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# Anatomical variations of hepatic veins in Vietnamese adults

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**SUMMARY**

The hepatic venous anatomic variations on hepatic resection and transplantation are very important and the least understood aspect of the liver. In particular, data are lacking in the literature with reference to Vietnamese patients. The objective of this study was to examine the morphologic and biometric variations of the hepatic veins in Vietnamese cadavers. Livers from 20 Vietnamese cadavers preserved in formalin solution were used in this study. Specimens were carefully scraped by curette to expose the branches of hepatic veins. Diameters, lengths and morphologic hepatic variations were recorded. The average diameters of veins were: 34.78 mm (IVC), 20.26 mm (RHV), 14.35 mm (MHV), 14.76 mm (LHV), and 22.49 mm (common trunk). The average length of the common trunk was 6.45 mm; 35% of cases in the short group (< 10 mm), and 65% in the long group (≥ 10mm). A common trunk was present in 90% of specimens. The morphology of the common trunk was comparable to that observed by other investigators. Only 10% of cases had accessory RHVs of Type II, with a main trunk and accessory branches to the IVC, in contrast to 90% of Type I, with a main trunk alone. The anatomical variations of the hepatic veins are very diverse. Knowledge of these variations prior to surgery is useful during both partial hepatectomy and segmental liver transplantation. Pre-operative hepatic venous imaging can allow for assessment of venous flow and morphology, and may lessen surgical complications.

**Key Words:** Hepatic Vein – Hepatectomy – Hepatic Transplantation

***Abbreviations:***

Computerized Topography (CT)
Hepatic Venous Outflow (HVO)
Inferior Vena Cava (IVC)
Left Hepatic Vein/Left Hepatic Veins (LHV/LHVs)
Living Donor Liver Transplantation (LDLT)
Magnetic Resonance Imaging (MRI)
Middle Hepatic Vein/Middle Hepatic Veins (MHV/MHVs)
Right Hepatic Vein/Right Hepatic Veins (RHV/RHVs)
Split Liver Transplantation (SLT)

## INTRODUCTION

Accurate knowledge of the anatomy of hepatic veins and their relation to the inferior vena cava (IVC) is important in liver surgery, including partial hepatic resection, hepatic trauma and liver transplantation (Nakamura and Tsuzuki, 1981). This understanding of hepatic veins and their anatomical variations helps to prevent massive bleeding, as well as air embolism due to large tearing of the

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major veins, and assists in the maintenance of adequate hepatic venous outflow (HVO) following surgery.

The effect of HVO on liver function is likely the least understood aspect of liver surgery. Maintaining HVO plays a key role in preventing hepatic dysfunction or failure, depending on the various degrees of HVO obstruction. However, the factors that yield adequate HVO after liver surgery still remain controversial.

Although hepatic vein ligation was tolerated in liver trauma patients (Ou and Hermann, 1984), human hemodynamic studies showed that, after ligation of a hepatic vein, an intrahepatic shunt occurred in the region of hepatic vein occlusion, with or without reversal of blood flow in the portal system (Ou and Hermann, 1984; Sakaguchi and Suzuki, 2010). This results in mild or moderate damage of liver function, which may lead to liver cell regeneration. In patients with cirrhosis, obstructive jaundice, or in a liver transplant patient (where the graft is of a borderline size), there may be occlusion of HVO in a part of the liver, greatly affecting the patient outcome. Therefore, the understanding of hepatic venous anatomy before surgery allows for optimal preoperative planning, and a wider margin of operative safety.

On the other hand, positive results in liver transplantation have extended both the quality and length of patient lives, leading to graft deficiency worldwide. Technical improvements in split liver transplantation (SLT) and living donor liver transplantation (LDLT) have increased the source of donor liver tissues for adults and children (Broering et al., 2008; Jin et al., 2004). LDLT is associated with risk of complications in donors, and it is important to minimize complications in both donors and recipients, to increase the success rate and the application of liver transplantation techniques. Most postoperative biliary and vascular complications are associated with surgical techniques and anatomical variations.

Although there are a range of modalities such as ultrasound in surgery, angiography, computed tomography (CT), magnetic resonance imaging (MRI), that are used routinely in living donors to delineate the blood vessels and bile anatomy (Marcos, 2000), these procedures are not routinely performed in liver transplant examination. Moreover, not all abnormalities can be delineated by these means, many of which are obvious only when specifically observed. Therefore, transplantation surgeons must understand the normal anatomy of the liver and be able to recognize the presence and implications of anatomical variants in hepatic vessels.

Restoration of hepato-venous circulation is the essential stage in liver transplantation. In these restoration techniques, preservation of the retrohepatic IVC of the recipient is critical (Belghiti et al., 1992; Bismuth et al., 1992; Calne and Williams, 1968; Meunier et al., 1994; Tzakis et al., 1989). First described by Calne (Calne and Williams, 1968) and then named the "piggy - back” technique as described by Tzakis (Tzakis et al., 1989), the “piggy - back” surgical method allows avoidance of the bleeding stage of retrocaval dissection and resection, especially in patients with cirrhosis (Chevalier, 1988).

Since Tzakis (Tzakis et al., 1989), several techniques for preserving the IVC have been described. Some of these allow for the maintenance of the caval circulation during construction of the anastomosis, avoiding total clamping of the IVC. Preservation of caval flow allows for stabilization of hemodynamics in the patient, and reduces the need for the use of an extracorporeal shunt, which has many complications (Shaw and Martin, 1984). One of these techniques, derived from the "piggy - back" technique of Tzakis (Tzakis, et al., 1889), consists of anastomosing the graft with the common trunk of the middle and left hepatic veins of the recipient. The performance of this anastomosis requires favorable anatomic conditions.

A review of the literature in Vietnam and abroad showed that there are few research studies on hepatic venous anatomy applied in liver resection and transplantation surgery, as well as a lack of data from Vietnamese patients. Therefore, the present research was conducted to provide knowledge of hepatic venous anatomic variations in Vietnamese cadaveric specimens for clinicians and anatomists.

## MATERIALS AND METHODS

### *Anatomical Donors and Preservation*

This study was conducted on the livers of 20 Vietnamese cadavers including 11 males and 9 females. These anatomical donors had been prepared for the use in the formal course in human gross anatomy in the Department of Anatomy at the University of Medicine and Pharmacy at Ho Chi Minh City, Vietnam. The age range of subjects in this cohort was 50 to 89 years with the average age of 68.5 years-old. Livers were excluded from this cohort if the subject had hepatic disease (i.e., cirrhosis, cancer, etc.). All guidelines were followed regarding the use and care of cadaveric materials, as well as all regulations set forth by the Vietnamese Anatomical Education Program.

The embalming procedure is a 2-phase procedure beginning within the first 24 hours after death. The first step of the first phase of the embalming procedure is an injection of an 18 L mixture composed of 37% Formalin (2 L); 1 M Phenol (1 L); Glycerin 1 L, 90% Alcohol (2 L) and water (12 L). Three days following injection, cadavers are placed into 300 L of solution composed of 37% Formalin (2 L); 1 M Phenol (3 L) and water (295 L). The specimens remain submerged in the vat for a minimum of 4 months.

***Dissection***

Briefly, the anterior abdominal wall was cut and opened. A vertical cut was made through the linea alba from the umbilicus to the xiphoid process, and a transverse cut, at the level of the umbilicus, perpendicular to the vertical line. The abdominal wall was reflected in such a way that the liver could be accessed; freeing fixation ligaments (i.e., ligamentum teres, falciform ligaments, triangular ligaments), and exposing the retrohepatic IVC. The liver was removed, including the retrohepatic vena cava. Cadaveric livers were carefully scraped using a curette, on the diaphragmatic and visceral surfaces, to expose the branches of hepatic veins.

***Measurements***

Using a caliper with a center distance attachment, the data were saved and evaluated using SPSS 14.0. The following data were recoded: (1) biometric variables of the hepatic veins and the IVC (i.e., diameter and length); (2) morphologic variables of the common trunk of the middle and left hepatic veins. Results were expressed as mean length (or diameter) in millimeters (mm) ± mm standard deviation (SD).

***Photography***

Digital photography of the external features of the livers and veins was done using a NIKON D3100 SLR Camera (B&H Foto & Electronic Corporation, NY) equipped with an 18-55 mm VR NIKKOR Macro lens and a Nikon 49 mm f/2.8G AF-S DX NIKKOR 2200 VR Micro lens.

## RESULTS

***Biometric Variables***

*Diameter of the IVC*

The mean diameter of the IVC at the site of the junction of the middle hepatic vein (MHV) and left hepatic vein (LHV) is 34.78 mm ± 4.43 mm SD, the largest is 44.83 mm, the smallest is 28.95 mm.

*Diameter of Hepatic Veins*

The right hepatic vein (RHV) was found to have the largest diameter (20.26 mm ± 3.93 mm SD), when compared to the LHV. However, the diameter of the common trunk of the MHV and LHV was larger (22.49 mm ± 4.2 mm SD). The results are shown in Tables 1 and 2.

**Table 1.** Diameter of the Hepatic Veins

| Hepatic Veins | Mean Diameter (mm) | Largest (mm) | Smallest (mm) |
|---|---|---|---|
| **Right Hepatic Vein** | 20.26 ± 3.93 | 27.19 | 11.69 |
| **Middle Hepatic Vein** | 14.35 ± 3.89 | 20.08 | 8.29 |
| **Left Hepatic Vein** | 14.76 ± 2.40 | 18.86 | 9.89 |

**Table 2.** Length of Common Trunks of the Middle and Left Hepatic Veins

| | Mean | Largest / Longest | Smallest / Shortest |
|---|---|---|---|
| **Diameter (mm)** | 22.49 ± 4.2 | 12.19 | 29.22 |
| **Length (mm)** | 6.45 ± 2.8 | 2.13 | 12.14 |

***Morphologic Variables***

*Drainage of Hepatic Veins*

There were 17 (85.00%) cases with 3 hepatic veins and 3 (15.00%) cases with 4 hepatic veins (Fig. 1; Fig. 2 and Fig. 3). Of the 20 specimens

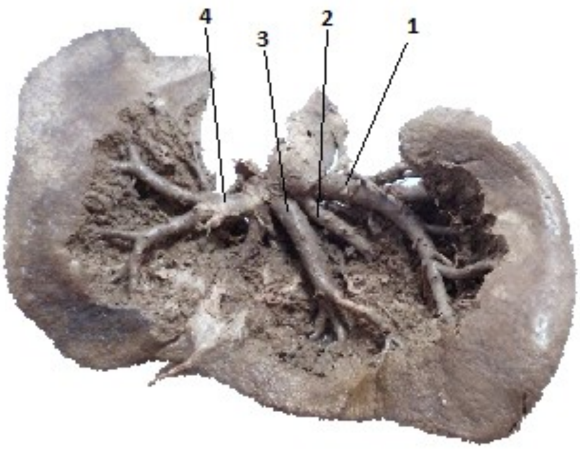


**Fig 1.** Liver specimen with four hepatic veins. This cadaveric specimen is representative of a liver with four (1-4) hepatic veins.


**Fig 2.** Variations of Middle Hepatic Vein. (**A**) drainage for III, IV, V segments; (**B**) drainage for IV, V, VI segments; (**C**) drainage for IV, V, VIII segments; (**D**) drainage for VIII segment.

**Fig 3.** Variations of Left Hepatic Vein. (A) drainage for II, III, IV segments; (B) drainage for IV, V segments. (1) left hepatic vein, (2) middle hepatic vein, (3) right hepatic vein.

**Table 3.** Drainage Types of Hepatic Veins

| | Drainage Segments Types (Couinaud's Segmentation) | Number of Case (percentage) |
|---|---|---|
| **Right Hepatic Vein** | V, VI, VII, VIII | 16 (80.00%) |
| | VI, VII, VIII | 4 (20.00%) |
| **Middle Hepatic Vein** | IV, V | 12 (60.00%) |
| | IV, (1 VIII accessory vein ) | 4 (20.00%) |
| | III, IV, V | 1 (5.00%) |
| | IV, V, VI | 1 (5.00%) |
| | IV, V, VIII | 1 (5.00%) |
| | V, VI, VII, VIII (1 VIII accessory vein) | 1 (5.00%) |
| **Left Hepatic Vein** | II, III | 16 (80. 00%) |
| | II, III, IV | 4 (20.00%) |

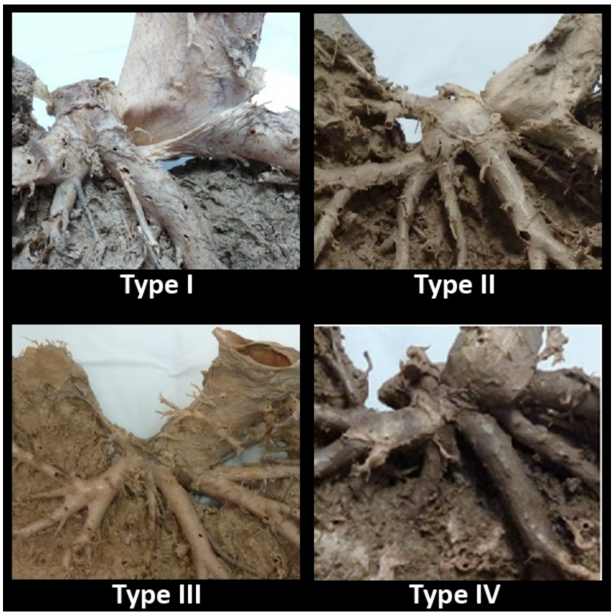


**Fig 4.** Types of the Common Trunk for the Middle and Left Hepatic Veins. Type I is a common trunk not receiving any branch in its last centimeter. Type II consists of a common trunk with 2 branches less than 1 cm from the IVC. Type III consists of a common trunk less than 1 cm, with 3 branches. Type IV includes a common trunk less than 1 cm, with 4 branches.

examined, 18 (90.00%) cases had a common LHV and MHV. The drainage of hepatic veins is shown in Table 3.

*Anatomo-clinical classification for the common trunk of the Middle and Left Hepatic Veins*

For cases with the common trunk of LHVs and MHVs, 7 (35.00%) cases were found to have a short common trunk (<1 cm), and the 13 remaining cases had a long common trunk (≥ 1 cm) (Fig. 4). The mean length was 20.49 ± 4.21 mm SD, the longest was 29.22 mm, the shortest was measured to be 12.19 mm. The general morphology of the MHV and LHV is presented in Table 4 (classification according to increasing difficulty in surgery).

*Morphology of the Right Hepatic Vein*

This study recorded 2 (10%) cases with accessory RHVs (Type I) and 2 types of hepatic veins presented (Table 5 and Fig. 5). The RHV was observed with the main trunk with accessory branch to the IVC.

## DISCUSSION

This study examined the anatomical parameters needed for reconstructing the anastomosis between the upper end of the IVC of the graft and the common trunk of the MHVs and LHVs of the recipient in liver transplantation. A common trunk was present in 90% of cases, and thus, the creation of a new orifice by transection of the MHV and LHV proximal to their junction likely helps achieve a diameter compatible with the IVC diameter. Therefore, this technique makes the anastomosis more suitable during transplantation surgery. Moreover, with this technique, the anastomosis is possible by

**Table 4.** Anatomo-clinical Classification of the Morphology of the Common Trunk of the Middle and Left Hepatic Veins

| Type | Morphologic Criteria | No. of Cases (percentage) |
|---|---|---|
| **I** | No branch < 1cm from the entry of the common trunk into the IVC. No branch emptying directly into the IVC | 5 (25.00%) |
| **II** | One or more branches < 1cm from the ostium of the common trunk except for branches opening directly into the IVC | 11 (55.00%) |
| **III** | One or more branches emptying directly into the IVC whatever the morphology of the common trunk | 2 (10.00%) |
| **IV** | No common trunk | 2 (10.00%) |

**Fig 5.** Accessory Branches of Hepatic Veins. This image shows a sample specimen of the right hepatic vein with two accessory branches.

**Table 5.** Morphology of the Right Hepatic Vein

| Type | Morphology | No. of Cases (percentage) |
|---|---|---|
| I | R hepatic vein with a main trunk | 18 (90.00%) |
| II | R hepatic vein with a main trunk and accessory branches to the IVC | 2 (10.00%) |

**Table 6.** The Proportion of the Common Trunk of the Middle and Left Hepatic Veins

| | Fang (Fang et al., 2012) (%) | Present Study (%) |
|---|---|---|
| Common trunk | 61 | 90 |
| No common trunk | 39 | 10 |

using isolated clamping of the common trunk or lateral clamping of the IVC, thus maintaining partial caval flow.

A common trunk for the MHV and LHV is present in 62 - 97% of cases (Bordei et al., 1996; Camargo et al., 1996; Chang and Shan-Quan, 1989; Couinaud, 1994; Hardy, 1972; Masselot and Leborgne, 1978; Nakamura and Tsuzuki, 1981) with a mean length of 10 mm. Classifications are based on the described morphology. Masselot and Leborgne (Masselot and Leborgne, 1978) recommended a simple classification of 3 types based on the length of the common trunk only (short, long, absent). However, this classification is not sufficient to include all the variations of the common trunk. Nakamura (Nakamura and Tsuzunki, 1981) described a classification based on the branching of the middle and left hepatic vein less than 1 cm from the IVC. These investigators considered 1 cm is the minimum length allowing control of the vein. Nakamura's study (Nakamura and Tsuzunki, 1981) also includes the branches opening either directly into the IVC or into the last centimeter of the common trunk. When the common trunk is less than 1 cm, the MHV and LHV are each considered as 2 separate branches. Type A includes common trunks ≥1 cm not receiving any branch in its last centimeter. Type B consists of common trunks with 2 branches less than 1 cm from the IVC (short trunks or a trunk of over 1 cm associated with a branch). Type C consists of a common trunk less than 1 cm, with 3 branches.

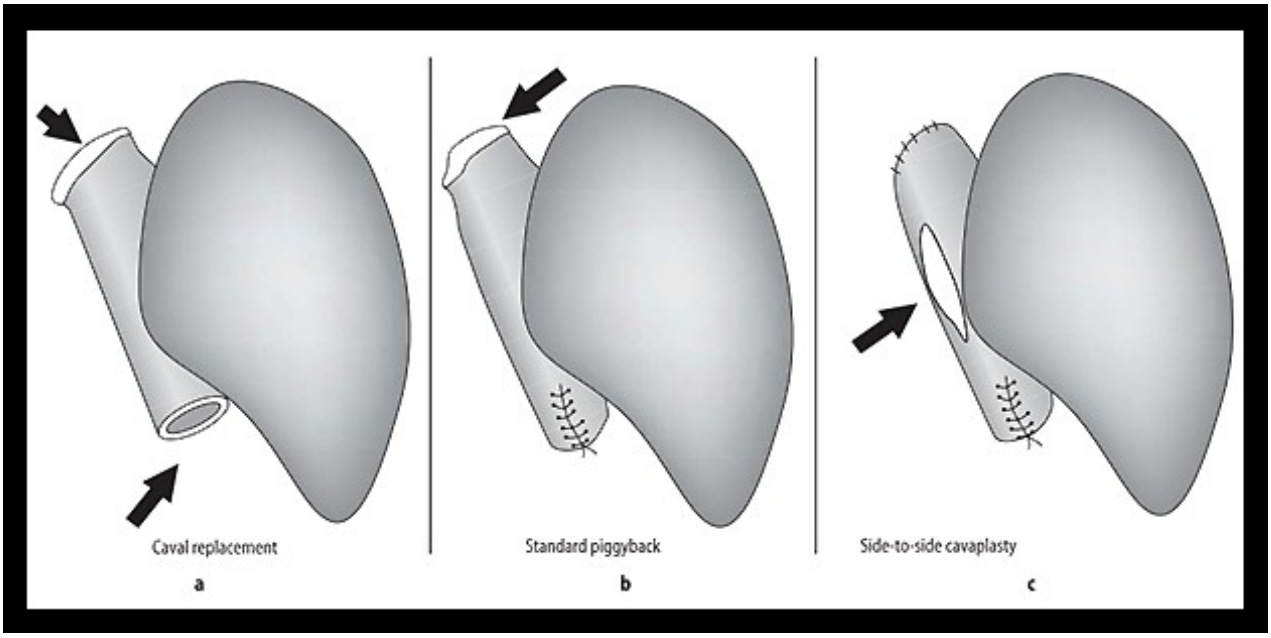


**Fig 6.** Piggy-back Technique. This diagram show a (**A**) caval replacement in contrast to the standard (**B**) piggy-back technique and (**C**) a side-to-side cavaplasty.

**Table 7.** Nakamura's Morphologic Classification of the Middle and Left Hepatic Veins

| Type | Wind et al. (1999) (%) | Nakamura and Tsuzuki (1981) (%) | Present Study (%) |
|---|---|---|---|
| A | 9.4 | 10.84 | 25 |
| B | 39.06 | 42.17 | |
| C | 25 | 26.51 | |
| D | 10.94 | 4.82 | 65 |
| E | 15.6 | 15.55 | 10 |

Type D includes a common trunk less than 1 cm, with 4 branches. Type E includes cases where there is no common trunk.

A common trunk of at least 1 cm, without a collateral branch, existed only 10% in Nakamura's study (Nakamura and Tsuzunki, 1981), 9.4% in a study by Wind (Wind et al., 1999), and 25% in the present study. Factors to assess the feasibility of vascular control of the common trunk are:

(1) its existence, (2) its length and (3) the presence of collateral branches emptying into the trunk or its branches into the IVC. Wind (Wind et al., 1999) recommends a simple classification based on these factors. Vascular control feasibility is directly related to the stage of classification (the higher the more difficult to control). This classification applies only when a common trunk is present: 84.34% in Nakamura's study (Nakamura and Tsuzunki, 1981), 84.4% in Wind's study (Wind et al., 1999) and 90% in the present study.

Calne and Williams (1968) were the first surgeons and investigators to retain the IVC of the recipient and to anastomose the orifice of one of the hepatic veins with the upper end of the IVC of the graft. Tzakis et al. (1989) suggested the construction of a new orifice by breaking the septum between 2 or 3 hepatic veins. Belghiti et al. (1992) proposed a side-to-side anastomosis between the IVC of the donor and that of the receiver. Meunier et al. (1993) suggested using a variant of the "piggy - back" technique when the recipient's common trunk was used to receive the upper extremity of the IVC of the graft. These techniques are collectively referred to as "piggy - back" (Fig. 6), a term illustrating the preservation of the IVC of the recipient. Critically, these techniques avoid dissection of the retrohepatic ICV, thus reducing blood loss. Even further, only one caval anastomosis is needed, reducing the time of liver function suspension. Some "piggy - back" techniques allow the preservation of caval flow when performing the anastomosis, with many advantages: no disturbance of hemodynamics, no postoperative renal dysfunction, reducing blood loss (Belghiti et al., 1992; Calne and Williams, 1968; Meunier et al., 1993; Tzakis, et al., 1989). Not clamping the IVC ensures the performance of a temporary portocaval anastomosis (Cherqui, et al., 1999; Tzakis and Reyes, 1993), allowing complete sectioning of the pedicle, thus making it easier to dissect the

**Table 8.** Wind's Morphologic Classification of the Middle Vein

| Type | Wind et al. (1999) | Present Study (%) |
|---|---|---|
| I | 32.81 | 25 |
| II | 43.78 | 55 |
| III | 7.81 | 10 |
| IV | 15.60 | 10 |

anterior aspect of the retrohepatic ICV. No common trunk means not electing to perform the "piggy - back" technique.

When using the common trunk, the caval flow can be maintained by just clamping the trunk or lateral clamping of the IVC. However, there may be incompatibility in diameter, whether this relates to the grafting of a hepatic lobe or child's liver into an adult. Thus, knowledge of morphometric anatomical variants is essential to both liver and transplant surgeons. Usually, the diameter of the common trunk is smaller than that of the IVC. Sectioning of this trunk proximal to the junction of the MHV and LHV creates a new orifice with a diameter close to that of the IVC at its diaphragmatic passage, allowing anastomosis without incongruence. However, this study did not predict hemodynamic effects due to the smaller diameter of the actual orifice of the common trunk at its outflow into the IVC. At this site, the diameter of the orifice is only about 50% of that of the IVC. The performance of a "piggy - back" (Fig. 6) techniques of the MHV and LHV on the common trunk may, in very few cases, lead to the obstacle of the venous drainage of the graft (Masselot and Leborgnu, 1978). Thus, some authors recommend creating a supplementary end-to-end anastomosis between the caudal end of the IVC of the graft and the IVC of the recipient (Merenda et al., 1997).

The RHV is the longest vein in the liver; it is single in 94% of cases and courses within the intersegmental plane between the anterior and posterior segments of the right lobe (Nakamura and Tsuzuki, 1981). The main trunk is created by the convergence of an anterior trunk located in the right portal fissure, draining mainly segment V and VI, and a posterior trunk draining chiefly segment VII (Delattre and Avisse, 2000). The MHV courses along Cantlie's line in the principal portal fissure and forms a common trunk with the LHV in about 85% of cases (Delattre and Avisse, 2000; Nakamura and Tsuzuki, 1981). The MHV drains the central sector of the liver, receiving constant tributaries from segment IV on the left and from segment V and VIII on the right (Ger, 1989). This is the main vein draining the anterior segment of the right lobe. In the present study, the drainage of the MHV was found to be very diverse in Vietnamese cadavers.

The LHV originates from the confluence of a transverse vein, draining segment II, and a sagittal vein draining segment III (Delattre and Avisse, 2000). Sometimes this vein receives a contribution from segment IV (i.e., one case in the present study). The main trunk, in the majority of cases, forms a common channel with the MHV, and opens into the suprahepatic IVC. Sometimes, it courses as an independent vein of the left lateral segment, draining separately from the MHV (i.e., 2 cases observed in the present study).

Short accessory (dorsal) RHVs (they should not be confused with the caudate lobe vein) drain the dorsal aspect of the liver (mainly segments VI and VII) and empty directly to the right of the retrohepatic IVC. The caudate lobe is drained mainly on the left by a single vein in 50% of cases, and by 2 or 3 veins in the remaining cases. In addition, there may be up to 20 small, short venules attaching the caudate lobe to the retrohepatic IVC (Dodson, 1993). In the present work on Vietnamese, there were 2 cases with accessory RHVs draining directly into the IVC.

The MHV and LHV form a common trunk in most cases. In addition, small individual veins, draining segment III or the superior part of segment IV (segment IVa), can empty directly into the suprahepatic IVC, close to the main LHV. This feature is often not seen on the right side (Nakamura and Tsuzuki, 1981). The intersegmental area between segment IV and left lateral segment constitutes the watershed between the drainage territories of the MHV and LHV.

The results of the present study showed that RHV is the main drainage vein of segments VI, VII, VIII, and V (Figs. 1-4; Table 3). The results further demonstrated that the MHV is the main drainage vein of segments IV, V; and that the LHV is the main drainage vein of segments II, III (Fig. 3; Tables 3 and 4).

### *Applications in Hepatic Transplantation*

Trinh Hong Son (2002) commented that there are 3 remarkable variations in hepatic vein anatomy applied in liver transplantation:

2 RHV type: MHV draining segment VI (12.3%). If taking the right lobe to transplant and keeping the MHV, then 5% of this type are documented in this study.

4 RHV type: MHV draining posterior and anterior sectors (2.5%). When dividing the liver to transplant or procuring the right lobe in volume-reduced transplantation, it is necessary to take the IVC with accessory hepatic veins of the donor for recipient. The present work showed 15% of 4 RHV type.

6 LHV type: MHV draining segment III (13.2%). In case of procuring the left lobe to transplant, it is needed to recognize this type during transplantation process to ensure the quality of the graft. The present study detected 5% of 6 LHV type. Such varieties should be known in advance to prepare for the venoplasty during transplantation (Trinh, et al., 1997; Trinh, et al., 1998).

The most common type of LST is to take the left lateral sector based on the LHV, and an extended right lobe based on MHV and LHV (Rela et al., 2013). Because the splitting line passes through the watershed zone, tributaries of the LHV and MHV are invariably encountered. These can be ligated without compromising the outflow of the left lateral sector or segment IV. However, care is required when dealing with the segment III vein draining into the MHV (5% according to this study; compared to 13.2% according to Trinh Hong Son (2002)). After parenchymal division, it may be impossible to reconstruct the outflow of the segment III and LHVs into a single opening if their orifice are wide apart, and both may need to be implanted separately to the recipient IVC.

This problem may be also encountered when a liver is being reduced, rather than split, down to a left lateral sector. Unexpected bleeding may occur during an in situ split or left lateral segment when a large branch of the LHV, draining part of segment IV, runs across the falciform ligament (Nakamura and Tsuzuki, 1981). Of the cases examined in the present study, 20% showed this variation. The presence of a transverse segment II vein, 10% in the cases examined herein, permits resection of this segment to reduce a left lateral graft down to a ‘monosegment’ for transplantation in a very small baby (Srinivasan and Vilca-Melendez, 1999), thereby overcoming a size discrepancy between donor and recipient.

Differences in the drainage patterns of the left hepatic venous system in the donor and the recipient can cause anastomotic misalignment after implantation of the left lateral segment graft, leading to outflow obstruction. An adequate outflow is very important for cut-surface hemostasis and optimal graft function. The triangulation technique for hepatic venous anastomosis has helped to resolve this potential problem (Edmond and Heffron, 1993). Intraoperative Doppler ultrasonography after liver reperfusion is useful in assessing the adequacy of vascular inflow and outflow, and help to determine the best position in which to anchor the graft in consideration of anatomical variants.

Techniques are evolving to split the liver into right and left lobe grafts of adequate and approximately equal mass for 2 adult recipients (Strasberg and Lowell, 1999). The plane of dissection lies to the right of the MHV. This interrupts the venous outflow of segment V and VIII (10% in the present investigation), which can cause congestion and troublesome bleeding from the cut surface of the right lobe after reperfusion. This can also compromise the functional volume of the right lobe graft. The IVC can be saved for either lobe, but it is preferred to keep it in the right lobe with large accessory RHV. Alternative options include opening the IVC longitudinally to take a patch containing all tributary veins, and performing a cavo- cavoplasty in the recipient (Gundlach et al., 2000). Trinh van

Minh (1999) remarked, in most cases, the MHV developed normally and was slightly shifted to the left of the portal bifurcation. So the plane of dissection should be at the right of the MHV. This technique saves the common trunk of middle and left hepatic veins for the left lobe, and avoids a variations of the umbilical fissure vein from the LHV into the MHV. The right lobe is drained by the RHV with abundant connecting branches (Van Minh, 1999).

Procurement of a right lobe in a living donor lobe can be also complicated by similar problems. It is helpful to map out the intrahepatic course of hepatic veins by intraoperative ultrasound (Dalattre and Avisse, 2000), especially that of the middle hepatic and accessory right hepatic veins in the donor right lobe. The length of a 1 cm extrahepatic RHV cuff is helpful for a right lobe living donor harvest because of the ease of dissection and graft implantation to the recipient IVC. If large accessory right hepatic veins are encountered, they must be implanted separately to the recipient IVC. Extended right lobe living donor is relatively infrequent for fear of insufficient liver mass in the donor. This can be more dangerous by inadvertent damage or torsion of the LHV at donor operation, especially when the MHV forms a common channel with the LHV.

The anatomy of the MHV is the key of right lobe living donor. In about 10% of cases, when the RHV is of a small caliber, the MHV can provide the sole drainage of the anterior sector of the right lobe. This is a contraindication to right lobe donation (Reichert and Renz, 2001). Congestion of the anterior sector of the right lobe occurs invariably after parenchymal transection. However, this sector develops ischemia after reperfusion, rather than congestion (Cui, et al., 2001). This would not persist in the presence of an adequate vascular inflow and outflow, and a well-functioning liver mass.

## CONCLUSION

Normal anatomical variants of hepatic veins are very diverse. A thorough knowledge of these variations is essential for the hepatic or transplant surgeon. Pre-operative imaging for elucidating morphology and the application of anatomy of these variants is suggested to be helpful for patients undergoing hepatic resection and segmental liver transplantation.

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## NOTES ON CONTIBUTORS

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## REFERENCES

BELGHITI J, PANIS Y, SAUVANET A, GAYET B, FE-

KETE F (1992) A new technique of side to side caval anastomosis during orthotopic hepatic transplantation without inferior vena caval occlusion. Surg Gynecol Obstet, 175(3): 270-272.

BISMUTH H, CASTAING D, SHERLOCK DJ (1992) Liver transplantation by "face à face" vena- cavaplasty. Surgery, 111: 151-155.

BORDEI P, ANTOHE D (1996) Etude anatomique des veines hepatiques moyenne et gauche. Surg Radiol Anat, 18: 250.

BROERING DC, WALTER J, BRAUN F, ROGIERS X (2008) Current status of hepatic transplantation. Anatomical basis for liver transplantation. Curr Probl Surg, 45(9): 587-661.

CALNE RY, WILLIAMS R (1968) Liver transplantation in man - I. Observations on technique and organisation in five cases. Br Med J, 4: 535-540.

CAMARGO AM, TEIXEIRA GG, ORTALE JR (1996) Anatomy of the ostia venae hepaticae and the retrohepatic segment of the inferior vena cava. J Anat, 188 (Pt 1): 59-64.

CHANG R, SHAN-QUAN S (1989) An applied anatomical study of the ostia venae hepaticae and the retrohepatique segment of the IVC. J Anat, 164: 41-47.

CHERQUI D, MALASSAGNE B, COLAU PI, BRUNETTI F, ROTMAN N, FAGNIEZ PL (1999) Hepatic vascular exclusion with preservation of the caval flow for liver resections. Ann Surg, 230(1): 24-30.

CHEVALIER JM (1988) Anatomic basis of vascular exclusion of the liver. Surg Radiol Anat, 10: 187-194.

COUINAUD C (1994) Intrahepatic anatomy. Application to liver transplantation. Ann Radiol (Paris), 37(5): 323-333.

CUI D, KIUCHI T, EGAWA H, HAVASHI M, SAKAMOTO S, UEDA M, KAIHARA S, UEMOTO S, INOMATA Y, TANAKA K (2001) Microcirculatory changes in right lobe grafts in living-donor liver transplantation: a near-infrared spectrometry study. Transplantation, 72(2): 291-295.

DELATTRE J, AVISSE C (2000) Anatomic basis of hepatic surgery. Surg Clin North Am, 80: 345-362.

DODSON TF (1993) Surgical anatomy of hepatic transplantation. Surg Clin North Am, 73: 645- 659.

EMOND JC, HEFFRON TG (1993) Reconstruction of the hepatic vein in reduced sized hepatic transplantation. Surg Gynecol Obstet, 176: 11-17.

FANG CH, YOU JH, LAU WY, LAI EC, FAN YF, ZHONG SZ, LI KX, CHEN ZX, SU ZH, BAO SS (2012) Anatomical variations of hepatic veins: three-dimensional computed tomography scans of 200 subjects. World J Surg, 36(1): 120-124.

GER R (1989) Surgical anatomy of the liver. Surg Clin North Am, 69: 179-192.

GUNDLACH M, BROERING D, TOPP S, STERNECK M, ROGIERS X (2000) Split-cava technique: liver splitting for two adult recipients. Liver Transpl, 6(6):703-706.

HARDY KJ (1972) The hepatic veins. Aust N Z J Surg, 42: 11-14.

JIN MB, SHIMAMURA T, TANIGUCHI M, NAGASAKO Y, SUZUKI T, KAMIYAMA T, MATSUSHITA M, FURUKAWA H, TODO S (2004) Liver regeneration in living-donor liver transplantation. Nihon Geka Gakkai Zasshi, 105(10): 674-679.

MARCOS A (2000) Right-lobe living donor liver transplantation. Liver Transpl, 6(6 Suppl 2): S59-563.

MASSELOT R, LEBORGNE J (1978) Etude anatomique des veines sus-hepatiques. Anat Clin, 1: 109-125.

MERENDA R, GERUNDA GE, NERI D, BARBAZZA F, DI MARZIO E, BRUTTOCAO A, VALMASONI M, ANGELI P, FACCIOLI AM (1997) Infrahepatic terminolateral cavo-cavostomy as a rescue technique in complicated "modified" piggyback liver transplantation. J Am Coll Surg, 185(6): 576-579.

MEUNIER B, BARDAXOGLOU E, CHARETON B, LANDEN S, CAMUS C, ROUMEAS J, LAUNOIS B (1993) "Piggyback" method in hepatic transplantation. Chirurgie, 119(10): 682-685.

MEUNIER B, BARDAXOGLOU E, SPILIOPOULOS G, LANDEN S, CAMUS C, ROUMEAS J, LAUNOIS B (1994) Liver transplantation with preservation of the inferior vena cava and "piggyback" reimplantation of the liver. Ann Chir, 48(11): 986-988.

NAGORNEY D (2010) The impact of hepatic venous anatomy on the hepatic remnant: need for assessment? Surgery, 147: 811-812.

NAKAMURA S, TSUZUKI T (1981) Surgical anatomy of the hepatic veins and the inferior vena cava. Surg Gynecol Obstet, 152: 43-50.

OU QJ, HERMANN ER (2001) The role of hepatic veins in liver operations. Surgery, 95: 381-391.

REICHERT PR, RENZ JF (2001) Anatomical variations hampering the use of right lobe in living donor liver transplantation. Liver Transpl, 7: C-85.

RELA M, KOTA V, SHANMUGAM V, VADEYAR H (2013) Middle hepatic vein to middle hepatic vein anastomosis in right lobe living donor liver transplantation. Liver Transpl, 19(2): 229-231.

SAKAGUCHI T, SUZUKI S (2010) Analysis of intrahepatic venovenous shunt by the hepatic venography. Surgery, 147: 805-810.

SHAW B, MARTIN DJ (1984) Venous bypass in clinical liver transplantation. Ann Surg, 200: 524-534.

SRINIVASAN P, VILCA-MELENDEZ H (1999) Liver transplantation with monosegment. Surgery, 126: 10-12.

STRASBERG SM, LOWELL JA (1999) Reducing the shortage of donor liver: what would it take to reliably split liver for transplantation into 2 adult recipients? Liver Transpl Surg, 5: 437-450.

TRINH HS (2002) Surgical anatomy of the liver in hepatic transplantation. Surgery, 5: 7-19 (in Vietnamese).

TRỊNH HS, DƯƠNG ĐH (1997) History of plastic surgery of hepatic veins. Practical Medicine, 12: 23-25.

TRỊNH HS, TÔN THẤT BÁCH (1998) Anatomical study of hepatic veins to the inferior vena cava, applied to hepatic resection, venoplasty and transplantation. Practical Medicine, 3: 37-41.

TZAKIS A, REYES J (1993) Temporary end to side porto - caval shunt in orthotopic hepatic transplantation in humans. Surg Gynecol Obstet, 176: 181-182.

TZAKIS A, TODO S, STARZL TE (1989) Orthotopic liver transplantation with preservation of the inferior vena cava. Ann Surg, 210(5): 649-652.

VAN MINH T (1999) The role of anatomy in hepatic resection and transplantation (review of history and personal opinion). Vietnam Medicine.

WIND P, DOUARD R, CUGNENC PH, CHEVALLIER JM (1999) Anatomy of the common trunk of the middle and left hepatic veins: application to liver transplantation. Surg Radiol Anat, 21(1): 17-21.