Impact of Short Hepatic Vein Reconstruction in Living Donor Adult Liver Transplantation Using a Left Liver Plus Caudate Lobe Graft

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OBJECTIVE: To investigate the impact of short hepatic vein reconstruction in the transplanted left liver plus caudate lobe graft.

METHODS: Six left liver plus caudate lobe grafts used for living donor adult liver transplantation were included in this study. The liver grafts were divided into two groups: those with (V1 group; n = 4) or without (control group; n = 2) short hepatic vein reconstruction. The changes in the transplanted left lobe (segments II–IV) and caudate lobe were compared between the two groups at 1 month after transplantation.

RESULTS: The addition of the caudate lobe increased the graft volume by 15 mL, which corresponded to a 4.3% gain of graft volume at the time of transplantation. Although the graft volume/standard liver volume ratio of the whole grafts after transplantation showed no difference between the two groups, the regeneration rate of the caudate lobe in the V1 group was significantly greater than that in the control group (p = 0.04).

CONCLUSION: Although no definite advantage from the V1 reconstruction was demonstrated, hepatic vein reconstruction with a significantly-sized short hepatic vein might provide an additional margin of safety for marginally-sized liver grafts during the early phase of graft regeneration. [Asian J Surg 2010; 33(1):8–13]

Key Words: caudate lobe, left liver graft, liver transplantation, short hepatic vein, venoplasty

Introduction

The large volume of right liver grafts in living donor adult liver transplantation (LDALT) provides a significant benefit to recipients, and is thus used most commonly worldwide. However, more extensive hepatectomy imposes a greater surgical risk on living donors.1 In contrast, left hemi-hepatectomy has a lower surgical risk for donors, but left liver grafts have a selection restriction for transplant candidates because they frequently yield small size grafts. To resolve this dilemma, concomitant resection of the caudate lobe (CL) with the left liver (LL) is applied in LDALT to enlarge the graft volume (GV).2 Based on the priority basis for living donor safety, LL plus CL grafts have been used routinely for LDALT in our institution.

A functional GV in LDALT is dependent largely on adequate venous drainage of the liver graft. Hepatic venous outflow block in a marginally-sized liver graft, especially...
in an LL graft, is associated with serious complications such as progressive graft dysfunction and septic complications in a transplant recipient. Therefore, most draining veins should be reconstructed for maximum use of LL plus CL grafts. However, there is no consensus on whether V1 (short hepatic vein) which drains the CL should be reconstructed or not.3 Thus, the present study investigated the impact of V1 reconstruction in the transplanted LL plus CL graft.

Patients and methods

Patients and grafts

Between May 2005 and February 2008, six consecutive LDALTs using LL plus CL graft were performed at our institute. The significantly-sized V1 (> 5 mm in diameter) that drained the CL was reconstructed in four of these grafts (V1 group). V1 was not reconstructed in the other two grafts (control group) because of a small-sized vein (< 5 mm in diameter) or the unavailability of an appropriate vein graft for venoplasty. The indications for LDALT in those patients were hepatitis C virus cirrhosis with hepatocellular carcinoma (n = 2), fulminant hepatitis (n = 1), primary sclerosing cholangitis (n = 1), Wilson’s disease (n = 1), and cholestatic liver disease (n = 1). Preoperative evaluation for a potential donor graft included laboratory data, abdominal computed tomography (CT), and three-dimensional (3D)-CT angiography. The branching type of the hepatic artery, the portal vein, and the hepatic veins were assessed by 3D-CT angiography. The branching type of the biliary tract was assessed by magnetic resonance cholangiopancreatography or drip infusion cholangiographic CT.

Graft estimation

The standard liver volume (SLV) of the recipient was calculated according to the formula of Urata et al.4 The predicted volume of the graft in each donor was calculated using the CT volumetric analysis before transplantation. The GV/SLV ratio was then calculated. The actual volume of the liver graft was measured on the back table immediately after procurement. The CT scans obtained from the recipients at 1 month after transplantation were subjected to volumetric analysis for the implanted grafts. The CL and other LL segment (segments II–IV) values were each determined with and without V1 reconstruction settings. The regeneration rate of the transplanted CL was determined by the following formula: (CL volume 1 month after transplantation—predicted CL volume before transplantation)/predicted CL volume before transplantation × 100%. The regeneration rate of the LL was calculated in a similar fashion.

Surgical techniques

The donor left hemi-hepatectomy was performed as previously reported.5 Although the indication for LL graft procurement with or without the middle hepatic vein (MHV) was based on the dominancy of the hepatic vein, the LL grafts were procured with the MHV. When the MHV trunk was not harvested, during the dissection of the liver parenchyma, MHV tributaries (V4) > 5 mm in diameter were preserved for vein reconstruction. Likewise, the V1 which drained the CL and was > 5 mm in diameter, was preserved. Venoplasty of the liver graft was performed on the back table. The trunks of the left hepatic vein (LHV) and MHV were connected to make a single orifice using the septoplasty technique or by a simple continuous suture.6 If the orifices of V4 or V1 were completely separate and far from the common orifice of the major hepatic veins, the conduit vein and patch vein grafts were used for venoplasty, to create a single wide orifice at the common orifice of the major hepatic veins (Figures 1A and 1B). The conduit vein grafts were obtained from the recipient’s superficial femoral vein, right hepatic vein, great saphenous vein, or cryopreserved venous graft provided by the University of Tokyo Tissue Bank. The distal side of a conduit vein graft was first cut longitudinally and then anastomosed to the orifice of V4 or V1. The proximal side of a vein graft was anastomosed half-way around to the posterior border of the common orifice of the major hepatic veins. A circular or redundant (dome-shaped) vein cuff was attached to the common orifice of the major hepatic veins of the graft. All of the sutures were carried out using a continuous suturing technique with 6-0 Prolene (Ethicon Inc., Somerville, NJ, USA).

In the recipient, total hepatectomy was performed, leaving the vena cava in the usual manner. The septum between the MHV and LHV was incised to create a common trunk. The single newly-created orifice of the hepatic veins of the liver graft was then anastomosed to this common trunk. The anastomosis was made using a continuous everted mattress or over-and-over suture using 6-0 Prolene (Ethicon Inc.). After reconstruction of the inflow, Doppler ultrasonography was performed to assess the hepatic venous drainage and patency.
Statistical analysis

Statistical analysis was performed using the Mann-Whitney U test. Data were expressed as the median with range. A p value < 0.05 was considered to be statistically significant.

Results

The predicted median GV of all grafts and the GV/SLV ratio were 361.8 mL (277.0–427.0 mL) and 31.2% (25.4–34.9%), respectively. Concomitant resection of the CL resulted in a median gain of GV by 4.3% at the time of transplantation. The actual volume of the graft at the back table did not differ from these values (data not shown).

Table 1 summarizes the procedure of venoplasty in each donor graft. Single V1s were preserved in four grafts (V1 group). These V1s were all reconstructed concurrently with the major hepatic veins. The preserved V1s had a median diameter of 5.3 mm (5.0–8.0 mm), and were located apart from the common orifice of the major hepatic veins by a distance of 27.5 mm (20.0–35.0 mm).

In the V1 group, two grafts connected V1s with the MHV and LHV orifices using the conduit vein grafts to make a single orifice. For the remaining two grafts, although the MHV trunk was not harvested, V1s were connected with the LHV orifices concurrently with the MHV tributaries (V4s) using branched-type conduit vein grafts. In the control group, the grafts only connected the MHV with the LHV. The conduit vein grafts for the V1 and V4 reconstructions were obtained from recipient’s superficial femoral vein, right hepatic vein, great saphenous vein.
or a cryopreserved venous graft kindly provided by the University of Tokyo Tissue Bank. The patch vein grafts attached to the common orifice were obtained from the recipient’s portal vein or great saphenous vein. The median cold preservation time of the liver graft was 184 minutes (142–227 minutes). Hepatic vein waveforms in all of the grafts showed a biphasic or triphasic pattern and graft congestion was not observed immediately after venoplasty.

All of the patients survived the operation. No graft was lost because of hepatic venous outflow block after a median follow-up of 12.9 months. There were no complications among the donors. The predicted LL volume and the GV/SLV ratio in the V1 group were 356.9 mL (335.5–410.4 mL) and 31.5% (29.4–33.6%); the predicted CL volume and GV/SLV ratio were 16.7 mL (12.4–17.4 mL) and 1.4% (1.1–1.6%), respectively. At 1 month after transplantation, the LL volume and GV/SLV ratio in the V1 group were 836.5 mL (722.4–1243 mL) and 72.3% (63.2–107.1%); the CL volume and GV/SLV ratio were 33.2 mL (21.2–57.6 mL) and 2.8% (1.9–5%), respectively (Table 2). On the other hand, the predicted LL volume and GV/SLV ratio in the control group were 310.0 mL (265.5–354.5 mL) and 26.8% (24.4–29.2%); the predicted CL volume and GV/SLV ratio were 13.6 mL (11.0–16.2 mL) and 1.2% (1–1.3%), respectively. At 1 month after transplantation, LL volume and GV/SLV ratio in the control group were 1073.0 mL (774.5–1371.5 mL) and 92.1% (71.3–112.9%); the CL volume and GV/SLV ratio were 4.5 mL (2.7–6.3 mL) and 0.4% (0.2–0.5%), respectively (Table 3).

Figure 2 shows the regeneration rate of the transplanted LL and CL with or without V1 reconstruction settings. The LL volume increased 1 month after transplantation in both groups with no significant difference. The regeneration rate of the LL was 138.5% for the V1 group and 239.3% for the control group. On the other hand, the CL exhibited a different pattern of regeneration 1 month after transplantation between the two groups. Namely, the regeneration rate of the transplanted CL in the V1 group was significantly greater than that in the control group (125% for the V1 group and 68.3% for the control group; \( p = 0.04 \)). However, the regeneration rate of

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**Table 2. Changes in graft volume (GV) in V1 group (with V1 reconstruction)**

<table>
<thead>
<tr>
<th>Case</th>
<th>SLV (mL)</th>
<th>Before transplantation</th>
<th>1 month after transplantation</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>LL (segment II–IV) CL LL (segment II–IV) CL</td>
<td>LL + CL</td>
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<tr>
<td></td>
<td></td>
<td>GV (mL) GV/SLV (%)</td>
<td>GV (mL) GV/SLV (%)</td>
</tr>
<tr>
<td>1</td>
<td>1143</td>
<td>336.0 29.4</td>
<td>12.4 1.1</td>
</tr>
<tr>
<td>2</td>
<td>1223</td>
<td>410.4 33.6</td>
<td>16.7 1.4</td>
</tr>
<tr>
<td>3</td>
<td>1161</td>
<td>377.8 32.5</td>
<td>16.6 1.4</td>
</tr>
<tr>
<td>4</td>
<td>1104</td>
<td>335.5 30.4</td>
<td>17.4 1.6</td>
</tr>
<tr>
<td>Median</td>
<td>1152</td>
<td>356.9 31.5</td>
<td>16.7 1.4</td>
</tr>
</tbody>
</table>

SLV = standard liver volume; LL = left liver; CL = caudate lobe.

**Table 3. Changes in the graft volume (GV) in the control group (without V1 reconstruction)**

<table>
<thead>
<tr>
<th>Case</th>
<th>SLV (mL)</th>
<th>Before transplantation</th>
<th>1 month after transplantation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LL (segment II–IV) CL LL (segment II–IV) CL</td>
<td>LL + CL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GV (mL) GV/SLV (%)</td>
<td>GV (mL) GV/SLV (%)</td>
</tr>
<tr>
<td>5</td>
<td>1215</td>
<td>354.5 29.2</td>
<td>16.2 1.3</td>
</tr>
<tr>
<td>6</td>
<td>1087</td>
<td>265.5 24.4</td>
<td>11.0 1.0</td>
</tr>
<tr>
<td>Median</td>
<td>1151</td>
<td>310.0 26.8</td>
<td>13.6 1.2</td>
</tr>
</tbody>
</table>

SLV = standard liver volume; LL = left liver; CL = caudate lobe.
the whole graft did not differ significantly between the two groups (134.9% for the V1 group and 226.4% for the control group; \(p \geq 0.05\)).

**Discussion**

Small-for-size graft syndrome after transplantation is a serious problem, especially for marginally-sized liver grafts in LDALT.\(^7\,^8\) To overcome this problem, right liver grafts with a larger volume have been introduced and are now used commonly worldwide. However, more extensive hepatectomy poses a greater surgical risk on living donors.\(^1\) Recently, the feasibility of left liver grafts for good-risk adult recipients in LDALT has been documented fully, successful results have been reported.\(^9\,^10\) To increase the functional volume in the left liver grafts, concomitant resection of the CL with the LL has been devised and has extended the indications for LDALT.\(^2\) For maximum use of liver grafts without increasing the surgical risk for donors, LL plus CL grafts, with or without MHV trunk, are used routinely in our institution. The CL provides a 2–8% gain in left liver graft weight.\(^2\,^3\,^5\) The present data showed that concomitant resection of the CL resulted in a median 4.3% gain in GV at the time of transplantation.

Hepatic venous drainage is the most important factor for the success of LDALT. Hepatic venous congestion in a LL graft can lead to a significant decrease in full graft viability and regeneration, unless the significantly-sized hepatic veins are reconstructed effectively. The indication for procurement of the MHV with the graft is based on the ramification patterns of the MHV, and the relationship between the hepatic venous drainage of the right anterior and the left paramedian (segment IV) sectors. A large part of the left paramedian sector is usually drained through the MHV.\(^11\) Thus, preservation of the venous outflow drainage from the left paramedian sector plays an important role in LDALT using the left liver graft. Leaving the MHV with the remnant liver places the left paramedian sector at risk for congestion. In such cases, the significantly-sized MHV tributaries should be reconstructed. In the current series, three MHV tributaries (V4s) were reconstructed effectively in two grafts using the conduit vein grafts.

On the other hand, there is no consensus on reconstructing the V1 that drains the CL, and little is known about the fate of the CL after V1 reconstruction. The initial series of LL plus CL grafts had no V1 reconstruction.\(^2\,^3\) These studies have shown that concomitant CL harvesting in left liver transplantation results in a modest increase in the CL, even if the V1 is not reconstructed. In contrast, the Tokyo group has recommended reconstruction of the V1 that drains the CL.\(^12\,^13\) In accordance with our principles, significantly-sized V1 were reconstructed in four grafts to achieve complete drainage of the hepatic veins. The results showed that the transplanted CLs with V1 reconstruction (V1 group) had proportionally regenerated with the LLs 1 month after transplantation. In contrast, the transplanted CLs without V1 reconstruction (control group) presented poor regeneration (atrophic

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**Figure 2.** (A) The regeneration rate of the transplanted left liver and (B) caudate lobe with (V1 group) or without (control group) V1 reconstruction. NS = not significant.
change) 1 month after transplantation. One possible reason may have been insufficient venous (V1) drainage from the harvested CL in the control group. Ikegami et al have also shown only a modest increase, but not a decrease in the CL in comparison to other segments for LL plus CL grafts without V1 reconstruction. There may be individual differences in graft regeneration after transplantation, which might result from individual anatomical variation in venous drainage. Couinaud has reported that some of the CL parenchyma is drained directly into the V1s, and some of that is drained through the major hepatic veins. Therefore, if there is a significantly large V1, it must be reconstructed because a vein of such size is large enough to drain the CL. On the other hand, although the CL with no sizable V1 vein to reconstruct might be drained through the major hepatic vein, such a drainage vein might be not enough to regenerate the CL.

Meanwhile, the current data showed no significant difference between the groups for the whole GV (LL plus CL) after transplantation, suggesting that other factors including graft quality, graft flow, technical issues, recipient conditions, and post-transplant complications might have affected graft regeneration. Although it is difficult to predict its long-term luminal patency after V1 reconstruction, concomitant resection of the CL, with V1 preservation, apparently has some beneficial gain in GV during the early stage of graft regeneration. However, there are technical difficulties associated with V1 reconstruction. As a result of variations in the anatomy of the CL and technical complexity, most V1s cannot be preserved without difficulty. Several techniques of outflow reconstruction dealing with recipient hepatic veins and the V1s that drain the CL have been devised. Sugawara et al have reported the conjoined reconstruction of the V1 to the MHV-LHV trunk orifice in LL plus CL grafts. Hashimoto et al have made a large venous reservoir by gathering the LHV, MHV and V1, using a conduit homograft vein. A conduit vein and patch vein grafts for single orifice vein reconstruction of multiple hepatic veins, including V1, have been employed in our institution as an effective means of simplifying graft-to-recipient cava anastomosis and avoiding unfavourable tension in the anastomosis. Furthermore, this technique of using the conduit vein graft should be useful when the distance between the orifice of the V1 and the common orifice of the major hepatic veins is large.

In conclusion, concomitant resection of the CL could produce a beneficial gain in GV at the time of transplantation. However, in the present study, no definite advantage, including liver function, was demonstrated clearly after V1 reconstruction, due to the limited number of cases, the volume variability of liver grafts and disease variability in patients. Although the impact of V1 reconstruction on overall graft outcome is still unclear, it might still be important to try to obtain a larger and more effective liver volume to prevent small-for-size syndrome during the early stage of graft regeneration.

References