ORIGINAL RESEARCH PAPER

Radio Diagnosis

A MDCT STUDY OF INCIDENCE, PATTERNS, AND CLINICAL IMPLICATIONS OF PORTAL VEIN VARIANTS.

KEY WORDS: Portal vein Variations, MDCT, Interventional procedures, Liver resection

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ABSTRACT

Knowledge of portal vein variants in percutaneous interventional procedures is also increasingly important. As the various liver vascular interventions by surgeons and radiologists expanding, Identification of branching patterns of the PV is an essential part in the planning of liver resection (so that portal perfusion to the remnant liver tissue is not inadvertently compromised), liver transplantation (to enable appropriate graft selection) so that complexity of portal venous anastomoses that might compromise the liver graft or a residual portion in a living donor can avoid. For this complexity, many surgeons routinely obtain preoperative CT or MR angiograms to check for replaced or accessory arterial and venous branches.

Aims: The purpose of this study was to evaluate the incidence and patterns of intrahepatic portal vein (PV) variations on Triphasic abdomen multietector CT (MDCT) and to discuss the surgical and radiological implications.

Methods and Material: A retrospective review of 1000 Triphasic MDCT abdomen scans was performed in patients sent for various liver and other abdominal pathologies between November 2017 and November 2019. The variations in the branching pattern of PV classified according to the classification used by Covey et al[2].

Results and conclusions: From the sample of 1000 patients with the exclusion of poorly opacified portal vein and various portal vein pathologies, classical anatomy seen in 767 patients, Trifurcation (TYPE II) in 85 patients, Right posterior vein as the first branch of the main PV (TYPE III) in 97, Segment VII branch as a separate branch of RPV (TYPE IV) in 30, Segment VII branch as a separate branch of RPV (TYPE V) in 14 patients, other miscellaneous variants of about seen in 7 patients.

INTRODUCTION

The liver is the largest abdominal organ, and it located most of the right hypochondrium, epigastrium and extended into the left hypochondrium as far as the left midclavicular line. The portal vein (PV) receives blood from the abdominal part of the digestive tract, the gall bladder, the pancreas, the spleen, and conveys it to the liver. In the liver, its branches like an artery and ends at sinusoids. PV provides about three-fourths of blood supply to the liver. This vein has a diameter of 13 mm in maximum and is 5-8 cm in length. In the liver, its branches like an artery and ends at sinusoids. Normal portal blood flow in humans is about 1000-1200 ml/min. The portal vein supply constitutes 40ml/min or 72% of the total oxygen supply to the liver. In the last ten years, a steady increase in the number of patients undergoing liver transplants. As a severe shortage of cadaveric livers, transplantation surgeons are performing living donor liver transplantation. Now the healthy adults can donate portions of their livers to compatible recipients who have a longterm illness from the end-stage liver disease most commonly caused by hepatitis C.

Preoperative imaging provides a vascular map, essential for the surgery. Variations in the PV occur in 1-24 % of the population. Modern imaging techniques multislice computed tomography (CT) now allow for three-dimensional (3D) reformation of the entire liver vascular structures. Various complex hepatic interventions now performed by interventional radiologists and surgeons, including portal vein embolization, anatomic resection, creation of transjugular intrahepatic portosystemic shunts and transplantation, understanding of normal and variant portal vein anatomy, and recognition of these variants increasingly important. The awareness of variations will help to prevent complications like uncontrolled bleeding.

MATERIALS AND METHODS

Data for the study collected from patients attending/referred to the department of Radiodiagnosis for Contrast-enhanced Computed Tomography of the abdomen at Kurnool Medical College Hospital, Kurnool.

A total of 1107 patients over 24 months were studied. We excluded 107 patients with a history of major upper abdominal surgery, who had undergone previous liver resections and patients with large central tumors and other pathologies obscuring the assessment of PV variations like portal vein thrombosis and portal cavernomas. A significant sample (n=1000) study was performed on Multidetector High-Resolution Computed Tomography (GE BRIGHT SPEED 16 SLICE CT), as it is the most performing and reliable investigation for knowing of portal venous anatomy. Bolus tracking method used for the post-contrast scan with the tracker placed in the descending aorta at the level of dome of the diaphragm. 70-80 ml of 350mg/ml non-ionic iodinated contrast (IOHEXOL) injected using pressure injector at the rate of 3-4ml/sec. The threshold set at150 Hounsfield units (HU) and delay of 3 seconds given after the attainment of the threshold for the arterial phase. Portal Venous phase acquired after a delay 60 seconds from the time of contrast injection. The raw imaging data obtained from MDCT processed on the available workstation for axial, coronal, and axial-oblique multiplanar reformation (MPR), volume rendering (VR) images in portal venous phase, reconstructed with 1.25 mm reconstruction intervals for detailed interpretation for portal vein variants. we classified the common PV variations into five types as classified by Covey et al. (Table 1) (Figure 1).

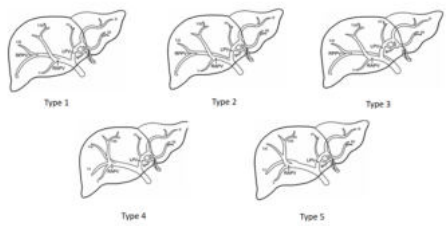

Table 1- Classification of variants.

TYPES	Anatomic Variations in Portal Vein
1	Standard anatomy
2	Trifurcation
3	Right posterior portal vein as the first branch of main portal vein
4	Segment VII branches as a separate branch of right portal vein
5	Segment VI branches as a separate branch of right portal vein
	Miscellaneous

RESULTS

In this study Group, all age groups ranging from 5 years to 71 years with a mean age of 41.5 ± 10.66 Years. In the present study, group 381 are females, and 619 are males. A statistically significant difference in the prevalence of PV variation was not detected between male and female patients (p= 0.07).

The portal vein branching patterns observed are Type I STANDARD PV (76.7%): main portal vein divides into right 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 (Figure 2).Type II (8.5%):Trifurcation of the main portal vein into RAPV, RPPV, and left portal vein branches LPV) (Figure 3). Type III (9.7%): RPPV is the first branch of the main portal vein, and LPV is the terminal branch, arising after the origin of RAPV so-called (Z type anatomy) (Figure 4). Type IV (3%): segment VII branch as a separate branch of right (RPV) (Figure 5).Type V (1.4%): segment VI branches as a separate branch of RPV (Figure 6). In 7 cases (0.7%), we found different variations. Other variations which encountered in our study were four cases of separate origin of Segment VI and Segment VII branch from RPV (Figure 7), one cases of Right anterior portal vein (RAPV) arising from LPV (Figure 8), one case of Right posterior portal vein (RPPV) trifurcation (Figure 9). The absence of PV bifurcation seen in one case (Figure 10). The detailed results of the study illustrated in (Table 2,3).

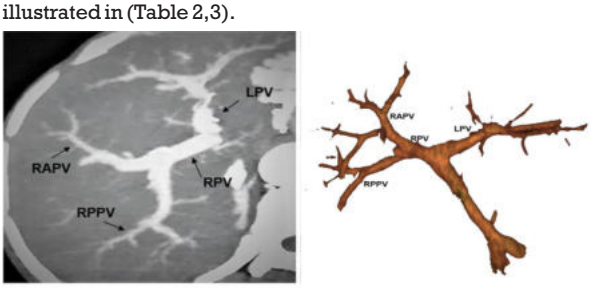

Fig -2 -CT axial reformatted and VR image in portal venous phase showing classic anatomy of portal vein branching

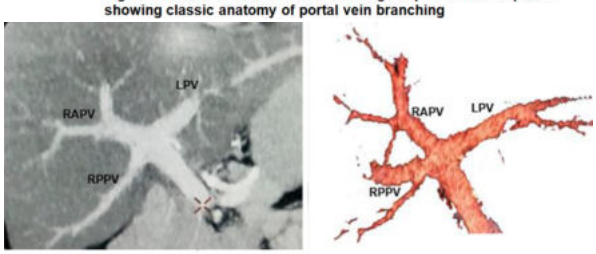

Fig -3 -CT axial reformatted and VR image in the portal venous phase showing trifurcated(Type II) portal vein

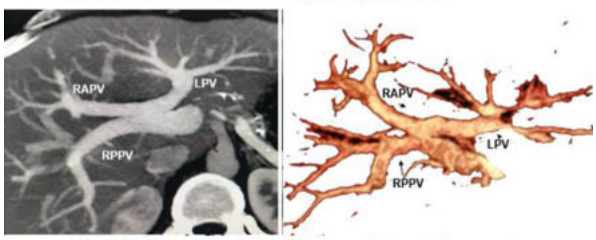

Fig- 4-CT axial reformatted MIP and VR image in the portal venous phase showing right posterior branch as the first branch (TYPE III) portal vein

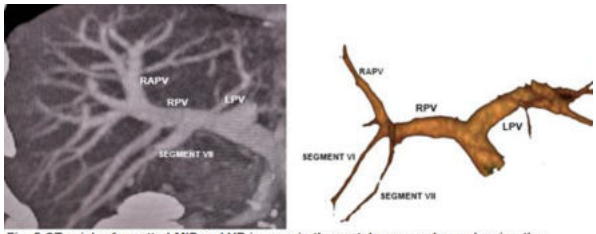

Fig- 5-CT axial reformatted MIP and VR images in the portal venous phase showing the separate origin of right posterior segment VII branches (TYPE IV) from the right portal vein

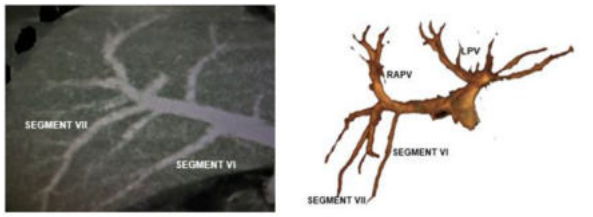

Fig-6-CT axial reformatted MIP and VR images in the portal venous phase showing the separate origin of right posterior segment VI branches (TYPE V) from the right portal vein

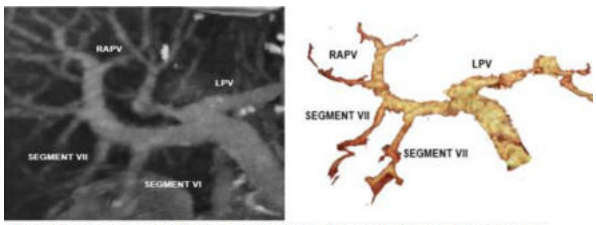

Fig-7- CT axial reformatted MIP and VR image in the portal venous phase showing separate origins of both right posterior segment branches from the right portal vein

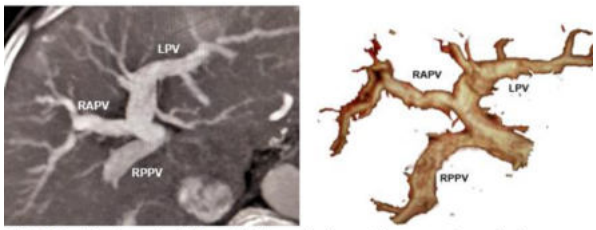

Fig-8-CT axial reformatted MIP and VR image in the portal venous phase showing RAPV branches from the Left portal vein

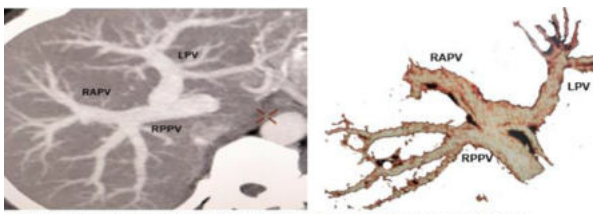

Fig-9-CT axial MIP reformatted and VR image in the portal venous phase showing Trifurcation of RPPV

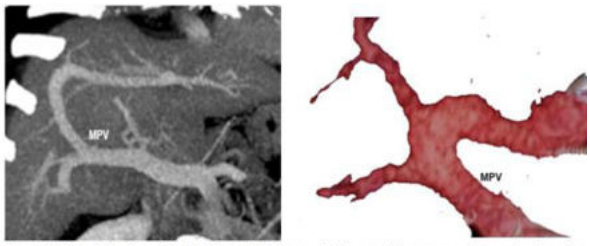

Fig -10- CT axial reformatted MIP and VR image in the portal venous phase showing the absence of bifurcation

Types	FEMALE		MALE		TOTAL	
	NUMBER	%	NUMBER	%	NUMBER	%
CLASSIC ANATOMY	289	26.5%	478	48%	767	76.7%
TRIFURCATION	31	3.5%	52	5.7%	85	8.5 %
RPV AS FIRST BRANCH	40	4.2%	57	6.2%	97	9.7%
SEGMENT VII AS SEPARATE BRANCH	11	1.2%	19	2.1%	30	3.0%
SEGMENT VI AS SEPARATE BRANCH	6	0.66%	8	0.88%	14	1.4%
MISCELLANEOUS	2	0.2%	5	0.5%	7	0.7%
TOTAL	381	36.4%	619	63.6%	1000	100%
INFERENCE	Statistically, a significant difference not detected between the prevalence of PV variations in male and female patients ($P = 0.58$).					

Table 2- Distribution of variants.

Author	Type I	Type II	Type III	Type IV	Type V	others
Gupta et al (1977)	88%	12%	-	-	-	-
Fraser hill et al (1990)	99.91%	0.01%	0.01%			0.05%
Atri et al (1992)	79.9%	10.9%	4.7%			4.5%
Soyer et al. (1995)	94%	4.3%				1.7%
Y. baba et al (2000)	89.1%	5.2%	2.6%			3.1%
Kamel et al (2001)	68%	24%	4%			4%
Akgul et al (2002)	86.2%	12.3%	0.3%			1.2%
Erby et al (2003)	77.5%	12%	8%			4%
Lee et al (2003)	91.1%	4.2%	3.7%	0.5%		0.5%
Covey et al (2004)	65%	9%	13%	1%	6%	6%
Saylisoy et al. (2005)	88%	6%	4%			2%
Atasoy et al. (2006)	65.5%	9.5%	23.5%	3.8%	0.8%	
Koc et al. (2007)	78.5%	11.1%	9.7%	0.6%	2.4%	
Maheswari (2011)	82%	12%	4%			2%
Munguti et al (2013)	51%	22%	22%			5%
Guler et al (2013)	88.2%	5.2%	5.4%			2%
Sureka et al. (2015)	79.94%	6.83%	4.96%	2.69%	1.34%	4.24%
Gunasekharan et al (2016)	67%	10%	6%	1%	8%	8%
Sharma et al (2017)	71%	5%	5%	7%	5%	7%
Current study	76.7%	8.5%	9.7%	3.0%	1.4%	0.7%

Table 3 –Comparsion with previous studies.

DISCUSSION

Identification of branching patterns of the PV is an essential part of the planning of liver resection (to ensure that portal perfusion to the remnant liver is not inadvertently compromised), liver transplant. The use of MDCT with volume rendering and reformatted sections obtained from thin axial CT sections seems the most efficient technique. In our study, we reported an incidence of 23.3% of portal vein variants in 900 patients. Axial-oblique images with MPR, MIP, and volume-rendered (VR) reformations are particularly crucial in discriminating variations, especially between Portal vein trifurcation, right posterior PV being the first branch of the MPV, and Segment VI and VII branching patterns and other miscellaneous variants.

In our study, the most common classical anatomy (TYPE 1) in 767(76.7%) out of 1000 patients. The prevalence of classic anatomy ranges from 51% by Munguti et al. (2013) to 91.1% by Lee et al., (2013). The prevalence of type 1 anatomy reported 77% by Soyer et al. studied on 69 patients,89.1 % by Y.baba et al. studied in 192 patients),68% by Kamel et al. studied in 25 patients, 86.2 % by Akgul et al. studied in 585 patients,77.5% by Erbay et al. studied in 207 patients, 65 % by Covey et al. studied in 200 patients,88 % by Saylisoy et al. studied in 52 patients, 65.5 % by Atasoy et al. studied in 200 patients,78.5% by Koc et al. studied in 1384 patients, 88.2% by Guler et al. studied in 386 cases, 79.94% by Surekha et al. studied in 967 patients. The most common variant in our study is Type III, right posterior portal vein arising from the main portal vein observed in 94 patients (10.4%) out of 900 patients. The prevalence of Type III PV variation ranges from 0.3%, as noted by Akgul et al., to 23.5%, as observed by Atasoy et al.

Type III is the most common variant in the previous studies (Atasoy et al. (23.5%), Covey et al. (13%), Munguti et al. (22%), Guler et al. (5.4%), Sharma et al. (5%). Type III variant reported by Y. baba et al., Kamel et al., Akgul et al., Erby et al., Lee et al., Saylisoy et al., Koc et al., Surekha et al., Maheswari and Gunasekharan et al. 2.64%,4%, 0.3%, 8%, 3.7%, 4%, 9.7%, 4.86%,4%, and 6% respectively. A type III portal vein variant is more difficult for the procedure because two portal vein anastomoses have to do on two separate veins in the recipient [4].

In the present study, Type II Portal vein variation observed in 84 patients (9.3 %), which is comparable to other studies. The prevalence of Type II PV variation ranges from 4.2%, as observed by Lee et al., to 24%, as observed by Kamel et al. Trifurcation of the Portal vein observed as the most common variant by previous studies (Erby et al. (12%), Koc et al. (11.1%), Munguti et al. (22%), Maheshwari (12%), Sureka et al. (6.83%), Akgul et al. (12.3%).

Type II variant reported in previous studies is 12% by Gupta et al., 4.3% by Soyer et al., 5.2% by Y. baba et al., 12.3% by, 9.5% by Atasoy et al., 9% by Covey et al., 22% by Munguti et al., 5.2% by Guler et al., 5% by Sharma et al., 4.2% by Lee et al., 6% by Saylisoy et al., 6.83% by Surekha et al. and 10% by Gunasekharan et al. In trifurcation, the left PV and the anterior, posterior branches of right portal vein branch at the same level, creating a surgical problem because there is no segment of the portal vein into which a clamp can appropriately place [12].

Segment VII branch as a separate branch of RPV (Type IV) observed in 3.3% cases in the present study, in contrast, to studying by 0.5% by Lee et al. (2003), 1% by Covey et al. (2004), 3.8% by Atasoy and Ozurek (2006), 0.6% by Koc et al. (2007) and 2.69% by Sureka et al. (2015), 1% by Gunasekharan et al. (2016), 7% by Sharma et al. (2017).

Segment VI branches as a separate branch of RPV (Type V) is observed in 1.3 % cases in the present study, in contrast, to studying by Covey et al. (2004), Atasoy et al. (2006), Koc et al. (2007), Sureka et al. (2015), Gunasekharan et al. (2016) and Sharma et al. (2017) where type V branching pattern reported in 6%, 0.8%,2.4 %, 1.34%,8% and 5% cases respectively. (Table 5)

In present study some uncommon variants reported such as RAPV arising from LPV (0.1%) , separate origin of segments VI &VII from RPV(0.3%), Absence of portal bifurcation(0.1%), right posterior portal vein trifurcation(0.1%). Absence of portal bifurcation, a single intrahepatic PV that crossed the entire liver parenchyma from right to left and with gradually decreasing diameter, also reported by previous studies by Koc et al. (0.5%) and Surekha et al. (0.1%).

An uncommon variant right posterior portal vein trifurcation (0.1%) reported in the current study as compared to previous studies reported 0.5% studied by Koc et al.

In our series, left portal vein variants were rare as compared to studies by Covey et al. None of the 1000 patients in this study had congenital duplication or absence of the portal vein. Congenital absence of PV known as Abernethy malformation [12]. As reported by Soyer et al. we did not detect the absence of any horizontal segment of LPV or an aberrant vessel. Some authors have reported uncommon PV variants like quadrification of the portal vein into segment VI branches, RAPV, RPPV, and LPV. Few unusual variations reported, such as total ramification of the PV branches coursing similarly to the umbilical vein, the origin of the segment VIII branch from the main PV.

CLINICAL AND RADIOLOGICAL SIGNIFICANCE

Portal vein embolization

Cross-sectional imaging for procedural planning is to be performed before PVE to document the extent of disease, FLR (future liver remnant) size, and portal venous anatomy. Variation in branching patterns like PV quadrifurcation and trifurcation, which result in unstable and difficult catheterization, and a higher risk for migration of

embolic materials and thus result in non-target embolization[1,12].

Failure to recognize these variations in the setting of hilar portal ligation leads to hepatic failure and death. Resection/liver transplantation may require portal vein resection and reconstruction, which greatly increases the complexity of these procedures

Liver resection

For a clean and safe hepatectomy, portal branches supplying those particular segments are to be completely obliterated. As these different patterns of variations, Type III PV variation is of much clinical importance to the surgeons because if the surgeon ligates only the right anterior branch, then there is a risk of active bleeding from the posterior branch[1,11,12].

Liver transplantation

Living donor liver transplantation (LDLT) has gained worldwide acceptance for the treatment of end-stage liver disease. Adult LDLT, right lobe (RL), generally preferred to provide a larger size liver graft; however, a higher incidence of vascular and biliary variations. Anatomical variations of the PV are also associated with higher rates of biliary variations.

Anatomic variation in the branching pattern of PV most relevant in liver transplantation surgery is Type II (trifurcation) and Type III variation.

Trifurcation variant increases the complexity as intraoperative clamping becomes difficult. Type III variant has its surgical importance in the recipient as well as in the donor. In the recipient, two PV anastomoses have to be performed on two separate veins, thus resulting in the complexity of the procedure. In the donor, the focus is on getting vascularization of remnant liver completely. If there are segmental variations, then removal of a particular lobe together with its Portal vein branch may revascularize a specific segment (particularly Segment IV and VIII)[1,11,12].

Transjugular *intrahepatic portosystemic shunt*

Transjugular intrahepatic portosystemic shunt (TIPS) created between the right hepatic vein and RPV. The key to successful TIPS creations lies in good knowledge of the standard and anatomic variation of PV. Puncture of extrahepatic main portal vein can lead to uncontrolled bleeding in anatomic variations of Type II and Type III. The clinical implications of these variants are that if there is an altered spatial relationship between these branches, one main larger right trunk may not be available. Thus the target may be smaller in calibre[1,12].

Congenital extrahepatic portosystemic shunt

According to the pattern of anastomoses between the Portal vein and systemic veins. Congenital extrahepatic portosystemic shunt (CEPS) or Abernethy malformation or classified into two types:

Total shunting with a complete absence of intrahepatic portal venous flow—type I; and partial shunting with some preserved hepatic portal venous flow—type II. CEPS is associated with hepatic encephalopathy, nodular liver lesions (focal nodular hyperplasia, regenerative nodular hyperplasia, hepatic adenoma) hepatopulmonary syndrome, and concomitant systemic congenital anomalies[1,12].

Segmental localization of hepatic lesions

Awareness of Portal vein variations is essential in identifying the location of liver lesions, Portal veins along with hepatic veins, determine the segmental anatomy[1].

CONCLUSION

MDCT is superior and confirming the portal vein and its branches through the development techniques of MIP, MPR, and VR images providing accurate detection of PV variants. Portal vein variants are frequent and easily recognizable with the increased quality of 3D VR reconstructions in CT. The implication of the reporting of variants is essential nowadays, as various vascular intervention procedures are of clinically indicated.

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