Introduction

Portal vein embolization (PVE) has been gaining increasing acceptance before major hepatectomy in liver malignancy, PVE has achieved significant improvement in the outcome of major hepatectomy, and has enlarged the candidate pool of liver resection as well ***(Liu and Zhu, 2009).***

Preoperative portal vein embolization is a safe and effective procedure in inducing liver hypertrophy to prevent post-resection liver failure due to insufficient liver remnant ***(Abulkhir et al.,2008).***

PVE prior to extensive resection in colorectal liver metastasis a necessity rather than an option ***(Belghiti and Benhaïm, 2009).***

Multiple studies were investigated to evaluate peri-operative outcome and survival after major hepatic resection for hepatocellular carcinoma (HCC) with and without PVE, revealed that PVE before major hepatic resection for HCC is associated with improved perioperative outcome and survival ***(Palavecino et al.,2009)***

Portal vein ligation is as effective as PVE in inducing hypertrophy of the remnant liver volume ***(Capussotti et al.,2008).***

Portal vein ligation is as effective as sequential portal vein and hepatic artery ligation in inducing contralateral liver hypertrophy so no additional benefit of arterial ligation was observed ***(Vetelainen et al.,2006).***

Aim of the Work

The aim of this work is to assess the value of portal vein embolization or ligation as a preoperative method to improve the outcome of hepatic resection in liver malignancy.

Anatomy of the Portal Vein

The portal venous system comprises all of the veins draining the abdominal part of the digestive tract (including the lower esophagus but excluding the lower anal canal) and from the spleen, pancreas, and gall bladder (Figure 1) ***(Gray, 2004).***

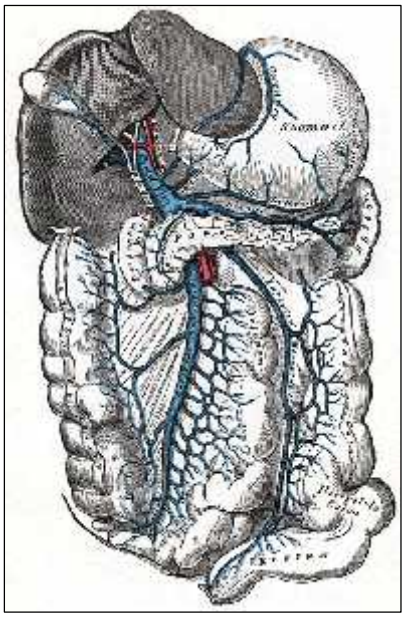

Figure (1): The portal vein and its tributaries ***(Gray, 2004).***

From these viscera the blood is conveyed to the liver by the portal vein. In the liver this vein ramifies like an artery and ends in capillary-like vessels termed sinusoids, from which the blood is conveyed to the inferior vena cava by the hepatic veins (Figure 2) ***(Gray, 2004).***

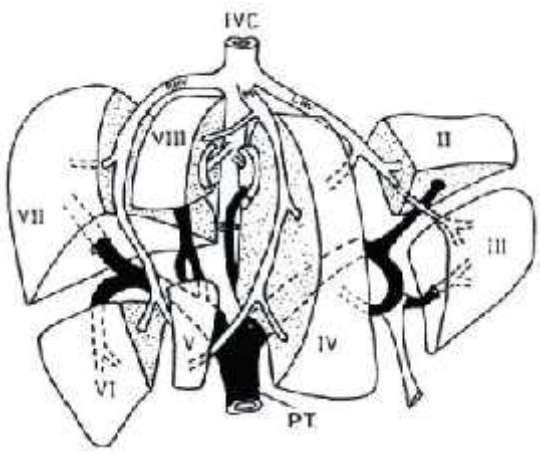

Figure (2): Segmental portal vein radicles and hepatic venous drainage to the I.V.C ***(Gray, 2004).***

From this it will be seen that the blood of the portal system passes through two sets of minute vessels:

(A) The capillaries of the digestive tube, spleen, pancreas, and gall bladder.

(B) The sinusoids of the liver ***(Gray, 2004).***

The portal vein is about 8 cm. in length, and is formed at the level of the second lumbar vertebra by the junction of the superior mesenteric and lineal veins, the union of these veins takes place in front of the inferior vena cava and behind the neck of the pancreas ***(Gray, 2004).***

It passes upward behind the superior part of the duodenum and then ascends in the right border of the lesser omentum to the right extremity of the porta hepatis, where it divides into a right and a left branch, which accompany the

corresponding branches of the hepatic artery into the substance of the liver. In the lesser omentum it is placed behind and between the common bile duct and the hepatic artery, the former lying to the right of the latter ***(Gray, 2004).***

The portal vein is surrounded by hepatic plexus of nerves, and is accompanied by numerous lymphatic vessels and some lymph glands ***(Gray, 2004).***

The right branch of the portal vein enters the right lobe of the liver, but before doing so generally receives the cystic vein. The left branch, longer but of smaller caliber than the right, crosses the left sagittal fossa and then enters the left lobe of the liver. As it crosses the left sagittal fossa it is joined in front by a fibrous cord, the ligamentum teres (*obliterated umbilical vein*), and is united to the inferior vena cava by a second fibrous cord, the ligamentum venosum (*obliterated ductus venosus*) ***(Gray, 2004).***

The main, right and left portal veins are in the hilar fissure. The portal bifurcation may be extrahepatic, intrahepatic, or located right at the entrance of the liver. On the right, there are usually two sectoral portal branches (anterior and posterior); on the left, there are two parts to the (main) left portal vein: the extrahepatic portion (the horizontal part) and the intrahepatic portion (the umbilical [vertical] part). In general, the sectoral branch divides into several segmental portal branches, which in turn supply the various segments ***(Madoff et al., 2002).***

One segmental branch usually supplies segments II, VI, and VII and, more rarely, segment III. Segments IV, V, and VIII are commonly supplied by more than one segmental branch. Segmental veins then divide into subsegmental branches, which further divide into small veins leading to the portal venule of the liver acinus (Figure 3) ***(Madoff et al., 2002).***

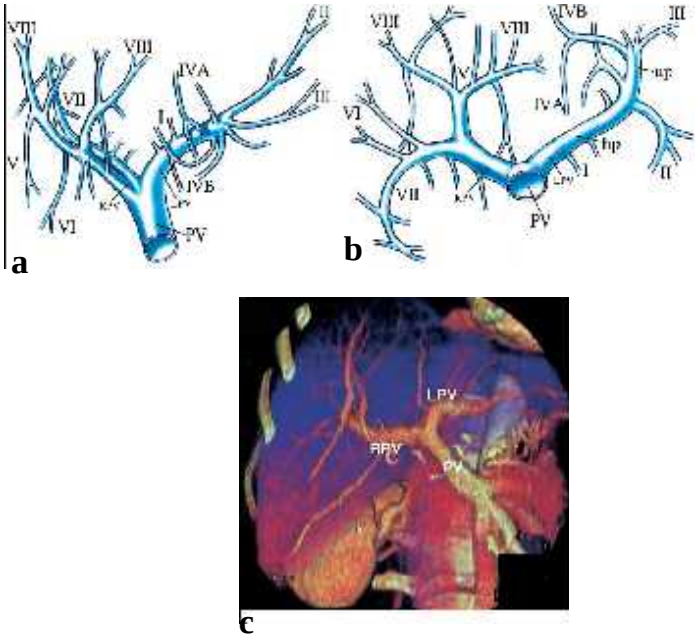

Figure (3): (a,b) Schematics illustrate the normal portal vein (PV) branches from anterior **(a)** and inferior **(b)** perspectives. Hp-horizontal part, LPV-left portal vein, RPV-right portal vein, up-umbilical (vertical) part. **(c)** Three-dimensional computed tomographic (CT) reformatted image (anterior view) demonstrates normal portal venous anatomy. LPV- left portal vein, PV-portal vein, RPV-right portal vein ***(Madoff et al., 2002).***

The liver is divided into two lobes (left and right, separated by the main portal fissure) and eight segments (Figure 4) ***(Madoff et al., 2002).***

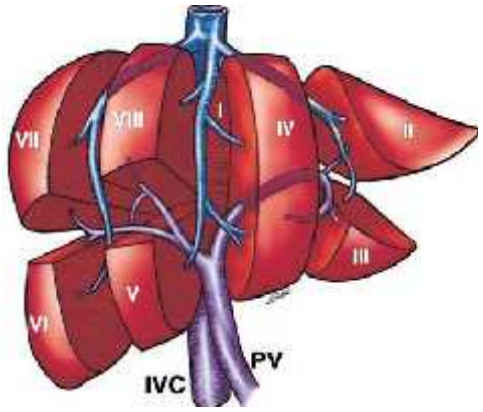

Figure (4): Couinaud segmental liver anatomy and the normal portal venous structures. IVC-inferior vena cava, PV-portal vein ***(Madoff et al., 2002).***

Hepatic segmentation is based on the distribution of the portal pedicles and the location of the hepatic veins ***(Gallego et al., 2002).***

The tributaries of the portal vein are:

1- Lienal.
2- Superior Mesenteric
3- Coronary.
4- Pyloric.
5- Cystic.
6- Paraumbilical (Figure 5)

(Gray, 2004).

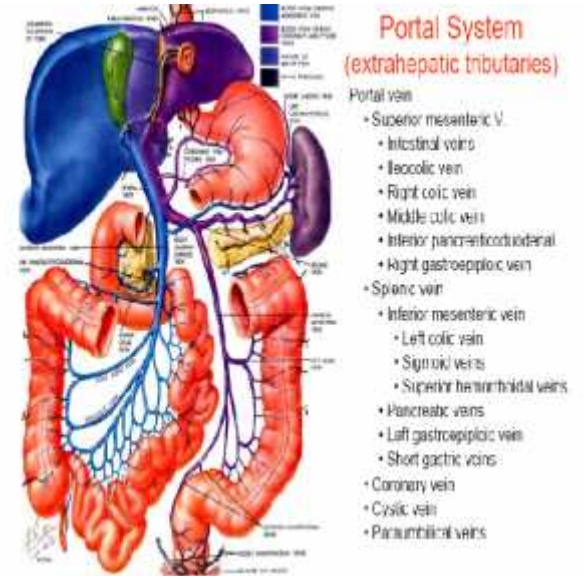

Figure (5): Portal vein and its extrahepatic tributaries ***(Madoff et al., 2002).***

1-Lienal Vein(*splenic vein*): It passes from left to right, grooving the upper and back part of the pancreas, below the lineal artery, and ends behind the neck of the pancreas by uniting at a right angle with the superior mesenteric to form the portal vein. The lienal vein is of large size, but is not tortuous like the artery.

Tributaries:

- *Short gastric veins.*
- *Left gastroepiploic vein.*
- *Pancreatic veins.*
- *Inferior mesenteric vein* ***(Gray, 2004).***

2-Superior Mesenteric Vein: It begins in the right iliac fossa by the union of the veins which drain the terminal part of the ileum, the caecum, and vermiform appendix, and ascends between the two layers of the mesentery on the right side of the superior mesenteric artery. In its upward course it passes in front of the right ureter, the inferior vena cava, the inferior part of the duodenum, and the lower portion of the head of the pancreas. Behind the neck of the pancreas it unites with the lienal vein to form the portal vein ***(Gray, 2004).***

*Tributaries:*Besides the tributaries which correspond with the branches of the superior mesenteric artery, viz., the *intestinal,*

ileocolic, right colic, and *midde colic veins***,** the superior mesenteric vein is joined by:-

- *Right gastroepiploic vein.*
- *Pancreaticoduodenal veins* ***(Gray, 2004).***

3-Coronary Vein (*gastric vein*): It derives tributaries from both surfaces of the stomach; it runs from right to left along the lesser curvature of the stomach, between the two layers of the lesser omentum, to the esophageal opening of the stomach, where it receives some esophageal veins. It then turns backward and passes from left to right behind the omental bursa and ends in the portal vein ***(Gray, 2004).***

4-Pyloric Vein: it is of small size, and runs from left to right along the pyloric portion of the lesser curvature of the stomach, between the two layers of the lesser omentum, to end in the portal vein ***(Gray, 2004).***

5-Cystic Vein: It drains the blood from the gall-bladder, and, accompanying the cystic duct, usually ends in the right branch of the portal vein ***(Gray, 2004).***

6- Paraumbilical Veins: In the course of the ligamentum teres of the liver and of the middle umbilical ligament, small veins (*paraumbilical*) are found which establish an anastomosis between the veins of the anterior abdominal wall and the portal,

hypogastric, and iliac veins. The best marked of these small veins is one which commences at the umbilicus and runs backward and upward in, or on the surface of, the ligamentum teres between the layers of the falciform ligament to end in the left portal vein ***(Gray, 2004).***

Embryology of the portal vein:

In the fifth week, The formation of the great veins of the embryo may be best considered by dividing them into two groups, visceral and parietal ***(Gray, 2004).***

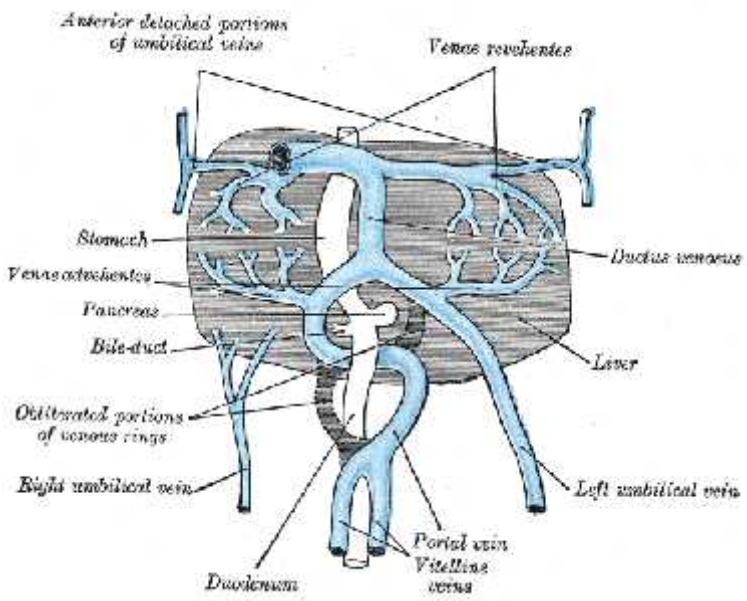

Figure (6): The liver and the veins in connection with it, of a human embryo, twenty-four or twenty-five days old, as seen from the ventral surface ***(Gray, 2004).***

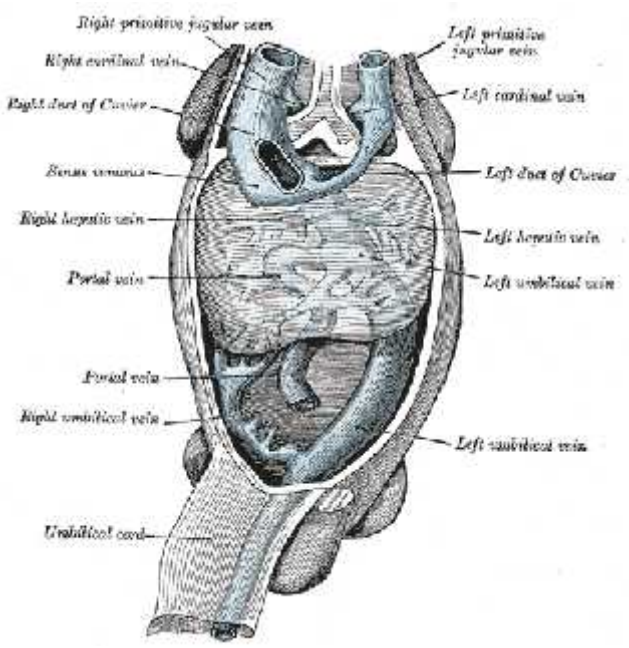

Figure (7): Human embryo with heart and anterior body-wall removed to show the sinus venosus and its tributaries ***(Gray, 2004).***

The visceral veins are the two vitelline or omphalo-mesenteric veins bringing the blood from the yolk-sac, and the two umbilical veins returning the blood from the placenta; these four veins open close together into the sinus venosus ***(Gray, 2004).***

The vitelline veins run upward at first in front, and subsequently on either side of the intestinal canal. They unite on the ventral aspect of the canal, and beyond this are connected to one another by two anastomotic branches, one on the dorsal, and the other on the ventral aspect of the duodenal

portion of the intestine, which is thus encircled by two venous rings (Figure 6); into the middle or dorsal anastomosis the superior mesenteric vein opens. The portions of the veins above the upper ring become interrupted by the developing liver and broken up by it into a plexus of small capillary-like vessels termed sinusoids (Minot). The branches conveying the blood to this plexus are named the venae advehentes, and become the branches of the portal vein; while the vessels draining the plexus into the sinus venosus are termed the venae revehentes, and form the future hepatic veins (Figure 7). Ultimately the left vena revehentes no longer communicates directly with the sinus venosus, but opens into the right vena revehentes. The persistent part of the upper venous ring, above the opening of the superior mesenteric vein, forms the trunk of the portal vein ***(Gray, 2004).***

The two umbilical veins fuse early to form a single trunk in the body-stalk, but remain separate within the embryo and pass forward to the sinus venosus in the side walls of the body. Like the vitelline veins, their direct connection with the sinus venosus becomes interrupted by the developing liver, and thus at this stage the whole of the blood from the yolk-sac and placenta passes through the substance of the liver before it reaches the heart. The right umbilical and right vitelline veins shrivel and disappear; the left umbilical, on the other hand, becomes enlarged and opens into the upper venous ring of the vitelline veins; with the atrophy of the yolk-sac the left vitelline

vein also undergoes atrophy and disappears. Finally a direct branch is established between this ring and the right hepatic vein; this branch is named the ductus venosus, and, enlarging rapidly, it forms a wide channel through which most of the blood, returned from the placenta, is carried direct to the heart without passing through the liver. A small proportion of the blood from the placenta is, however, conveyed from the left umbilical vein to the liver through the left vena advehens. The left umbilical vein and the ductus venosus undergo atrophy and obliteration after birth, and form respectively the ligamentum teres and ligamentum venosum of the liver***(Gray, 2004).***

In the adult the portal vein and its tributaries do not contain valves; in the fetus and for a short time after birth valves can be demonstrated in the tributaries of the portal vein; as a rule they soon atrophy and disappear, but in some subjects they persist in a degenerate form ***(Gray, 2004).***

Anatomical variants of the portal venous system:

Congenital anomalies of the portal venous system comprise total or partial agenesis of the portal vein, abnormal branching of the portal vein, venous malposition (in situs inversus totalis or in midgut malrotation), arterio-venous malformations, and persistence of fetal valves. The etiology of aneurysms of the portal venous system and some intrahepatic porto-systemic shunts is still controversial ***(Gallego et al., 2002).***

Branching Variants of the Portal Vein:

The portal vein results from the confluence of the superior mesenteric and splenic veins posterior to the neck of the pancreas. In its most common branching pattern, it divides at the porta hepatis into right and left portal veins. As it courses cranially, the right portal vein first gives off branches to the caudate lobe and then divides into anterior and posterior branches, which subdivide into superior and inferior segmental branches to supply the right lobe of the liver. The left portal vein first has a horizontal course to the left and then turns medially toward the ligamentum teres (umbilical portion), supplying the lateral segments (segments II and III) of the left lobe. It describes a wide and anteriorly concave curve and ends in the superior and inferior segmental branches of segment IV ***(Gallego et al., 2002).***

The landmarks that we use to describe the normal anatomy of the portal venous system at the liver are the main and right portal vein, the lateral segment and umbilical portion of the left portal vein, the ligamentum teres, the inferior vena cava, and the fossa for the gall bladder. The Cantlie line is defined as a line passing through the gall bladder toward the inferior vena cava and corresponds to the median fissure. It serves as a boundary between the right and left lobes (Figure 8) ***(Gallego et al., 2002).***

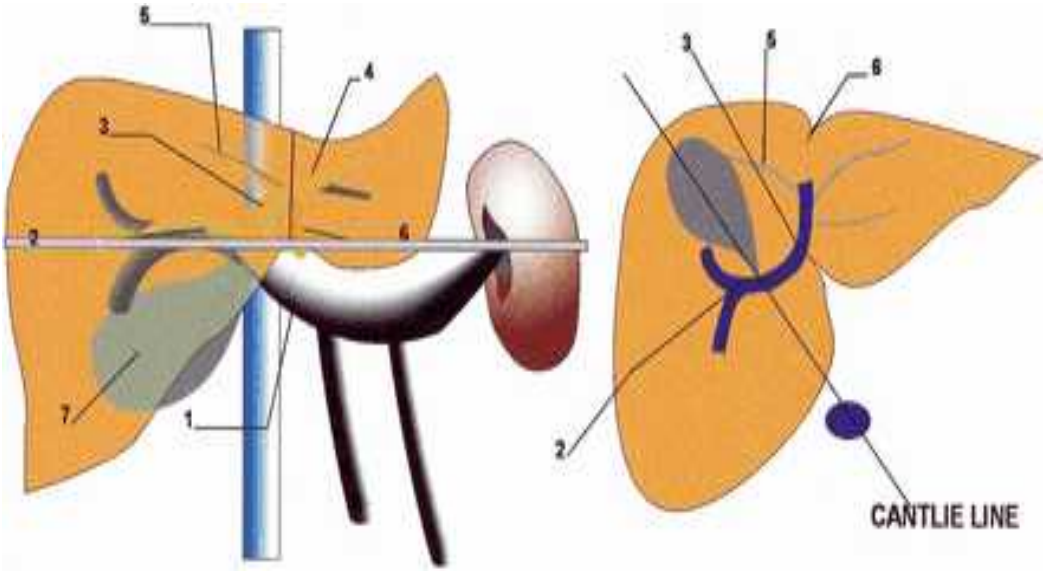

Figure (8): Normal branching pattern of the portal vein. Coronal (left) and axial (right) diagrams show that the main portal vein (1) divides into the right (2) and left portal veins. The left portal vein first courses horizontally (horizontal portion [3]), then turns anteriorly (umbilical portion [4]) toward the ligamentum teres (6). The Cantlie line corresponds to the median fissure and extends from the gallbladder (7) to the inferior vena cava. It is located to the right of the umbilical ligament and divides the liver into right and left lobes. 5 = branch to segment IV ***(Gallego et al., 2002).***

A spectrum of branching variants of the portal vein associated with mal-position of the gall bladder has been described in recent years. Findings comprise an abnormal course of the horizontal portion of the left portal vein and an abnormal umbilical portion that is located above the gall bladder fossa. The gall bladder is deviated to the left and may lie to the left of or astride the ligamentum teres. The Cantlie line does not serve as a boundary between the right and left lobes in these cases (Figure 9) ***(Gallego et al., 2002).***