with further division of RPV into RAPV and RPPV.

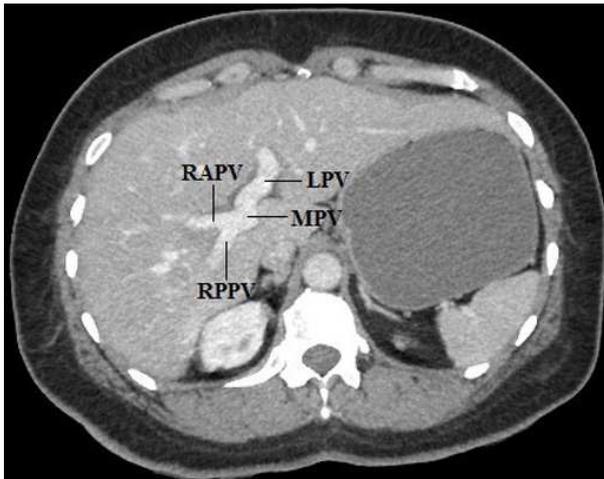


Fig. 2. Axial oblique MIP image of 54-year-old female with type II PV anatomy showing MPV dividing into three branches i.e. LPV, RAPV and RPPV.



Fig. 3. Axial oblique MIP image of 80-year-old male with type III PV anatomy with RPPV arising as the first branch of the MPV and having LPV as the terminal branch, arising after the origin of RAPV.

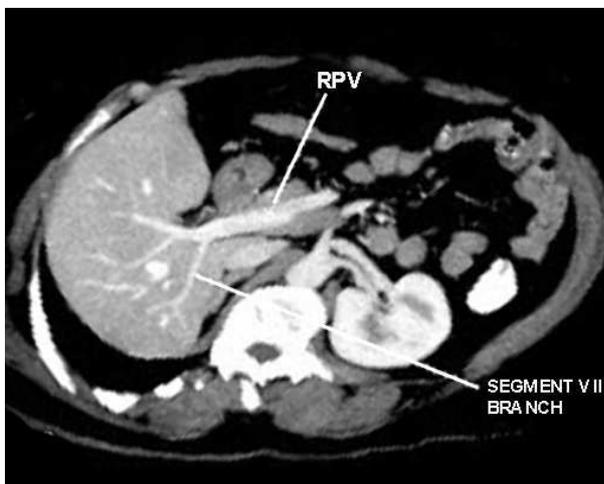


Fig. 4. Axial oblique MIP image of 52-year-old female showing segment VII branch as a separate branch of RPV.



Fig. 5. Coronal MIP image of 58-year-old male showing segment VI branch as separate branch of RPV.

and left portal branches. The right portal vein then gives rise to anterior (RAPV) and posterior (RPPV) sectorial branches that supply Couinaud liver segments V and VIII and segments VI and VII, respectively. (Standard portal vein anatomy) (Fig. 1). Type II (12%): Trifurcation of the main portal vein into RAPV, RPPV and left portal vein branches (LPV) (Fig. 2). Type III (5%): RPPV is the first branch of the main portal vein and LPV is the terminal branch, arising after origin of RAPV. (Z type anatomy) (Fig. 3). Type IV (7%): segment VII branch as separate branch of right (RPV) (Fig. 4). Type V (5%): segment VI branch as separate branch of RPV (Fig. 5). Uncommon variants were not found in the study.

Prevalence of PV variation was observed in 29% cases. Trifurcation (type II) was the most common

variant. Type IV was the next common variant.

Out of 60 female patients PV variations were detected in 18 (30%) patients. Type II variant was the most common variant in females. Out of 40 male patients PV variations were detected in 11 (27.5%) patients. Type II was the most common variant in males as well.

A statistically significant difference in the prevalence of PV variation was not detected between male and female patients ($p=0.07$).

DISCUSSION

Identification of branching patterns of the PV is an important part of the planning of liver resection (to ensure that portal perfusion to the remnant liver is not inadvertently compromised), liver transplan-

tation (to enable appropriate graft selection so that complex portal venous anastomoses that might compromise the graft or a residual portion of the liver in a living donor can be avoided) and percutaneous interventional procedures (to allow safe, effective completion) (Lee et al., 2011).

Normally in Type I, at the hilum, PV divides into right and left branches. The right branch divides into RPPV and RAPV. The RPPV supplies segments VI and VII. The RAPV supplies segments V and VIII. The LPV goes medially and supplies segment II, III, IV and also gives a branch to the caudate lobe. Embryologically, the PV is formed in the second month of gestation by selective involution of the vitelline veins, which have multiple bridging anastomoses anterior and posterior to the duodenum. Normally, the stem of the portal vein is formed by left vitelline vein and posterior anastomosis; the left branch is formed by a part of left vitelline vein and cranial anterior anastomosis and finally the right branch is formed by part of the right vitelline vein. Any deviation in this normal obliterative process results in variations in branching of the portal vein (Hu et al., 2008; Walsh et al., 1995).

Clinical and Radiological significance

Portal Venous Embolisation (PVE) is a vascular interventional technique performed to increase the size of the liver preoperatively before major hepatectomy. Normally hepatobiliary surgeons prefer at least 25% future liver remnant (FLR) after hepatectomy. When the expected FLR low, PVE is performed as to increase FLR. PVE can be performed by ipsilateral/contralateral approach. When PV anatomy is normal, very few technical difficulties are encountered. When contralateral approach is used in a case of type III PV variation, a reversed curved catheter is required for the procedure.

Trifurcation and quadrification of PV also result in difficult and unstable catheterization. There is higher risk of migration of embolic material and thus resulting in non-target embolization (Sukuhara et al., 2012; Schmidt et al., 2008).

Hepatic Resection The major hepatectomy procedures like extended right hepatectomy (right trisegmentectomy) and extended left hepatectomy (left trisegmentectomy) require embolization of both right and left PV branches. A detailed knowledge of the portal vein branching pattern is required to avoid reflux of embolizing material into branches of future FLR remnant liver tissue. Complete obliteration of PV branches supplying particular segments (to be resected) is required for safe and clean hepatectomy. In this respect, type III PV variation is of much clinical importance to the surgeons, because, if the surgeon ligates only RAPV, there is risk of active bleeding from RPPV (Madoff et al., 2002; Schmidt et al., 2008).

Liver transplantation Type II and type III varia-

tions are most relevant in liver transplantation. Intraoperative clamping is difficult in type II variation. Type III variation is important both in donor and recipient. In the recipient two portal vein anastomosis have to be performed on two separate veins. In the donor, complete vascularisation of remnant liver is required (Erby et al., 2003; Kamel et al., 2001).

Transjugular intrahepatic portosystemic shunt (TIPS). In many cases, TIPS is created between right hepatic vein and RPPV. The success of this procedure depends upon accurate knowledge of normal and anatomic variations of PV. The puncture of extrahepatic MPV can lead to uncontrolled bleeding. Type II and Type III variations are of significant value due to altered spatial relationships of PV branches, because larger right PV may not be available and target vein may be smaller (Saad et al., 2008).

Association with biliary variations. Variations in PV are usually associated with variant biliary anatomy; embryologically, the development of primary division of PV occurs earlier than development of hepatic duct and extrahepatic bile ducts develop from bipotent liver progenitor cells in contact with mesenchyme of PV (Sureka et al., 2015).

Segmental localisation of hepatic lesions. PV variations are important in identifying the localization of liver lesions, as PV and the hepatic vein determine segmental anatomy of the liver (Sureka et al., 2015).

The variant anatomy of the portal vein is found in 29% of the population. The variant anatomy of PV has the prevalence ranging from 12%, as observed by Saylisoy et al. (2001), to 49%, as observed by Munguti et al. (2013). Munguti studied 100 livers from adult black Kenyan population, and on dissection found the PV in 49% of African population. Maheshwari (2011) conducted the same study on Indian population and observed variant anatomy in 18% population (Table 2). The difference could be due to racial or geographical reasons. All other studies were radiological. The values in the present study are comparable to other studies.

The most common variation in the study is Type II (trifurcation of PV) in 12% of cases. The prevalence of Type II PV variation ranges from 6%, as observed by Saylisoy et al. (2005), to 19%, as observed by Erby et al. (2011). In the present study, Type II PV variation is observed in 12%, which is comparable to other studies. Trifurcation of the PV was observed as the most common variant in accordance with previous studies (Erby et al., 2003; Gallego et al., 2002; Kamel et al., 2001; Koc et al., 2007; Madoff et al., 2002; Maheshwari, 2011; Sahani et al., 2002; Sureka et al., 2015).

The prevalence of Type III PV variation ranges from 2.5% as observed by Kamel et al. (2001) to 23.5% as observed by Atasoy and Ozurek (2006). In the present study, the prevalence of type III PV

Table 2. Incidence of the branching pattern of portal vein

S.No	Author	Type I	Type II	Type III	Type IV	Type V
1.	Kamel et al. (2001)	62.5%	2.5%	2.5%	-	-
2.	Gallego et al. (2002)	80%	4.7%	4.7%	-	-
3.	Madoff et al. (2002)	85%	5%	5%	-	-
4.	Sahani et al. (2002)	83.4%	4.7%	4.7%	-	-
5.	Erby et al. (2003)	63%	13%	13%	-	-
6.	Covey et al. (2004)	65%	13%	13%	-	-
7.	Hwang et al. (2004)	79.7%	12.7%	12.7%	-	-
8.	Saylisoy et al. (2005)	88%	4%	4%	-	-
9.	Atasoy et al. (2006)	64.5%	23.5%	23.5%	3.8%	-
10.	Koc et al. (2007)	78.5%	9.7%	9.7%	0.6%	2.4%
11.	Maheshwari (2011)	82%	4%	4%	-	-
12.	Munguti et al. (2013)	51%	22%	22%	-	-
13.	Sureka et al. (2015)	79.94%	6.83%	4.96%	2.69%	1.34%
14.	Present study	71%	5%	5%	7%	5%

variation is 5%. Type III is the most common variant in the previous studies (Atasoy and Ozurek, 2006; Covey et al., 2004; Hwang et al., 2004; Munguti et al., 2013; Sureka et al., 2015). In the present study, type III is the third common variant.

Segment VII branch as separate branch of RPV (Type IV) is observed in 7% cases in the present study in contrast to study by Atasoy and Ozurek (2006), Koc et al. (2007) and Sureka et al. (2015), where Type IV branching pattern was reported in 3.8%, 0.6% and 2.69% cases respectively. It is the second most common variant in the present study.

Segment VI branch as separate branch of RPV (Type V) is observed in 5% cases in the present study in contrast to study by Koc et al. (2007) and Sureka B et al. (2015), where type V branching pattern was reported in 2.4% and 1.34% cases respectively.

Statistically significant difference in prevalence of PV variations was not detected between male and female patients in the present study in accordance to study by Koc et al. (2007).

Some authors have reported uncommon PV variants like quadrification (Koc et al., 2007) of the portal vein into segment VI branch, RAPV, RPPV and LPV. Congenital absence of PV known as Aberrant malformation (Northrup et al., 2002) and RAPV arising from LPV or LPV arising from RAPV (Akgul et al., 2002; Schroeder et al., 2006). Kouadio et al. (2011) reported absence of PV bifurcation in an asymptomatic 39-year female on CT. There was a single intrahepatic PV which crossed the entire liver parenchyma from right to left and with gradually decreasing diameter. Yadav et al. (2012) reported segment VIII branch arises from LPV, in addition LPV also supplies segment I, II, III, and IV. In a study on 50 vascular casts and 200 CT angiographies of the upper abdomen, the author (Macchi et al., 2015) observed PV bifurcation in 75%, trifurcation in 20%, and quadrifurcation in 5% in cast studies, and in the radiological study

PV presented bifurcation in 90% and trifurcation in 10% cases.

Rare or uncommon variants were not detected in the present study. It could be due to small sample size or it could be the racial difference.

PV variations can be demonstrated with routine MDCT examinations. PV variations are asymptomatic and patients do not have any problem throughout life. But these variations increase the complications during surgical procedures and percutaneous interventional procedures. Variations can be recognised in routine imaging techniques, so these variations should be reported.

Conclusion

It was concluded that PV variations are easily detected in routine CT examinations. Awareness of PV variations is important in surgical resection and transplantation. PV variations are also important in percutaneous interventional procedures. Preoperative or intraoperative lack of awareness can result in injury, and their knowledge can reduce the incidence of complications. Therefore, clinically important PV variants should be reported on CT.

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