INTRODUCTION

Portal vein thrombosis (PVT) is a common complication of end-stage liver disease with an incidence of 0.6–16% in patients with well-compensated disease ***(Nonami et al., 1992; Fimognari et al., 2008; Sobhonslidsuk et al., 2002)*** increasing up to 35% in cirrhotic patients with hepatocellular carcinoma ***(Nonami et al., 1992).***

Portal vein thrombosis is thought to be occurred secondary to a complex combination of decreased portal blood flow, portal hypertension, peri-portal lymphangitis, and increased coagulability ***(Fimognari et al., 2008; Sobhonslidsuk et al., 2002).***

Portal vein thrombosis has proven to be an independent risk factor for variceal bleeding, because PVT may critically increase portal resistance even in patients without previous severe portal hypertension ***(Amitrano et al., 2004).***

The etiology, not yet fully understood, is based on the thrombotic tendency related to several factors: altered liver anatomy that increases the intrahepatic resistance to portal flow, endothelial injury due to an elevated portal pressure, and coagulation abnormalities ***(Orlando et al., 2004; Bayraktar et al., 2006).***

Despite progress in preoperative and cross-sectional imaging, a substantial number of cases of PVT or SVT are still discovered at the time of LT ***(Francoz et al., 2005; Dumortier et al., 2002).***

Doppler-ultrasound examination remains the most common initial diagnostic tool. However, it has limitations in detecting thrombosis due to (spontaneous or medical) recanalization and because of thrombus extension to the mesenteric veins, which cannot always be visualized clearly. Therefore, computed tomography and magnetic resonance angiography have an important role in diagnosing this condition ***(DeLeve et al., 2009).***

The preoperative identification of PVT enables surgical planning and the exclusion of patients with malignant thrombosis from listing for LT. Several classifications have been proposed so far; the Yerdel classification gained the greatest acceptance and widespread clinical application ***(Yerdel et al., 2000).***

Yerdel et al. (2000) described the grading scheme for PVT as follows: Grade 1, minimally or partially thrombosed portal vein, in which the thrombus is mild or, at the most, confined to 50% of the vessel lumen with or without minimal extension into the superior mesenteric vein; Grade 2, 50% occlusion of the PV, including total occlusions, with or without minimal extension into the superior mesenteric vein; Grade 3, complete thrombosis of both portal vein and proximal superior mesenteric vein. Distal superior mesenteric vein is open; Grade

4, complete thrombosis of the portal vein and proximal as well as distal superior mesenteric vein.

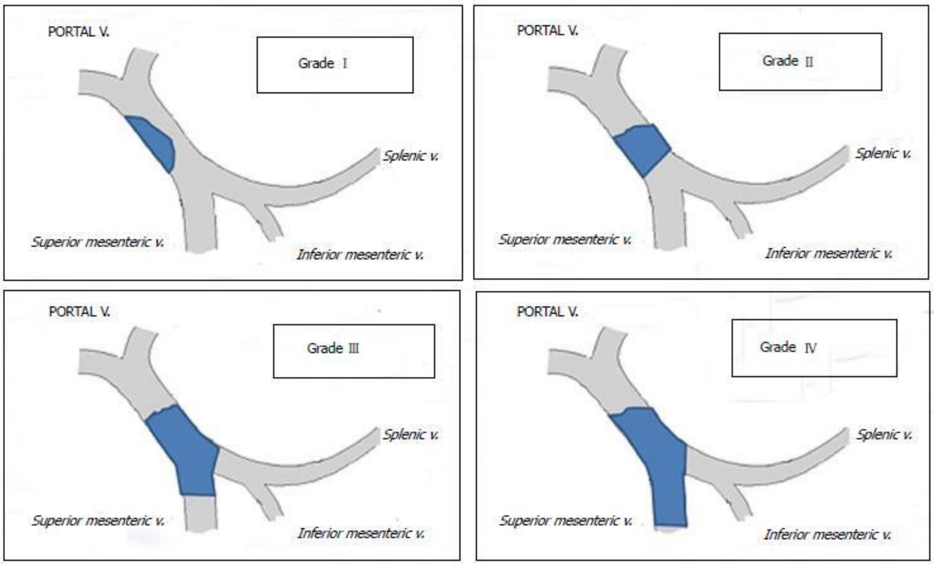

Figure (1): Portal vein thrombosis classification according to ***Yerdel et al. (2000).***

PV: Portal vein; SMV: Superior mesenteric vein.

Accordingly, patients with PVT have distinct characteristics, which can affect their perioperative course. The presence of PVT used to be a contraindication to living donor liver transplantation (LDLT). This is related to the technical difficulties of PV reconstruction, prolonged warm ischemia time, and operative blood loss. Also, the increased risk for postoperative PV anastomotic stenosis may cause relapse of PVT, affecting seriously the function of the liver graft and the recipient survival.

Nowadays, with the development of strategies for vascularization of the portal graft portal and refinement of surgical techniques, liver transplantation in patients with PVT is part of the routine in major transplant centers.

Nevertheless, PVT still remains a serious risk factor. During surgery, the initial attempt to overcome PVT is thrombectomy. It has been reported to be successful in 31–95% ***(Bertelli et al., 2005)***.

The surgical strategies are: resection of the affected segment and primary anastomosis, thrombectomy, grafting to superior mesenteric vein, to the splenic vein or varix, and portal arterialization, hemitransposition cavoportal, renoportal anastomosis and multivisceral transplant.

Eversion thrombectomy is the standard technique for removal of PV thrombus at time of transplant. The PV is transected high in the hilum, and the walls are grasped with tonsil clamps. Gentle traction is applied to the edge of the thrombus with a clamp, and a plane between the clot and vessel endothelium is gently developed with a Freer elevator ***(Dumortier et al., 2002)***

Recently modified eversion technique was developed which is the same as eversion thrombectomy with some important modifications. ***(Song et al., 2016)***

In some cases with a well-organized, chronic thrombus densely adherent to the vessel wall, the intima is also separated from the media of the vein wall (thrombendvenectomy) ***(Molmenti et al., 2002).***

However, failed thrombectomy may necessitate vessel grafting. Vessel grafts, which are used as a bypass or bridge, can be easily obtained from a cadaveric donor during the process of cadaveric liver transplantation, which is not possible in LDLT.

In the presence of complete thrombosis of the venous mesentericoportal system (grade IV) and in the absence of other tributaries for revascularization, hemi-transposition cavoportal, renoportal anastomosis, portal arterialization and multivisceral transplantation are alternatives.

Despite the improved results, this group of patients should still be considered high risk and should be referred to centers with experience in this type of complication.

Choosing the optimal approach in an individual case depends on the preoperative diagnosis and the surgeon’s preference.

The aim of the study is to compare between thrombectomy of PVT using vascular clamps "eversion" & manual technique "modified eversion" during liver transplantation regarding

- Operative time
- Degree of blood loss
- Portal vein rethrombosis.
- Post-operative mortality.

AIM OF THE WORK

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ANATOMY

The liver is the largest gland in the body and in adults it measures roughly 1500 g, constituting 2.5% of total body weight ***(Si-Tayeb et al., 2010).***

Embryologically, the liver develops from foregut endoderm during the third week of gestation. The blood supply to the fetal liver includes the portal and the umbilical veins ***(Olyuinka et al., 2007)***.

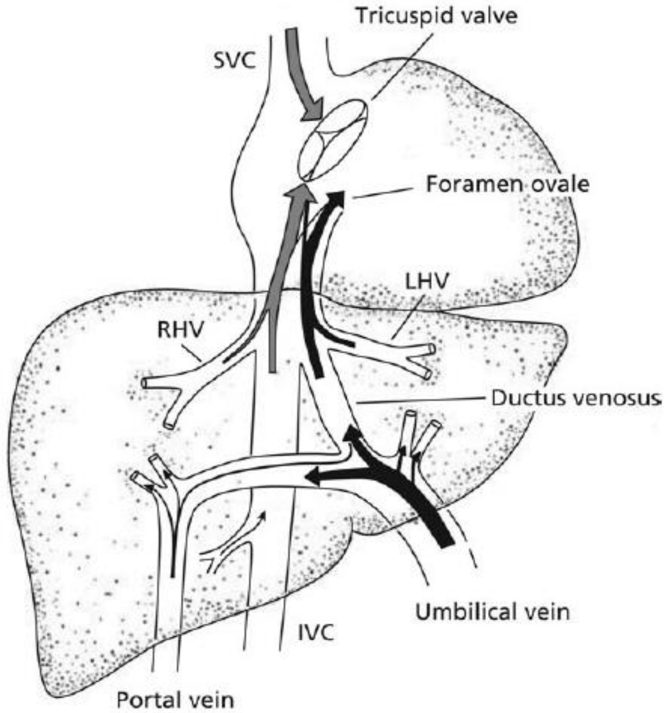

Figure (2): Fetal circulation: the umbilical and portal veins supply the liver caudally while the hepatic veins drain the liver cranially. The ductus venosus is obliterated shortly after birth. Rudolph AM, Congenital Disease of the Heart: Clinical- Physiological Considerations. 3rd Ed. 2013 John Wiley & Sons, Inc.

Anatomical understanding of the liver has changed dramatically through the centuries. Historically, the most fundamental segmentation of liver parenchyma was based on liver topography and produced the concept that the anatomical division between the right and left hemilivers lay at the falciform ligament.

In 1897, Sir James Cantlie changed that framework with observations at autopsy of a patient with an atrophic right lobe ***(Juza et al., 2014).***

Importantly, Cantlie noted that the line of atrophy was lateral to the falciform ligament, along a line described as running from the fundus of the gallbladder to the IVC as it exits the liver superiorly; this is now known as Cantlie's line ***(Chen et al., 2013)***.

He correctly proposed that this line represented the true anatomical division between the right and left liver and further supported his work by identifying it as the demarcation between the distributions of the right and left portal veins.

In the decades since Cantlie, multiple publications have further classified hepatic anatomy to help in the performance of advanced surgeries of the hepatobiliary system. In each case, the respective authors worked to divide the liver anatomically to allow surgical resection and aid communication among liver surgeons.

Therefore, while the works of previous authors have made important contributions to understanding hepatic anatomy, it is Couinaud's fundamental system that has been most readily adopted by the surgical community, albeit with important modifications ***(Juza et al., 2014).***

Segmental anatomy of the liver

Modern hepatic surgery, especially hepatic resection, is based on the segmental anatomy as described by Couinaud, which describes eight distinct liver segments ***(Juza et al., 2014)***.

Each of these segments has its own portal venous supply and separate hepatic venous and biliary ductal drainage and could therefore theoretically be individually resected or survive on its own. The Couinaud system of nomenclature is also being used with increasing frequency by radiologists performing cross-sectional imaging studies of the liver ***(Gazelle et al., 1993; Lafortune et al., 1991; Sugarbaker et al., 1990).***

There are eight distinct hepatic segments. Segment I is the caudate lobe. The remainder of the liver is divided into the "left liver' and the "right liver" by the middle hepatic vein.

Segments II, III, and IV are within the left liver and are supplied by branches of the left portal vein; segments V- VIII are within the right liver and are supplied by branches of the right portal vein. The left liver is divided into two sectors by the left hepatic vein; segments III and IV (anterior sector) are anterior to the vein, whereas segment II (posterior sector) is posterior to it.

Within the anterior sector, segment III is separated from segment IV by the umbilical fissure and falciform ligament. The right liver is separated from the left liver by the main portal scissura (Cantlie line)-a parasagittal plane that passes through the inferior vena cava and the long axis of the gallbladder and contains the middle hepatic vein.

The right liver is divided into the anterior sector (which includes segments V and VIII) and the posterior sector (which contains segments VI and VII) by the right portal scissura an off-coronal plane containing the right hepatic vein and the inferior vena cava.

Finally, segments V and VI (inferior segments) are separated from segments VII and VIII (superior segments) by an axial plane containing the “horizontal” portion of the right portal vein.

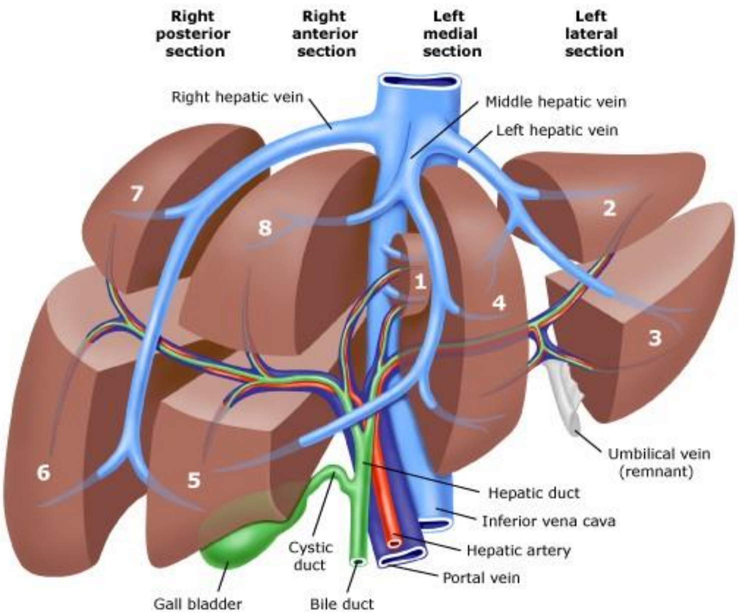

Figure (3): Segmental anatomy of the liver ***(Pauli et al., 2012)*.**

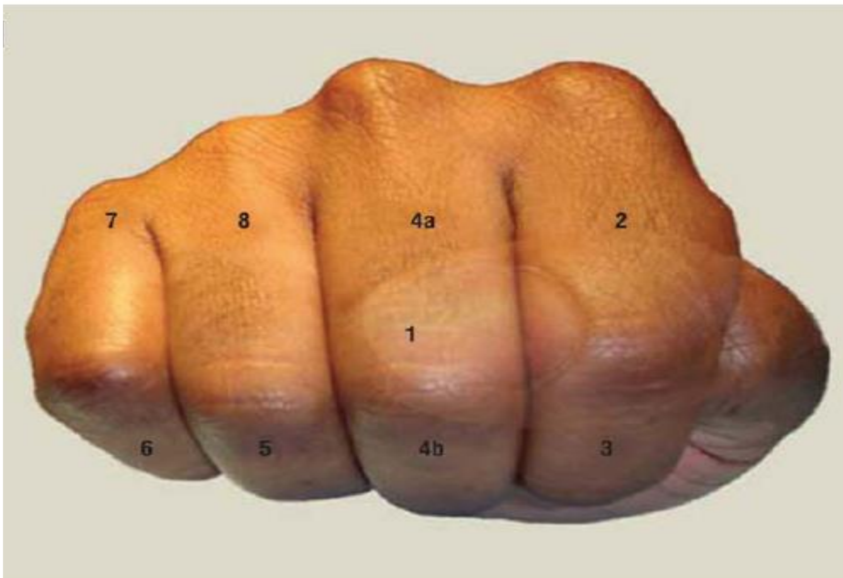

Figure (4): Segmental anatomy of the liver ***(Pauli et al., 2012)*.**

Portal vein anatomy

Intrahepatic portal vein anatomy was described many years ago on cadaveric liver dissection and with corrosion casts of explanted liver ***(Schmidt et al., 2008).***

Modern imaging techniques such as multi-slice computed tomography (CT) or magnetic resonance imaging (MRI) now allow for three-dimensional (3D) reformation of the entire liver vascular structures, and offer an interactive platform for surgeons and interventional radiologists to decide preoperatively the best treatment options ***(Atasoy et al., 2006; Kitami et al., 2006; Koc et al.,2007).***

Recent developments in liver surgery, with living donor transplantation ***(Bassignani et al., 2001)*** or complex liver resection, and in interventional radiology with portal vein embolization (PVE) techniques ***(de Baere et al., 1993; Denys et al., 2002)*** has made mandatory the precise and reliable preoperative imaging of vascular anatomy.

The normal portal vein anatomy is defined as the portal trunk divides in the liver hilum into two branches: the left portal vein branch and the right portal vein branch. The right portal vein branch divides secondarily into two branches: the right anterior portal vein feeding segments V and VIII and the right posterior vein feeding segments VI and VII.

Any deviation from this anatomy is considered an anatomical variant. The normal anatomy is encountered in 65 to 80% in the studies using multi-detector CT with reconstruction of the portal anatomy ***(Atasoy et al., 2006; Koc et al., 2007).***

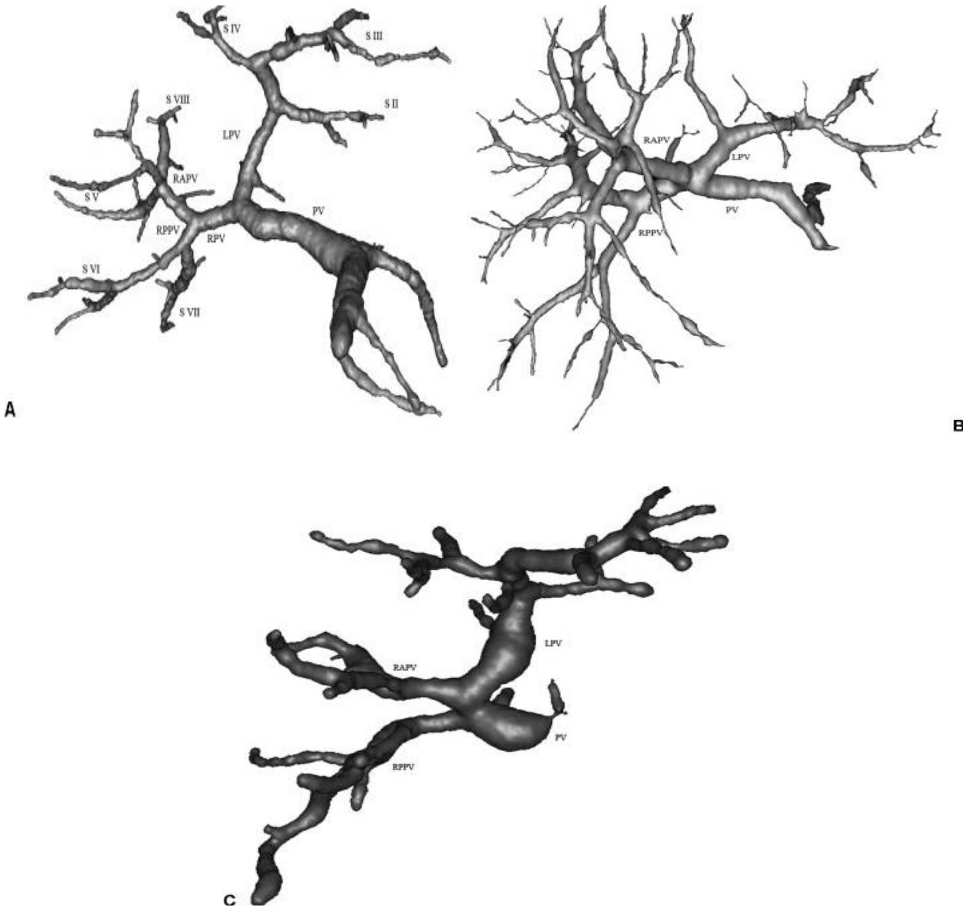

Figure (5): Three-dimensional (3D) reformation of the main types of portal vein division. (A) Antero-inferior view of 3D reformation of the portal system. The normal anatomy is defined by division of the portal trunk into a left portal vein branch (LPV), and a right portal branch (RPV) that subsequently divides in an anterior (RAPV) and a posterior (RPPV) branch. (B) Anterior view of a 3D reformation of the portal system of a patient with a trifurcation. This patient has a portal vein that divides directly in three branches the LPV, RAPV, and RPPV. (C) Antero-inferior view of a 3D reformation of a patient with a RPPV with an early origin on the portal vein (PV).

There are number of variants for the anatomy of portal vein.

The most common variant is the so called ‘‘portal vein trifurcation’’ where the main portal vein divides into three branches: the left portal vein, the right anterior portal vein, and the right posterior portal vein.

The second most common variant is a right posterior portal vein originating as the first branch of the portal vein.

These two variants account for the majority of main portal vein variation. Their relative incidence varies from study to study and the reported incidence of these variants increases with the use of the most recent imaging modalities.

The use of 3D reconstruction obtained from thin axial CT images seems the most efficient technique with reported incidences of 27 and 35% ***(Atasoy et al., 2006; Koc et al., 2007; Covey et al., 2004).***

Less common portal vein variations have been described but their incidence has not been found to be higher than 2% ***(Atasoy et al., 2006; Koc et al., 2007).*** The variants include quadrification in which the portal vein divides into a left portal branch and three separate right portal branches and a more complex variant is the so-called ‘‘absence of portal vein bifurcation’’ ***(Koc et al., 2007).***

In the latter case, the portal vein gives only a single right portal branch in the liver hilum, the origin of the left portal branch being absent. A large portal branch coming from segment VIII crosses segments VIII and VI and ends in the umbilical portion of the portal vein and then supplies a small segment of left portal branch that gives the segments II, III, and IV branches.

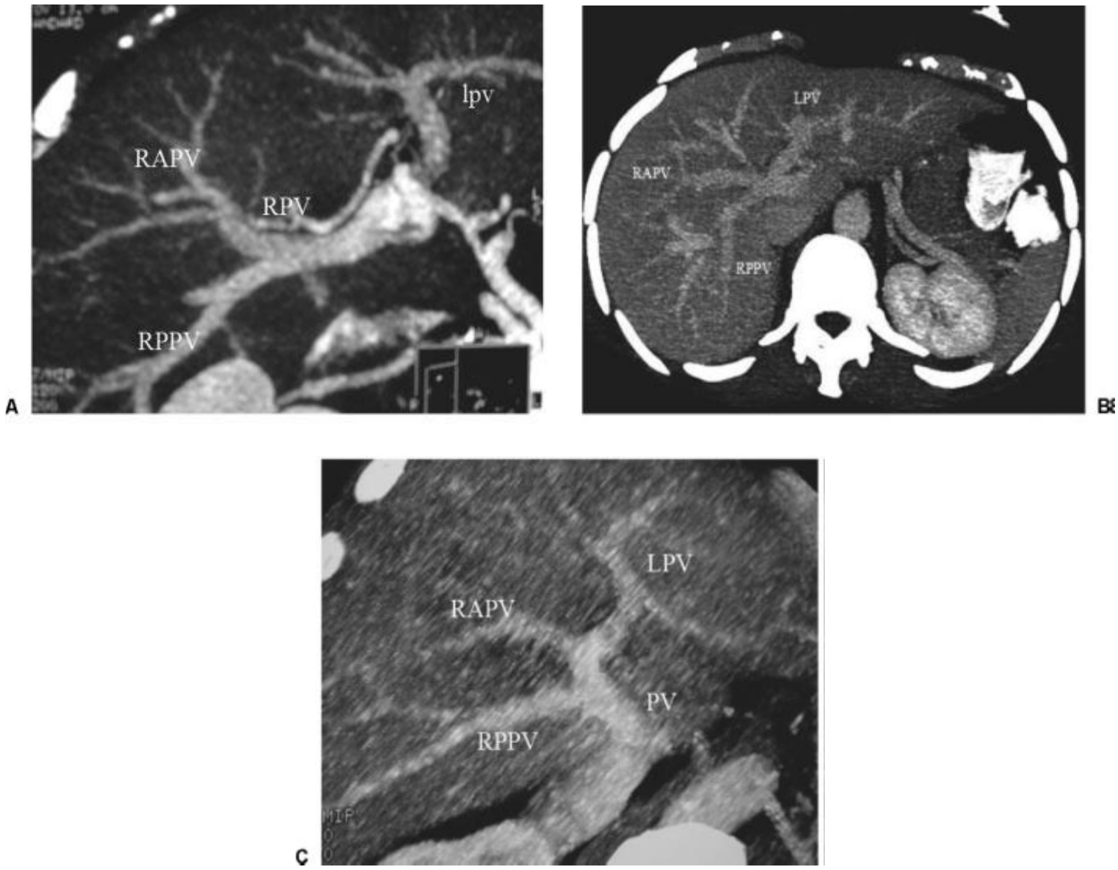

Figure (6): Maximal intensity projection view of the portal vein bifurcation. (A) Normal anatomy is demonstrated on this view with the division of the portal vein in right and left portal branches. (B) Portal trifurcation is shown as the portal vein divides in three branches the LPV, RAPV, and RPPV. (C) A type 3 division is shown as the RPPV originates as the first branch of the portal vein, which gives then a branch that divides after in LPV and RAPV.