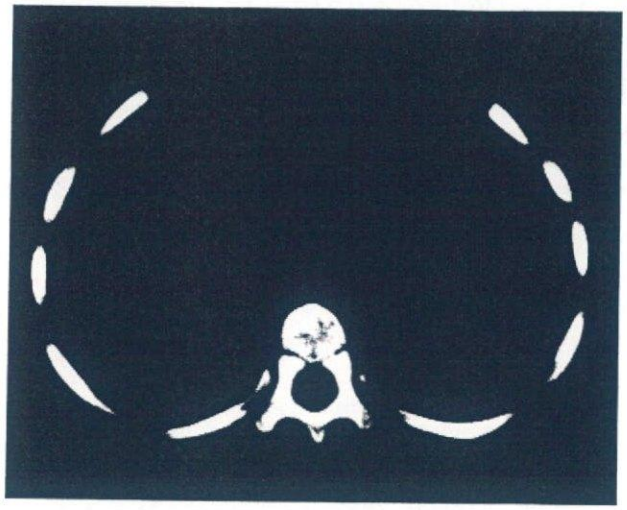

Figure 3. Abdominal computed tomography 1 month after APOLT. The graft and native liver were well accommodated. The PV was intact on the side of the graft.

Prolene sutures (Johnson & Johnson K.K., Tokyo, Japan) under an operative microscope. A color Doppler ultrasonogram confirmed excellent portal, arterial, and venous flow in the graft. Bile duct reconstruction was conducted using Roux-en-Y hepaticojejunostomy with interrupted 6-0 PDS sutures over a 2.0-mm external drainage tube, which was brought out from the wall of the Roux-en-Y limb. The operative time was 12.3 hours, with transfusion of only 100 mL of red blood cells. Estimated blood loss was 487 mL, including ascites.

Posttransplant recovery was prompt with a quickly normalizing ammonia level and liver function tests. An abdominal computed tomography scan taken 1 month after transplant revealed a well-accommodated graft and the remnant native liver (Fig. 3). The graft PV was patent. The patient was discharged 88 days after transplant and is currently enjoying a normal life with normal liver function tests and ammonia and galactose levels.

DISCUSSION

The first account of an absent PV and congenital mesenterico-caval shunt was given by John Abernethy in 1793.[12] Howard and Davenport[13] indicated that there are possibly 2 types of shunts. In type 1 abnormality, there is complete diversion of portal blood into the vena cava, with CAPV. In type 2 abnormality, on the other hand, the PV is intact, but the portal blood is diverted into the vena cava through side-to-side extrahepatic communication. This condition is usually associated with cirrhotic livers and the congenital extrahepatic type is far less common. To date, many cases of CAPV have been reported with varied clinical manifestations, such as cardiac abnormalities and hepatic tumors, including hepatoblastoma, hepatocellular carcinoma, focal nodular hyperplasia, and hepatic adenoma or hyperplastic nodule. The condition is often complicated by hyperammonemia, hepatic encephalopathy, and progressive brain damage. T1-weighted hyperintensity on the globus pallidus has also been described,[11] as have been pulmonary manifestations, including hepatopulmonary syndrome.[7] However, long-term prognosis of this disease is controversial and not yet defined.

Consequently, indication for liver transplantation in patients with CAPV has not been established, and so far, only 4 cases of CAPV treated with liver transplantation have been reported,[8] including 1 case with LDLT.[11] Indication for liver transplantation in all cases was due to hyperammonemia or encephalopathy, which are resistant to medical therapy. In Japan, at least 4 children, including the present case and the above-mentioned case,[7] have undergone LDLT for CAPV (personal communication). Liver transplantations in all these reported cases were shown to be successful, proving the technical feasibility of this complex procedure. We therefore believe that liver transplantation should be indicated for patients with CAPV who have treatment-resistant hyperammonemia or encephalopathy, as well as progressive, severe brain damage. Furthermore, 1 in 3 children with CAPV, including the present case, has severe pulmonary hypertension on referral, which precludes LDLT. In addition, 5 of 8 children with CAPV who have been followed up in our institution have already developed pulmonary hypertension, and 3 of them died due to complications related to pulmonary hypertension before considering LDLT. Pulmonary hypertension and right-sided heart failure are known to occur in patients with patent ductus venosus, in which a significant portion of the portal venous flow bypasses the liver to the systemic circulation.[14,15] Although there is no literature suggesting an association between the development of pulmonary hypertension and CAPV, the pathophysiology of pulmonary hypertension in patients with patent ductus venosus is thought to be almost the same as that of CAPV. Therefore, we believe that prophylactic liver transplantation is justified in patients with CAPV before the development of fatal pulmonary complications such as pulmonary hypertension or hepatopulmonary syndrome, which might complicate or preclude liver transplantation. Nonetheless, all children with CAPV should be closely followed up and monitored for the development of such complications.

We herein report the first successful case of APOLT for a patient with CAPV. APOLT involves transplantation of a partial graft while preserving part of the native liver. APOLT was introduced initially as a tentative or permanent support for patients with potentially reversible fulminant hepatic failure[16] and is expected to result in spontaneous recovery and hypertrophy of the native liver and subsequent removal of the grafted liver. The indication has now been extended to congenital metabolic deficiencies such as Crigler-Najor syndrome,[17] ornithine transcarbamylase deficiency,[18] and hypercitrullinemia,[19] which show otherwise normal liver function. Furthermore, it has been utilized as an

aid in small-for-size grafts to larger recipients during LDLT.[20]

However, the portal steal phenomenon, in which portal venous flow to the graft is competitively stolen by the native liver, sometimes occurs, and as a result, diversion of the portal flow is sometimes required.[21-24] In this context, APOLT is an ideal procedure for patients with CAPV, because there is no portal inflow to the native liver and diversion of portal flow is not necessary.

Generally, reconstruction of the shunt vessel is the main aim of this procedure. The shunt vessel can be short, and therefore, a vascular interposition graft might be necessary. In the setting of cadaveric liver transplantation, vascular grafts of sufficient length and caliber, such as iliac veins, are usually available; however, in the setting of LDLT, vascular grafts of appropriate size are difficult to obtain. Furthermore, although recipient hepatectomy can be performed without clamping the shunt vessel, total clamping of the large shunt vessel during vascular anastomosis is mandatory and can cause gastrointestinal congestion and edema, as well as hemodynamic instability due to the poor development of collateral vessels. Therefore, preceding end-to-side anastomosis between the interposition graft and shunt vessel, followed by anastomosis between the donor PV and interposition graft without clamping of the shunt vessel, might be an option. In the present case, we utilized the inferior mesenteric vein of the donor to obtain a graft of sufficient length and caliber (Fig. 2), which proved to be successful. The patient was hemodynamically stable during vascular anastomosis, and although gastrointestinal congestion temporally developed, it was resolved immediately after reperfusion. Appropriate preoperative planning is essential and should be individualized, especially in the setting of LDLT; therefore, technically demanding procedures like this should be performed only by an experienced team.

Another drawback of APOLT is the potential risk of developing hepatic tumors (e.g., focal nodular hyperplasia) in the remnant native liver. Close follow-up is therefore imperative, and if tumor development does occur in the remnant liver, removal of the native liver should still be possible. In conclusion, APOLT was revealed to be feasible and perhaps an ideal procedure for patients with CAPV. Further accumulation of cases is therefore warranted.

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ORIGINAL ARTICLE

Biliary Strictures in Living Donor Liver Transplantation: Incidence, Management, and Technical Evolution

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Biliary complications, biliary strictures (BS) in particular, continue to be a significant cause of morbidity after LDLT despite technical refinement. In this study, we assessed the incidence of BS and their management in living donor liver transplantation (LDLT) with special reference to the type of biliary reconstruction. A total of 182 LDLTs performed at our institution for either adult (n = 157) or pediatric (n = 25) patients were included in the study. The duct-to-duct (DD) biliary reconstruction was performed for 106 cases, while the conventional Roux-en-Y hepaticojejunostomy (HJ) was utilized for the remaining 76 cases. Overall, BS developed in 46/182 (25.3%) of the cases (DD, 26.4%; HJ, 25.0%). The 1- and 3-year cumulative incidences of BS were 22.9% and 31.9%, respectively, in the DD group, and 15.2% and 29.1%, respectively, in the HJ group (*P* = not significant). The left-lobe LDLT was more prone to develop BS. Continuous anastomosis tended to be associated with the high incidence of BS in the DD group. The incidence of anastomotic leak was significantly lower in the DD group. Intervention via either precutaneous or endoscopic approach was successful in the majority of cases, although recurrence could occur in some patients. In conclusion, BS was not associated with the type of reconstruction in LDLT. The primary radiological or endoscopic interventions were satisfactory treatments of choice. Technical refinement is an important factor to reduce the incidence of BS. *Liver Transpl 12:979-986, 2006.* © 2006 AASLD.

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Despite continual refinement in the surgical techniques of orthotopic liver transplantation, including living donor liver transplantation (LDLT), biliary complications are still associated with significant morbidity and mortality.[1,2] The 2 most commonly performed biliary reconstructions in orthotopic liver transplantation are a duct-to-duct (DD) choledochocholedochostomy with or without a stent (e.g., T tube) and a Roux-en-Y hepaticojejunostomy (HJ) with or without a stent. A Roux-en-Y HJ has been believed to be the only choice for bile duct reconstruction in segmental liver grafts, including LDLT, using either a right or a left lobe graft. The rationale for using HJ for biliary reconstruction in segmental liver grafts including LDLT and split-liver transplantation is based on the small size of the recipient bile duct and inadequate length of the donor bile duct. In addition, especially for small children, the underlying liver disease (e.g., biliary atresia) often mandates a HJ. Furthermore, the vascular integrity of partial grafts has long been questioned regarding the feasibility of direct DD reconstruction. However, DD reconstruction has been increasingly performed especially for right lobe (RL) grafts with yet unknown risks for biliary complications.

In particular, biliary strictures (BS) after liver transplantation have been reported to occur in up to 5% of

Abbreviations: LDLT, living donor liver transplantation, BS, biliary strictures, DD, duct-to-duct reconstruction, HJ, hepaticojejunostomy, LL, left lobe, RL, right lobe ; RTBD, retrograde transhepatic biliary drainage; PTBC, percutaneous transhepatic balloon cholangioplasty; ERBC, endoscopic retrograde balloon cholangioplasty

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TABLE 1 Demographics of the Recipients

Variables	Group		*P* Value
	DD* (n = 106)	HJ (n = 76)	
Recipient			
Age (y)	52.6 ± 12.7	31.6 ± 20.2	±0.0001
Male/female	53/53	30/46	NS
Adult/pediatric	103/3	54/22	<0.0001
Indications (n)			<0.0001
Liver cirrhosis (HCC)	70 (56)	10 (3)	
Cholestatic disease	19	39	
Fulminant hepatic failure	17	18	
Retransplantation	0	4	
Others	0	5	
Donor			
Age (y)	35.4 ±11.2	37.7 ± 11.0	NS
Male/female	75/31	48/28	NS
Blood type			NS
Identical	88	35	
Compatible	16	21	
Incompatible	2	0	
Graft			
Graft type (n)			<0.0001
Lateral segment	0	14	
Left lobe	67	51	
Right lobe	39	11	
GV (g)	513.9 ± 100.2	415 ± 128.6	<0.0001
GV/SLV ratio (%)	44.7 ± 8.5	50.0 ± 21.2	0.022
GRWR (%)	0.86 ± 0.20	1.20 ± 0.78	<0.0001
Follow-up (y)	1.74 ± 1.19	3.82 ± 2.60	<0.0001

NOTE: Data espressed as mean ± SD. **Abbreviations:** NS, not significant; HCC, hepatocellular carcinoma; GV, graft volume; GV/SLV, graft-to-standard liver volume; GRWR, graft-to-recipient weight ratio. *Duct-to-duct reconstruction.

deceased-donor whole liver transplantations.[3] On the other hand, those of LDLT have been reported to occur more frequently: 7.3-60.0% in right-lobe grafts[4-11] and 24% in left lateral segment grafts.[12,13] The incidence in left lobe (LL) grafts remains unknown. Furthermore, the result of the management of biliary strictures after LDLT remains unknown.

In the present study, we retrospectively analyzed our data and compared the time-dependent frequency of BS as well as other biliary complications between DD and HJ. Also, we assessed the efficacy of the treatment by either radiological or surgical approach. Furthermore, technical evolution related to biliary reconstruction was presented and discussed.

PATIENTS AND METHODS

Patients

Between October 1996 and March 2005, 182 consecutive LDLTs were performed at Kyushu University, Fukuoka, Japan, after obtaining approval from the Ethics and Indications Committee of Kyushu University. There were 157 adult (≥18 years old) patients and 25 pediatric (<18 years old) patients. The grafts consisted of left lateral segment grafts (n = 15), LL grafts (n = 107) and RL grafts (n = 50). LL grafts included the left lobe with (n = 85) or without (n = 15) the caudate lobe. The etiology of liver disease consisted of liver cirrhosis (n = 80) including 56 hepatocellular carcinoma, cholestatic liver disease (n = 48), fulminant hepatic failure (n = 35), retransplantation (n = 4), and others (n = 5). The demographics of the recipients and donors are listed in Table 1.

As for the biliary reconstruction, we exclusively used HJ with or without stent for the first 50 cases. Since June 2001, we have prospectively used DD biliary reconstruction if possible for both RL and LL LDLT in adult patients. In total, DD biliary reconstruction was performed for 106 cases, while the conventional Roux-en-Y HJ was utilized for the remaining 76 cases. Methods of biliary reconstruction, including number of bile duct, number of reconstruction, kinds of stents used and suture methods, are summarized in Table 2.

Evaluation of the Bile Duct Anatomy

The preoperative evaluation of the donor bile duct anatomy consisted of MR-pancreatocholangiography or three-dimensional drip infusion cholangiography computed tomography. We prefer drip infusion cholangiography computed tomography because of the high rate of success in delineating the anatomy, although the risk of allergic response does exist. Immediately before infusion of a contrast, 100 mg of hydrocortisone was

TABLE 2 Methods of Biliary Reconstruction

Variables	Group		*P* Value
	DD (n = 106)	HJ (n = 76)	
Number of bile ducts (n)			NS
1	95	71	
2	11	5	
Number of reconstructions (n)			NS
1	104	74	
2	2	2	
Stents (n)			<0.0001
None	0	31	
Internal	0	19	
External	106	26	
T tube	47	0	
RTBD tube	59	26	
Anastomotic methods (n)			<0.0001
Continuous-continuous*	32	5	
Interrupted-continuous	64	18	
Interrupted-interrupted	10	53	

*Anterior-posterior wall anastomosis

routinely given. Additionally, an intraoperative cholangiography was routinely performed before cutting the bile duct and before closing the abdomen.

Donor Surgical Procedure

This procedure is described in detail elsewhere.[14] Briefly, a cholecystectomy was performed and a catheter for later intraoperative cholangiography or leak test was inserted through the cystic duct. A parenchymal transection was thereafter performed using the Cavitron Ultrasonic Surgical Aspirator (CUSA system 200, Valleylab Inc., Boulder, CO) and the electrocautery was usually carried out without any vascular inflow interruption on either side of the liver. After parenchymal transection, an intraoperative cholangiography was performed to confirm the biliary anatomy and to decide the cutting line. The expected cutting line was marked with 2 metal clips. The left or right hepatic ducts were then transected sharply. Dissection around the bile duct should be minimal with as much as tissue as possible preserved around the bile duct. Particular care was taken not to injure the right posterior hepatic duct, which sometimes arises from the left hepatic duct. The bile leakage test was performed through the cystic duct using indocyanine green solution to detect any leakage from the bile duct or the cut surface. After experiencing a case with bile duct stricture in a donor, postoperative cholangiography became a mandatory procedure to check the consistency of the bile duct before closing the abdomen.

Recipient Surgical Procedure

The recipient total hepatectomy was performed usually without venovenous bypass while preserving the inferior vena cava. For cases of DD anastomosis, the recipient bile duct was dissected at the hilar plate with as much surrounding tissue attached as possible and divided sharply distal to the bifurcation, leaving as much of the vascular connections between the common bile and the hepatic artery intact as possible. Preservation of the axial periductal microcirculation with minimal dissection on periductal connective tissue was mandatory. The hepatic artery was reconstructed under magnification with an operative microscope. The bile duct reconstruction was exclusively performed by Roux-en-Y HJ for the first 52 cases with (n = 19) or without (n = 31) an internal stent or an external stent (n = 2). After the first 52 cases, we started performing DD anastomosis for either a left or a right lobe graft, if it was feasible. A DD anastomosis was performed over a T tube (3-mm T tube, Create Medic Co., Yokohama, Japan) or (RTBD) tube (2.0-3.0-mm RTBD tube, Sunitomo Bakelite Co., Ltd., Tokyo, Japan) with 6-0 PDS-II sutures. Sufficient arterial bleeding from the cut stump of the recipient common bile duct or the hepatic duct was confirmed before starting anastomosis. The control of excessive bleeding from the stumps was achieved with the figure-of-8 6-0 Prolene sutures. The T tube or the RTBD tube was pulled out through the hole made on the common bile duct. The exit site was doubly reinforced with a 5-0 PDS-II purse-string suture. The RTBD tube was anchored to the anterior or posterior wall of the recipient bile duct with a 5-0 Monocryl or a 6-0 PDS stitch. A leakage test using indocyanine green solution and a cholangiogram were routinely performed after completing anastomosis to confirm biliary integrity and to rule out any bile leakage. Postoperatively, the T tube or RTBD tube was clamped when serum total bilirubin decreased below 5 mg/dL after confirming that there was no bile leakage from the anastomosis or the tube exit site.

Removal of the Stent

The stent tube was usually left in place for at least 3 months after transplant and then removed after confirming the integrity of the bile duct by a cholangiogram. Two doses of antibiotics coverage were routinely given during or after biliary manipulation. After experiencing several cases of local peritonitis upon tube removal, we decided to change our policy on tube removal. Our new policy is that the tube should be left placed for at least 4 months after LDLT to assure complete fistula formation. Then the stent tube was partially removed, and the tip of the tube was left in place in the fistula approximately 3 cm from the exit of the common bile duct until bile output completely stopped. Since introducing this maneuver, we have not experienced bile peritonitis due to fistula break upon tube removal.

Diagnosis of Biliary Stricture

BS is primarily suspected when liver function tests cholestatic enzymes, including alkaline phosphatase and γ-glutamyl transpeptidase, are elevated. Symptoms such as itching, fever, and jaundice are sometimes (but not always) present.

Confirmation of intrahepatic bile duct dilatation on imaging studies including regular abdominal ultrasound and computed tomography scan was possible in the majority of the cases. There needs to be a high index of suspicion and a low threshold for initiating the diagnostic and therapeutic interventions, including precutaneous transhepatic biliary drainage or endoscopic retrograde cholangiopancreatography.

Treatment of biliary stricture. The primary treatment of BS consisted of a percutaneous transhepatic balloon cholangioplasty (PTBC) for all patients with HJ. A PTBC or an endoscopic retrograde balloon cholangioplasty (ERBC) or a combination of both procedures were utilized as indicated for patients with DD anastomosis. For patients with HJ, percutaneous transhepatic biliary drainage tube was initially placed, followed by three sessions of PTBC at a week interval using an 8- to 10-mm balloon. The internal-external stent tube up to 14 to 16 F was capped and left in place over the anstomotic strictures for at least 3 to 6 months. The stent tube was exchanged at a month's interval to prevent occlusion and infection. For patients with DD reconstruction, 1 to 3 sessions of ERBC followed by the placement of plastic internal stent tube was the initial treatment of choice. However, failure of ERBC was common, for which subsequent PTBC was performed. Surgical revision was indicated when these modalities failed.

Statistical Analysis

Continuous variables were compared using a 2-tailed, unpaired *t* test for independent samples. All values are expressed as mean ± SD. Categorical data were compared using the chi-square test. Analysis of patient survival was performed using the Kaplan-Meier method and compared among groups using the log-rank test. *P* values <0.05 were considered to be significant. All statistical analyses were done with the StatView 4.5 software for Macintosh (Abacus Concepts, Berkeley, CA).

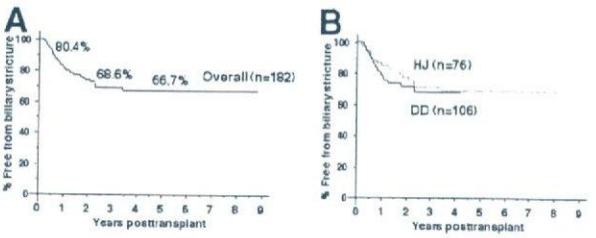

Figure 1. The time-dependent rates of freedom from biliary strictures for (A) all patients and (B) according to the type of biliary reconstruction.

RESULTS

Incidence of Biliary Strictures by Type of Biliary Reconstruction

Forty-six (25.3% of the total) patients developed BS at an average of 394.4 ± 457.7 days. Figure 1A demonstrates the time-dependent rates of from BS in all of the patients. The overall 6-month and 1-, 3-, and 5-year rates of freedom from BS were 91.5%, 80.4%, 68.6%, and 66.7%, respectively. The 6-month, 1-year, and 3-year rates of freedom from BS in the DD group were 90.6%, 77.1%, and 68.1%, respectively, and the rates were comparable to the rates in the HJ group (Fig. 1B).

Incidence of Biliary Strictures by Type of Graft

Figure 2 shows the time-dependent rates of freedom from BS by the type of graft and biliary reconstruction. The 6-month and 1-, 3-, and 5-year rates of freedom from BS in patients with left lateral segment grafts were all 92.9%. Those of patients with LL grafts were 93.4%, 77.5%, 63.1%, and 60.6%, respectively, and tended to be lower than but comparable to those of patients with RL grafts (86.8%, 84.4%, 80.4%, and 80.4%, respectively). These results showed that the graft type per se was not associated with the high incidence of BS. Figures 2B and 2C demonstrated the incidence of BS by the type of reconstruction in RL grafts (Fig. 2B) and LL grafts (Fig. 2C). There was no difference in the incidence of BS between the DD and the HJ group both in RL and LL grafts.

Incidence of Biliary Strictures by Type of Suture Method

In the DD group, the 1- and 3-year rates of freedom from BS were 67.4% and 54.1%, respectively, in continuous anastomosis (n = 32), while those of continuous-interrupted (n = 64) and interrupted (n = 10) anastomosis were 81.5% and 77.4%, and 90.0% and 90.0%, respectively. In the HJ group, the 1- and 3-year rates of

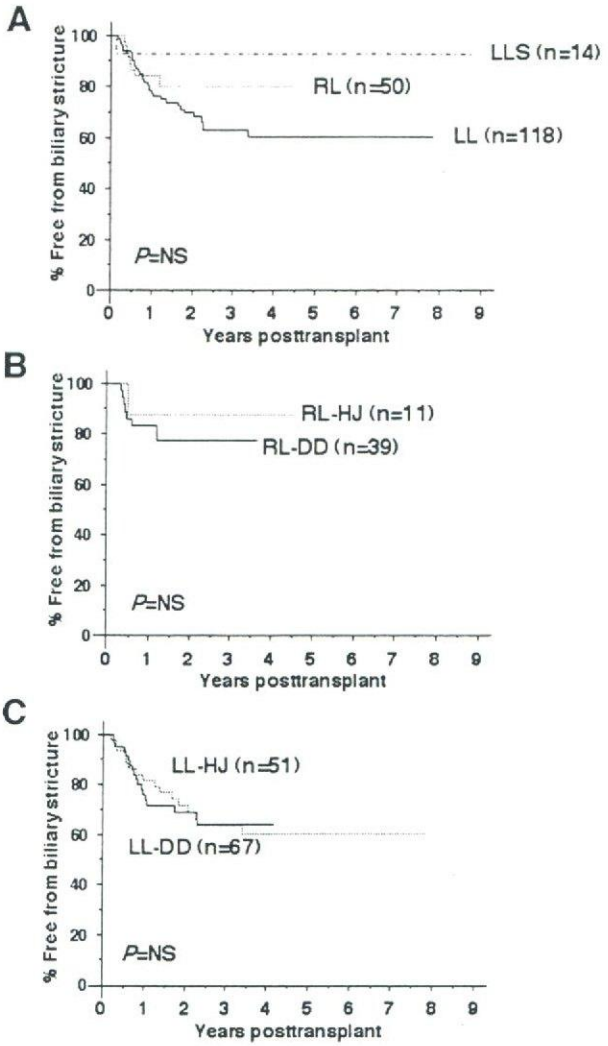

Figure 2. The time-dependent rates of freedom from biliary strictures according to (A) graft type, (B) type of biliary reconstruction in right lobe grafts, and (C) type of biliary reconstruction in left lobe grafts. LLS left lateral segment grafts.

freedom from BS were both 100% in continuous anastomosis (n = 5), while those of continuous-interrupted (n = 18) and interrupted (n = 53) anastomosis were 87.7% and 78.0%, and 80.7% and 68.2%, respectively. These data suggested that continuous anastomosis, especially in the DD group, were more prone to result in BS.

Incidence of Other Biliary Complications by Type of Biliary Reconstruction.

Table 3 shows the summary of biliary complications according to the type of reconstruction. The incidence of biliary complications including BS was 34.0% in the DD group compared to 50.0% in the HJ group. Bile leakage developed in 9 patients with DD reconstruction and in 12 patients with HJ reconstruction. In the DD group, 5 of 9 patients developed bile leakage upon tube removal. Only 1 patientin the DD group developed anastomotic leakage. The rate is significantly lower than that of the HJ group ($P < 0.02$; 11 out of 12 cases of bile leakage). Biliary sepsis exclusively occurred in patients with HJ. One case of anastomotic bleeding that required endoscopic hemostasis was encountered in the HJ group.

Incidence of Biliary Strictures According to Period of LDLT

Figure 3 depicts the decreased incidence of BS after DD reconstruction according to the period of LDLT. Currently, the 1-year cumulative incidence of BS is less than 10%. This data revealed that the technical evolution was an important factor in the prevention of BS.

Treatment Results

Figure 4 demonstrates the summary of the treatment results. The primary treatments for all of the patients with BS were performed by either a PTBC or an ERBC. The primary ERBC was successful in 15 out of 24 patients (62.5%) in the DD group. Those who failed ERBC were all converted to PTBC or a combination of ERBC and PTBC. The rate of successful outcome in the DD group was 100%, without anyone requiring surgical revision. A PTBC were performed for all of the patients with BS in the HJ group. In total, 3 patients in the HJ group underwent surgical revision due to recurrent BS after PTBC. The surgical revision of the first 2 patients was very difficult due to dense adhesion. These 2 patients had recurrent BS after surgery, for which a PTBD was performed again. The third patients underwent surgical revision due to unidentified ligation of the B2 during the donor operation.

Technical Evolution of Biliary Reconstruction in Kyushu University

Figure 5 summarizes the technical evolution of biliary reconstruction in Kyuhsu University. Currently, a DD reconstruction with interrupted sutures over an RTBD tube is our preferred choice.

DISCUSSION

Biliary reconstruction has been labeled the "achilles' heel" of liver transplantation.[15] This remains true for LDLT, in which a significantly small bile duct has to be reconstructed. The optimal approach to biliary reconstruction remains to be defined in LDLT and has proven to be the most challenging technical aspect of LDLT.

The DD biliary reconstruction is a quicker and preferred method in adult cadaveric liver transplantation when using the whole liver. However, this method has not always been feasible in the LDLT setting because of the type of recipient disease (e.g., biliary atresia) or the uncertainty of the vascular integrity of anastomosis.

Which type of reconstruction is associated with the

TABLE 3 Summary of Biliary Complications

Causes	Group		
	DD (n = 106)	HJ (n = 76)	*P* Value
Biliary stricture (n)	27	19	NS
Bile leakage	9	12	NS
Anastomosis	1	11	0.001
Cut surface	2	1	NS
Tube exit	1	0	N/A
Tube removal	5	0	N/A
Bleeding	0	1	N/A
Stent occlusion	0	1	N/A
Biliary sepsis	0	5	0.02

Abbreviations: NS, not significant; N/A, not applicable.

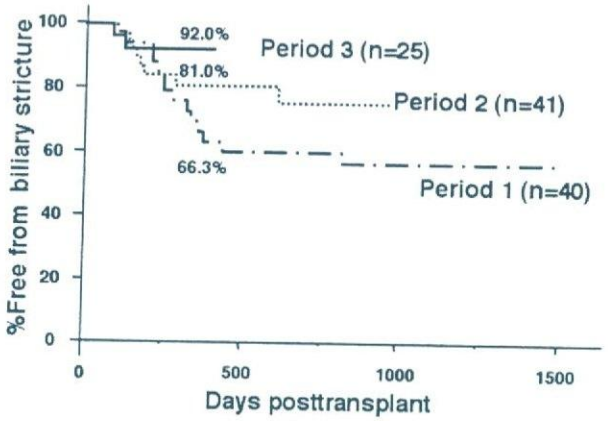

Figure 3. The time-dependent rates of freedomfrom biliary strictures in duct-to-duct biliary reconstruction according to the period of transplant. Period 1, the first 40 cases; Period 2, cases 41-82; and Period 3, the last 25 cases.

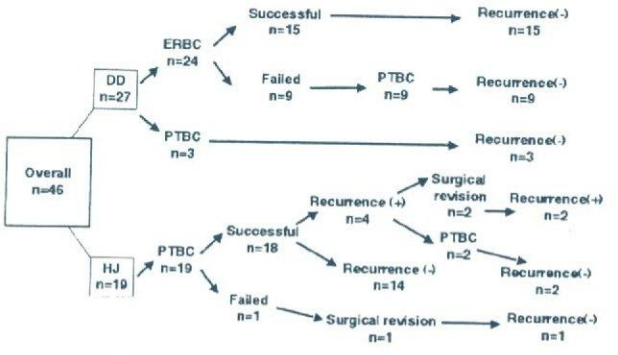

Figure 4. Summary of treatment results. ERBC, endoscopic retrograde balloon cholangioplasty.

high incidence of BS after LDLT? In cadaveric full-liver transplantation, the reported incidence of biliary complications is between 5% and 15%.[3,16] The cadaveric series revealed that bile leaks occurred with equal frequency in both DD and HJ, although most instances of death came in patients with leaks occurring after HJ.[16]

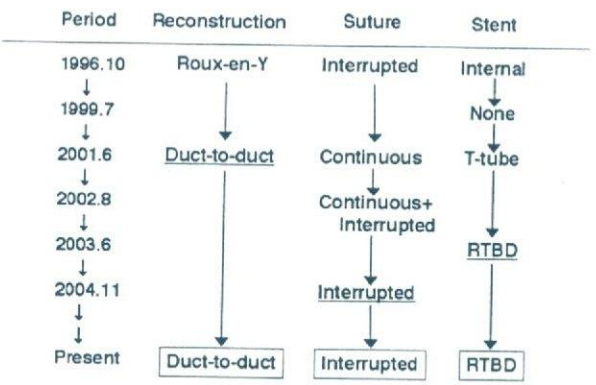

Figure 5. Chronological evolution in biliary reconstruction technique in Kyushu University.

However, strictures were more common after an HJ than a DD type of biliary reconstruction (52.9% and 36.4%, respectively). In pediatric LDLT, when using the left lateral segment of the liver, including segments 2 and 3, the reported incidence of biliary complications was approximately 4% to 6%, with a significant decrease after the early experience in which the incidence ranged from 15% to 20%.[17]

The incidence of BS was reported to occur in 20% in some LDLT series.[18] In adult LL LDLT utilizing a Roux-en-Y hepaticojejunostomy, biliary leaks were reported to develop in 25% of the recipients, while biliary strictures developed in only 8.4%.[5] Recently, an RL donation procedure has been developed to overcome the graft size problem with good results reported in both donors and recipients. However, the incidence of leaks with RL grafts (cu-edge and anastomotic) may be as high as 40%. Furthermore, the incidence of multiple ducts or anatomical variations has been reported to be very high.[4] However, with increasing experience, DD biliary reconstruction has been shown to be feasible and has been widely performed.[19] Testa et al.[5] reported the overall complication rate to be 26.6% and BS to be 13.3% in 30 cases of RL LDLT utilizing DD hepaticocholedochostomy. This rate correlated directly with the type of anastomosis and number of bile ducts. Our

series confirmed the finding: 10/50 (20%) of RL grafts and only 5/107 (4.7%) of LL grafts had multiple openings. However, the incidence of BS in patients with multiple bile ducts was 2/10 (20%) in RL grafts and 2/5 (40%) in LL grafts, which were not significantly different from those with a single bile duct in our series. Marcos et al.[4] reported that the biliary complication rate decreased after the introduction of the transanastomotic stent from 24% to 13% with Roux-en-Y HJ. Gondolesi et al.[11] reported on their experience of biliary complications in 96 consecutive right lobe LDLTs. In their series, HJ was performed in 55.2% of cases, DD in 40.6%, and both procedures in 4.2%. Biliary complications occurred in 40.6% of cases, which comprised 21.9% of biliary leaks and 22.9% of biliary strictures. Patients with DD had a lower incidence of leaks (7.3%) but a higher incidence of strictures (31.7%), while the opposite was true following HJ. Moreover, one-third of patients with biliary strictures required surgical revision. The anastomotic bile leak is believed to lead to sequential BS later. In the present series, the incidence of anastomotic biliary leaks, especially in DD group, was extremely low (0.9%). Therefore, it is impossible to investigate the influence of early bile leakage on the development of BS after DD anastomosis. The incidence of BS was similar between the DD and HJ groups in our series, although bile leakage was more common in the HJ group. It is possible that anastomotic bile leakage is just one factor that affects the development of BS. Ishiko et al.[8] reported the incidence of biliary complications after DD reconstruction in 52 right lobe LDLTs. The incidence of BS was 23.0% of the cases and the rate was significantly higher in the cystic drainage group. They concluded that continuous suture with an external stent was a superior option for DD reconstruction. Although some differences in the technique of biliary reconstruction have been seen among institutions, overall incidence of BS seems to be around 20% to 35% for right lobe LDLTs. Our data confirmed the above series—that is, that the overall incidence of BS is 25.8% (DD, 26.4%; HJ, 25.0%). However, we found that the type of reconstruction was not associated with the incidence of BS. Continuous sutures were found to be associated with the high incidence of BS in DD biliary reconstruction; therefore, such a suture method should be avoided in the setting of LDLT. Furthermore, LL grafts tended to result in high incidence of BS as compared to RL grafts and left lateral segment grafts, although incidence of BS was not statistically significant. We have reported on the feasibility of DD anastomosis in LL LDLT.[20] However, the incidence of BS in LL LDLT remains to be elucidated. The present study, for the first time in the large series, revealed the increased tendency of BS in LL LDLT.

As tfor stent use, Liu et al.[21] reported their experience of biliary complications in 41 right lobe LDLTs without stents. The incidence of BS was similar to those of the previous reports—24.0% with a median follow-up of 13.3 months. We found that the use of T tube concomitant with continuous sutures was associated with the extremely high incidence of BS (data not shown). However, we believe that placement of an external drainage tube (e.g., RTBD tube) is still a viable option that may exclude early BS and facilitate to differentiate abnormal liver function tests.

With regard to the management of BS, Hisatsune et al.[22]reported their experience of an endoscopic approach in 22 patients with suspected BS who underwent RL LDLT. Of 19 patients diagnosed with BS, 14 patients (73.7%) were successfully treated endoscopically by inserting inside stents ranging from 7 to 12 Fr in size. The complication occurred in only 1 patient, for whom surgical revision was required. Park et al.[23] reported the success rate of biliary complications after LDLT to be 100% with an endoscopic approach and 78%with a percutaneous transhepatic approach. Sung et al.[24] treated 76 patients with BS after liver transplantation with percutaneous transhepatic approach. The success rate was rather low (51.3%); 14 (18.4% of the total) patients for whom the approach failed underwent surgical revision. These interventional procedures demand a high level of expertise and experience, especially in the setting of LDLT. Corporation with excellent and reliable interventional radiologists or endoscopists is the key to the success of the treatment of BS.

According to our data, balloon dilation and stenting via either an endoscopic or percutaneous transhepatic approach are safe; moreover, the results were satisfactory. Therefore, incidence of BS might be considered as the procedure of choice in the setting of LDLT. Nonetheless, more invasive surgery should be reserved for patients who failed the nonsurgical treatment.

We have had significant progress in reducing complication rates such as BS and leaks by introducing various surgical modifications. We believe that technical expertise as well as standardization in technique might reduce the incidence of BS and is essential to perform such a demanding procedure as LDLT. As for the indication of DD anastomosis, our data shows that DD has a lower incidence of bile leakage and the same incidence of BS as compared to HJ. Furthermore, DD anastomosis takes less time than HJ. Based on these findings, we believe that DD anastomosis is always indicated for both LL and RL grafts, if feasible.

In conclusion, our experiences demonstrate that BS is not associated with type of reconstruction. The primary radiological or endoscopic intervention is a satisfactory treatment of choice. Technical refinement is an important factor in reduced incidence of BS. Further sophistication in surgical techniques and treatment modalities should contribute to the reduce of the complication.

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Feasibility of Left Lobe Living Donor Liver Transplantation Between Adults: An 8-Year, Single-Center Experience of 107 Cases

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Operative mortality for a right lobe (RL) donor in adult living donor liver transplantation (LDLT) is estimated to be as high as 0.5–1%. To minimize the risk to the donor, left lobe (LL)-LDLT might be an ideal option in adult LDLT. The aim of the study was to assess the feasibility of LL-LDLT between adults based on a single-center experience of 107 LL-LDLTs performed over 8 years. The mean graft weight of LL grafts was 452 g, which amounted to 40.5% of the estimated standard liver volume of the recipients. The overall 1-, 3- and 5-year patient survival rates in LL-LDLT were 81.4, 76.9 and 74.7%, respectively, which were comparable to those of RL-LDLT. Twenty-six grafts (24.3%) were lost for various reasons with three losses directly attributable to small-for-size graft syndrome. Post-operative liver function and hospital stay in LL donors were significantly better and shorter than that in RL donors, while the incidence of donor morbidity was comparable between LL and RL donors. In conclusion, LL-LDLT was found to be a feasible option in adult-to-adult LDLT. Further utilization of LL grafts should be undertaken to keep the chance of donor morbidity and mortality minimal.

Key words: Left lobe graft, living donor liver transplantation, small-for-size graft, small-for-size syndrome

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Introduction

Living donor liver transplantation (LDLT) was first initiated in children in 1989 in response to a severe organ shortage from pediatric donors (1,2). Since the first successful report on adult-to-adult LDLT published in 1994 (3), the indication for this modality has been actively extended to adult recipients, especially in countries like Japan and other Asian countries where the availability of brain-dead donors is severely restricted. It has evolved to be an accepted and established alternative to deceased-donor liver transplantation (DDLT) in Western countries and is expected to minimize the mortality of patients awaiting transplantation.

At the start of adult LDLT, left lobe (LL)-LDLT was the only option available because of the potential risk for the donor in right lobe (RL)-LDLT. However, the use of LL grafts for adults was severely limited due to their size limitation. Generally, a LL graft can provide only 30–50% of the required liver volume for an adult recipient, and has been thought to be too small for adult recipients to sustain their metabolic demand (4). Recently, RL-LDLT has emerged to overcome the graft size problem, which resulted in a rapid increase in number of cases with yet unknown risks for donors. In the context of these size problems, the concept of LL donation for adult recipients has almost been abandoned, without sufficient data available, especially in the United States and Europe.

The crucial prerequisite to performing LDLT is a minimal morbidity and mortality risk to the healthy living donor. Unfortunately, sporadic donor deaths associated with RL donations have been reported in the United States (5) and Europe (6), as well as in Japan (7). It is reported that operative mortality for the RL donor is estimated to be as high as 0.5–1% (8). To minimize the risk to the donor, LL-LDLT could be an ideal option in adult-to-adult LDLT. However, information on the results of adult-to-adult LL-LDLT is, so far, very scarce.

Therefore, the objective of this study was to assess the feasibility of LL-LDLT between adults based on the largest to date, single-center experience.

Patients and Methods

Patients

Between October 1996 and March 2005, 182 consecutive LDLTs were performed at Kyushu University Hospital, Fukuoka, Japan, after obtaining approval from the Ethics and Indications Committee of Kyushu University. This comprised 157 adults (aged ≥18 years) and 25 children (aged <18 years). Of

Table 1: Patient characteristics

Factors	Left lobe ($n = 107$)	Right lobe ($n = 50$)	P
Recipient			
Age (years)	49.6 ± 12.9	50.2 ± 12.8	NS
Sex (M/F)	50/57	27/23	NS
Body weight (kg)	57.0 ± 9.7* (range, 40.0–86.0)	64.2 ± 12.0 (range, 34.8–93.4)	0.0001
Etiology (n)			0.0097
Liver cirrhosis	9	12	
HCC	37	22	
Cholestatic disease	28	11	
FHF	27	4	
Retransplant	3	0	
Other	3	1	
Child-Pugh classification (n)			0.0002
A	16	5	
B	29	8	
C	31	33	
MELD score (n)			NS
0–10	34	16	
11–20	48	24	
21–30	20	8	
31–40	4	2	
Status (n)			0.033
ICU-bound	29	6	
Hospitalized	35	26	
At home	42	18	
Graft			
GV (g)	452 ± 90	593 ± 82	<0.0001
GV/SLV ratio (%)	40.5 ± 8.1	50.5 ± 7.9	<0.0001
GRWR (%)	0.81 ± 0.19	0.95 ± 0.21	<0.0001
Donor			
Age (years)	35.8 ± 11.7	37.9 ± 11.8	NS
Sex (M/F)	86/21	23/27	<0.0001
Blood type (n)			NS
identical	88	34	
compatible	18	15	
incompatible	1	1	
Relationship (n)			0.0139
Father/mother	10	5	
Son/daughter	58	24	
Brother/sister	11	10	
Husband/wife	23	9	
Other	5	2	

*mean ± SD, Abbreviations: FHF, fulminant hepatic failure; GRWR, graft recipient weight ratio; GV, graft volume; HCC, hepatocellular carcinoma; MELD, model for end-stage liver disease; SLV, standard liver volume.

the 157 adults, a total of 107 patients underwent LDLTs using LL grafts with (n = 94) or without (n = 13) the caudate lobe, while 50 patients received RL grafts with (n = 2) or without (n = 48) the middle hepatic vein. Comparison of the characteristics of recipients, grafts and donors who underwent either LL-LDLT or RL-LDLT is shown in Table 1. Forty of 60 patients with HCC (including four with incidental HCC) had HCC beyond the Milan criteria. The indications for retransplantation included hepatic artery thrombosis (n = 1), small-for-size graft syndrome (n = 1) and anterior graft congestion after RL-LDLT (n = 1). Thirty-five cases (29 LL, six RL) were highly urgent and received intensive care pre-operatively. The mean model for end stage liver disease (MELD) score in LL and RL was 14.1 ± 7.4 and 14.6 ± 8.3, respectively (p = NS).

Graft selection criteria

At the start of our adult LDLT program in 1997, LL-LDLT was the only option available for all adult patients. Our general selection criteria for grafts in adult-to-adult LDLT included a graft volume-to-recipient standard liver volume (GV/SLV) ratio >30%. However, on some occasions, grafts of GV/SLV <30% were accepted and utilized. In October 1998, we performed the first LDLT using a RL graft for patients with glycogen storage disease. Since then, RL grafts have been used sporadically. From December 2000, we decided to use RL grafts more often, especially for patients whose GV/SLV ratio was going to be <35% if LL grafts were selected or for patients with a high MELD score. Currently, our selection criteria for LL grafts include a predicted GV/SLV >35%, while those for RL grafts include an estimated remnant

liver volume ≥35% in the donor. However, graft selection is still carried out on a case-by-case basis, considering various factors including anatomical variations and recipient conditions. Graft weight was measured at the back table after flushing the graft with University of Wisconcin solution.

The indication in patients with HCC included neither extrahepatic metastasis nor macroscopic vascular invasion in conventional imaging studies. We did not set any limitations regarding the size and number of tumors.

Surgical procedure

The transplant procedures for both donors and recipients were described previously (9). Hepatic arteries were always reconstructed under the microscope. Duct-to-duct biliary reconstruction has been a routine procedure since June 2000. Intentional splenectomy (n = 8) or ligation of the proximal splenic artery (n = 12) were added in some patients with LL graft in order to decrease the portal flow, thereby expecting decreased relative hyperperfusion of small-for-size grafts.

Immunosuppression

The immunosuppressive regimen consisted of a combination of calcineurin inhibitor (tacrolimus or cyclosporin) and steroid with or without mycophenolate mofetil. Steroid was tapered off by 6 months after transplantation. Since July 2002, a steroid-sparing regimen including basiliximab (Simulect®, Novartis Pharma AG, Basle, Switzerland) and mycophenolate mofetil has been employed for patients with HCC- or hepatitis C-related cirrhosis. Basiliximab 20 mg was given i.v. within 6 h of graft reperfusion and on post-operative day 4. Steroid injection was given intra-operatively (methylpredonisolone 1000 mg) and tapered off by day 7. Currently, the treatment is completely free of steroids, which are used only intraoperatively for patients with HCC or hepatitis C. Mycophenolate mofetil 1000 mg/day was started from post-operative day 1 and completed by 3 months. Maintenance immunosuppression consisted of low-dose tacrolimus or cyclosporine from post-operative day 7.

Definition of small-for-size graft syndrome

Small-for-size (SFS) graft syndrome is hard to define because it may overlap with other causes of graft dysfunction. However, in order to determine the impact of SFS graft on the outcome, we defined SFS graft syndrome as having both prolonged functional cholestasis and intractable ascites. Prolonged functional cholestasis was defined as total bilirubin >10 mg/dL at post-operative day 14, without any other definitive causes for cholestasis (10). Intractable ascites was defined as a daily production of ascites of >1 l at post-operative day 14 or >500 mL at post-operative day 28. Ascites production was defined as the daily amount of ascites through indwelling drains (plus leakage through the drain orifice).

Statistical analysis

Continuous variables were compared using a two-tailed, unpaired *t*-test for independent samples. All values are expressed as mean ± SD. Categorical data were compared using the chi-square test. A logistic regression analysis was performed to identify causes for SFS syndrome. Analysis of patient survival was performed using the Kaplan-Meier method and compared between groups using the log-rank test. The p-values <0.05 were considered to be significant. All statistical analyses were done with the StatView® 4.5 software for Macintosh (Abacus Concepts, Berkeley, CA, USA).

Results

Graft size and its distribution

The mean GV of LL grafts was 452 g (range 220–650 g), which was significantly smaller than that of RL grafts (593 g, range 400–760 g, p < 0.0001). The mean GV/SLV ratio and graft-to-recipient weight ratio (GRWR) were 40.5% (range 21–66.1%) and 0.81% (0.41–1.51%), respectively in LL grafts, which were, again, significantly smaller than those of RL grafts. Figure 1 depicts the graft size distribution of LL and RL grafts according to the GV/SLV ratio. Ten LL grafts were extremely small, namely, GV/SLV <30%. The smallest one was a LL graft of GV/SLV 21%, for which auxiliary partial orthotopic liver transplantation was performed in patients with primary screlosing cholangitis (11).

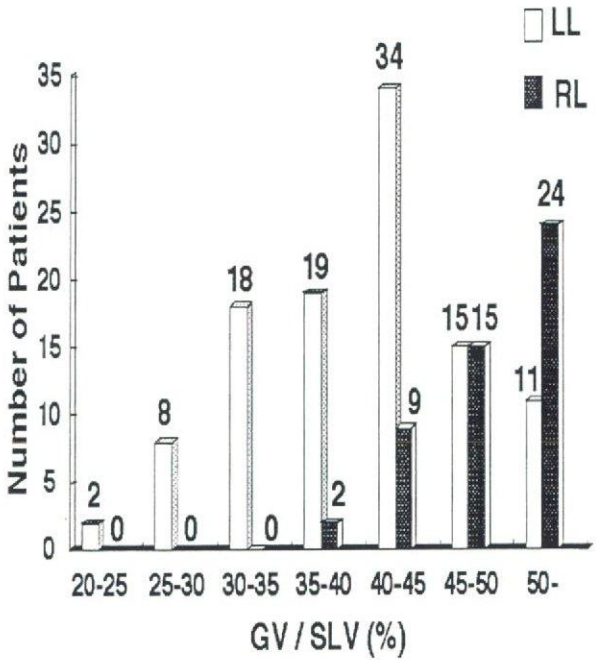

Figure 1: Graft size distribution according to GV/SLV ratio. Mean GV/SLV ratio in LL and RL grafts was 40.5 ± 8.1% and 50.5 ± 7.9%, respectively.

Overall patient and graft survival rates

The mean follow-up after transplant was 1044 days (range: 4–2982 days) in LL grafts and 541 days (range 22–1646 days) in RL grafts (p < 0.0001). The cumulative overall 1-, 3- and 5-year patient survival rates were 81.4, 76.9 and 74.7%, respectively, in patients with LL grafts, which were not significantly different from those of patients with RL grafts (Figure 2). The cumulative 1-, 3- and 5-year graft survival rates were 79.1, 74.7 and 72.6%, respectively, in LL grafts, which were not significantly different from those of RL grafts (data not shown). Figure 3 shows patient survival in LL grafts according to the GV/SLV ratio. The GV/SLV ratio was classified into four groups as follows: <30% (n = 10); ≥30%, <40% (n = 34); ≥40%, <50% (n = 47) and ≥50% (n = 11). Although grafts of GV/SLV ≥50% tended to show worse prognosis, graft size itself did not influence the survival rates. Grafts of GV/SLV ≥30%, <40% demonstrated the best result with 1-, 3- and 5-year patient survival rates 91, 86.6 and 81.5%, respectively.

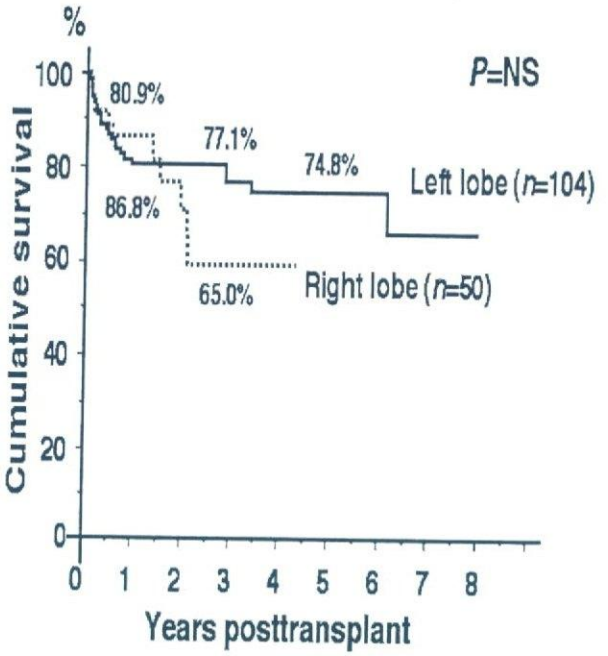

Figure 2: Comparison of cumulative patient survival between LL- and RL-LDLT.

Operative outcomes

Figure 4 shows the comparison of operative outcomes between LL and RL grafts. The mean operative time was significantly shorter in LL grafts (766 ± 154 min) than that of RL graft (849 ± 182 min, $p < 0.01$). Blood loss as well as the use of red blood cells tended to be less in LL grafts, but it did not reach statistical significance.

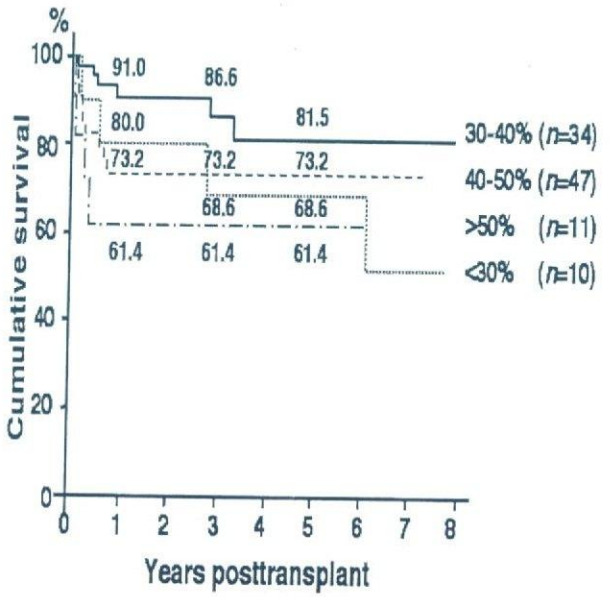

Figure 3: Comparison of cumulative patient survival according to GV/SLV ratio. The log-rank test found no statistically significant differences.

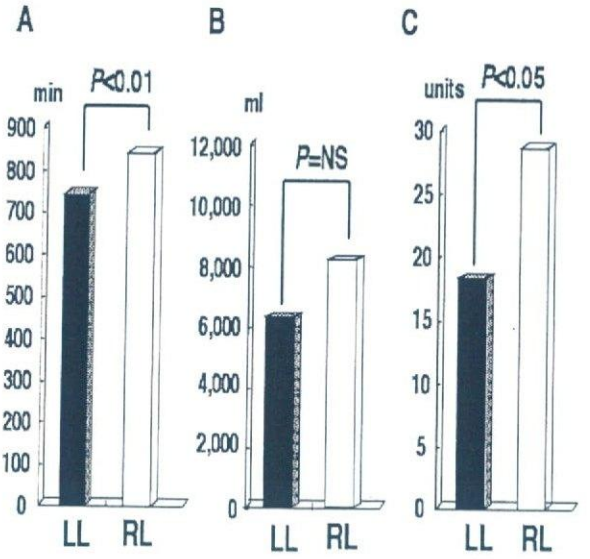

Figure 4: Comparison of operative data between LL- and RL-LDLT. A, operative time; B, estimated blood loss and C, amount of transfusion of packed red blood cells.

Cause of graft loss

Table 2 shows the cause of graft loss both in LL grafts and RL grafts. Of the 107 LL grafts, 26 were lost to hepatic artery thrombosis (n = 2), chronic rejection (n = 2), hepatic infarction (n = 4), graft dysfunction/sepsis (n = 3), SFS graft syndrome/sepsis (n = 3), graft-versus-host disease (n = 1), recurrent hepatitis C (n = 2), recurrent HCC (n = 4), *de novo* malignancy (n = 1) and other causes (n = 4) including portal vein thrombosis (n = 1), hepatic infarction due to precutaneous transhepatic biliary drainage (n = 1), pancreatic juice leakage leading to arterial disruption (n = 1)

Table 2: Cause of graft loss

Causes	Left lobe ($n = 107$)	Right lobe ($n = 50$)	Total
HAT	2	0	2
Chronic rejection	2	0	2
Hepatic infarction	4	0	4
SFS graft syndrome	3	0	2
Graft dysfunction/sepsis	3	5	8
Congestion	0	1	1
GVHD	1	0	1
Disease recurrence	6	3	9
De novo malignancy	1	0	1
Others	4	2	6
Total	26 (24.2%)	11 (22%)	39

Abbreviations: HAT, hepatic artery thrombosis; GVHD, graft-versus-host disease; SFS, small-for-size.

and brain herniation (n = 1). In RL grafts, cause of graft loss consisted of recurrent hepatitis C (n = 2), recurrent HCC (n = 1), multiple liver abscess (n = 1), graft dysfunction/sepsis (n = 5), anterior segment congestion (n = 1) and other causes (n = 1).

Incidence of small-for-size graft syndrome

We identified SFS graft syndrome in 27 (25.2%) patients with LL grafts while only in three (6%) with RL grafts ($p < 0.01$). In LL grafts, the mean GV/SLV ratio in patients who developed the syndrome was 36.2%, which was significantly smaller than that in patients who did not develop the syndrome (41.9%, $p < 0.01$). If we plotted the graft size according to the existence of portal hypertension or cirrhosis, patients with portal hypertension tended to develop SFS graft syndrome more frequently (22/76, 28.9%) as compared to patients without portal hypertension (5/31, 16%), although the difference did not reach statistical significance (Figure 5A). If we stratified the incidence by the Child classification, Child B (10/29, 34.5%) or C (8/31, 25.8%) patients developed SFS graft syndrome more frequently than Child A (3/16, 18.8%) patients, even when the graft size was relatively large (Figure 5B). In Child A patients, none developed SFS graft syndrome if graft size exceeded 35%. However, A logistic regression analysis including the presence of cirrhosis, graft type (LL or RL), GV/SLV ratio, MELD score and Child-Pugh classification revealed that only GV/SLV ratio was significant (relative risk, 0.901; 95% confidence interval, 0.840–0.966; $p < 0.0008$). The 1-, 3- and 5-year patient survival rates in patients who develop the syndrome were 74.1, 67.9 and 67.9%, respectively, which were comparable to those of patients who did not develop the syndrome (83.5, 79.7 and 77%, respectively).

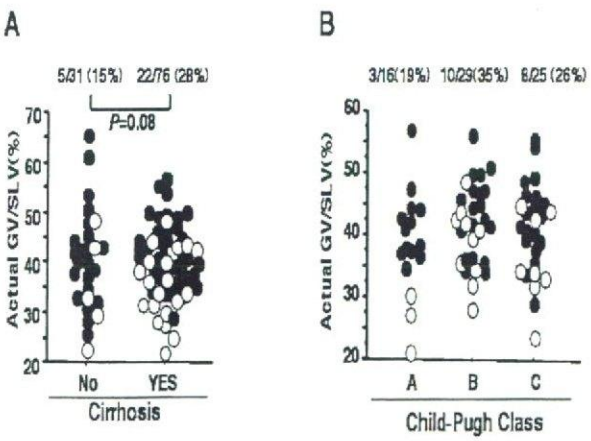

Figure 5: Incidence of small-for-size graft syndrome according to presence of cirrhosis (A) and Child-Pugh classification (B). Open circles represent patients with small-for-size (SFS) graft syndrome. Closed circles represent patients free from SFS graft syndrome.

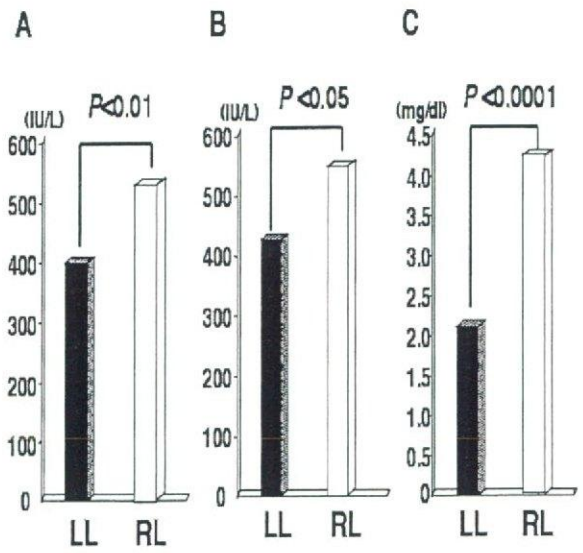

Figure 6: Comparison of post-operative liver function tests between LL- and RL-donor. (A) Peak aspartate aminotransferase. (B) Peak alanine aminotransferase. (C) Peak total bilirubin.

Donor morbidity

In terms of donor post-operative liver functions, including peak aspartate aminotransferase, alanine aminotransferase and peak total bilirubin, those of LL donors were significantly lower than those of RL donors (Figure 6). However, the morbidity rate did not show evidence of a difference between the two groups (Table 3). None of the complications led either to mortality or to long-term sequelae in either group. The mean post-operative hospital stay in LL donors was 11.2 days, which was significantly shorter than that in RL donors (20.2 days, $p < 0.01$). Only one relaparotomy was performed for a LL donor (case 10) due to biliary stricture caused by a stitch on the bile duct. These data *clearly* suggest that LL donation is potentially safer than RL donation, although no donor mortality was seen in either group.

Table 3: Donor morbidity

Complications (*n*)	Left lobe (*n* = 107)	Right lobe (*n* = 50)	Total (%)
Arm paralysis	3	1	4 (2.5%)
Bile leakage	1	5	6 (3.8%)
Bile duct stricture	2	3	5 (3.2%)
Peptic ulcer	2	0	2 (1.3%)
Depression	0	2	2 (1.3%)
Iatrogenic hemothorax	0	1	1 (0.6%)
Gastric stasis	4	0	4 (2.5%)
MRSA infection	1	0	1 (0.6%)
Alopecia	4	2	6 (3.8%)
Total	17 (16%)	14 (28%)	31 (20%)

Discussion

With the increasing success of LDLT as a modality for adult patients with end-stage liver disease, the demand for this procedure continues to grow. In 2004, 323 LDLTs (5.2% of the total) were performed in the United States, while 5844 DDLTs were performed (12). The total number of LDLTs reached 2623 cases by the end of 2004. In Japan, a total of 2667 LDLTs had been accumulated by the end of 2003 and it exceeded 3000 by the end of 2004, while only 28 DDLTs had been performed as of June 2005. In Europe, 675 LDLTs have been performed since 1991, of which 276 (41%) were carried out in adults (13).

Which type of graft should be used for adult-to-adult LDLT, LL or RL? All forms of LDLT are subject to varying degrees of complications and mortality, depending on the complexity of the procedure, and despite good intentions and experienced hands, there can be no argument that there is a definite mortality risk to the donor. Undoubtedly, the safety of donors must have priority when considering LDLT and the inevitable risk for donors must be balanced against the potential benefit for the recipient. However, the risks of living donation are difficult to quantify. It is conceivable that the LL donation is potentially safer than RL donation because the remnant volume of the liver may be larger. In fact, Umesita et al. (14) reported on the incidence of donor complications based on 1853 donors from the Japanese Registry of LDLT. The incidence of complications was significantly higher in donors of RL than LL and lateral segment grafts. Lo CM et al. (15) also reported the incidence of donor complications based on a survey of 1508 cases in five Asian centers. Again, the complication rate was higher in RL (28%) donors than in left lateral segment (9.3%) or LL (7.5%) donors. Moreover, RL donors had more serious complications such as cholestasis (7.3%), bile leakage (6.1%), biliary stricture (1.1%), portal vein thrombosis (0.5%), intra-abdominal bleeding (0.5%) and pulmonary embolism (0.5%). However, our data did not demonstrate statistically significant difference in complication rates between RL and LL donors. RL donation is known to be associated with significant hyperbilirubinemia and prolonged prothrombin time after surgery, although these usually resolve spontaneously without any adverse sequelae. The most serious potential consequence of a right lobectomy or extended right lobectomy is death of the donor. To the best of our knowledge, at least 10 donors have died to date after living donation worldwide. Among them, eight deaths occurred after RL donation in Japan (n = 1), Brazil (n = 1) (16), the United States (n = 2) and Europe (n = 4). However, even in LL-LDLT, the possibility of donor mortality is real because at least two deaths have been reported in lateral segment graft donors in the United States (n = 1) and Europe (n = 1). Nonetheless, it is clear that RL donation carries significantly more risks than LL donation.

Balancing the safety of the donor with a satisfying outcome of the recipient is a key issue in the process of living donation. Can LL graft be sufficient to sustain the metabolic demand of adult recipients? The initial report of 13 LL-LDLTs between adults by Kawasaki et al. (17) revealed satisfactory results in both donors and recipients, with 11 out of 13 patients surviving. However, their cohort included seven cases of metabolic disease that may have normal liver function. Tanaka K et al. (18) reported in their early series of 39 LL-LDLTs that survival was 82.1% in patients with a GRWR $\geq$0.8 (n = 28), but only 54.5% in those with a GRWR <0.8 (n = 11). Based on these unsatisfactory results, they have adopted RL graft to overcome this size problem. Almost all reports from the United States (19–21), Hong Kong (22), Europe (23) and Japan (24) advocate the superiority of RL-LDLT in view of recipient safety. On the other hand, survival data in the LL-LDLT cohort were comparable to those of the RL-LDLT cohort, although the LL recipients were significantly smaller, far less likely to have portal hypertension (more likely to be patients with fulminant hepatic failure) and have lower Child-Pugh score. Moreover, patient and graft survival rates were comparable to those of RL-LDLT published to date from other institutions (19–25). These results suggest that LL-LDLT, if carefully and properly selected, could offer the same result as RL-LDLT. More precisely, in less sick smaller patients, the outcomes of LL-LDLT are comparable to those of RL-LDLT whose recipients are relatively larger and more sick. Therefore, experienced LDLT centers may contemplate the use of LL grafts in selected patients for a potential, but yet unproven decrease in donor morbidity. In other words, RL-LDLT is not uniformly necessary for all adult patients.

Therefore, the question arises: does graft size really matter in the setting of LDLT? Is it really necessary to subject donors to a more risky procedure like RL-LDLT? In terms of graft size, we previously demonstrated that graft size per se does not influence outcome (26). Our present data show that graft size itself does not directly influence patient survival rate in LL-LDLT. On the other hand, Kiuchi et al. (27) analyzed the influence of graft size on the outcome of LDLT and showed that the use of SFS grafts (<1% of recipient body weight) led to lower graft survival, probably through enhanced parenchymal cell injury and reduced metabolic and synthetic capacity. However, in addition to the donor risks, RL grafts confer many problems such as reconstruction of venous tributaries draining the anterior segment of the liver (27,28) and increased incidence of biliary complications due to anatomical variations (29,30). On the other hand, anatomical variations of the LL graft are usually simple and easily managed.

As to the SFS graft syndrome, our present data revealed that SFS graft syndrome did occur in 25% of patients with a LL graft. We also found that SFS graft syndrome did not necessarily lead to graft loss. Only three patients lost their graft directly due to SFS syndrome. The SFS graft syndrome is characterized clinically by a combination of prolonged functional cholestasis, intractable ascites and a delayed recovery of both prothrombin time and

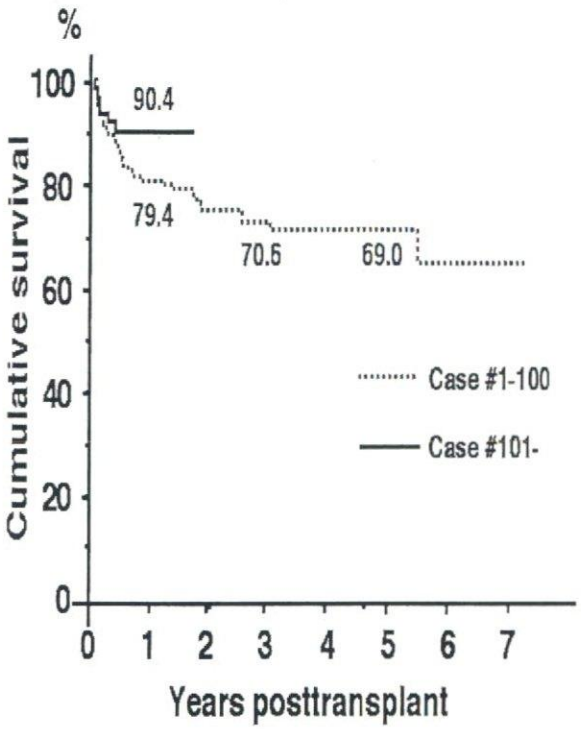

Figure 7: Trend in patient survival after adult-to-adult LDLTs. Better results have been archived in the last 50 cases with a 1-year survival rate of 90.4%.

encephalopathy (4). However, it is often difficult to discriminate SFS graft syndrome with other complications because of possible symptom overlap. It is known that the syndrome is often multifactorial. Furthermore, the characteristics of this syndrome have not been fully examined in a large series of patients. The mechanism of SFS graft syndrome remains unknown. When transplanted under conditions of portal hypertension, small grafts are supposed to be exposed to a relatively excessive portal perfusion and pressure, as compared to grafts under normal portal pressure. Experimental data suggest that hyperperfusion of the liver is detrimental and improved results are obtained with portal decompression of small grafts (31). In addition, gut derived endotoxin and substrates, including fatty acids, may further deteriorate the small graft after reperfusion (4). Clinically, some groups have advocated the use of temporal portocaval shunt to reduce or minimize the influence of such substances accumulating during portal clamping (32). There are some reports of successful LDLT using a very small graft by making a portocaval shunt, which diverts excessive portal flow to the systemic circulation, thereby reducing liver hyperperfusion (33,34). Our unpublished data suggest an association between SFS graft syndrome and the amount of portal flow after transplantation. Therefore, our current approach in managing the problem of SFS grafts is to reduce the relatively excessive portal flow by ligating the proximal splenic artery or performing splenectomy, if necessary (35). As to the susceptibility to such syndrome, we previously reported our initial experience of 50 LDLTs using LLs and proposed that minimum graft volume in adult-to-adult LDLT should be a GV/SLV ratio >30% for recipients without cirrhosis and >45% for patients with cirrhosis (11). The Mount Sinai group reported that pre-transplant disease severity of recipients is one of the important factors involved in developing SFS syndrome (36). They analyzed 22 adult recipients who received LL (n = 10) or RL grafts (n = 12) from living donors. Child B or C recipients who received small grafts (GRWR <0.8%) had an inferior graft survival of 25% (1/4), whereas the graft survival of Child A recipients was 100% (8/8) without showing any symptoms related to SFS grafts. They conclude that the pre-transplant disease severity significantly affects the graft survival of recipients with SFS grafts.

With refinement of surgical procedures and better graft selection, we have achieved significant progress in outcomes. The 1-year patient and graft survival rate in the last 50 cases is now >90% (Figure 7). We therefore currently think that, with appropriate graft size matching and careful recipient selection, adult-to-adult LDLT can be successful with either a left or a right lobe.

In conclusion, adult-to-adult LL-LDLT was found to be feasible without affecting patient and graft survival rates. Further utilization of LL grafts should be undertaken to keep the chance of donor morbidity and mortality minimal.

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Surgical technique

Reconstruction of the middle hepatic vein tributaries using the recipient's recanalized umbilical vein in right-lobe living-donor liver transplantation

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Background. *Right-lobe grafts without the middle hepatic vein (MHV) can cause severe congestion of the anterior segment in living-donor liver transplantation (LDLT). However, the indications and methods for reconstructing the MHV or its tributaries remain controversial.*
Methods. *We herein describe two cases of the successful use of the recipient's recanalized umbilical vein as an interposition graft to drain the major MHV tributaries in right-lobe LDLTs.*
Results. *After surgery, both right-lobe grafts are currently functioning well and all of the reconstructed venous tributaries have been confirmed to be patent by doppler ultrasonography. The histopathological features of the recanalized umbilical vein showed an intact intima with thickened media.*
Conclusions. *The use of the recipient's recanalized umbilical vein is a good option for reconstructing MHV tributaries in right-lobe LDLTs. (Surgery 2006;139:442-5.)*

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LIVING-DONOR LIVER TRANSPLANTATION (LDLT) has become an accepted and established alternative to cadaveric donor liver transplantation for small children and adults. A right-lobe LDLT (RL-LDLT) first was introduced in 1994 and since then has become an increasingly popular option, especially for adult patients. Although the results of RL-LDLT have been reported to be comparable with that of cadaveric donor liver transplantation, some technical issues associated with the management of the venous outflow remain controversial. A right-lobe graft without the middle hepatic vein (MHV) is used most commonly, however, such an approach may result in severe congestion of the anterior segment of the liver (corresponding to Couinaud segments V and VIII)[1,2] unless venous drainage of the anterior segment is preserved adequately. Various solutions to overcome this problem have been reported, including the use of an extended right-lobe graft including the MHV[3] or a modified right-lobe graft with the reconstruction of the MHV tributaries using various interposition vein grafts.[4] We report 2 the successful use in 2 patients of the recipient's recanalized umbilical vein as an interposition graft to drain the major MHV tributaries in RL-LDLT and we also discuss the importance of MHV reconstruction.

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PATIENTS AND METHODS

Between October 1996 and June 2003, a total of 19 RL-LDLT, including a patient with the use of the extended right-lobe graft, were performed exclusively for adult recipients at our institution. In this report, we describe use of a segment of the recipient's recanalized umbilical vein as an interposition graft to drain the MHV tributaries for 2 consecutive RL-LDLTs.