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ORIGINAL ARTICLE

Reconstruction of middle hepatic vein in living donor liver transplantation with modified right lobe graft: a single center experience

Jian Wu, Weilin Wang, Min Zhang, Yan Shen, Tingbo Liang, Pengfei Yu, Xiao Xu, Sheng Yan and Shusen Zheng

Department of Hepatobiliary and Pancreatic Surgery, The First Affiliated Hospital, College of Medicine, Zhejiang University, Hangzhou, China

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Correspondence
Shusen Zheng, Department of Hepatobiliary and Pancreatic Surgery, The First Affiliated Hospital, College of Medicine, Zhejiang University, Hangzhou 310003, China.
Tel.: +86 571 87236601; fax: +86 571 87236609; e-mail: zyzss@zju.edu.cn

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Summary

Although a right liver graft without the middle hepatic vein (MHV) can cause congestion in the anterior segment, the reconstruction of MHV tributaries and the complex procedure remain controversial. Between November 2006 and October 2007, right liver transplantation without the MHV was performed in 31 cases. A retrospective analysis was conducted on clinical data and two groups were formed: with MHV reconstruction (Group I, $n = 16$) and without MHV reconstruction (Group II, $n = 15$). We analyzed the serum liver function markers at 3 weeks postoperatively and evaluated vascular flow in the graft and interpositional vein daily by Doppler ultrasonography during the hospital stay and monthly follow-up after discharge. One patient (6.7%) died of liver congestion and acute hepatic rejection on the postoperative day 10 in Group II. Congestion was observed in another three cases (20%) of Group II and one case (6.25%) of Group I. The levels of alanine transferase and aspartate transferase in Group II was higher than those in Group I in the first week after transplantation, albeit not significantly. In Group I, most of the interpositional vein grafts were the recipient's portal veins. Venoplasty in the graft was performed in three cases. All the interpositional veins and tectonic outflow orifices were detected to be patent by ultrasonography within 14 days after transplantation. The reconstruction of the MHV tributaries is necessary in the right liver graft without MHV according to our policy and better criteria for MHV reconstruction should be established. The recipient's portal vein is an optimal choice for the interpositional vein and hepatic venoplasty in living donor liver transplantation can simplify the operation and ensure excellent venous drainage.

Introduction

Living donor liver transplantation (LDLT) using right lobe is now a standard method for adult patients to alleviate the problem of graft size insufficiency [1]. Hepatic venous outflow of the median sector (corresponding to Couinaud segment V, VIII and IV) is drained mainly into the middle hepatic vein (MHV) [2]. A right liver graft with MHV trunk (extended right liver graft) often provides an adequate graft volume for recipients, but it also extends the donor operation and therefore raises an important ethical issue in LDLT [3]. Without including MHV into right-lobe graft (modified right liver graft) may cause various degrees of congestion in the anterior segment (segment V and VIII) [1], which leads to severe graft dysfunction and septic complications [4]. In such cases, Lee *et al.* [5] recommended to reconstruct the MHV tributaries with venous grafts, because this method could obviate the potential congestion in the anterior segment and

provide a functioning liver mass comparable to an extended right liver graft [3]. However, other centers did not perform the MHV tributaries reconstruction, as they found that collateral circulation could develop after ligation of the major hepatic veins and successful transplantations had been reported without congestion [6,7].

For a modified right liver graft, there would be another technical difficulty in case additional reconstruction of the MHV tributaries is necessary. One issue concerns the source of optimal vessel graft for reconstruction, whether from the graft donor, recipient, or cadaveric donor [8]. Another issue concerns a wide outflow orifice for adequate venous drainage.

Therefore, the necessity of the MHV reconstruction and the complex procedures remain the topics of heated debate. We presented here the surgical indications, techniques, and results for hepatic vein reconstruction in modified right liver graft in our center.

Materials and methods

Patients

Between November 2006 and October 2007, we performed 31 cases of adult LDLT using the right lobe. All grafts did not include the MHV. The 31 patients consisted of 27 men and four women, aged from 15 to 60 years (mean 42.2 years). Their body weight ranged from 42 to 72 kg (mean 59 kg). The indications for LDLT included acute liver failure in 12 (38.7%) pateints, hepatitis B virus-related cirrhosis in 5 (16.1%), and hepatocellular carcinoma in 14 (45.2%, within UCSF criteria). We divided the patients into two groups: Group I with the MHV tributaries reconstruction and Group II without the MHV tributaries reconstruction. Demographic data of the patients are listed in Table 1.

The donors consisted of 29 men and two women. Their ages ranged from 20 to 49 years (mean 31 years) and they weighed 58–79 kg (mean 67 kg). All transplantations were approved by the ethical committee of Zhejiang University.

Preoperative evaluation of donor Liver

Right-lobe liver volume was preoperatively estimated by computed tomography (CT) scans. The candidate donors whose right liver volume represented more than 70% of the whole liver were rejected as prospective donors. The graft to recipient weight ratio (GRWR) of 0.8% was the lowest limit for transplantation.

The number and diameter of the MHV tributaries were evaluated by CT before transplantation. The tributaries are classified as V8 that drains the segment VIII of a liver graft and V5 that drains the corresponding segment V.

Table 1. Data of the patients with or without middle hepatic vein (MHV) reconstruction.

	Group I (n = 16) with MHV reconstruction	Group II (n = 15) without MHV reconstruction
Recipients		
Age (year)		
Mean (range)	42.3 (15–60)	42.1 (17–59)
Gender		
M/F	15/1	12/3
Diseases		
HBV, LF	5	7
LC	3	2
HCC	8	6
Donors		
Age (year)		
Mean (range)	30.6 (20–46)	31.3 (22–49)
Gender		
M/F	15/1	14/1
GRWR		
<0.8	0	0
0.8–1.0	6	6
>1.0	10	9
Complications		
Congestion	1	4
Acute rejection	1	2
Pulmonary infection	1	1
Bile leakage	1	2
Renal insufficiency	0	2
Mortality	0	1

GRWR, graft to recipient weight ratio; HBV, hepatitis B virus; LF, liver failure; LC, liver cirrhosis; HCC, hepatocellular carcinoma.

Intraoperative evaluation of hepatic venous congestion

Hepatic venous congestion in the right anterior segment was evaluated intraoperatively after parenchyma transection. First, we identified and clamped the right hepatic artery and the MHV tributaries and then observed whether the liver surface in the right anterior segment was discolored compared to other sectors. Second, we performed intraoperative Doppler ultrasonography to evaluate the flow in the veno-occlusive area. In case the portal flow of the paramedian sector was hepatofugal, congestion in this area was confirmed.

According to the policy of our center, venous reconstruction is recommended when the diameter of V5 and V8 was more than 5 mm. When the congested area that was dominant by the clamping test or ultrasonography was larger than half of the surface of the anterior segment, the MHV tributaries also should be reconstructed.

Operative procedures

Donor right lobectomy (hemihepatectomy) was performed without the main trunk of MHV. Parenchymal

transection was performed 5 mm to the right of Cantlie line with a Cavitron Ultrasonic Surgical Aspirator (CUSA) in the absence of vascular inflow occlusion. All of the MHV tributaries and the inferior right hepatic vein (RHV) with a significant size (>5 mm in diameter) were isolated and preserved. The harvested liver graft was flushed with 1 l University of Wisconsin (UW) solution through the right portal vein.

The recipient's RHV orifice was incised caudally to conform to the size disparity between the recipient and graft hepatic vein. After this modification, the RHV was anastomosed in an end-to-end fashion using a continuous 5-0 prolene suture. The reconstruction of MHV tributaries from segment 5 (V5) or segment 8 (V8) or both was performed in the case of sufficient size (>5 mm in diameter). Recipient's portal veins were mainly used as interpositional vein grafts. Wherever necessary, recipient's MHV or umbilical vein was harvested from the recipients for interposition (Fig. 1). These venous grafts were anastomosed to the MHV tributaries (V5,V8) and the recipient's inferior vena cava (IVC) with a continuous 6-0 prolene suture. The reconstructed tributaries consisted of V5, V8, and both V5 and V8.

When V8 was adjacent to RHV, hepatic venoplasty between V8 and RHV was performed to avoid V8 reconstruction using interpositional vein. The V8 was joined to the RHV to form a common triangular orifice, and then

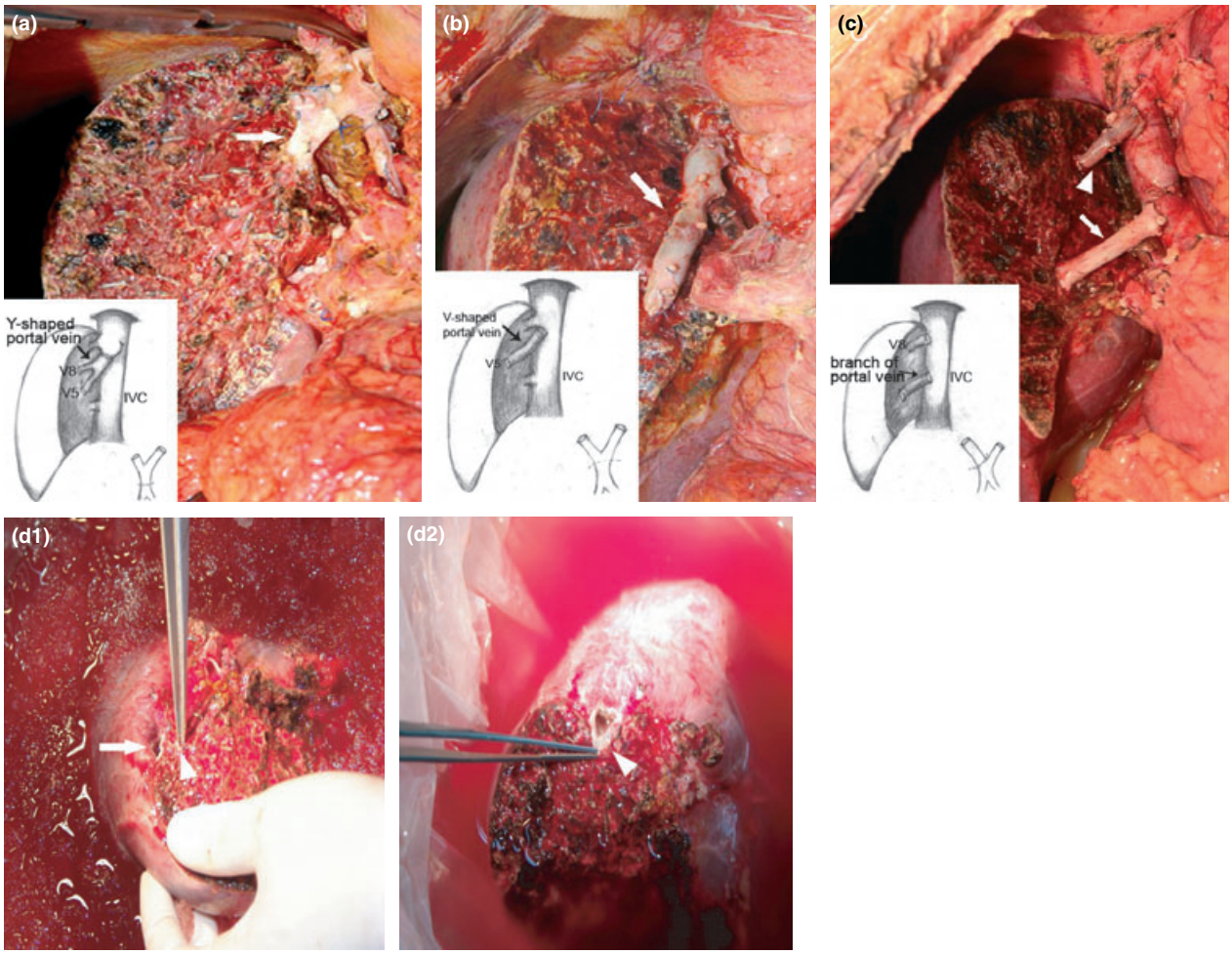

Figure 1 (a) a Y-shaped portal vein graft (arrow) was harvested from the recipient. The right and the left branch of the portal vein were anastomosed to V5 and V8, respectively, and the distal site of the vein graft was anastomosed to the recipient's inferior vena cava. (b) A V-shaped recipient's portal vein(the segment of furcation) (arrow) was used as a jump graft. We reshaped it by suturing the basilar part of the V-shaped furcation, and the two sides were anastomosed to V5 and the recipient's inferior vena cava, respectively. (c) The recipient's umbilical vein(arrowhead) was used as an interpositional graft between the recipient's IVC and V5. Another vein graft, the right branch of portal vein (arrow) was anastomosed to the V8 and the recipient's IVC. (d1) The V8(arrowhead) was adjacent to the RHV (arrow). (d2) The V8 was joined to the RHV to form a triangular common orifice (arrowhead).

the orifice was anastomosed directly to a matched-size triangular opening in the recipient's IVC (Fig. 1).

Postoperative evaluation

International normalized ratio (INR), total bilirubin (TB), alanine transferase (ALT), and aspartate transferase (AST) were measured daily for 3 weeks after LDLT. Vascular flow in the graft and interposition vein patency was evaluated daily by Doppler ultrasonography during the hospital stay and monthly after discharge. Enhanced CT and magnetic resonance imagining (MRI) were performed monthly for consecutive 3 months after LDLT.

Results

One patient (6.7%) died of severe liver congestion and acute hepatic rejection on the postoperative day (POD) 10 in Group II. Mild congestion was observed in three cases (20%) of Group II and one case (6.25%) of Group I (Fig. 2). Other complications included acute rejection (one in Group I, one in Group II), pulmonary infection (one in Group I, one in Group II), bile leakage (one in Group I, two in Group II), renal insufficiency (two in Group II). The postoperative serum ALT, AST, TB, and INR in all patients gradually returned to the normal range during the hospital stay. The levels of ALT and AST in Group II were higher than those in Group I during the first week after transplantation, albeit not being significant (Fig. 3).

In the reconstruction group (Group I, $n = 16$), the MHV tributaries consisted of V5 ($n = 3$), V8 ($n = 5$), both V5 and V8 ($n = 5$). The interpositional vein grafts harvested from the recipient included Y-shaped portal vein ($n = 2$), V-shaped portal vein ($n = 2$), right branch of portal vein ($n = 6$), left branch of portal vein ($n = 3$), MHV ($n = 1$) and umbilical vein ($n = 1$). Venoplasty between V8 and RHV was performed in three cases (Table 2). No anticoagulation strategy was attempted under strict monitoring by ultrasonography. The patency of the interpositional veins and outflow orifices were 100% (16/16) on POD 14; 93.75% (15/16) on POD 30; 75% (12/16) on POD 60 and 56.25% (9/16) on POD 90. The liver graft volume and graft function were not affected after the resolution of occlusion of interpositional veins.

Thirty recipients were discharged in condition within 1 month after transplantation and no further mortality have occurred up till now. Neither mortality nor life-threatening postoperative complications were found in the donors and they all recovered well within 3 weeks after operation.

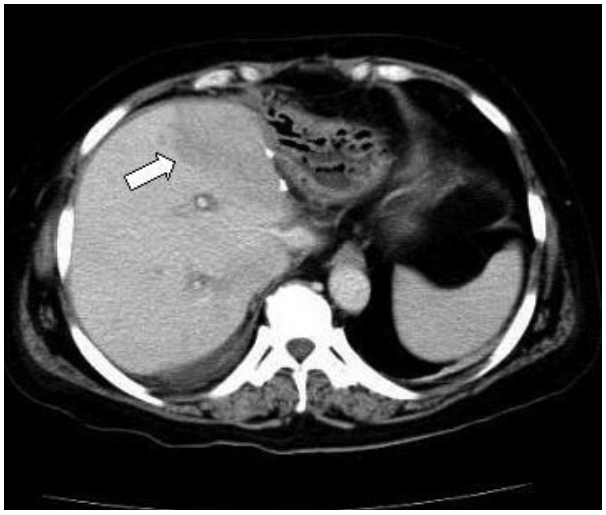

Figure 2 Computed tomography image shows congestion in the anterior segment of the right lobe graft after LDLT.

Discussion

In adult LDLT using the right liver graft, the efficacy and necessity of MHV reconstruction are still controversial. It was suggested that intrahepatic collateral could produce venous flow into the RHV after the ligation of tributaries of the MHV. This kind of venous collateral developed within 10 days after transplantation [9] and the partial congestion in the anterior segment after ligation could be tolerated by the liver [8]. From this point of view, the reconstruction of MHV appeared to be not necessary. However, Lee *et al.* [10] reported that several patients without MHV reconstruction suffered severe congestion of the right paramedian sector, resulting in progressive graft dysfunction and septic complication. Other researches showed that the relatively poor regeneration of the anterior segment was associated with preoperatively dominant MHV tributaries, indicating that congestion could lead to inadequate regeneration of the affected area [11].

In view of this heated debate, some centers introduced their experience either with or without MHV reconstruction. The Tokyo group suggested the reconstruction of the hepatic vein or its tributaries if the graft volume excluding the discolored area under arterial clamping was estimated to be insufficient for postoperative metabolic demand [12]. Other centers concerned mainly about vessel diameter. Lee *et al.* [13] indicated that when the V5 or V8 during donor hepatectomy were larger than 5 mm in diameter, the reconstruction of MHV drainage from the anterior segment is recommended, and Mizuno *et al.* [14] suggested 7 mm as the demarcation for the MHV tributaries reconstruction.

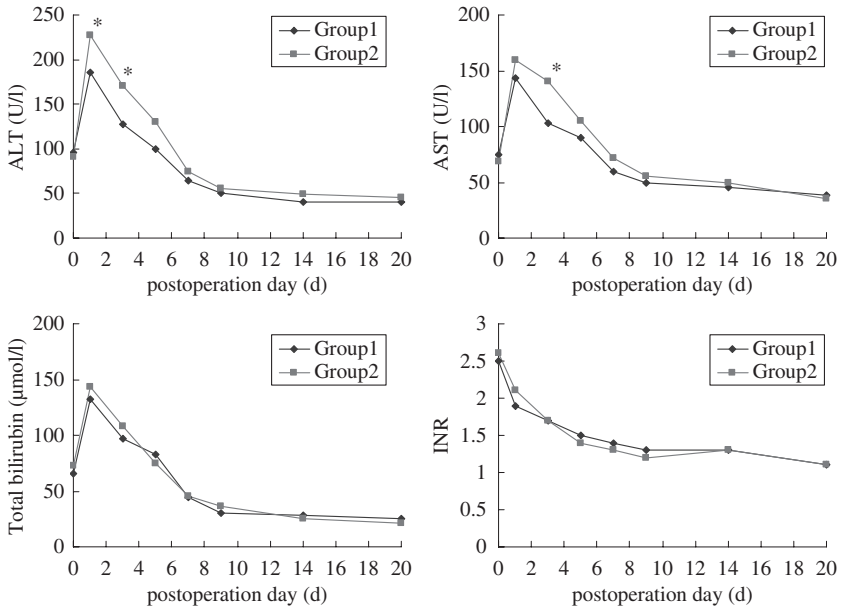

Figure 3 Serial change of liver function markers (ALT, AST, TB, INR) in all patients after LDLT. *$P < 0.05$.

Table 2. Detail of the reconstruction of the middle hepatic vein (MHV) tributaries.

	Number (or rate)
Reconstructed veins	
V5	3
V8	5
V5/V8	5
Venoplasty(V8 and RHV)	3
Vein grafts	
Y-shaped PV	2
V-shaped PV	2
Right branch of PV	6
Left branch of PV	3
Recipient's MHV	1
Recipient's UV	1
Patency rate	
POD 14	100% (16/16)
POD 30	93.75% (15/16)
POD 60	75% (12/16)
POD 90	56.25% (9/16)

RHV, right hepatic vein; PV, portal vein; UV, umbilical vein.

The policy of our center for the right lobe LDLT without MHV (modified right liver graft) had been above. The number and diameter of MHV tributaries (V5 and V8) were assessed by CT, and further evaluations were carried out during the operation, including observation of the discolored area after occlusion of the hepatic artery and MHV tributaries and the use of Doppler ultrasonography to reveal hepatic vein anatomy and its flow.

However, of the 31 recipients, liver congestion occurred in 5 (16.1%). One patient died of severe liver congestion and acute hepatic rejection in Group II. We assumed that the lack of reconstruction or insufficient reconstruction of the MHV tributaries was the cause of congestion and that some small MHV tributaries (<5 mm in diameter) still need reconstruction. Therefore, better criteria for the MHV tributaries reconstruction should be established and the diameter of the vessels (V5/V8), the congestion area to the total graft volume, the GRWR and other critical elements should be fully taken into account. Further investigations have been initialized and in progress in our center.

As the reconstruction of the MHV tributaries using venous grafts is recommended in selective cases, the optimal vessel for interposition has emerged as a new problem. Many types of vein grafts have been used for the reconstruction of the MHV, including saphenous vein [15], umbilical vein, left portal vein, mainly from the recipient; the inferior mesenteric vein (IMV) and iliac vein [1,5,16], mainly from the donor. Some of the vein grafts, such as the IMV, umbilical vein, and saphenous vein are too small to maintain flow for long time and usually need venoplasty to increase its diameter. Other vessels, such as the iliac vein, which has a similar size to the MHV, requires extensive dissection. Recently, some cryo-preserved veins have been introduced for hepatic vein reconstruction [17,18], but this type of vein grafts may have the problem of vein graft obstruction in the long-term observation period [18].

In our center, we mainly use the recipient's portal vein (main portal vein and its branch) as the interpositional MHV graft. This vein graft has several advantages over

other vessels. First, it is always available and easy to expose after the resection of the liver and eliminates the extensive dissection in the recipient or donor. Second, the suitable caliber, thick wall, and natural curvature of the portal vein can reduce the risk of thrombosis after transplantation [16]. In our study, the recipient's portal veins (Y-shaped segment, V-shaped segment, main portal vein, right/left right branch of portal vein) were used as the main interpositional vein grafts in 13 patients and showed successful results.

We performed venoplasty between V8 and RHV in three patients in order to form a large common orifice and ensure adequate venous drainage. Lo *et al.* [19] reported this technique as a standard one to right lobe grafts with the MHV. During the operation, proper adjustment of the anastomosed veins to the exact length, orientation, and diameter was difficult and the consequent incompatible anastomosis usually caused the obstruction of venous outflow. The hepatic venoplasty can minimize these difficulties. The common orifice of the hepatic veins after the venoplasty can be directly anastomosed to or indirectly anastomosed with a shorter interpositional graft to an opening of similar size and shape in the IVC. Venoplasty between hepatic veins can not only avoid reconstruction using interpositional vein, but also decrease the possibility of obstruction because of kinking or misalignment. As a result, hepatic venoplasty can simplify the operation and guarantee excellent venous drainage [19,20]. In our experience, it can be well performed in right lobe grafts without the MHV.

In summary, we prefer to perform the reconstruction of the MHV tributaries in the right liver graft without MHV according to our policy. The recipient's portal vein is an optimal choice for interpositional vein graft. Hepatic venoplasty in LDLT can simplify the operation and ensure excellent venous drainage. Further clinical studies should aim at establishing better criteria for the MHV reconstruction and innovating in reconstructive surgical techniques on prognosis.

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Authorship

JW: designed and performed research; wrote paper. WW, MZ, YS and TL: designed and performed research. PY: designed research; collected data; wrote paper. XX: performed research; collected and analyzed data. SY: performed research; collected and analyzed data. SZ: designed and performed research; analyzed data.

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