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REVIEW

The technical advance and impact of caudate lobe venous reconstruction in left liver: additional safety for living-related donor liver transplantation

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Summary

The key to obtaining good overall outcomes in small-for-size liver-graft transplantation is ensuring sufficient blood flow to the graft during the initial period after surgery. In left lobe liver grafting, various reconstruction techniques have been devised to maximize the limited graft volume. The reconstructions of the caudate lobe (CL) vessels were one of the main streams. In this article, we focus on the clinical significance of CL vessel reconstructions after small-for-size liver-graft transplantation and discuss the roles of various techniques. These techniques contribute to the enlargement of the margin of safety with respect to small-for-size liver-graft transplantation.

Introduction

Advances in surgical procedures and perioperative management have extended the application of small-for-size liver-graft transplantation. As a result, the number of small-sized liver grafts has been increasing. The criterion for the minimum graft size to adults has been defined as more than one-third in the ratio of the predicted graft volume/standard liver volume of the recipient. The graft volume and function together is an independent predictor of mortality during the early postoperative period [1]. While addressing this issue, performance of the concomitant caudate lobe (CL) resection has been a standard procedure for donor hepatectomy in marginal size graft. Left liver plus CL graft is a useful option for adult living-related donor liver transplantation (LDLT), because the addition of the CL can provide an 8–12% increase in graft weight [2].

Serious problems can affect grafts, especially in the initial few weeks after small-for-size liver-graft transplantation. Blood-vessel deformation and stenosis caused by rapid graft regeneration can be lethal [3]. One of the major challenges in LDLT is small vessels reconstruction in small-for-size liver grafts. Various reconstruction techniques have been devised to minimize vessel deformation and increase blood flow to the CL, to ensure full functioning of the graft. These techniques might increase the margin of safety for small-for-size liver-graft transplantation.

In this article, we summarized the advances made in the techniques and impact of CL venous reconstruction in left liver graft for increasing additional safety margin in living-donor-related liver transplantation.

Outflow reconstruction

Classical end-to-side direct anastomosis of a liver graft to the inferior vena cava (IVC) can cause twisting and deformation at the anastomotic site because of graft regeneration. This is significant in the first few weeks after surgery, when the caval window of the IVC is thin and the distance from the IVC is short [3]. End-to-end anastomosis has been widely used to overcome this problem. A large orifice with two (left and middle hepatic veins) or three (left, middle, and right hepatic veins) major hepatic veins is commonly created at the recipient site [2]. Various reconstruction techniques (simple venoplasty, septoplasty, rectangular plasty, venoplasty with a vein graft patch, and creation of a wide circular cuff by vein grafting) are used depending on the grafted vessels [4–7].

In recent cases with a marginal predicted graft size relative to the recipient's metabolic demand, the short hepatic vein (SHV) was aggressively reconstructed [3,8]. Venous drainage from the CL occurred through the SHV and intraparenchymal communication. Good blood flow from other segments to the CL parenchyma might have facilitated graft growth. Without SHV reconstruction, the CL was often atrophied or regenerated slowly [9].

As reported in a previous study, the regeneration rates of the CL and other segments 1 month after LDLT without SHV reconstruction were 62 ± 24% and 152 ± 35%, respectively [10]. This was potentially attributable to insufficient venous drainage from the CL. By contrast, the regeneration rate of the CL with SHV reconstruction was greater than or equal to those of other segments. When the SHV was <3 mm in diameter or near the main hepatic vein, it had poor significance for reconstruction and the drainage domain was small. Caudate lobe regeneration was dependent on the tissue-perfusion area. In one study, a single SHV suitable for reconstruction was found in 22 out of 27 (81.5%) donors. The CL blood flow was classified according to the perfusion state as good ($n = 15$; 142.6 + 31.4%), fair ($n = 7$; 118.4 + 22.4%) or poor ($n = 5$; 90.1 + 36.5%) [9].

As shown in Fig. 1, the one-orifice technique simultaneously allows complete drainage of all veins, including the SHV, and minimal deformation of the outflow channel [7,11]. It can be used when there is a long distance between the IVC and SHV. The advantage of this method is that there were adequate suture margins between the IVC and the liver graft and single *in situ* vessel anastomosis. All intricate surgical procedures are performed on the back table, and a wide venous reservoir of the liver graft is simply attached end-to-end to the caval window. The vein graft functions as a circular cuff and conduit from the SHV. While it appears that the regeneration rate of the CL tends to be higher than that after conventional end-to-side SHV reconstructions (Fig. 2), this proposition needs further confirmation in more trials.

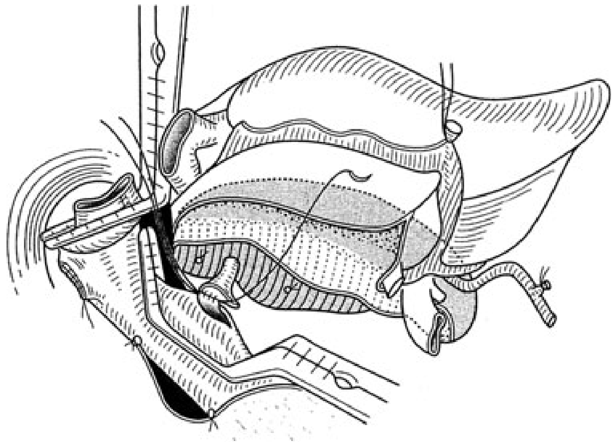

Figure 2 The conventional end-to-side direct anastomosis of the short hepatic vein to the inferior vena cava (IVC). Double outflow reconstructions were performed. (Main hepatic veins and short hepatic vein.) (Takayama *et al. J Am Coll Surg* 2000).

Inflow reconstruction

The isolated portal branch of CL is generally thin and not conventionally used in adult LDLT. An isolated portal branch of CL was found in 13.4% (9/67) of the donors, and 4.5% (3/67) of the cases were suitable for reconstruction [12].

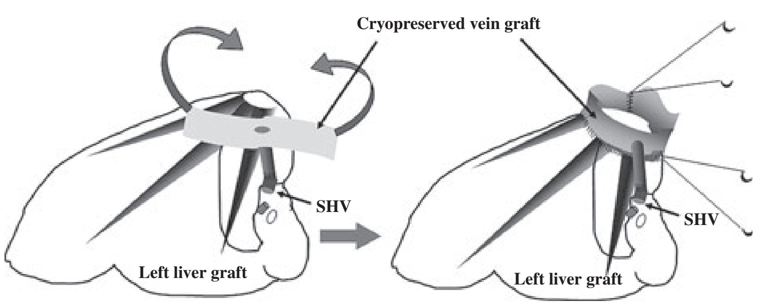

Figure 1 The one-orifice technique of the left liver graft. It allows complete drainage of all veins, including the SHV, and minimal deformation of the outflow channel. It can be used when there is a long distance between the inferior vena cava (IVC) and SHV. (Yamazaki *et al. Liver Transpl* 2009.)

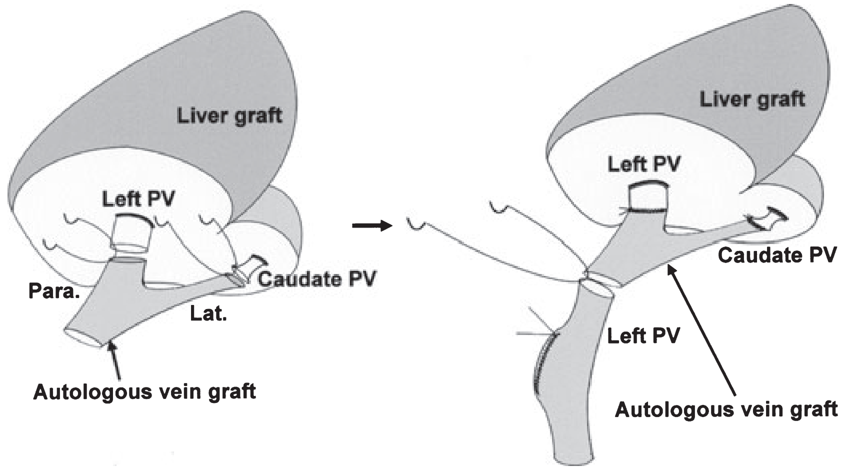

Figure 3 The autologous interposition methods of the portal vein (PV) reconstruction. The PV graft was extracted from the recipient's right PV branch together with the paramedian and lateral branches. The extracted autologous vein graft was interposed to the recipient's left PV branch in the back table. The lateral branch was sutured to the caudate PV and the paramedian branch was sutured to the left PV of the liver graft. (Yamazaki *et al. Liver Transpl* 2005.)

As reported in previous studies, an isolated portal branch of CL with a diameter <2 mm was considered to have poor significance for reconstruction, whereas CL inflow reconstruction was aggressively performed after small-for-size liver-graft transplantation when the diameter was >2 mm. The portal branch of CL was selected depending on the diameter and proximity to the left portal vein (PV) during graft harvesting. It was preserved with part of the recipient's PV like the Carrel's cuff. The recipient's autologous vein graft of the left PV with isolated portal branch of segment 1 or the right PV branches were used in most case (Fig. 3). The extracted PV together with the branches was interposed and extended [12,13]. Hence, inflow reconstruction may have a potential impact on small-for-size liver-graft transplantation.

Discussion

The graft-size mismatching is the most critical factor for success in LDLT while technical advances have enabled the use of relatively small-for-size grafts. The graft blood flow in the initial few weeks after surgery was reported to influence the overall outcome of small-for-size liver-graft transplantation [1]. Small-for-size grafts can experience problems relating to high PV pressure and high growth demands. Persistent PV hypertension and overperfusion in the initial few days after LDLT is the trigger of small-for-size syndrome (SFSS). Graft to recipient weight ratio of <1.0%, or <30% to 50% of standard/estimated liver volumes, have been used to define SFSS in previous studies [14,15]. The clinical manifestations of SFSS include delayed synthetic function followed by prolonged parenchymal damage of the liver. It also leads to prolonged cholestasis, coagulopathy, gastrointestinal bleeding, hyperbilirubinemia, and nonfunction or loss of the primary graft [16]. The pathogenesis of the SFSS is periportal injury in most cases. Whether the additional impact of the CL transplantation and revascularization contributes to the graft pressure gradients is unknown.

Although the CL volume is small, it is important when the graft volume is critical. Ikegami *et al.* have shown that the regeneration rate of the transplanted CL and other left lobe graft segments. The regeneration rate of the CL 1 month after transplantation was smaller (62 ± 24%) than that of other left lobe graft segments (152 ± 35%). With reconstruction of the inflow [12] or outflow [7], the regeneration rate of the CL was noted to be equal to or more than that of the other left lobe graft segments. The additional functional volume afforded by CL venous reconstruction might provide an additional safety margin.

As shown in Table. 1 various CL venous reconstruction techniques were devised as one of the feasible solutions to overcome the small-for-size graft. The CL outflow reconstruction is now widely performed and suitable for most left liver grafts. Direct anastomosis of the hepatic veins to a thin IVC can sometimes cause a bend at the anastomotic site, which results in outflow occlusion. The deformation of the outflow anastomosis caused by graft regeneration can lead to hepatic vein stenosis and graft congestion. This phenomenon is common when the outflow tract is narrow and the distance from the IVC is short. To overcome these problems, techniques for reconstructing hepatic vessels have been reported [8]. The CL regeneration rate might depend on the blood drainage to the reconstructed SHV. The width and length of the SHV are indicators of the adequacy of the blood flow. When

Table 1. The trends in the left liver plus caudate lobe venous reconstruction.

Author	Year	Reconstruction	Procedure
Miyagawa	1998	Without reconstruction	
Takayama	2000	Outflow	End-to-side
Ikegami	2001	Without reconstruction	
Sugawara	2002	Outflow	End-to-end
Kokudo	2004	Inflow	Autologous vein graft: recipient's left portal branch
Hwang	2004	Outflow	ND
Hashimoto	2005	Outflow	Cryopreserved vein graft wrapping
Yamazaki	2005	Inflow	Autologous vein graft: recipient's right portal branch

ND, not discussed.

the graft size is marginal with respect to the recipient's metabolic demand, outflow reconstruction of the SHV might have particular value. According to Couinaud's study, 69% (66/96) of CLs have a single vein and most of all the veins directly entered to the vena cava [17]. This result shows that the largest SHV reconstruction is the optimal method for outflow reconstruction.

To assure full graft viability and functioning, all of the feeding and drainage vessels for the CL should be reconstructed. However, it would be difficult to add inflow reconstruction of the portal branch of CL to the standard operation schedule, because it is possible in only <5% of all reported cases [12]. Inflow vascular reconstruction reportedly facilitates graft growth and small-for-size liver-graft transplantation; however, the operation time and liver-graft cold-preservation time on the back table are longer than those for procedures without revascularization. Recently, Kokudo *et al.* reported that the existence of isolated caudate PV was encountered in only 5.9% of 67 donors. Thereafter, only one case was reported about CL inflow reconstruction [13]. Thus, more results are needed to estimate the clinical value of caudate lobe PV reconstruction.

Inflow reconstruction thus is only of theoretical interest at present.

Complex venous reconstruction requires autologous and/or cryopreserved vein grafts, the use of which remains controversial. The main issues associated with cryopreserved vein grafts are the prolonged cold-ischemic time, underlying diseases, and graft shortages. The cryopreserved vein graft contains high rates of complications, such as aneurysm, thrombosis, and stricture of cryopreserved vascular grafts. Kuang *et al.* [18] report that six out of the seven vein grafts were complicated in a study published in 1996. Millis *et al.* [19] followed the report in pediatric patients, wherein 22 out of 42 patients (52%) encountered vein graft stenosis and thrombus. Recently, Sugawara *et al.* [20] reported that the preservation of integrity of patency of the cryopreserved vein graft used in transplant in 5 years was 58%. The complication rate of the cryopreserved vein graft is higher than that of autologous vein graft. Thus, the use of cryopreserved vein graft should be limited when autologous vein graft are available. Evidence of the larger outcomes is lacking and long-term follow-up remains necessary in this category of transplant recipients.

In conclusion, there is significant impact of the CL venous reconstruction in left liver graft. During liver harvesting, particular effort should be made to preserve the caudate branches in case of small-for-size liver grafting.

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