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ORIGINAL ARTICLE

Venous drainage map of the liver for complex hepatobiliary surgery and liver transplantation

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Abstract

Background: Inflow and outflow patency of the liver parenchyma is required to maximize the metabolic function of the liver. However, the definition and distribution of hepatic venous drainage regions has yet to be reported. The aim of this study was to define major hepatic venous tributaries and investigate the mean drainage volume of each territory.

Methods: Three-dimensional (3D) simulations from the livers of 100 healthy donors were reviewed for living donor liver transplantation to determine the distribution of the significant hepatic venous tributaries and the drainage patterns of each segment.

Results: The left hepatic vein (LHV), middle hepatic vein (MHV), and right hepatic vein (RHV) contributed a mean drainage of 20.7%, 32.7%, and 39.6% of the entire liver, respectively. Accessory hepatic veins accounted for remaining 7.0%. The middle right hepatic vein (MRHV) and inferior right hepatic vein (IRHV) accounted for a mean total drainage of 8.0% and 10.6%, respectively, when they present. In addition, major tributaries of hepatic veins were clearly detected, and their typical distributions were described.

Conclusions: Knowledge of hepatic venous territories is necessary for complex hepatobiliary surgery. This "venous drainage map" may provide useful information for complex liver surgery and transplantation.

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Introduction

Knowledge of the vascular anatomy is important for safe liver resection and transplantation. It has been widely accepted that patency of the three major hepatic vascular structures, the hepatic artery, portal vein and hepatic vein, and biliary tree is required for maximum function of the corresponding liver territories.

Progress in liver surgery has highlighted the substantial deleterious effects of venous congestion on remnant liver function and/or regeneration.[1,2] A recent study reported that veno-occluded regions have approximately 40% of the maximum function of corresponding regions.[3] As the volume of future liver remnant (FLR) is not always equal to the residual function of the liver, venous reconstruction is recommended in cases where congested regions in FLR develop because of excessive venous deprivation after hepatectomy and insufficient net functional reserve of FLR.[4]

Recent developments in computer simulation techniques have enabled visualization of the intrahepatic structures in three-

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dimensional (3D) formats from any angle preoperatively. This precise visualization of the hepatic vascular territories has provided new insights into the surgical anatomy of the liver.[5] The 3D liver analysis is widely used as a component of preoperative work-up for liver resection and transplantation. However, despite recent technical innovations in imaging studies, unexpected intraoperative decision-making is frequently required during complex hepatobiliary surgery and knowledge of the surgical anatomy of the liver remains crucial in such situations.

In the history of liver surgery, the segmental anatomy of the liver has been actively studied for more than 100 years according to the patterns of portal or arterial/biliary ramification. However, because of the technical difficulty of precisely evaluating the distribution of venous drainage areas, only a few studies have described the venous ramification patterns of the liver, particularly regarding the peripheral distribution of venous tributaries. In the present study, we describe the drainage patterns of major venous tributaries of the liver based on the results of 3D vascular analysis of 100 living donors for liver transplantation.

Table 1 Definition of major hepatic venous tributaries

Tributaries of the LHV	
Left superficial vein (LSV)	
	A tributary of the LHV or an isolated vein draining into IVC, not observed on the left portal fissure, running beneath the diaphragmatic surface of Segment II, and draining cranial portion of Segment II
Umbilical fissure vein (UFV)	
	A tributary arising from the LHV, MHV, or their confluence, not observed on the left portal fissure, running toward the umbilical fissure, and draining both Segment III and Segment IV
Tributaries of the MHV	
Superior vein for Segment IV (V4sup)	
	A tributary of the LHV, MHV, or their confluence, not observed on the umbilical fissure, draining superior part of Segment IV, and never draining left side of umbilical fissure
Inferior vein for Segment IV (V4inf)	
	Tributaries of left peripheral portion of the MHV, draining inferior half of Segment IV, and usually forming the MHV trunk meeting with the drainage veins of Segment V
Ventral vein for Segment VIII (V8v)	
	A tributary of MHV, draining ventral part of Segment VIII and not draining dorsal part of Segment VIII
Intermediate vein for Segment VIII (V8i)	
	A tributary of the MHV, not observe on the main portal fissure, running between ventral and dorsal part of Segment VIII, and draining both ventral and dorsal part of Segment VIII
Veins for Segment V (V5)	
	Tributaries of right peripheral portion of the MHV, draining Segment V, and forming the MHV trunk meeting with the inferior veins for Segment IV
Tributaries of the RHV	
Right superficial vein (RSV)	
	A tributary of the RHV or an isolated vein draining into IVC, running beneath the diaphragmatic surface of Segment VII, and draining cranial portion of Segment VII
Dorsal vein for Segment VIII (V8d)	
	A tributary of RHV, draining dorsal part of Segment VIII and not draining ventral part of Segment VIII
Accessory veins	
Inferior right hepatic vein (IRHV)	
	An isolated vein draining into IVC, usually running along P6 and draining entire or caudal part of Segment VI
Middle right hepatic vein (MRHV)	
	Isolated veins draining into IVC, draining Segment VII, never draining Segment VI

Methods

Subjects and 3D image reconstruction

The present study comprised 100 healthy donor candidates (median age, 40 years; range, 20–63 years; male:female ratio, 52:48) who underwent 3D-CT analysis as part of preoperative assessment for living donor liver transplantation (LDLT) at the University of Tokyo Hospital between February, 2004 and May, 2009. All donor candidates underwent protocol contrast-enhanced scanning and 3D reconstruction of intrahepatic structures using liver simulation software (Organs Volume Analysis; Hitachi Medico Inc, Tokyo, Japan), as reported previously.[6]

Individual extraction of the portal and hepatic veins allowed free compounding with each other or with liver parenchymal data on a 3D workstation in order to determine intrahepatic vascular structures and corresponding interrelations. The use of this system allowed the vascular territories of the portal or hepatic venous tributaries to be delineated in a 3D manner, and semi-automatic estimation of the respective absolute and relative volumes.

Definition of segment and venous tributaries

Liver segments were classified according to Couinaud's classification and nomenclature used in the present study was in accordance with the Brisbane 2000 terminology.[7] Segment VIII was subdivided into ventral and dorsal parts according to the anatomical findings we reported previously.[8] Definitions of venous tributaries are summarized in Table 1, which presents an extension of our previous work on the venous drainage pattern of the left liver.[6]

Data analysis

Clinical data were recorded using an Excel 2010 (Microsoft) spreadsheet and analyzed using the statistical software, JMP 9 (SAS Institute Japan, Tokyo, Japan). Non-parametric methods were used for all statistical analyses. P-values < 0.05 were considered statistically significant. All analyses in the present study were performed in accordance with the ethical guidelines for clinical studies of the University of Tokyo Hospital.

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