

Use of 3-Dimensional Computed Hepatic Venous Visualization for Graft Outflow Venoplasty in Adult Left Living-Donor Liver Transplant

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Abstract

Objectives: A surgeon must be aware of hepatic vascular variations to safely perform living-donor liver transplant. The ramification patterns of the hepatic veins with tributaries for left lobe graft outflow venoplasty should be evaluated preoperatively with 3-dimensional computed tomography of the donor.

Materials and Methods: Twenty-four potential donors were examined between October 1999 and July 2006 for living-donor liver transplant using the left lobe. They underwent triphasic helical computed tomography of the liver on a multidetector helical computed tomographic scanner. All images, including 2-dimensional reformation and 3-dimensional reconstructed models with maximum intensity projection and volume rendering, were sent to a workstation for postprocessing.

Results: The ramification patterns of the left and middle hepatic vein were classified into 2 groups; they formed a common trunk (type 1), which had 3 variations; type 1A (13 cases): in which the left hepatic vein and the middle hepatic vein without any tributaries on their confluence; type 1B (8 cases): in which there was venous confluence in the

left hepatic vein with the left superficial vein and middle hepatic vein; type 1C (2 cases): in which the hepatic venous confluence in the left hepatic vein and middle hepatic vein and the left superficial vein directly joining into the inferior vena cava; type 2 (1 case) had the left hepatic vein and middle hepatic vein joining into the inferior vena cava separately; type 1B underwent 2 venoplasty procedures, but the others underwent only a single venoplasty.

Conclusions: We demonstrated the anatomic interrelation of the hepatic veins for hepatic outflow venoplasty of adult left lobe living-donor liver transplant with 3-dimensional computed tomography scanning to help surgeons preoperatively determine the appropriate technique or form of reconstruction.

Key words: Adult living-donor liver transplant, 3D-CT, Graft outflow venoplasty, Hepatic vein anatomy, Preoperative vascular estimation

Introduction

In liver surgery including liver transplant, preoperative imaging can play an important role in patient selection and surgical planning.¹⁻⁵ The main goal of imaging is to provide vascular mapping for guiding a light to prevent surgical pitfalls. In a liver transplant, postoperative graft function depends on adequate inflow and outflow. Successful hepatic venous reconstruction is one of the most important factors because outflow obstruction may cause graft failure.⁷⁻¹² In living-donor liver transplant, we must require hepatic venous anastomosis under limited working anastomotic space because of the primary importance of donor safety.^{7, 8, 10-13}

From the ¹Department of Surgery, Institute of Gastroenterology, Tokyo Women's Medical University, Tokyo, Japan; and the ²Department of Transplant Surgery, Jichi Medical University. **Acknowledgements:** The authors thank the entire transplant team at Jichi Medical University, all of whom played an integral role in the care of these patients. T.U. did the study organization and wrote the paper. H.K. and M.Y. performed the study. K.M., Y.S., T.W., and H.K. were all supervisors. There were no funding sources for this study.

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Experimental and Clinical Transplantation (2012) 4: 350-355

To overcome this, some anastomotic variations recommend reconstructing the venous flow. In our institutes, similar with the previous reports,¹⁰⁻¹² we perform a graft hepatic venoplasty with a recipient cavoplasty for a left living-donor lobe graft because this procedure is simple and prevents outflow obstruction.

To estimate the necessity of reconstruction of the hepatic veins, various combinations of computed tomography (CT), magnetic resonance imaging, Doppler ultrasound, and conventional angiography are performed, but there is no universal protocol. Three-dimensional CT (3D-CT)-based visualizations allow us to visualize variations of hepatic veins and the confluence of the inferior vena cava (IVC).¹⁻⁶ Therefore, it is expected to be an important diagnostic tool in routine noninvasive preoperative evaluation of the graft venous anatomy to better plan the graft venoplasty. We report preoperative evaluation of 3D-CT visualization for graft venoplasty in a left living-donor liver graft.

Materials and Methods

Twenty-four potential donors (14 men, 10 women; mean age, 35 y; range, 26-65 y) were examined at our institute between October 1999 and July 2006 for preoperative evaluation of living-donor liver transplant using the left lobe. These grafts consisted of a left lobe with a caudate lobe (n=1) and without a caudate lobe (n=23). Their mean body mass index was 26.4 (range, 21-33). After they were medically cleared as potential donor, all patients underwent triphasic helical CT of the liver (noncontrast, hepatic-arterial phase, and portal-venous phase) on a multidetector helical computed tomographic scanner. Preoperative helical CT images were made using 3-mm thick slices represented on a CT machine (X Vigor Real, Toshiba Medical Systems Corporation, Otawara-shi, Tochigi-ken, Japan). Enhancement was achieved by an intravenous bolus of 130 to 180 mL of contrast agent (Iopamiron 370; Schering, Erlangen, Germany) at a rate of 3.5 to 5.0 milliliters per second. This allowed us clear visualization of the hepatic veins. All images, including 2-dimensional reformation and 3-dimensional reconstructed models with maximum intensity projection and volume rendering, were sent to a workstation (X tension Version 2.2, Toshiba Medical Systems) for processing.

Surgical considerations for hepatic outflow venoplasty

In our standard procurement for left-sided liver graft, a venotomy is done in the left portal branch after it has been clamped at its juncture with the main portal trunk, and the portal vein catheter is inserted. Donor hepatectomy was done without any vascular occlusion according to a technique that had been reported previously.¹³ After procurement, the left lobe graft was weighed, and the vascular components were carefully inspected. Before starting the venoplasty on the back table, we planned how many venoplasties would be required in each graft by checking the hepatic venous anatomy for a left liver graft on 3D-CT. When 2 or more orifices were found on 3D-CT, a venoplasty would be performed to fashion a single wide outflow orifice. If 2 hepatic veins were connected by a relatively long intervening septum, a plasty of this septum was done to make the outflow circumference uniform and to remove the septum. We made a linear or triangular incision perpendicular to the septum and stitched it with continuous polypropylene Prolene 6-0 sutures were used to close the incision. Both ends of the sutures had knots on the extraluminal side. We did not use previously reported techniques that removed the underlying liver parenchyma using a Cavitron ultrasonic surgical aspirator.^{10, 11}

Surgical techniques for recipients

The operation for the recipient is described elsewhere.¹³ We selected resected segments from the donors by need to obtain calculated graft volume preoperatively on a CT scan of more than 30% of the recipient's standard liver volume, and included the left lobe, the extended left lobe, and the extended left lobe with the caudate lobe. Hepatic graft resection in donors is performed without intermittent inflow occlusion of the glissonian pedicle. After parenchymal transection, the hepatic grafts are flushed in situ and preserved in cold University of Wisconsin solution. We usually do a graft venoplasty for the wide outflow. The total hepatectomy is performed without a venovenous bypass, but with preservation of the IVC. After reinstitution of portal venous inflow, the hepatic artery is anastomosed under a surgical microscope. After vascular reconstruction is accomplished, intra-graft vascular flow is confirmed by Doppler ultrasound. The biliary tract is reconstructed by hepaticojejunostomy with a

Roux-en-Y jejunal limb, or by an end-to-end anastomosis of the recipient's bile duct to the graft bile duct. The remnant falciform ligament of the graft is fixed to the diaphragm to prevent graft dislocation.

Hepatic venous anatomy and terminology

Each branch described by 3D-CT was more than 2 mm in diameter. To classify the complicated venous ramification patterns in the left liver, major venous tributaries started from 2 main venous trunks: the LHV and the MHV. The LHV trunk is one of the main venous trunks of the liver, running precisely in the left lobe portal fissure (the plane between the segment II and segment III of Couinaud classification),¹⁴⁻¹⁶ while the MHV trunk is another main venous trunk, observed in the main portal fissure (the watershed plane between the right and left portal venous territories). At the confluence of the hepatic veins for the left lobe graft, 2 major venous tributaries should be considered: the left superficial vein (LSV) is a tributary of the LHV or an isolated vein draining into the IVC, which runs beneath the diaphragmatic surface of segment II. The umbilical fissure vein (UFV) is a tributary arising from the LHV, MHV, or their confluence, which runs toward the umbilical fissure.⁶

Results

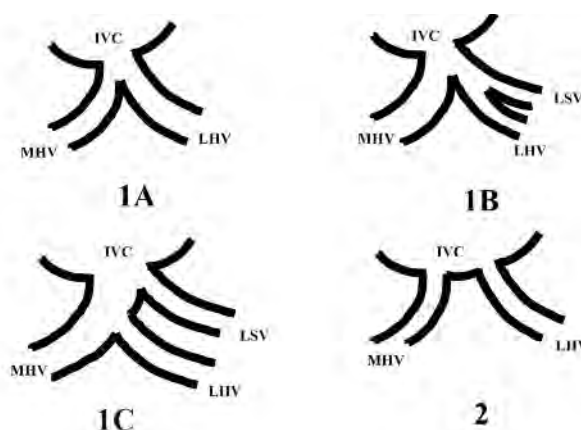
Hepatic venous anatomy for left liver graft on 3D-CT Among all 24 potential donor candidates, the LHV and MHV could be identified and visualized completely at the hepatocaval junction on 3D-CT scanning. The ramification patterns of the LHV and MHV were classified into 2 major groups (Figure 1A, 1B, 1C). One had hepatic venous confluence in which the LHV and MHV form a common trunk (type 1) and another one had the LHV and MHV joining into the IVC separately (type 2). Type 1 also had 3 subtype variations based on hepatic venous tributaries: type 1A had only 1 bifurcation of the LHV and MHV without any tributaries on their confluence; type 1B had hepatic venous confluence in which the LHV with the LSV and MHV form a common trunk before joining up with the IVC (Figure 2); type 1C had a hepatic venous confluence in which the LHV and MHV form a common trunk, and the LSV joins this common trunk directly before joining up with the IVC. Among 24 candidates in whom the LHV and MHV were identified, 13 candidates (54.2%) had type

1A, 8 candidates (33.3%) had type 1B, 2 candidates (8.3%) had type 1C, and 1 candidate (4.2%) had type 2.

Hepatic outflow venoplasty on the back table procedure

In these cases, we had 2 technical options for a venoplasty, depending on preservation of the vessels. If 1 intervening septum of the hepatic vein branches has a short length (< 10 mm) from the edge of the orifice, we require 1 venoplasty for this septum. If 2 intervening septums have a short length (< 10 mm)

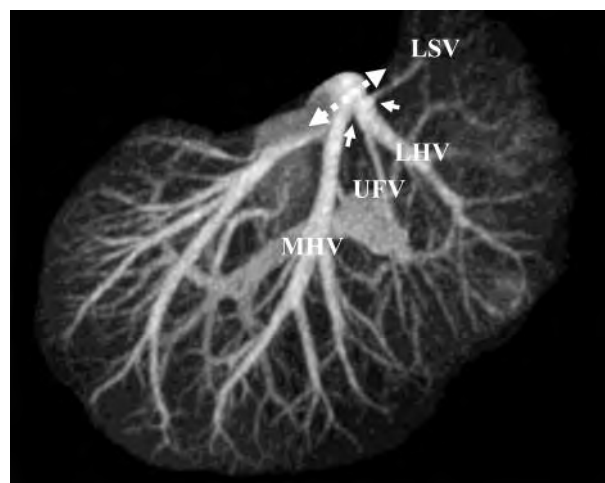
Figure 1. Anatomic Variations of the Hepatic Veins Joining Into the IVC



Type 1, which has 3 subtype variations (1A, 1B, 1C), has hepatic venous confluence, in which the left hepatic vein (LHV) and middle hepatic vein (MHV) form a common trunk. The LHV and MHV join up with the IVC separately in type 2.

Abbreviations: IVC, inferior vena cava

Figure 2. Three-Dimensional MIP Image From CT



The MIP image demonstrates the hepatic venous confluence, in which the left hepatic vein (LHV) with the left superficial vein (LSV) and middle hepatic vein (MHV) form a common trunk before joining up with the inferior vena cava (IVC) (type 1B). The dotted white arrow demonstrates the transaction plane of the hepatic veins, requiring 2 venoplasties of the graft (white arrows). No venoplasty may be required on the confluence of the LHV and the umbilical fissure vein (UFV).

from the edge of the orifice, we require a venoplasty (Figures 3 and 4). The UFV could be detected in 83.3% of cases (20/24 cases), but no venoplasty was required on the confluence of the UFV because it had sufficient length from the edge of the orifice in all cases.

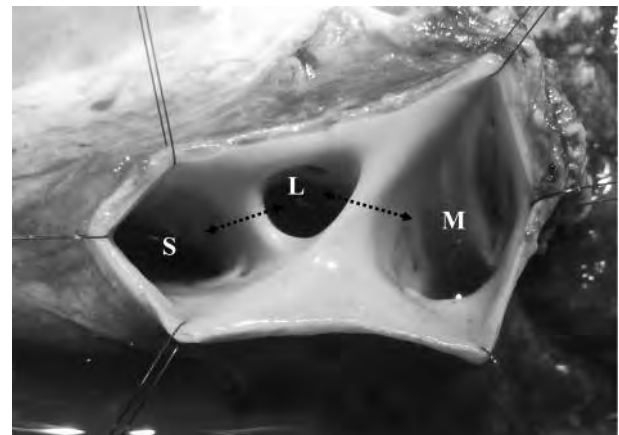
The results of the diametric analyses between 3D-CT and the back table for each hepatic vein, tributary, and length from each septum to the edge of the orifice are shown in Table 1. No difference was considered significant between the 2 groups. The diameter of the graft hepatic vein before venoplasty was 27.8 ± 1.7 mm, and the diameter after venoplasty was 33.6 ± 4.2 mm. The diameter after venoplasty in all cases was larger after than before venoplasty. Thirteen cases with type 1A, 2 with type 1C, 1 with type 2 had 1 venoplasty. Eight cases that had type 1B ramification underwent 2 venoplasties.

Outflow patency and velocity using 2D Doppler ultrasonography were checked after graft reperfusion. All anastomoses were patent, with flow velocities between 30 to 40 cm/s, and biphasic and triphasic waveforms. Graft congestion was not observed just after the operation. Doppler ultrasound examination was routinely performed twice a day for 2 weeks postoperatively, and there were no hepatic venous complications.

Discussion

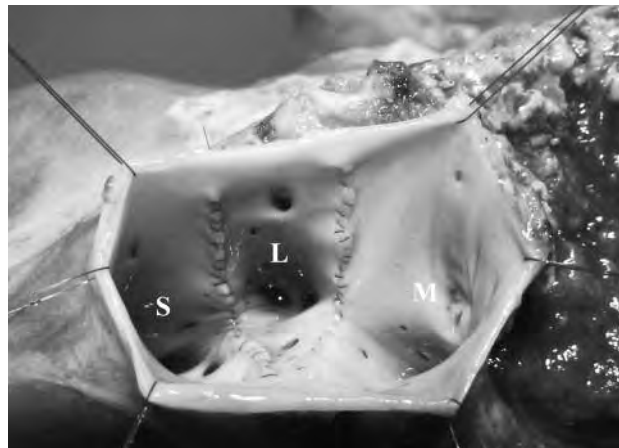
Three-dimensional CT visualization is helpful to understand the anatomy of a donor's hepatic vessels. As such, when there is an anomaly with regard to hepatic veins, it is relatively easy to develop a

Figure 3. Before Graft Hepatic Vein Venoplasty



This case was classified as type 1B and the graft hepatic vein had a short neck (< 10 mm from the edge of the orifice to each septum). Two septo-venoplasties were required to ensure adequate wide outflow orifice; 2 incisions across the septa were made (dotted arrow lines). L, left hepatic vein; M, middle hepatic vein; S, left superficial vein

Figure 4. After Graft Hepatic Vein Venoplasties



Two running 5-0 Prolene sutures were placed to close the incisions and to make one wider outflow orifice. L; left hepatic vein, M; middle hepatic vein, S; left superficial vein

Table 1. Diametric Analyses on 3D-CT and the Back Table in Left Lobe Grafts

	Diameter on 3D-CT	Diameter on the Back Table	P Value
LHV trunk	8.6 ± 2.2	9.4 ± 1.8	.72
MHV trunk	9.3 ± 1.7	10.2 ± 2.6	.78
LSV	4.5 ± 2.3	4.8 ± 2.6	.91
UFV	3.8 ± 2.2	4.3 ± 1.3	.82
Length from each septum to the edge of the orifice type 1A			
LHV+MHV type 1B	4.2 ± 2.6	4.5 ± 1.2	.89
LSV+LHV	5.8 ± 3.6	6.2 ± 3.2	.68
LHV+MHV type 1C	4.1 ± 1.6	4.3 ± 2.2	.82
LSV+MHV	2.6 ± 1.2	2.5 ± 1.3	.95
LHV+MHV type 2	12.1 ± 3.6	13.2 ± 3.2	.78
LHV/MHV	1.2	0.9	-

Abbreviations: 3D-CT, three-dimensional computed tomography; LHV, left hepatic vein; LSV, left superficial vein; MHV, middle hepatic vein; UFV, umbilical fissure vein

Parametric variables are expressed as the mean $\pm$ standard deviation (SD).

*P value < .05 was considered to be statistically significant.

surgical strategy.¹⁻⁶ Operative simulations using these anatomic images not only reduce risks faced by the donor, but they also reduce the stress of donor surgery. Many vascular variants using recent 3D-CT venography have been described on the surgical anatomy in liver transplant.¹⁻⁶ However, preoperative evaluation of the graft venous anatomy to make better planning of the graft venoplasty has not been reported. In this study, we thought that 3D hepatic venous visualization would be significantly more precise for planning hepatic outflow venoplasty.

Hepatic outflow venoplasty is important in preventing outflow block syndrome in technical-

variant liver grafts, especially in living-donor cases.¹⁰⁻¹² Congestive area after graft reperfusion should be avoided in the graft because it is thought to be insufficient for postoperative metabolic demand and may lead to graft dysfunction and even early graft failure, especially in marginally sized donor grafts.^{6, 10-12} Several series of outflow reconstruction have been done, most dealing with left lobe grafts and recipient hepatic veins. A triangulation method to create a wide outflow orifice,⁹ to widen the outflow by venoplasty of the recipient MHV and LHV with right caudal extension in the inferior vena cava,⁷ to use triple recipient hepatic vein reconstruction with creation of a long venous trunk⁸ have been advocated. Graft septoplasty and recipient vena cava orifice widening by cutting across the intervening septum among the 3 recipient hepatic veins and trimming of irregular edges were developed in living-donor liver transplant.¹⁰⁻¹² Although obtaining multiple graft hepatic veins in 1 orifice is a big advantage for patency of graft outflow, the presence of an intervening septum may limit the flexibility and distort the configuration of the vessels. The septoplasties are designed to make the configuration of the outflow orifice uniform and easier to anastomose to the recipient hepatic vein. In the current series, graft venoplasties could be performed without any issues that would prevent multiple anastomoses, which helped reduce ischemia time and outflow problems.

On the recipient side, we use the anterior IVC wall to create sufficient outflow trunk. For left side grafts including left lateral segment graft for pediatric cases and left lobe grafts for both pediatric and adult, we used the LHV or common orifice of the MHV and LHV for an end-to-end anastomosis. A previous report⁷ noted a 10.2% complication rate with this technique, while another report⁹ mentioned 33% hepatic outflow obstruction with an end-to-end LHV anastomosis in their earlier cases of reduced-size liver transplant. Reconstruction of multiple recipient hepatic veins may be difficult and should be avoided to consume operative time, especially prolonged ischemia time.^{11, 12}

Based on these technical refinements in the left lobe graft, it is important to confirm variations in branching and confluence of the LHV and MHV, and to detect any possible patterns in hepatic venous tributaries, especially in cases that undergo 2 venoplasties. When 2 intervening septums had a short length (< 10 mm) from the edge of the orifice,

we considered 2 venoplasties for these cases, but it might depend on the anatomic interrelation of the hepatic veins with the LSV. Indeed, 9 donors (37.5%) with the LSV in our series showed type 1B ramification and required 2 venoplasties. The UFV, which usually drains into the LHV, could be detected in 83.3% of cases, but no venoplasty was required on the confluence of UFV because it was of sufficient length from the edge of the orifice in all cases. Regarding hepatic outflow venoplasty in left lobe graft, 2 venoplasties should be considered when we checked hepatic venous anatomy and found type 1B ramification on 3D-CT before surgery. Meanwhile, the findings of our study suggest that type 1A, IC, and segment II ramifications may be preferable for simple outflow venoplasty because they usually require only 1 venoplasty. This classification will help us to preoperatively determine the appropriate technique or form of reconstruction.

We demonstrated the anatomic interrelation of the hepatic veins and other hepatic vasculatures for hepatic outflow venoplasty of an adult left lobe living-donor liver transplant with 3D-CT scanning. According to our findings, these detailed preoperative evaluations are essential for success of adult living-donor liver transplant using a left lobe, and they have an effect on donor selection that allows better planning of a safer surgical approach for the graft, which can be expected to reduce postoperative complications.

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