LIVER TRANSPLANTATION 12:264-268, 2006

ORIGINAL ARTICLE

# Donor Graft Outflow Venoplasty in Living Donor Liver Transplantation

**Allan Concejero,[1] Chao-Long Chen,[1] Chih-Chi Wang,[1] Shih-Ho Wang,[1] Chih-Che Lin,[1] Yeuh-Wei Liu,[1] Chin-Hsiang Yang,[1] Chee-Chien Yong,[1] Tsan-Shiun Lin,[1] Salleh Ibrahim,[1] Bruno Jawan,[2] Yu-Fan Cheng,[3] and Tung-Liang Huang[3]**

[1]*Department of Surgery,* [2]*Department of Anesthesiology,* [3]*Department of Diagnostic Radiology, Liver Transplantation Program, Chang Gung Memorial Hospital, Kaohsiung Medical Center, Kaohsiung, Taiwan*

**Hepatic venous outflow reconstruction is a key to successful living donor liver transplantation (LDLT) because its obstruction leads to graft dysfunction and eventual loss. Inclusion or reconstruction of most draining veins is ideal to ensure graft venous drainage and avoids acute congestion in the donor graft. We developed donor graft hepatic venoplasty techniques for multiple hepatic veins that can be used in either right- or left-lobe liver transplantation. In left-lobe grafts, venoplasty consisting of the left hepatic vein and adjacent veins such as the left superior vein, middle hepatic vein, or segment 3 vein is performed to create a single, wide orifice without compromising outflow for anastomosis with the recipient's vena cava. In right lobe graft where a right hepatic vein (RHV) is adjacent with a significantly-sized segment 8 vein, accessory RHV, and/or inferior RHV, venoplasty of the RHV with the accessory RHV, inferior RHV, and/or segment 8 vein is performed to create a single orifice for single outflow reconstruction with the recipient's RHV or vena cava. Of 35 venoplasties, 2 developed hepatic venous stenoses which were promptly managed with percutaneous interventional radiologic procedures. No graft was lost due to hepatic venous stenosis. In conclusion, these techniques avoid interposition grafts, are easily performed at the back table, simplify graft-to-recipient cava anastomosis, and avoid venous outflow narrowing.** *Liver Transpl 12:264-268, 2006.* © 2006 AASLD.

Received May 24, 2005; accepted August 29, 2005.

Variable venous anatomy increases the risk of outflow complications in living donor liver transplantation (LDLT). Preoperative mapping of the hepatic venous system is indispensable to provide information for decision making as to cutting plane during graft retrieval and the method of venoplasty and anastomosis.[1] However, no consensus has emerged to guide optimal venous outflow reconstruction in LDLT.[2] It is recognized that the venous drainage of the graft depends largely on the tributaries of the hepatic veins. Failure to effectively reestablish this venous drainage may result in congestion, dysfunction, and eventual graft failure.[3,4] Techniques to overcome acute graft congestion by reconstruction of all significantly-sized tributaries of hepatic veins have been the rule for most surgeons utilizing either the right or left liver lobe.

We describe our techniques for donor graft hepatic vein venoplasty, devised to ensure a single, wide orifice in the hepatic veins, for a single outflow anastomosis with the recipient's hepatic veins or vena cava.

## PATIENTS AND METHODS

Between June 1994 and December 2004, we performed 203 consecutive LDLT including 1 dual graft transplantation. A total of 115 left and 89 right donor grafts were used. In the 115 left donor grafts, 29 underwent venoplasty. In the 89 right donor grafts, 6 underwent venoplasty. Table 1 summarized the disease indication for transplantation in the recipients and the grafts used. The operative records, outcome, and follow-up of all recipients and donors whose graft underwent veno-

**Abbreviations:** LDLT, living donor liver transplantation; RHV, right hepatic vein.
Supported by a program project grant from the National Health Research Institutes, Taiwan (NHRI-EX 93-9228SP).
Address reprint requests to Chao-Long Chen, M.D., Liver Transplantation Program, Department of Surgery, Chang Gung Memorial Hospital, Kaohsiung Medical Center, 123 Ta-Pei Road, Niao-Sung, Kaohsiung 83305, Taiwan. Telephone: 886-7-731-7123 Ext. 8097; FAX: 886-7-732-4855; E-mail: clchen@adm.cgmh.org.tw

DOI 10.1002/lt.20699
Published online in Wiley InterScience (www.interscience.wiley.com).

**TABLE 1. Disease Indication for Transplantation in Recipients and Graft Used (N = 35)**

| Diagnosis | N | % | Graft used |
|---|---|---|---|
| Biliary atresia | 20 | 57 | LL-2, LLS-12, ELLS-6 |
| GSD | 6 | 17 | LL-3, LLS-1, ELLS-2 |
| Neonatal hepatitis | 3 | 8 | LLS-3 |
| HBV-related cirrhosis without HCC | 3 | 8 | RL-3 |
| HCV-related cirrhosis without HCC | 1 | 3 | RL |
| HBV-related cirrhosis with HCC | 1 | 3 | RL |
| Alcoholic cirrhosis | 1 | 3 | RL |

**Abbreviations:** GSD, glycogen storage disease; HBV, hepatitis B virus; HCV, hepatitis C virus; HCC, hepatocellular carcinoma; LL, left lobe; LLS, left lateral segment; ELLS, extended left lateral segment; RL, right lobe.

plasty were reviewed. The minimum recipient follow-up was 6 months.

## Technique of Graft Venoplasty

Donors underwent detailed hepatic vascular imaging. Two-dimensional Doppler ultrasonography and magnetic resonance venography with angular reconstruction were used to evaluate the hepatic venous anatomy.[1] Computed tomography was used for liver volumetry and to assess fatty content of the donor liver.[5] The number and configuration of the hepatic veins to be taken with the graft were determined preoperatively. Multiple veins may be detected as separate on preoperative imaging studies, but were often harvested with an attached intervening septum.

Our technique of donor hepatectomy has previously been described in detail.[6,7] The graft consisted of either the left lateral segment (segments 2 and 3), extended left lateral segment (segments 2, 3, part of 4), or right lobe (segments 5, 6, 7, and 8). Donor hepatectomy was performed without vascular occlusion. The graft was flushed with University of Wisconsin solution through the portal vein on the back table, where venoplasty was also performed. After graft procurement, the hepatic veins were carefully inspected at the back table. In the left lateral segment or extended left lateral grafts, if 2 or more orifices, i.e., left hepatic vein, left superior hepatic vein, middle hepatic vein, or segment 3 or 4 veins, were found, a venoplasty was performed to fashion a single, wide outflow orifice. Three techniques of venoplasty were employed depending on the presentation of the vessels. First, if 2 veins were connected by a long intervening septum (>1 cm), a plasty of this septum (septoplasty) was performed in order to make the outflow circumference uniform and to depress the septum. This septoplasty was done by making an incision perpendicular to the septum and removing the underlying liver parenchyma using a cavitron ultrasonic surgical aspirator (CUSA Excel$_{TM}$, Valleylab, Inc., Boulder, CO). This incision was then stretched along the axis of the septum and the vessel edges were approximated using interrupted polyglyconate (Maxon) 7-0 suture with the knots on the extraluminal side[6] (Fig. 1). Second, if the bridging septum was short, sutures approximating the cut edges of the veins on either side of the septum were placed to lengthen the attachment between the 2 vessels (Fig. 2). Third, if the orifices were completely separate but not far apart (no intervening septum), they were joined together by continuous suture. If necessary, liver tissue between vessels was removed to facilitate approximation and relieve tension. The orifice di-

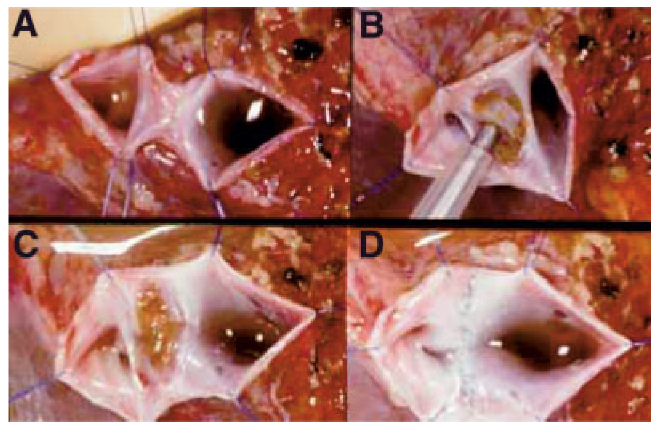


**Figure 1. Clockwise from left top. (A) Septum with intervening tissue separates segments 2 and 3 veins. (B) Septoplasty of this septum is performed in order to make the outflow circumference uniform and to depress the septum. This is done by making an incision perpendicular to the septum and removing the underlying liver parenchyma using a cavitron ultrasonic surgical aspirator (CUSA). (C) This incision is then stretched along the axis of the septum. (D) The vessel edges are approximated using interrupted polyglyconate (Maxon) 7-0 suture with the knots on the extraluminal side.**

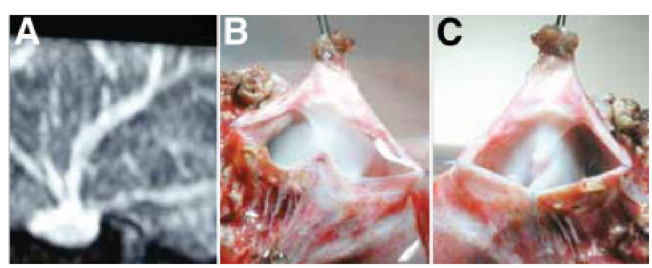


**Figure 2. (A) CT angiography showing the middle hepatic vein (MHV), left hepatic vein (LHV), and left superior hepatic vein (LSV). (B) LSV and LHV with short bridging septum in between. (C) Venoplasty is done by interrupted suture approximating the cut edges of the veins on either side of the septum to lengthen the attachment between the 2 vessels.**

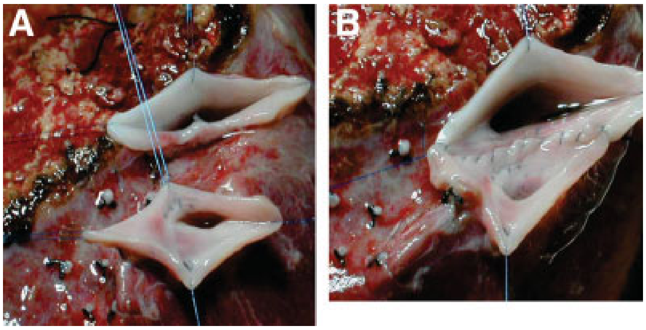


**Figure 3. (A) RHV and accessory RHV. No bridging septum. No tension when vessel edges are approximated. Stay-sutures are used to approximate vessel edges. (B) Vessel edges are joined together by continuous polydioxanone (PDS) 6-0 suture. The knots are placed extraluminally.**

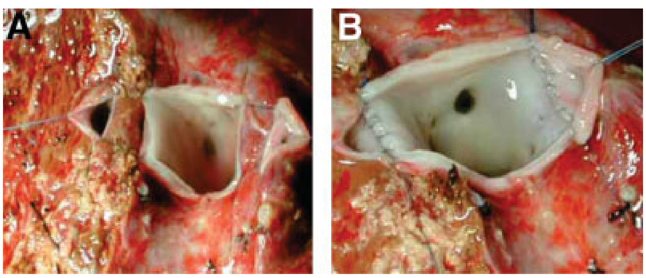


**Figure 4. (A) Right hepatic vein, accessory RHV, and segment 8 vein (V8). Stay-sutures are placed to assure correct orientation of vessel edges prior to approximation. (B) Completed venoplasty of the RHV, accessory RHV, and V8 vein. Note the wide, single orifice created after joining the 3 openings.**

**Figure 5. An inferior RHV opening is noted caudal to a newly created venoplasty orifice of RHV, accessory RHV, and segment 8 vein (V8) (as in Fig. 4). This opening is not incorporated into the venoplasty due to a long intervening parenchyma distance causing tension in vessel edges when approximated.**

ameter was measured by a caliper before and after venoplasty.

In right lobe grafts, if 2 or more orifices were found, i.e., right hepatic vein (RHV), accessory RHV, inferior RHV, or segment 8 vein, venoplasty was also performed to fashion a single, wide outflow orifice. These techniques were as described above. The objective was to make a single orifice out of several orifices (Figs. 3 and 4). If there was tension between veins during approximation, it was prudent not to incorporate all the veins into one orifice in favor of creating 2 orifices out of the 4 openings or incorporating 3 vein openings to form a single orifice and the remaining vein was reconstructed with an interposition graft (Fig. 5).

The segment 8 vein was usually thin and fragile. Refinements in technique must be exercised to avoid lacerating this vein during venoplasty.

Our technique of recipient total hepatectomy has also been described previously in detail.[6] In a recipient requiring a left lobe graft, a triple recipient hepatic venoplasty was performed to create a wide outflow orifice. The lumina of the 3 main hepatic veins were made confluent by cutting across the vessel walls between them, thus creating a big opening. Redundant, irregular tissues were trimmed when necessary. This recipient outflow orifice was tailored to be wider than the measured graft hepatic vein venoplasty. In a recipient requiring a right lobe, the recipient longitudinal RHV orifice was enlarged by trimming it longitudinally along the anterior wall of the vena cava and enlarging the same to a wider-size opening compared to the graft venoplasty.

This single, newly-created graft venoplasty opening was then anastomosed to the wider-size opening created in the recipient's inferior vena cava or hepatic veins using polypropylene 5-0 suture, assuring the correct orientation of the graft and recipient vessels. These techniques avoid interposition grafts, were easily performed at the back table, simplify graft-to-recipient cava anastomosis, and avoid venous outflow narrowing by creating a wide donor graft outflow orifice. Intraoperative Doppler ultrasonography was routinely performed to assess vascular patency and flow velocities upon completion of vascular anastomoses, and before and after closure of the abdomen.

## RESULTS

A total of 29 left and 6 right graft venoplasties were performed. Tables 2 and 3 summarize the graft vessels that underwent venoplasty. Veno-venous bypass was not used in any recipient. Table 4 summarizes the recipient operative outcomes. Outflow patency and velocity determinations using 2-dimensional Doppler ultrasonography were done after reconstruction. All anastomoses were patent, with flow velocities between 30 and 40 cm/second, and either biphasic or triphasic waveforms. Graft congestion was not observed and there was no complication related to hepatic vein anastomosis immediately after venoplasty surgery. All grafts functioned well.

There were 2 outflow stenoses in which donor graft venoplasty was used, both using left donor grafts (2/29; 7%). Both occurred in pediatric patients and beyond 3 months after transplant. In the above hepatic venous

**TABLE 2. Vessels Which Underwent Venoplasty in Left Grafts (N = 29)**

| Vessels included in venoplasty | N | % |
|---|---|---|
| LHV + LSV | 23 | 79 |
| LHV + segment 3 vein | 3 | 10 |
| LHV + MHV | 2 | 7 |
| LHV + LSV + segment 4 vein | 1 | 3 |

**Abbreviations:** LHV, left hepatic vein; LSV, left superior vein; MHV, middle hepatic vein.

**TABLE 3. Vessels that Underwent Venoplasty in Right Grafts (N = 6)**

| Vessels included in venoplasty | N | % |
|---|---|---|
| RHV + aRHV | 2 | 33 |
| RHV + IRHV | 1 | 17 |
| IRHV + IRHV | 1 | 17 |
| RHV + aRHV + segment 8 vein | 1 | 17 |
| Segment 8 vein + MHV + IRHV | 1 | 17 |

**Abbreviations:** RHV, right hepatic vein; aRHV, accessory right hepatic vein; IRHV, inferior right hepatic vein; MHV, middle hepatic vein.

obstruction, both donor grafts (LDLT 96 and 127) underwent left hepatic vein + left superior hepatic vein venoplasty. Both recipients developed hepatic vein stenoses and were successfully treated by percutaneous balloon angioplasty. The overall hepatic vein outflow complication rate involving donor graft venoplasty in this series was 5.5% (2/35). The mean follow-up was 41.5 months (range 8-75 months) for left graft recipients and 14.5 months (range 6-23 months) for right graft recipients. There was no reoperation or hospital mortality in the recipients. There was no graft loss due to outflow stenosis, and all recipients are surviving with the original graft.

There was no complication among donors. The mean blood loss in donors was 84 mL (range 10-300 mL) for left grafts and 117 mL (range 80-200 mL) for right grafts. No donors required blood or blood product transfusions perioperatively. In our initial cases of graft venoplasty, vessel apposition was done using interrupted polyglyconate (Maxon) 7-0 suture with the knots placed extraluminally. Currently, we perform the venoplasty using a continuous suturing technique with polydioxanone (PDS) 6-0 suture. This latter technique is faster and easier to perform.

## DISCUSSION

The manner of hepatic vein outflow reconstruction is a major issue in LDLT, in which partial liver transplantation is performed with preservation of the inferior vena cava.[8,9] Several techniques of outflow reconstruction have been developed, most dealing with recipient vessels and left lobe grafts. A triangulation method to create a wide outflow orifice is advocated by Emond et al.[10] Tanaka et al.[8] widens the outflow by venoplasty of the recipient middle hepatic vein and left hepatic vein with a right caudal extension in the inferior vena cava, whereas Matsunami et al.[11] used triple recipient hepatic vein reconstruction with creation of a long venous trunk. Graft septoplasty and recipient vena cava orifice widening by cutting across intervening septa among the 3 recipient hepatic veins and trimming of irregular edges were developed by De Villa et al.[6] in LDLT. Recently, Sugawara et al.[12] recommends using a V-shaped patch vein graft on the anterior wall of the recipient hepatic vein to widen and elongate the orifice in right lobe outflow reconstruction, whereas Hwang et al.[13] developed a quilt venoplasty technique using autologous greater saphenous vein graft to reconstruct multiple or variant short hepatic veins in right liver grafts.

Congestion should be avoided in the graft during reperfusion as this leads to graft dysfunction and even early graft failure, especially in marginally-sized donor grafts, as venous outflow disturbance adversely affects the regenerative capacity of a partial liver graft.[14] Some authors advocate reconstruction of most sizeable hepatic veins to inclusion of the middle hepatic vein to guarantee uniform venous drainage and optimum graft function. But reconstruction of multiple hepatic veins may be technically difficult, time consuming, and prolong ischemia time.

Liu et al.[15] and Lo et al.[16] have developed a hepatic venoplasty technique in which the RHV and middle hepatic vein are joined together to form a triangular cuff for single anastomosis to a matched triangular opening in the recipient's inferior vena cava to ensure excellent drainage in the right lobe graft. In addition, Kinkhabwala et al.[2] in a review of 48 right lobe LDLT stressed that outflow obstruction can be avoided if close attention is given to creating a wide RHV anastomosis.

As much as possible, multiple hepatic veins are reconstructed by direct end-to-end anastomosis. Vein graft either from cryopreserved or recipient native veins is also used in reconstruction of multiple hepatic veins for adequate graft drainage. Extra anastomoses are made unnecessary. The adjustments in the exact length, diameter, and orientation of the vessels may be difficult, time consuming, and may lead to graft dysfunction or failure as result of obstruction. The present techniques minimize these technical difficulties and offer the distinct advantage of avoiding the possibility of obstruction due to kinking or malalignment of graft-cava vessels because the direct anastomosis of the graft hepatic vein venoplasty orifice to a wider opening in the vena cava is short.

The good results of the venoplasties described in this series are evident in the excellent biphasic or triphasic waveforms and >30 cm/second velocities demonstrated by Doppler ultrasound, and in the low complication rate. There have been no technical problems encountered during the procedure. All recipients toler-

**TABLE 4. Operative Outcomes (N = 35)**

| Recipient outcome | Left lobe grafts (N = 29) | Right lobe grafts (N = 6) |
|---|---|---|
| Mean operative time | 510 minutes (423–1049 minutes) | 743 minutes (662–973 minutes) |
| Mean cold ischemia time | 62 minutes (25–113 minutes) | 100 minutes (70–155 minutes) |
| Mean warm ischemia time | 43 minutes (31–57 minutes) | 75 minutes (52–93 minutes) |
| Average intraoperative blood loss | 207 mL (13-1,480 mL) | 4,285 mL (220-12,700 mL) |
| Average packed red cell transfusion | 158 gms (0-1,480 gm) | 2,138 gms (0-4,203 gm) |
| Postoperative outflow complication | 2/29 | 0/6 |
| Mean follow-up | 41.5 months (8–75 months) | 14.5 months (6–23 months) |

ated shortened inferior vena cava clamping time, thus avoiding veno-venous bypass.

In summary, we have developed these donor graft hepatic vein venoplasty techniques for multiple hepatic veins that can be used in either right- or left-lobe liver transplantation. They are devised to ensure a single, wide orifice in the hepatic veins for a single-outflow anastomosis with the recipient's hepatic veins or vena cava. The techniques described are simple, are easily performed at the back table, obviate the need for interposition grafts, simplify graft-to-recipient cava anastomosis, and avoid graft venous outflow narrowing by creating a large orifice, thus ensuring adequate venous drainage.

## REFERENCES


1. Cheng YF, Chen CL, Huang TL, Chen TY, Lee TY, Chen YS, et al. Magnetic resonance of the hepatic veins with angular reconstruction: application in living-related liver transplantation. Transplantation 1999;68:267-271.
2. Kinkhabwala MM, Guarrera JV, Leno R, Brown RS, Prowda J, Kapur S, Emond JC. Outflow reconstruction in right hepatic live donor liver transplantation. Surgery 2003;133:243-250.
3. Lee S, Park K, Hwang S, Lee Y, Choi D, Kim K, et al. Congestion of the right graft in living-donor liver transplantation. Transplantation 2001;71:812-814.
4. Belghiti J, Goere D, Kianmanesh R, Sommacale D, Sauvanet A, Farges O, Durand F. Complete venous drainage improves early function of living right liver graft. Liver Transpl 2001;7(C-85):340.
5. Cheng YF, Chen CL, Lai CY, Chen TY, Huang TL, Lee TY, et al. Assessment of donor fatty livers for liver transplantation. Transplantation 2001;71:1221-1225.
6. De Villa VH, Chen CL, Chen YS, Wang CC, Wang SH, Chiang YC, et al. Outflow tract reconstruction in living donor liver transplantation. Transplantation 2000;70:1604-1608.
7. Chen CL, Chen YS, De Villa VH, Wang CC, Lin CL, Goto S, et al. Minimal blood loss living donor hepatectomy. Transplantation 2000;69:2580-2586.
8. Tanaka K, Uemoto S, Tokunaga Y, Fujita S, Sano K, Nishizawa T, et al. Surgical techniques and innovations in living related liver transplantation. Ann Surg 1993;217:82-91.
9. Egawa H, Inomata Y, Uemoto S, Asonuma K, Kiuchi T, Okajima H, et al. Hepatic vein reconstruction in 152 living-related donor liver transplantation patients. Surgery 1997;121:250-257.
10. Emond JC, Heffron TG, Whitington PF, Broelsch CE. Reconstruction of the hepatic vein in reduced size hepatic transplantation. Surg Gynecol Obstet 1993;176:11-17.
11. Matsunami H, Makuuchi M, Kawasaki S, Hashikura Y, Ikegami T, Nakazawa Y, et al. Venous reconstruction using three recipient hepatic veins in living related liver transplantation. Transplantation 1995;59:917-919.
12. Sugawara Y, Makuuchi M, Imamura H, Kaneko J, Ohkubo T, Kokudo N. Outflow reconstruction in recipients of right liver graft from living donors. Liver Transpl 2002;8:167-168.
13. Hwang S, Lee SG, Park KM, Kim KH, Ahn CS, Moon DB, Ha TY. Quilt venoplasty using recipient saphenous vein graft for reconstruction of multiple short hepatic veins in right liver grafts. Liver Transpl 2005;11:104-107.
14. Maema A, Imamura H, Takayama T, Sano K, Hui AM, Sugawara Y, Makuuchi M. Impaired volume regeneration of split livers with partial venous disruption: a latent problem in partial liver transplantation. Transplantation 2002; 73:765-769.
15. Liu CL, Zhao Y, Lo CM, Fan ST. Hepatic venoplasty in right lobe live donor liver transplantation. Liver Transpl 2003; 9:1265-1272.
16. Lo CM, Fan ST, Liu CL, Wong J. Hepatic venoplasty in living-donor liver transplantation using right lobe graft with middle hepatic vein. Transplantation 2003;75:358-360.