[13] Akabayashi A, Slingsby BT, Fujita M. The first donor death after living-related liver transplantation in Japan. Transplantation 2004;77: 634 (letter).
[14] Marcos A, Ham J, Fisher R, Olzinski A, Posner M. Single-center analysis of the first forty living donor transplants using the right lobe. Liver Transpl 2000;6:296–301.
[15] Pomfret EA, Pomposelli JJ, Gordon FD, Erbay N, Lyn Price L, Lewis WD, et al. Liver regeneration and surgical outcome in donors of right-lobe liver grafts. Transplantation 2003;76:5–10.
[16] Marcos A, Ham JM, Fisher RA, Olzinski AT, Shiffman ML, Sanyal AJ, et al. Emergency adult-to-adult living donor liver transplantation for fulminant hepatic failure. Transplantation 2000; 69:2202–2205.
[17] Marcos A, Killackey M, Orloff MS, Mieles L, Bozorgzadeh A, Tan HP. Hepatic arterial reconstruction in 95 adult right lobe living donor liver transplants: evolution of anastomotic technique. Liver Transpl 2003;9:570–574.
[18] Tan HP, Marcos A. Hepatic arterial anatomy for right liver procurement from living donors. Liver Transpl 2004;10:134–135.
[19] Testa G, Malago M, Nadalin S, Hertl M, Lang H, Frilling A, et al. Right-liver living donor transplantation for decompensated end-stage liver disease. Liver Transpl 2002;8:340–346.
[20] New York State Health Department. New York State Committee on quality improvement in living liver donation 2002.
[21] Marcos A, Ham JM, Fisher RA, Olzinski AT, Posner MP. Surgical management of anatomical variations of the right lobe in living donor liver transplantation. Ann Surg 2000;231:824–831.
[22] Gondolesi GE, Varotti G, Florman S, Munoz L, Fishbein TM, Emre SH, et al. Biliary complications in 96 consecutive right lobe living donor transplant recipients. Transplantation 2004;77: 1842–1848.
[23] Lo CM, Fan ST, Liu CL, Yong BH, Wong Y, Lau GK, et al. Lessons learned from one hundred right lobe living donor liver transplants. Ann Surg 2004;240:151–158.
[24] Brown Jr RS, Russo MW, Lai M, Shiffman ML, Richardson MC, Everhart JE, et al. A survey of liver transplantation from living adult donors in the United States. N Engl J Med 2003;348: 818–825.
[25] Todo S, Furukawa H. Japanese study group on organ transplantation. Living donor liver transplantation for adult patients with hepatocellular carcinoma: experience in Japan. Ann Surg 2004; 240:451–459.
[26] Trotter JF. Living donor liver transplantation: is the hype over? J Hepatol 2005;42:20–25.
[27] Garcia-Retortillo M, Forns X, Llovet JM, Navasa M, Feliu A, Massauer A, et al. Hepatitis C recurrence is more severe after living donor compared to cadaveric liver transplantation. Hepatology 2004; 40:699–707.
[28] Sugawara Y, Makuuchi M. Should living donor liver transplantation be offered to patients with hepatitis C virus cirrhosis? J Hepatol 2005; in press.
[29] Shiffman ML, Stravitz RT, Cantos MJ, Mills AS, Sterling RK, Luketic VA, et al. Histologic recurrence of chronic hepatitis C virus in patients after living donor and deceased donor liver transplantation. Liver Transpl 2004;10:1248–1255.
[30] Russo MW, Shrestha R. Is severe recurrent hepatitis C more common after living donor liver transplantation? Hepatology 2004;40: 524–526.
[31] Bozorgzadeh A, Jain A, Ryan C, Ornt D, Zand M, Mantry P, et al. Impact of hepatitis C viral infection in primary cadaveric liver allograft versus primary living-donor allograft in 100 consecutive liver transplant recipients receiving tacrolimus. Transplantation 2004; 77:1066–1070.
[32] Tan HP, Madeb R, Kovach SJ, Orloff M, Mieles L, Johnson LA, et al. Hypophosphatemia after 95 right-lobe living donor hepatectomies for liver trasplantation is not a significant source of morbidity. Trasplantation 2003;76:1085–1088.

What is the best technique for right hemiliver living donor liver transplantation? With or without the middle hepatic vein? Duct-to--duct biliary anastomosis or Roux-en-Y hepaticojejunostomy?

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Adult-to-adult right hemiliver living donor liver transplantation (LDLT) has become an accepted procedure in both Western and Eastern societies. It provides a realistic hope of new life for thousands of recipients worldwide who otherwise would have limited or delayed access to a cadaveric organ [1]. There is much variation in the surgical technique of LDLT in different transplant centers, and controversies exist in the surgical management of the patients. The necessity of providing venous drainage to the right anterior sector of a right hemiliver graft in LDLT has been controversial. Inclusion of the middle hepatic vein (MHV) in the right hemiliver graft to ensure better early graft function is also under debate. Hepatico-jejunostomy has been the standard approach for biliary reconstruction since the first reported series of right hemiliver LDLT [2]. Duct-to-duct biliary anastomosis has several theoretic advantages over hepatico-jejunostomy and has gained popularity in liver transplant centers worldwide. However, the incidence of

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Abbreviations: LDLT, living donor liver transplantation; MHV, middle hepatic vein; RHV, right hepatic vein.

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biliary complications remains high after LDLT. In this review, the current status of LDLT with reference to the venous drainage of the right anterior sector and biliary reconstruction of the right hemiliver graft is discussed.

1. Venous drainage of the anterior sector of the right hemiliver graft

Although graft size is one of the important factors for the success of liver transplantation, the importance of a uniformly good venous drainage of the anterior sector of the right hemiliver graft as a crucial factor for the postoperative liver function in LDLT has been recognized [3]. Venous congestion of Couinaud's segments V and VIII of the right hemiliver graft is frequently observed if MHV tributaries from these segments are ligated and the MHV is not included in the liver graft. The consequences of compromised venous outflow can be evident in some cases after portal vein reperfusion. Segments V and VIII can become swollen and turgid, and have a dusky discoloration. Graft rupture has been reported in the situation of severe congestion of the anterior sector after reperfusion [4]. Recipients may also manifest a 'small-for-size' graft syndrome characterized by prolonged cholestasis, coagulopathy, and persistent ascites because the right posterior sector may sustain damage by the increased blood flow. Furthermore, poor venous outflow increases the risk of hepatic artery thrombosis and impairs graft regeneration by elevating sinusoidal pressure and disrupting sinusoidal endothelium [5,6].

Although venous congestion can resolve when intrahepatic venous collaterals to the right hepatic vein (RHV) enlarge during the first postoperative week [7], it may persist and contribute to the development of graft dysfunction and failure. In order to have a good quality functional right hemiliver graft without venous congestion to the anterior sector and to ensure satisfactory operative outcomes of the recipients, different approaches have been adopted in various transplant centers, ranging from selective reconstruction of the venous drainage on the basis of criteria such as appearance of dusky area, result of hepatic artery or hepatic vein occlusion test [8], donor–recipient body weight ratio, or presence of dominant segments V and VIII hepatic veins [9], to routine inclusion of the MHV in the graft [10].

Lee et al. reported the initial experience of five LDLTs without drainage of the right anterior sector in 2001 [11]. Two of the five recipients showed graft congestion, massive ascites, sepsis, or poor graft function, and one of them died 20 days after operation. It was suggested that preservation and reconstruction of the MHV tributaries are required to prevent congestion of the right hemiliver graft. Lee et al. advocated reconstruction of hepatic venous drainage of the segments V and VIII into the inferior vena cava using recipient's autogenous interposition vein graft including an external iliac vein or saphenous vein [12]. Using these 'modified right liver grafts', they reported a satisfactory survival outcome of the recipients [13].

Makuuchi et al. proposed to provide venous drainage to the right anterior sector in selected cases [8]. Instead of routine inclusion of the MHV in the graft, the prominent segments V and VIII hepatic vein branches are anastomosed to the recipient MHV and left hepatic vein using a homologous or cryo-preserved vein graft. Two tests were proposed to predict graft congestion and the need for the provision of venous drainage to the right anterior sector. The first test is to clamp the MHV at donor operation and observe the flow pattern in the right anterior sector portal vein by intraoperative ultrasonography. If reverse flow in the portal vein is seen, reconstruction of segments V and VIII branches is necessary [14]. The second test is to clamp the right hepatic artery and MHV at donor operation. If the right anterior sector is dusky, hepatic vein reconstruction is needed [8]. Among the 30 LDLT recipients reported by the Tokyo group [8], MHV tributaries were reconstructed according to the results of the tests described in 18 grafts. Plasty of recipient hepatic veins was performed in 15 patients. All patients survived the operation and regeneration of the anterior and posterior sectors of the right hemiliver grafts was equivalent on subsequent computed tomography.

De Villa et al. proposed an algorithm based on donor–recipient body weight ratio, right hemiliver-to-recipient standard liver volume estimation, and donor hepatic venous anatomy to determine whether the MHV should be included in the right hemiliver graft in LDLT [9]. The MHV is not included in the graft if the donor is bigger than the recipient. If the estimated graft volume by computed tomographic volumetry is greater than 50% of the standard liver volume after correction for steatosis, the RHV is large, and segments V and VIII hepatic veins are less than 5 mm in size, the MHV is also not included in the right hemiliver graft.

Although various criteria have been adopted by different investigators for selective inclusion of the MHV in the liver graft or selective reconstruction of the segments V and VIII venous tributaries, there is no consensus on the indications for the selective approach on venous reconstruction. Moreover, the long-term patency of venous conduit draining segments V and VIII are not known. In order to obtain uniformly satisfactory operative outcomes of LDLT recipients with a uniformly good venous drainage of the liver graft, we recommend routine inclusion of the MHV with the grafts [10]. It is considered crucial in providing sufficient functioning liver volume with good venous drainage to meet the high metabolic demand of recipients with poor liver function reserve. In patients with fulminant hepatic failure or acute decompensation of chronic liver failure, this has resulted in favorable survival outcome [15]. Instead of separate end-to-end venous anastomoses of the donor RHV and MHV to recipient RHV and MHV, respectively, we proposed a technique of hepatic venoplasty [16]. The MHV is joined to the RHV in the right hemiliver graft at the back table to form a triangular common orifice.