Observational Study

Medicine®

OPEN

# Diamond-shaped patch technique for right hepatic vein reconstruction in living-donor liver transplant

## A simple method to prevent stenosis

Tae Beom Lee, MD[a,b], Byung Hyun Choi, MD[a,b,*], Kwang Ho Yang, MD[a,b], Je Ho Ryu, MD[a,b], Young Mok Park, MD[c], Chong Woo Chu, PhD[c]

**Abstract**

Patency of the right hepatic vein (RHV) of the liver graft is essential for successful living-donor liver transplant (LDLT). We developed a simple technique for RHV reconstruction that does not require the use of cadaveric veins or additional time to prevent stenosis.

Of 159 patients who underwent LDLT at our institution between May 2010 and April 2016, we included 152 in this study. Conventional RHV reconstruction was performed in 100 patients, while the diamond-shaped patch (D-patch) technique was performed in 53. For the D-patch technique, the posterior aspect of the RHV needs to be dissected from the liver parenchyma during donor hepatectomy, which prevents stenosis due to liver rotation after graft regeneration. A D-patch obtained from the hepatic vein of the recipient liver was used on the anterior aspect of the RHV for reconstruction. The Student's $t$ test and $\chi^2$ test were used for statistical analysis.

Rates of intervention for RHV stenosis during the first month were significantly different between the conventional reconstruction and D-patch groups (19.2% vs 3.8%; $P=.01$). The time taken to perform the D-patch technique was similar to that for conventional reconstruction (anhepatic period, $104.9 \pm 47.3$ minutes vs $106.7 \pm 42.0$ minutes; $P=.82$).

The D-patch technique for RHV reconstruction in LDLT is a simple, fast, and feasible surgical technique that can be performed without using cadaveric or saphenous veins.

**Abbreviations:** ALT = alanine aminotransferase, AST = alanine transaminase, CT = computed tomography, D-patch = diamond-shaped patch, LDLT = living-donor liver transplant, MELD = model for end-stage liver disease, MHV = middle hepatic vein, RHV = right hepatic vein, vs = versus.

**Keywords:** diamond-shaped patch, hepatic vein reconstruction, liver transplant

## 1. Introduction

Living-donor liver transplant (LDLT) requires more complex surgical techniques than do all other organ transplant procedures. One of the main technical issues in LDLT is reconstruction of the right hepatic vein (RHV). Compared with cadaveric liver transplant, RHV reconstruction in living donors requires special surgical techniques to prevent stenosis because the site of reconstruction can be altered owing to graft regeneration and rotation.[1] We describe a novel technique for RHV reconstruction that is simple and fast, and does not require cadaveric or artificial vessels or additional time.

*Editor: Yan Li.*

*The authors have no conflicts of interest to disclose.*

*[a] Division of Hepato-Biliary-Pancreatic Surgery and Transplantation, Department of Surgery, Pusan National University Yangsan Hospital, [b] Research Institute for Convergence of Biomedical Science and Technology, Pusan National University Yangsan Hospital, Yangsan, South Korea, [c] Department of Organ Transplantation Center, Vinmec Hospital, Hanoi, Time City, Vietnam.*

*[*] Correspondence: Byung Hyun Choi, Pusan National University Yangsan Hospital, 20 Geumo-ro, Moolgeum-eup, Yangsan-si, Kyungsangnam-do, South Korea (e-mail: gmoolpop@gmail.com).*

*Copyright © 2018 the Author(s). Published by Wolters Kluwer Health, Inc. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.*

*Medicine (2018) 97:34(e11815)*

*Received: 26 November 2017 / Accepted: 17 July 2018*

*http://dx.doi.org/10.1097/MD.0000000000011815*

## 2. Materials and methods

### 2.1. Patient selection

One hundred fifty-nine patients underwent LDLT at our institution between May 2010 and April 2016. Medical records were reviewed retrospectively to gather data on the patients' perioperative, intraoperative, and postoperative profiles, including age, etiology of liver disease, laboratory data, patency of interposition vessel graft, and postoperative complications. The need for ethical approval was waived because of the retrospective nature of this study.

### 2.2. Diagnosis and treatment of RHV stenosis

Strict evaluation of RHV stenosis was performed in all LDLT cases. We performed Doppler ultrasonography intraoperatively and on postoperative days 1 to 3 to evaluate the anastomotic sites, including the hepatic artery, portal vein, reconstructed middle hepatic vein (MHV), and RHV. All patients were checked after hepatic artery anastomosis was completed. Doppler ultrasonography was used to routinely determine the inflow and outflow of graft patency. We also performed computed tomography (CT) on postoperative days 1, 7, and 14 and at months 1, 6, and 12 after LDLT to evaluate venous outflow, graft regeneration, and graft tissue perfusion.

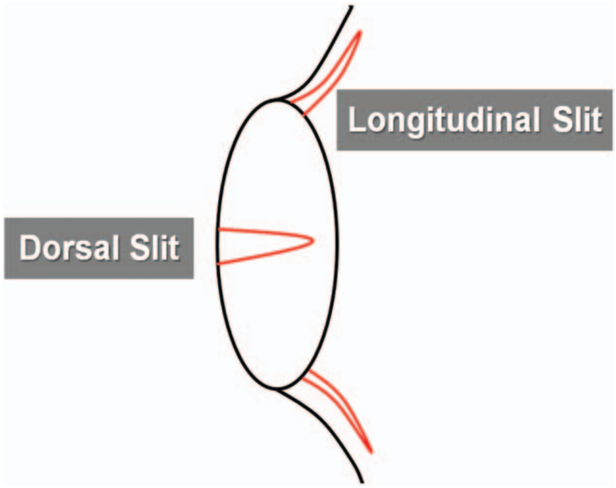


**Figure 1.** Schema of conventional right hepatic vein (RHV) anastomosis. An incision is made on the dorsal side of the RHV. Longitudinal incisions are made in the upper and lower sides of the RHV to widen the size of the primary outflow. RHV = right hepatic vein.

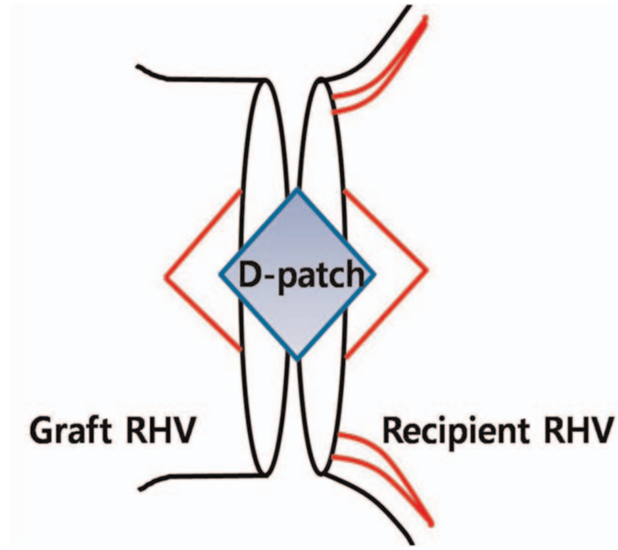


**Figure 2.** Schema of right hepatic vein reconstruction using a diamond-shaped patch. The hepatic or portal vein of the explanted liver of the recipient or a cryopreserved vein is used as the patch.

CT was performed if RHV stenosis was suspected based on Doppler ultrasonographic findings. Venography was performed when a nonopaque hepatic vein was observed or when focal luminal narrowing at the RHV anastomotic site was >50% compared with the adjacent normal hepatic venous diameter, as determined by CT. If the pressure gradient across the stenotic area between the distal hepatic vein and right atrium was >5 mm Hg by manometry, balloon angioplasty, or stent insertion was performed to relieve stenosis of the RHV. The intervention was chosen based on radiographic findings rather than laboratory findings.

### 2.3. Surgical techniques

**2.3.1. *Conventional technique.*** The size of the RHV was measured without any additional procedures after right lobe graft procurement (Fig. 1). An incision was made on the anterior side of the RHV after recipient hepatectomy. Then, longitudinal incisions were made on the upper and lower sides of the RHV to increase the primary outflow. The grafted RHV and widened hepatic vein of the recipient were anastomosed using Prolene 5-0 sutures (Ethicon Inc., Somerville, New Jersey).

**2.3.2. *Diamond-shaped patch technique.*** Modification of the surgical technique for RHV reconstruction was required based on the high rate of stenosis in the conventional reconstruction group (Fig. 2). The dorsal (or parenchymal) side of the RHV was dissected approximately 1.5 to 2 cm using a Cavitron ultrasonic surgical aspirator (Cooper Medical, Santa Clara, California) before graft procurement during donor hepatectomy. Next, a 1.5 to 2-cm incision was made on the anterior side of the RHV before creating the diamond-shaped patch (D-patch) during reconstruction (Fig. 3).

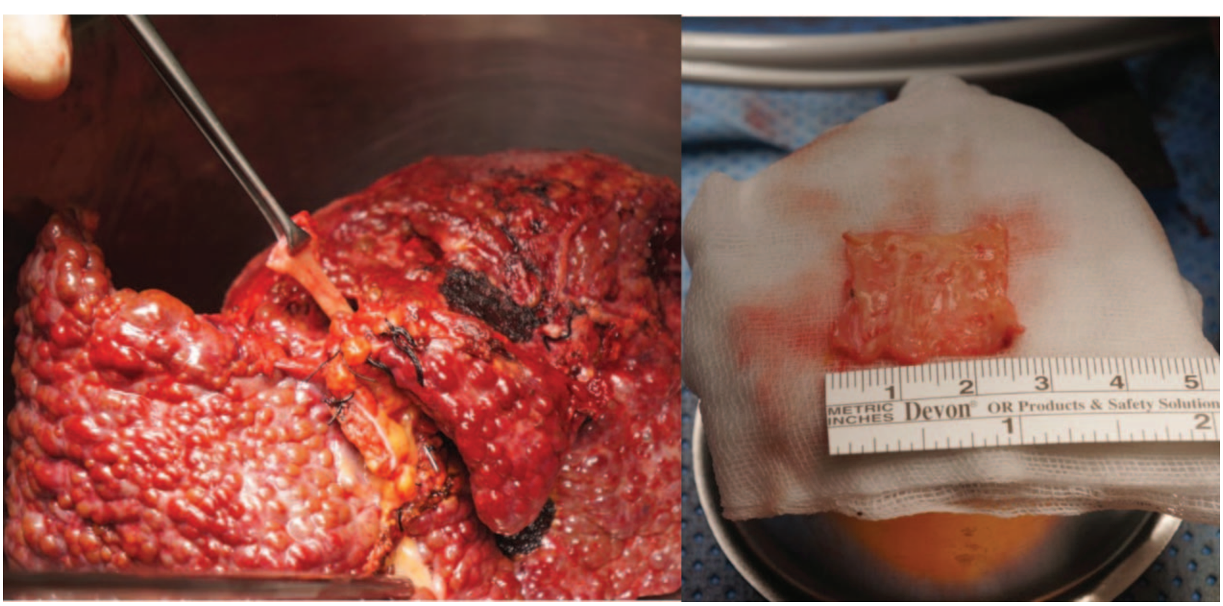


**Figure 3.** Procurement of a diamond-shaped patch from the hepatic vein of the explanted liver.

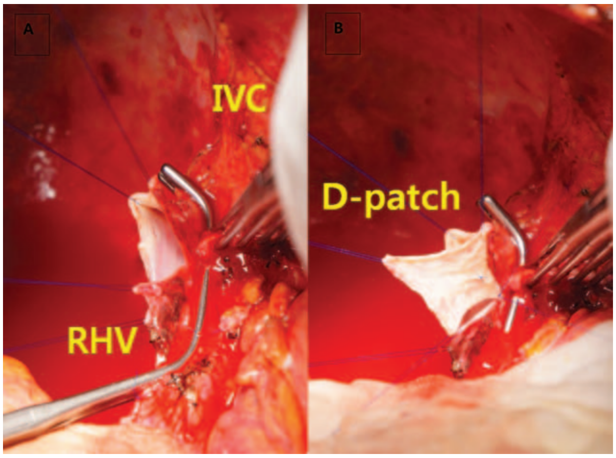


Figure 4. (A) An approximately 1.5-cm transverse incision is made on the anterior wall of the right hepatic vein (RHV) of the graft and recipient. If necessary, a longitudinal incision is made on the cephalic and caudal sides of the RHV of the recipient. (B) All openings are sutured before anastomosis because of the presence of many small tributaries in the RHV patch. RHV = right hepatic vein.

The bench procedure was completed by using an artificial vessel after the MHV was reconstructed.

The RHV of the explanted liver was dissected, and a 2 × 2-cm D-patch was obtained from the recipient hepatic vein after total recipient hepatectomy. All openings were sutured before anastomosis because of the presence of many small tributaries in the RHV patch. The portal vein of the explanted liver was used as the D-patch if the hepatic vein was deemed unsuitable for use. A 1.5 to 2-cm incision was made on the anterior side of the recipient RHV. Then, the D-patch was applied during the anhepatic period, which was defined as the period from recipient hepatectomy to portal vein reperfusion (Fig. 4A and B). Another incision at the proper site of the grafted RHV was made, and the RHV was anastomosed with the D-patch (Fig. 5).

***2.3.3. MHV procedure.*** We attempted to reconstruct all MHV tributaries measuring ≥5 mm in diameter using various interposition vessel grafts and bench work. The size and shape of a vessel allograft suitable for MHV reconstruction were determined after parenchymal transection of the donor liver. First, vein segment 5 was anastomosed to the interposition graft in an end-to-end fashion using 5–0 polypropylene continuous sutures. Vein segment 8 was anastomosed to the interposition graft in an end-to-side manner. Finally, the reconstructed MHV graft was anastomosed to the middle-left hepatic vein stump.

### 2.4. Primary outcome and statistical analysis

The rate of intervention, including stent insertion or balloon angioplasty, after transplant was observed. In addition, the anhepatic period was investigated because the D-patch technique was performed during that time.

Categorical variables are expressed in terms of absolute and relative frequencies. Quantitative variables are expressed as mean and standard deviation. The Student's $t$ test was used to compare the results of quantitative variables, whereas the $\chi^2$ test was used to compare categorical variables. Repeated measures analysis of variance (repeated ANOVA) was used to compare the changes in serial laboratory findings, such as the levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and total bilirubin and prothrombin time, in the same recipients. Differences were considered significant when $P < .05$. Patient survival and RHV patency were analyzed using the Kaplan–Meier method. Statistical calculations were performed using PASW statistics, version 20 for Windows (SPSS Inc., Chicago).

## 3. Results

Three patients who died within 30 days postoperatively and 4 who received left liver grafts were excluded from the study.

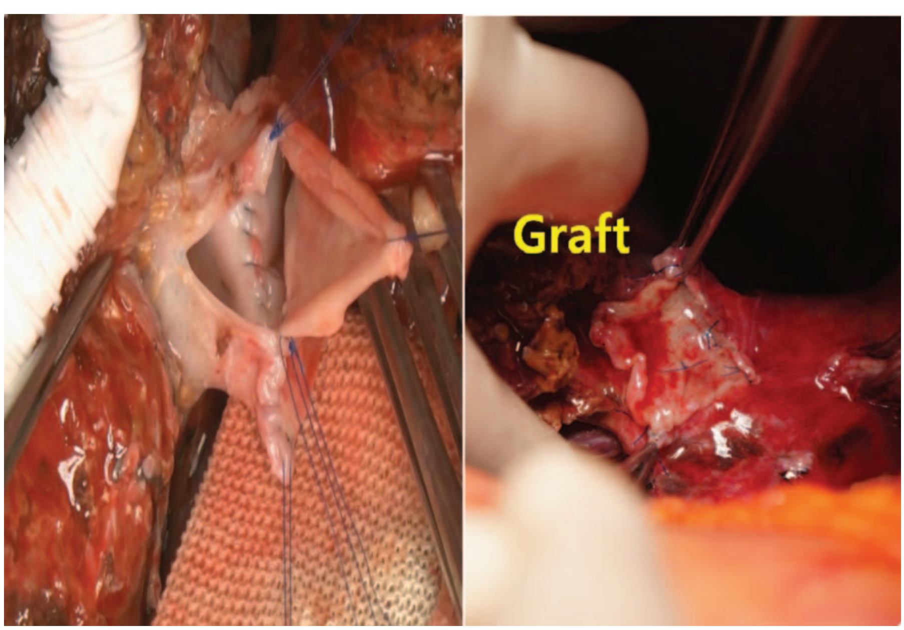


Figure 5. An anterior incision is made at the proper site of the grafted right hepatic vein (RHV), and the RHV is anastomosed with the diamond-shaped patch. RHV = right hepatic vein.

**Table 1**

**Baseline characteristics in the conventional method applied group (n=100) versus the D-patch applied group (n=53).**

| | Conventional group (n=100) | D-patch group (n=53) | *P* value |
|---|---|---|---|
| Age | 51.7±8.9 | 51.3±8.8 | .8 |
| Male sex (%) | 73 (73.7%) | 41 (77.4%) | .697 |
| Donor age | 27.8±9.4 | 28.7±10.3 | .551 |
| Cause of liver transplant | | | |
| Hepatocellular carcinoma | 66 (66%) | 32 (60.4%) | |
| Alcoholic liver cirrhosis | 16 (16%) | 7 (13.2%) | .683 |
| Viral liver cirrhosis (B or C) | 9 (9%) | 9 (17.0%) | |
| Others | 9 (9%) | 5 (9.4%) | |
| CTP | | | |
| A | 57 (57%) | 22 (41.5%) | .257 |
| B | 19 (19%) | 18 (34.0%) | |
| C | 24 (24%) | 13 (24.5%) | |
| MELD score | 12.3±7.3 | 15.3±9.3 | .028 |
| Graft weight, gram | 710.9±134.7 | 668.5±115.9 | .054 |
| GRWR | 1.08±0.26 | 1.07±0.26 | .864 |

All data are expressed either as mean±standard deviation or incidence (%).

CTP=Child–Turcotte–Pugh, GRWR=graft-to-recipient weight ratio, MELD=model for end-stage liver disease.

Finally, 152 patients were included in this study. Conventional RHV reconstruction was performed in 100 patients, while the D-patch technique was performed in 53.

### 3.1. Patient profiles

The most common etiology of liver disease was hepatocellular carcinoma (n=98). Patients' mean age was 51.2±9.4 years, and the male-to-female ratio was 114:49. The mean model for end-stage liver disease (MELD) score was 13.3±8.2. There were no significant differences in age, sex distribution, donor age, graft weight, or cause of liver transplant between the conventional reconstruction and D-patch groups (Table 1). The graft volume-to-recipient body weight ratio was similar between the groups, whereas the MELD scores were higher in the D-patch group than in the conventional reconstruction group.

### 3.2. Postoperative liver function and recovery

Statistically, the D-patch technique did not contribute to changes in the AST or total bilirubin level during the postoperative period. However, the liver enzyme levels (AST and ALT) on postoperative day 1 were significantly lower in the D-patch group than in the conventional reconstruction group. This showed that the D-patch technique was not associated with an increased risk of ischemic damage compared with conventional reconstruction. Compared with the conventional reconstruction group, the D-patch group also had lower ALT levels and a prolonged international normalized ratio. It reflected the conventional group had a quick recovery on ALT level, while the D-patch group had a better recovery on INR. However, most of the recipients of the two groups had normal laboratory findings at 1 month postoperatively (Table 2). These laboratory findings did not affect the patients' recovery.

### 3.3. Survival outcomes

The rate of intervention for RHV stenosis was significantly lower in the D-patch group than in the conventional reconstruction group (20% vs 3.8%; *P*=.01). The time taken to perform the D-patch technique was similar to that for conventional reconstruction (anhepatic period, 104.9 minutes vs 106.7 minutes; *P*=.82). Overall RHV patency was significantly different between the groups (*P*=.027), whereas overall patient survival was not (conventional reconstruction group, 95.0% vs D-patch group, 98.1%; *P*=.613; Fig. 6A, B). The rate of intervention for RHV stenosis was significantly lower in the D-patch group than in the conventional reconstruction group (19.2% vs 3.8%; *P*=.01; Table 2), whereas overall graft survival was not significantly different between the groups (conventional reconstruction group, 95.0% vs D-patch group, 100.0%; *P*=.098; Fig. 7). In particular,

**Table 2**

**Serial changes in liver functional index during 1 month after LDLT between the 2 groups (repeated measures ANOVA was used for statistical analysis in laboratory findings).**

| | | Conventional group (n=100) | D-patch group (n=53) | *P* value |
|---|---|---|---|---|
| | POD 1 | 381.0±299.2 | 259.5±320.3 | |
| | POD 3 | 105.2±73.1 | 113.0±113.7 | |
| AST, IU/L | POD 7 | 69.8±49.4 | 73.1±41.2 | .119 |
| | POD 28 | 33.4±26.7 | 43.6±52.7 | |
| | POD 1 | 384.5±287.4 | 228.2±195.6 | |
| | POD 3 | 188.7±127.7 | 156.9±124.2 | |
| ALT, IU/L | POD 7 | 157.4±154.5 | 146.9±92.3 | .013 |
| | POD 28 | 59.5±70.5 | 66.5±105.3 | |
| | POD 1 | 5.1±4.8 | 4.4±3.4 | |
| | POD 3 | 3.1±3.7 | 3.0±2.8 | |
| Total bilirubin, mg/dL | POD 7 | 2.9±2.7 | 2.5±2.6 | .437 |
| | POD 28 | 1.1±1.5 | 1.0±1.2 | |
| | POD 1 | 1.64±0.23 | 1.84±0.30 | |
| Prothrombin time, INR | POD 3 | 1.38±0.15 | 1.51±0.32 | <.001 |
| | POD 7 | 1.22±0.12 | 1.29±0.17 | |
| | POD 28 | 1.09±0.16 | 1.09±0.18 | |
| Number of intervention (%) | | 20 (20%) | 2 (3.8%) | .012 |
| Anhepatic phase period, minutes | | 104.9±47.5 | 106.7±42.0 | .819 |

All data are expressed either as mean±SD or incidence (%).

ALT=alanine aminotransferase, AST=aspartate aminotransferase, LDLT=living-donor liver transplant, POD=Post operative day.

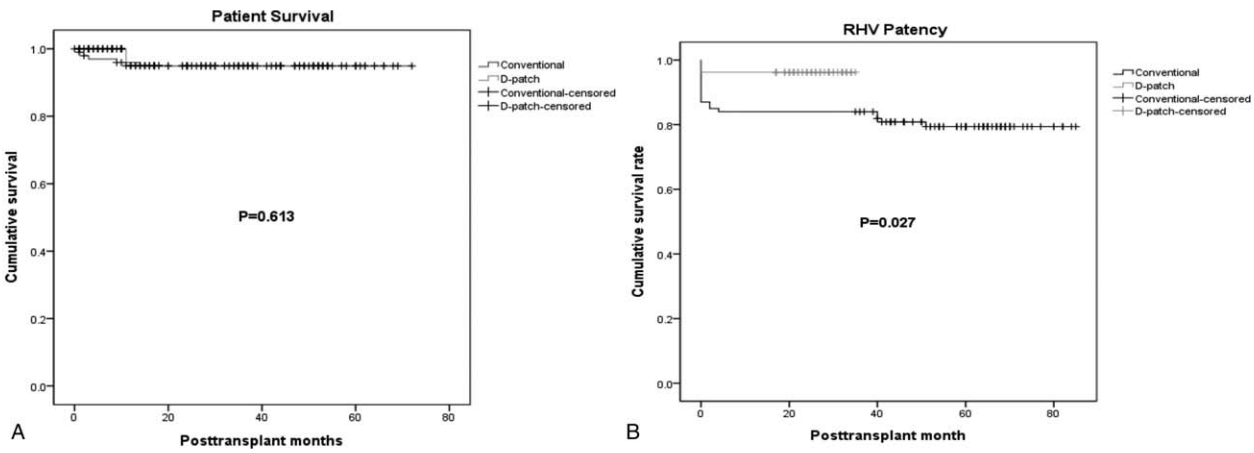


**Figure 6.** Overall survival curves for both groups. No significant difference in overall survival is observed (A), but there is a significant difference in right hepatic vein patency (B).

no graft failure was observed in the D-patch group. In both groups, there was no recurrence of stenosis after stent insertion.

## 4. Discussion

RHV reconstruction without stenosis or obstruction is essential for successful LDLT because the RHV is the primary outflow of tract the right liver graft.[2] The hemodynamics of the system must be considered to prevent stenosis or obstruction of the hepatic vein outflow.[3] Hwang et al[3] emphasized that wide, short, and blunt lower anastomotic borders are essential for RHV reconstruction in terms of hemodynamics. In addition, conformational changes in the hepatic venous system due to graft growth after transplant should be considered.[4]

Every experienced health care center has its own procedure for preventing the risks associated with hepatic vein reconstruction. Soejima et al[5] suggested one-step venous reconstruction for the right liver graft. They created one orifice outflow for the middle, inferior, and right hepatic veins by using cadaveric veins or the recipient saphenous vein. Kim et al[6] suggested a similar technique for hepatic outflow reconstruction; they conjoined the middle and right hepatic veins into an orifice, after which they created a barrier around the orifice using cadaveric veins. Asan Medical Center is the largest center in the world in which LDLT is performed[7]; Dr Lee's group created a barrier on the lower border of the RHV through the bench procedure and excised the inferior vena cava for RHV reconstruction.

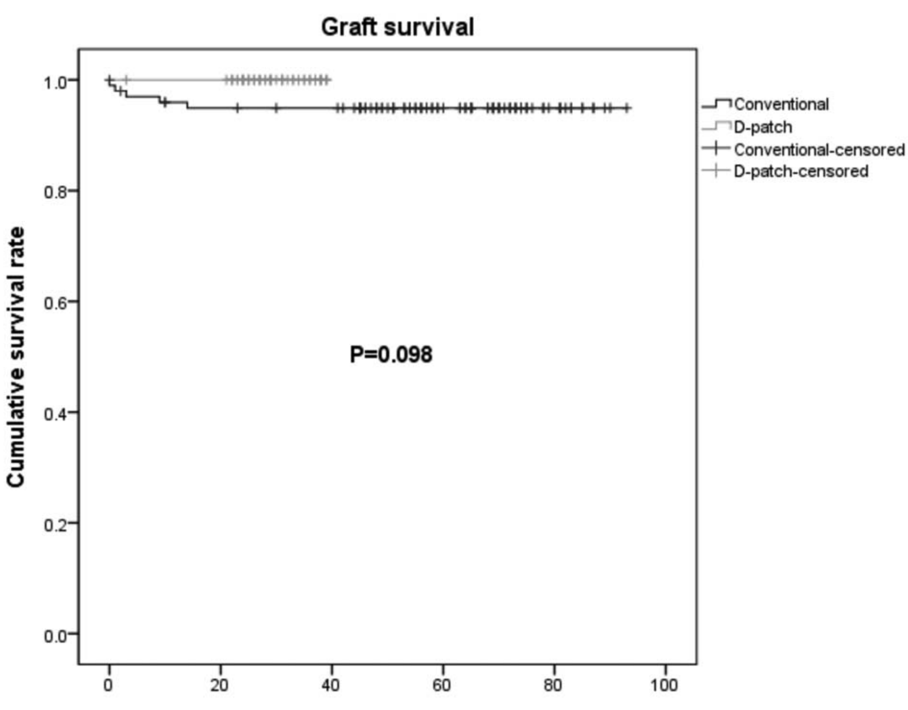


**Figure 7.** Graft survival curves for both groups. No significant difference in graft survival is observed.

All of these aforementioned authors showed excellent outcomes in terms of hepatic vein outflow reconstruction. However, there are some disadvantages to these techniques. First, the steps in the bench procedure require more time and effort, which extend the cold ischemic time. Second, cadaveric veins are not always available, and the recipient great saphenous vein can be used when cadaveric veins are inadequate; this is especially true in the Asan Medical Center. Procurement of the great saphenous vein is more harmful for the recipient and may be accompanied by complications, such as lymphoceles in the harvesting site. Third, the surgical procedures are complex; thus, centers that do not manage a large number of patients cannot easily apply the techniques.

The D-patch technique does not increase the cold ischemic time. This occurs because the dorsal side of the RHV is dissected during donor hepatectomy, which has the same effect as creating a barrier for the lower border, and this step is not included in the bench procedure. Then, the D-patch is applied after total hepatectomy during the bench procedure for MHV reconstruction. We use the recipient hepatic vein after total hepatectomy because cadaveric and saphenous veins are not needed. The procedure is simple, anhepatic period is almost the same as the cold ischemic time, and warm ischemic time is not extended.

In the conventional reconstruction group, the intervention rate was about 20%, which is substantially higher than that at other health care centers. There are some reasons for this. First, a learning period for the surgical and radiographic procedures was necessary at our center during the early transplant period. We started the LDLT program in May 2010, and LDLTs were performed using conventional RHV reconstruction during the early period. Second, the strategies for the intervention were strict in this study. Clinical findings, such as abnormal liver enzyme levels or an elevated bilirubin level, disqualified patients from further intervention. If stenosis was suspected based on CT or Doppler ultrasonographic findings, the hepatic vein pressure gradient was checked, and then the intervention was performed using a high pressure gradient as a preventive measure, even if laboratory findings revealed normal liver enzyme levels.

The main limitation of this study was its retrospective design. In addition, the 2 groups had different follow-up periods. Many cases in the conventional reconstruction group were from the early period of LDLT, whereas all cases in the D-patch group were from the later period. Thus, more experience in LDLT might have caused the improvements in the outcomes of the D-patch group, although the procedure was associated with a worse MELD score and a lighter graft weight (Table 1). Furthermore, we did not report the RHV patency after intervention in this study because it was already shown in a previous study.[8] The patency rate was 80% at 3 years after stent placement.

In conclusion, the D-patch technique for RHV reconstruction in LDLT is a simple, fast, and feasible surgical technique that can be performed without using cadaveric or saphenous veins.

## Author contributions

**Conceptualization:** Byung Hyun Choi, Kwang Ho Yang, Je Ho Ryu, Chong Woo Chu.
**Data curation:** Tae Beom Lee, Byung Hyun Choi, Kwang Ho Yang, Je Ho Ryu, Young Mok Park, Chong Woo Chu.
**Formal analysis:** Tae Beom Lee, Byung Hyun Choi, Kwang Ho Yang, Je Ho Ryu, Young Mok Park, Chong Woo Chu.
**Investigation:** Tae Beom Lee, Byung Hyun Choi, Je Ho Ryu.
**Methodology:** Tae Beom Lee, Byung Hyun Choi, Je Ho Ryu, Young Mok Park, Chong Woo Chu.
**Project administration:** Byung Hyun Choi.
**Resources:** Tae Beom Lee, Byung Hyun Choi.
**Software:** Young Mok Park.
**Supervision:** Byung Hyun Choi, Chong Woo Chu.
**Validation:** Je Ho Ryu.
**Visualization:** Kwang Ho Yang.
**Writing – original draft:** Tae Beom Lee, Byung Hyun Choi.
**Writing – review & editing:** Byung Hyun Choi.
Tae Beom Lee: 0000-0002-9245-5066

## References

[1] Liu CL, Zhao Y, Lo CM, et al. Hepatic venoplasty in right lobe liver donor liver transplantation. Liver Transpl 2003;9:1265–72.
[2] Sugawara Y, Makuuchi M, Imamura H, et al. Outflow reconstruction in recipients of right liver graft from living donors. Liver Transpl 2002;8:167–8.
[3] Hwang S, Ha TY, Ahn CS, et al. Hemodynamics-compliant reconstruction of the right hepatic vein for adult living donor liver transplantation with a right liver graft. Liver Transpl 2012;18:858–66.
[4] Takahashi M, Fukumoto T, Kido M, et al. Morphometric analysis of conformational changes in hepatic venous system after right lobe living donor liver transplantation. Hepatol Res 2011;41:318–27.
[5] Soejima Y, Ueda N, Fukuhara T, et al. One-step venous reconstruction for a right lobe graft with multiple venous orifices in living donor liver transplantation. Liver Transpl 2008;14:706–8.
[6] Kim JD, Choi DL, Han YS. Simplified one-orifice venoplasty for middle hepatic vein reconstruction in adult living donor liver transplantation using right lobe grafts. Clin Transplant 2014;28:561–8.
[7] Lee SG. A complete treatment of adult living donor liver transplantation: a review of surgical technique and current challenges to expand indication of patients. Am J Transplant 2015;15:17–38.
[8] Jang JY, Jeon UB, Park JH, et al. Efficacy and patency of primary stenting for hepatic venous outflow obstruction after living donor liver transplantation. Acta Radiol 2016;58:38–40.