Ghobrial et al.[46] reported that the time interval to HCV recurrence (n = 11) was significantly shorter in LDLT patients than in patients who received grafts from deceased donors (n = 510). The University of Colorado group[47] reported that serum alanine aminotransferase and total bilirubin levels increased more rapidly after the operation in LDLT patients (n = 24) than in cadaveric graft recipients (n = 41). In addition, LDLT patients had greater serum aspartate aminotransferase levels at 1, 3, and 6 months, compared with a matched group of cadaveric controls.[48]

Gaglio et al.[49] reported that the overall incidence of severe sequelae of hepatitis C recurrence—either cholestatic hepatitis, grade III-IV inflammation, and/or hepatitis C–induced graft failure requiring retransplantation—were not different between cadaveric grafts (n = 45) and those grafts from living liver donors (n = 23). However, the morbidity of cholestatic hepatitis C was more severe in LDLT patients (0% vs. 17%, respectively; $P = .001$). These preliminary reports indicate that more intensive antiviral therapy might be necessary for recipients of living donor grafts. All of these reports, however, have some limitations, which include small numbers of patients, lack of standard virologic evaluation, and short-term follow-up. The results must be confirmed in larger, multicenter studies.

Hepatocellular Carcinoma

LDLT is an established therapeutic option for patients with hepatocellular carcinoma. From 1990 to the end of 2002, LDLT for hepatocellar carcinoma was performed in 225 cases in Japan.

Prof. Furukawa from the Hokkaido University reported in the Tokyo meeting that 160 patients were alive, with a recurrence rate of 5%, while 65 patients were dead, with a recurrence rate of 32%. Multivariate analysis revealed that alpha-fetoprotein levels, tumor size, and invasion of hepatic and portal veins are significant predictors for outcome. When the subjects were categorized into two groups (patients meeting the Milan criteria, and those beyond), difference both in patient and recurrence-free survival reached significance (76% vs. 52%, respectively; $P = .001$; and 76% vs. 50%,respectively; $P = .001$).

Conclusions

During the 10-year period, many technical innovations have been developed for LDLT, contributing to a better patient outcome. LDLT was originally devised and performed in countries where organs from deceased donors are extremely scarce. The contributions made by Asian countries with regard to the design of several graft types, including left liver graft with caudate lobe, right liver, modified right liver, and right lateral sector grafts, are noteworthy. A recent review by Grewal,[50] however, has failed to acknowledge the significant Asian contribution to LDLT.

In LDLT, the physical and psychological sacrifice by the donor is significant and is associated with high expectations regarding a good outcome for themselves and the recipient. We should not be satisfied with the present outcome and need to strive to achieve 0% donor mortality.[15] Firm criteria for graft selection and further technical advances will be helpful in reaching this goal.

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SURGICAL REPAIR FOR LATE-ONSET HEPATIC VENOUS OUTFLOW BLOCK AFTER LIVING-DONOR LIVER TRANSPLANTATION

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The incidence of hepatic venous complications in partial liver transplantation is more frequent than that in whole liver transplantation. There are no reports of a surgical strategy for hepatic venous outflow block (HVOB) after living-donor liver transplantation. HVOB was diagnosed when the pull-through pressure gradient across the anastomotic site was over 5 mm Hg. Reoperation for venous anastomosis was performed if the angioplasty was unsuccessful. After dissection around the hepatic venous anastomotic site, a patch venoplasty of the anastomosis was performed. When the inferior vena cava was constricted, venoatrial anastomosis was performed. In 6 years, 5 of 223 patients experienced HVOB. Balloon angioplasty was successfully performed in two patients, a patch venoplasty of the anastomosis in two, and venoatrial anastomosis in one. In all patients, the ascites stopped. HVOB must be diagnosed as soon as possible with Doppler ultrasound and venography. Prompt surgical revision can salvage the grafts.

The limited supply of cadaveric donor organs for liver transplantation has fostered the use of segmental liver graft with reduced-size grafts, split-liver transplantation, and living-donor liver transplantation (LDLT). The overall survival rates of recipients using these technical innovations is equivalent to those achieved with whole liver grafts. Nonetheless, the use of a partial liver graft demands more meticulous surgical procedures, resulting in an increase in various vascular complications. The incidence of hepatic venous complication in partial liver transplantation is more frequent (2%–13%) (*1, 2*) than that in whole liver transplantation (1%–2%) (*2, 3*).

The occurrence of hepatic venous outflow block (HVOB) can be divided into two categories on the basis of the timing of onset (*3*): early, in the immediate postoperative period; and late, thereafter. The cause of early-onset HVOB often includes technical problems, and late-onset HVOB might be caused by subsequent fibrosis with inflammatory processes such as bile leakage, abscess formation, and compression or twisting of the anastomosis caused by the graft growth (*4*). Graft salvage is difficult without prompt revision in both types of HVOB. Our surgical techniques for HVOB are presented in this article.

From January 1996 to April 2003, 223 patients underwent LDLT at our hospital (153 adults and 70 children). The mean follow-up period was 603 days. The indications for LDLT in these patients included biliary atresia (n=69), primary biliary cirrhosis (n=43), hepatitis C virus cirrhosis (n=33), hepatitis B virus cirrhosis (n=22), fulminant hepatic failure (n=18), cryptogenic cirrhosis (n=13), metabolic disorder (n=13), primary sclerosing cholangitis (n=6), and autoimmune hepatitis (n=6). The most commonly used type of graft was the left liver with or without the caudate lobe (n=84), followed by right liver (n=73), segments II and III (n=51), and right lateral sector (segments VI and VII, n=15). The transplantation procedure and donor selection criteria are described elsewhere (*5*).

HVOB was suspected with massive pleural effusion and ascites and one of the following Doppler ultrasound (US) findings: (1) a decrease in hepatic vein flow velocity; (2) a flat waveform of the hepatic vein, especially in cases with a previously multiphasic pattern (*6*); (3) mild dilatation of the distal venous tributaries; and (4) a decrease in portal flow. When HVOB was suspected on the basis of US findings, venography was performed. Patients can be diagnosed with HVOB when the pull-through pressure gradient across the anastomotic site is over 5 mm Hg (*7*). Balloon angioplasty was performed first, followed by 1 week of intravenous administration of heparin (200 U/kg/day). Reoperation for venous anastomosis was performed when the angioplasty was unsuccessful.

When dissection around the hepatic venous anastomotic site was possible, a patch venoplasty of the anastomosis was performed. After vascular exclusion, the right wall of the suprahepatic inferior vena cava (IVC) above the anastomosis was incised longitudinally and passed through the anastomosis and extended to the left and middle hepatic veins (Fig. 1). The IVC defect was covered by a triangle-shaped cryopreserved venous patch, allowing the patch to expand outside. Sutures were continuous using 6-0 monofilament. The vein grafts were provided by the University of Tokyo Tissue Bank. They were obtained from cadavers or non–heart-beating donors within 24 hr after cardiac arrest after obtaining informed consent. When inflammatory changes around the IVC were severe and the IVC was constricted, a venoatrial anastomosis was performed. The pericardium was incised. The bottom of the right atrium was then side-clamped and anastomosed with the hepatic veins of the graft (Fig. 2).

Five patients (2%) experienced HVOB. HVOB was not suspected in any other patients in the series. The demo-

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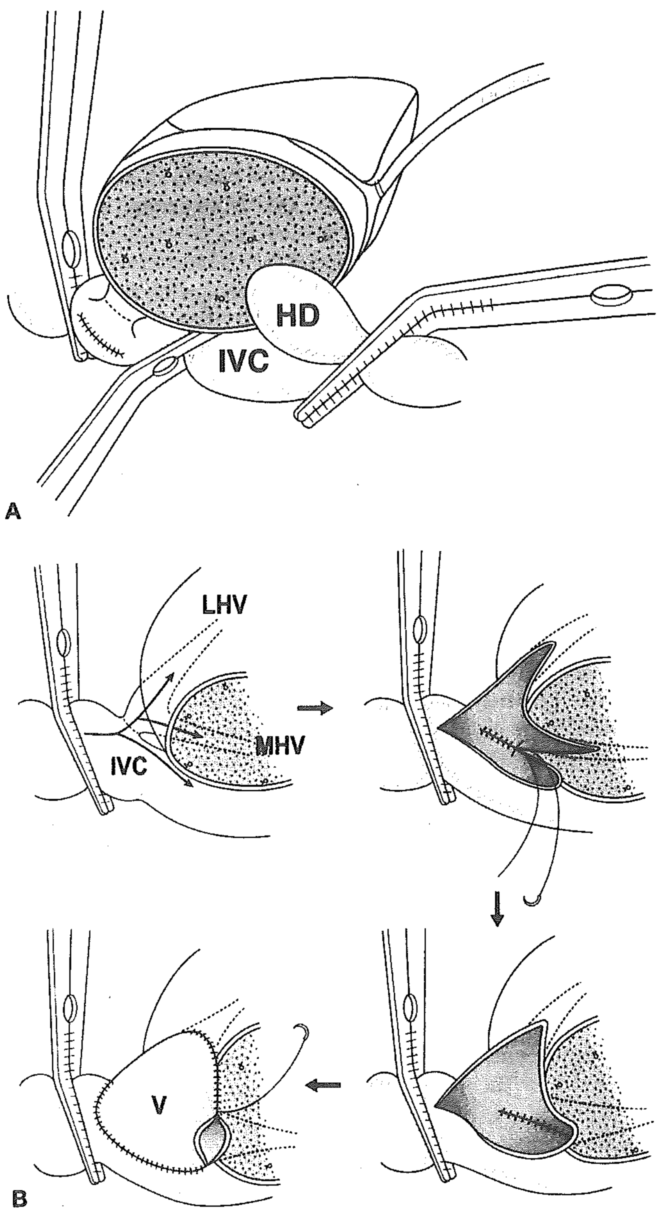

FIGURE 1. A patch plasty for hepatic venous reconstruction. (A) Total vascular occlusion and cold perfusion of the graft. (B) Venoplasty of the stenotic anastomosis using a venous patch. HD, Hepatic artery, portal vein, and common bile duct; LHV, left hepatic vein; MHV, middle hepatic vein; IVC, inferior vena cava; V, venous patch.

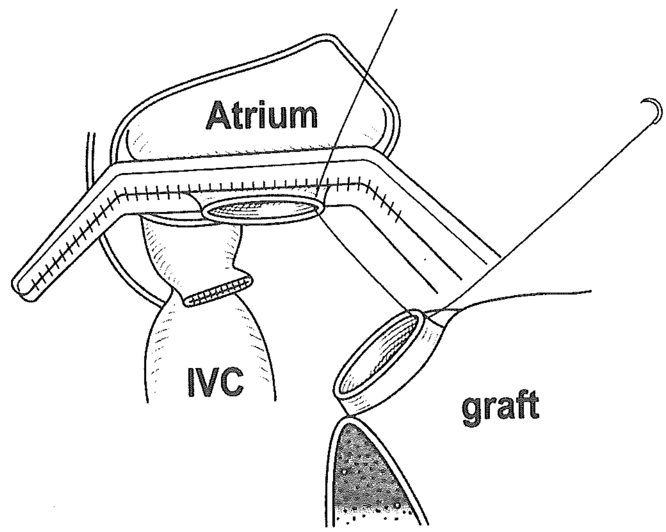

FIGURE 2. A venoatrial anastomosis. The pericardium was incised. The bottom of the right atrium was then side-clamped and anastomosed with the hepatic veins of the graft. IVC, Inferior vena cava.

graphics of the five HVOB patients are shown in Table 1. In two patients, balloon angioplasty was successfully performed. The profile of the other three patients in whom a revision operation was necessitated is described in detail.

In patient 2, during LDLT, a fresh femoral venous graft from a cadaver was used as a conduit from the superior mesenteric vein of the recipient to the graft portal vein because the native portal vein was completely thrombosed. Hepatic venous reconstruction was performed using the technique described previously (*8*). The patient's postoperative course was uneventful, and the patient was symptom-free for 4 years after LDLT. Ascites retention occurred and was first managed with diuretics and periodic abdominocentesis but increased beyond conservative treatment 5 years after LDLT. Doppler US indicated that hepatic venous flow was still biphasic in its waveform and maintained its velocity (30 cm/sec). The portal flow was slow, down to 5 cm/sec. Celiac angiography revealed that the jumping graft was stenotic, probably because of thrombosis. The venogram indicated hepatic venous stenosis with a 7-mm Hg pull-through pressure gradient. The patient underwent surgical venoplasty with the technique shown in Figure 1. After thrombectomy near the anastomotic site of the superior mesenteric vein, portal inflow was reinstated using a cryopreserved femoral vein from a cadaver between the superior mesenteric vein (end-to-side) and umbilical portion of the graft (end-to-side). The ascites completely stopped within 2 weeks after the revision.

In patient 4, who weighed 13 kg, ascites and pleural effusion increased over 700 mL/day, 5% of the patient's body weight, 1 month after the LDLT. On postoperative day (POD) 54, a venogram was obtained using a percutaneous transhepatic approach that revealed hepatic venous obstruction and an 18-mm Hg pull-through pressure gradient. Successive angioplasty using a 12-mm-diameter balloon catheter was performed. The amount of ascites and pleural effusion transiently decreased just after the angioplasty. The hepatic vein, however, thrombosed 1 month after the angioplasty. Retransplantation using the left liver graft from the child's mother was performed 8 months after the first LDLT. The ABO blood-type was incompatible. Because severe fibrosis was observed around the previous venous anastomotic site and suprahepatic IVC, a venoatrial anastomosis was performed. The patient was discharged from the hospital 104 days after the operation; however, the child died because of chronic rejection 28 months after the first LDLT.

In patient 5, on POD 47, open drainage was performed for biloma formation in the right subphrenic space. After the operation, the amount of ascites and right pleural effusion gradually increased. On POD 110, total fluid was over 5,000 mL/day, which was 12% of the body weight. Doppler US

TABLE 1. Profile of the patients with hepatic venous outflow block

Patient	Age (yr)	Gender	Indication	Graft type	Onset (mo after LDLT)	Angioplasty (times)	LDLT to reoperation	Results
1	1	F	BA	SII+III	3	2	—	Alive 74 mo
2	48	F	PBC	Left liver	48	1	Patch plasty	Alive 65 mo
3	12	M	BA	LL+CL	5	3	—	Died 11 mo for biliary infection
4	2	M	BA	SII+III	2	1	Venoatrial anastomosis	Died 28 mo for chronic rejection
5	14	F	FH	LL+CL	2	3	Patch plasty	Alive 9 mo

BA, Biliary atresia; PBC, primary biliary cirrhosis; FH, fulminant failure; LDLT, living-donor liver transplantation; LL+CL, left liver with caudate lobe; SII+III, segments II and III; mo, months after transplantation.

revealed that the hepatic vein waveform was monophasic and the flow speed was 7.6 cm/sec. Venography revealed severe stenosis of the hepatic venous anastomosis, and the patient was diagnosed with HVOB. The pull-through pressure gradient was 19 mm Hg. Balloon angioplasty was performed three times at 14-day intervals with transjugular or transsubclavian catheterization. Even after the angioplasty, the amount of ascites did not decrease. The preoperative splenic volume was 240 mL, which increased to 880 mL in the post-LDLT period. On POD 160, patch venoplasty was performed as shown in Figure 1. Doppler US after the revision revealed a biphasic sharp waveform with the peak flow speed of 120 cm/sec. The amount of ascites dramatically decreased within 10 days after the revision.

Balloon angioplasty might be the first line of treatment for HVOB. Buell and colleagues (*2*) reported a 75% success rate (six of eight). In spite of their successful results, generally balloon angioplasty alone might yield unsatisfactory results as in our cases because of the fibrotic nature of the lesions. Stenosis refractory to angioplasty might be an indication for stent placement. Recent studies on the results of stenting for HVOB (*2*) reported a 72% success rate (18 of 25). In partial liver transplantation, as in whole liver transplantation using piggyback techniques, stenting is not always secure. Double stents might be necessary—one in the IVC and the other across the venous anastomotic site—which can slip off. In our patients, we chose surgical revision instead of stent placement because in patients with partial liver grafts, stent dislocation might occur along with graft regeneration and patient growth in pediatrics.

There are few reports of successful surgical treatment for late-onset HVOB. Lerut and associates (*9*) reported that one patient with a whole liver graft died during the revision operation for HVOB. Eid and colleagues reported successful whole liver graft salvage by retrohepatic cavoatrial shunt using a 16-mm, ring-enforced polytetrafluoroethylene graft (*10*). A French group (*3*) reported a 2% incidence of venous complications (21 of 1,361). Of these, four patients experienced late-onset HVOB. Details of the therapy and the results, however, were not reported. In pediatric LDLT cases, HVOB is treated with angioplasty (*4*) and stenting. There are no reports of a surgical strategy for HVOB, especially in LDLT. The severe liver graft shortage in Japan has made retransplantation extremely difficult, which forces us to choose the most reliable treatment for HVOB.

In an LDLT series of 223 patients, there were 5 cases of late-onset HVOB. It is important to diagnose HVOB as soon as possible with Doppler US and venography before irreversible congestive changes occur in the grafts. Prompt surgical revision could salvage the grafts, although it requires meticulous surgical technique.

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Duct-to-Duct Biliary Reconstruction in Adult Living-Donor Liver Transplantation

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Background. Bile duct-to-duct reconstruction is now used in living-donor liver transplantation (LDLT) for adult patients.
Methods. The results of duct-to-duct reconstruction were retrospectively analyzed. The subjects were 81 adult patients who underwent LDLT at the University of Tokyo Hospital with a follow-up period of at least 1 year. The hilar plate of the recipient was dissected to at least the second-order branch of the bile ducts. Duct-to-duct anastomosis was performed with interrupted sutures, and an external stent tube was inserted from the orifice opposite the hilar plate.
Results. During the observation period (median, 664 days), biliary complications were observed in 26 cases (32%). The complications included bile juice leakage at the anastomosis or dissection plane of the graft in 12 patients, anastomotic stenosis in 10 patients, and tube trouble in 6 patients. Two patients had bile juice leakage followed by stenosis. Of the 26 patients, 21 required surgical revision.
Conclusions. The current technique did not reduce morbidity as expected. Further technical advancement and refinement are needed for better results.

Keywords: Bile leakage, Anastomotic stricture, Standard liver volume.

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Various refinements in surgical techniques, organ preservation, and immunosuppressive management have reduced the incidence of complications after liver transplantation. Biliary tract complications, however, continue to be a significant cause of morbidity after liver transplantation (*1*, *2*).

Living-donor liver transplantation (LDLT) was initially performed for pediatric patients with biliary atresia. Therefore, the type of biliary anastomosis was limited to hepaticojejunostomy. Now, LDLT is widely performed for adults, and duct-to-duct direct biliary reconstruction is enthusiastically presented in some institutions (*3–7*). These reports advocate the advantages of duct-to-duct biliary reconstruction over hepaticojejunostomy (i.e., it could preserve physiologic bilioenteric and bowel continuity, thus preventing delayed bowel movement). Duct-to-duct reconstruction is described as allowing easy endoscopic access to the biliary tree for diagnostic and therapeutic instrumentation and management and to prevent ascending cholangitis (*3*, *7*, *8*).

These advantages are optimistically described but are not clearly established as beneficial. The number of patients who underwent LDLT and received duct-to-duct reconstruction is small, and the length of the follow-up periods is thus far limited. To confirm the feasibility of biliary reconstruction in LDLT, the results of duct-to-duct reconstruction were retrospectively analyzed in our series. The subjects were limited to those with a follow-up of at least 1 year.

PATIENTS AND METHODS

At the University of Tokyo Hospital, duct-to-duct biliary reconstruction was started in May 2000. By the end of 2002, 86 patients received LDLT with the reconstruction. Of these, five patients died within 1 year after LDLT and were excluded from the study. The remaining 81 patients were the subjects of the present study. They were 42 men and 39 women (average age, 50±10 years).

The most common indication for LDLT was viral hepatitis and cirrhosis with or without hepatocellular carcinoma (n=39), followed by cholestatic disease (n=27), including primary biliary cirrhosis, autoimmune hepatitis, primary sclerosing cholangitis, fulminant hepatic failure (n=9), metabolic diseases (n=4), and cryptogenic cirrhosis (n=2). The most commonly used graft type was the right liver in 46 patients, followed by the left liver with or without the caudate lobe in 29 patients, and the right lateral sector in 6. The donors were 56 men and 25 women (average age, 35±11 years). Their relation to the patients was child (n=41), sibling (n=14), spouse (n=12), nephew (n=7), parent (n=4), or other (n=3).

Donor Operation

Standard techniques were previously described (*9*). In brief, after cholecystectomy, a Phycon cholangiocatheter (Fuji Systems Corp., Tokyo, Japan) was inserted through the cystic duct stump for intraoperative cholangiography to ver-

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ify the transection point of the hepatic duct. The hepatic duct was sharply severed near the confluence and the remnant stump was carefully sutured closed with 4-0 Vicryl (Ethicon, Inc., Somerville, NJ). After harvesting, completion cholangiography was performed to confirm that there was no bile juice leakage or stricture.

Recipient Operation

The technique was described previously (*4*). In brief, in total hepatectomy of the patients, the hilar plate was dissected sharply at or distal to the second-order branch of the bile ducts. In dissection, careful attention was paid to preserve as much as possible of the surrounding tissues with an adequate blood supply to the bile duct. To maintain the blood supply from the right hepatic artery to the bile duct, dissection between the right hepatic artery and the bile duct was avoided.

An end-to-end anastomosis between graft and patient bile duct was performed using an interrupted 4-0 Vicryl suture. When the bile duct of the graft was larger than the recipient's duct, bile duct plasty of the hilar plate was performed (Fig. 1). Then, on the patient's hilar plate, an external stent tube was inserted into the bile duct from the orifice opposite the duct for which anastomosis was planned. When there were multiple bile duct orifices in the graft, stent tubes were used separately for each of them. When two bile ducts in the graft were located close to each other, they were joined into one. If they were widely separated, they were anastomosed independently. A stent tube was fixed not at the anastomotic site but rather at the orifice site opposite the hilar plate. The anastomosis was begun at the posterior wall. The needle was inserted into the bile duct of the graft from outside to inside, and then to the orifice of the hilar plate from inside to outside. The knots were always outside of the bile duct. The anastomotic site can be turned around for better access. Thereafter, anastomosis of the anterior wall was started. For feeding or injection of the drained bile juice, a 4-French polyethylene tube was inserted from the stump of the cystic duct and introduced into the duodenum. The tubes for bile duct stenting and feeding were removed 3 months after LDLT.

The postoperative care and our immunosuppression regimen have been described previously (*10*). Biliary complications were classified into three categories: bile juice leakage, bile duct stenosis, and tube trouble. Bile juice leakage was diagnosed when the total bilirubin level of the discharge around the dissection plane of the graft was over 5 mg/dL. Bile duct stenosis was suspected on the basis of laboratory data,

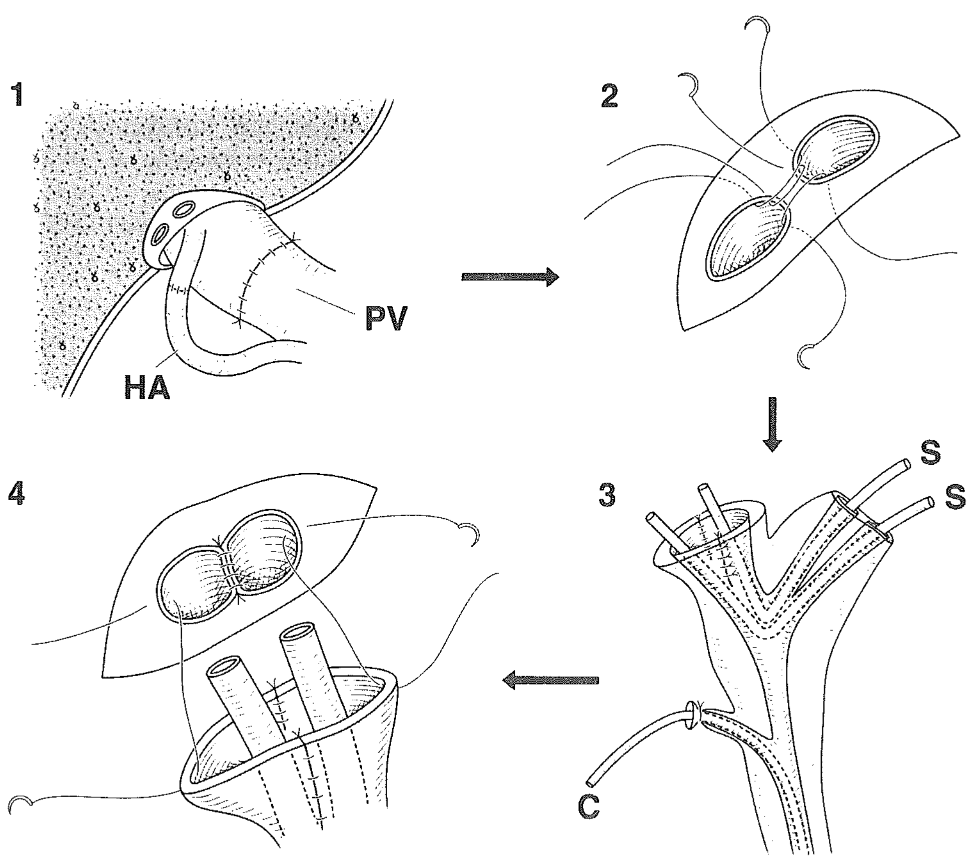

FIGURE 1. When there are two closely located bile duct orifices in the graft, the bile ducts in the hilar plate and graft were sutured into one. A stent tube (*S*) is introduced from the orifice opposite the hilar plate where the tube will be fixed to the plate. For nutrition or bile juice feeding, a 4-French polyethylene tube (*C*) was inserted from the stump of the cystic duct and introduced into the duodenum. The anastomosis was begun at the posterior wall and the needle was inserted into the bile duct in the graft from outside to inside; then, the orifice of the hilar plate was inserted from inside to outside. The knots were always outside of the bile duct. HA, Hepatic artery; PV, portal vein.

including a significant increase of γ-glutamyl transpeptidase and alkaline phosphatase, and was diagnosed radiologically by ultrasound, computed tomography, and cholangiography, showing slight dilatation of the graft bile duct.

A multivariate analysis was performed to find a predictor of bile juice leakage or bile duct stenosis. The independent factors consisted of seven intraoperative and two postoperative factors. Intraoperative factors included graft weight-to-standard liver volume ratio, duration of biliary reconstruction, blood loss per patient body weight, cold ischemic time of liver graft, warm ischemia time, number of bile duct orifices of the graft, and number of sutures used for biliary reconstruction. Two postoperative factors were acute rejection and cytomegalovirus infection. Differences were considered significant at a value of $P<0.05$. Data were shown as mean±SD or median and range.

RESULTS

Donors

The average duration of operation for the donors was 567±93 min. The average blood loss volume was 536±281 mL, which was replaced by 385±351 mL of autologous blood. The most common type of procedure was right liver resection (n=46), followed by left liver resection (n=29) and right lateral sectorectomy (n=6). There were no significant complications in the postoperative period. The mean postoperative hospitalization was 15±2 days. The donors have all returned to their normal daily activity.

Recipients

The average duration of operation for the recipients was 887±184 min. The duration for biliary reconstruction was 66±16 min. The average blood loss volume per body weight was 109±50 mL/kg. The mean graft weight was 577±177 g, which corresponded to 50±11% of the recipient's standard liver volume. Cold and warm ischemic times of the grafts were 99±37 and 71±10 min, respectively. The number of bile duct orifices was one (n=39), two (n=34), or three (n=8), with an average of 1.6±0.7 (Table 1). The number of sutures used for anastomosis was 12±4, ranging from 6 to 23.

During the observation period, biliary complications were observed in 26 patients (32%). The complications included bile juice leakage (n=12), anastomotic stenosis (n=10), and tube trouble (n=6). Two patients experienced complications with leakage followed by stenosis. Of the 26 patients, 21 complications necessitated surgery. For leakage, percutaneous drainage under ultrasound guidance was possible in five patients. The other patients underwent reoperation for drainage. The onset of leakage ranged between 4 and 65 days after LDLT. All of the patients with anastomotic stenosis underwent surgical revision. The procedure included a T-tube insertion from the common bile duct into the intrahepatic bile duct through stenosis (n=5), conversion to hepaticojejunostomy (n=3), dilation of anastomosis using a Kelly clamp under radiographic guidance (n=1), and transhepatic bile duct drainage (n=1). Nine of the 10 events occurred within 1 year after LDLT. The details of the anastomotic stenosis and outcome of the patients after each procedure are shown in Table 2. Briefly, three of the five patients with T-tubes are waiting for T-tube removal, one patient underwent retransplantation for refractory cholangitis, and one was cured. All of the patients with conversion to hepaticojejunostomy were cured and the patient with transhepatic bile duct drainage died as a result of sepsis. Because of the severe adhesion of the hepatic hilum, safe dissection of the bile duct and conversion to hepaticojejunostomy was not possible in one patient. Intraoperative cholangiography of this patient showed an anastomotic stricture and sludge formation on the graft side of the bile duct. A Kelly clamp was inserted into the hepatic hilum from the opposite side of the anastomosis, and all of the sludge was removed. Then, under radiographic guidance, dilatation of the anastomosis was performed and the external tube was changed with a new one. This patient was cured after the procedure.

TABLE 1. Number of bile duct orifices

Graft	1	2	3	Total
Left liver	14	12	3	29
Right liver	20	21	5	46
Right lateral sector	5	1	0	6
Total	39	34	8	81

A common cause of tube trouble was mislocation of the external drainage tube in three patients. The location was corrected in these patients to allow the tube to adequately drain bile juice 1, 3, and 5 days after LDLT. Complications in the other two patients included bile peritonitis after removal of external tubes. One patient was treated conservatively and the other underwent reoperation for irrigation and drainage. In another patient, 13 days after LDLT, there was bile juice leakage around a 4-French polyethylene tube introduced into the duodenum for feeding. Contrast medium injection through the tube revealed leakage from the stump of the cystic duct. The 4-French polyethylene tube was retracted until the tip was in the common bile duct for drainage. The peritonitis subsided thereafter.

Multivariate analyses failed to detect any significant predictors for bile juice leakage or bile duct stenosis (Table 3). The incidence of acute rejection was 27%. Portal vein thrombosis occurred in one patient and was successfully treated with anticoagulants, and none of the patients had hepatic arterial thrombosis. Cytomegalovirus infection occurred in 17% of the patients.

All but two patients are alive with normal liver function at a median follow-up period of 664 days. The patient with autoimmune hepatitis died 13 months after LDLT because of thrombocytopenic purpura. Bile duct stenosis occurred in the other patient, who underwent transhepatic bile duct drainage. The cholangitis was resistant to conservative therapy, however, and the patient died as a result of sepsis 13 months after LDLT.

DISCUSSION

The morbidity rate was 32% during the 1-year observation period, and the results are comparable among other series of right liver transplantation (Table 4). The rate might be higher, however, than that after whole liver transplanta-

TABLE 2. Detail of bile duct stenosis

Patient	Age/Gender	Onset (day)	Treatment	Result
1	57/F	89	Hepaticojejunostomy	Cured
2	20/M	214	Hepaticojejunostomy	Cured
3	54/F	810	T-tube drainage	Waiting for T-tube removal
4	52/F	334	Hepaticojejunostomy	Cured
5	50/M	73	T-tube drainage	Retransplantation for refractory cholangitis
6	34/F	44	Dilation of anastomosis by Kelly clamp and reinsertion of the external tube under radiographic guidance	Cured
7	67/M	18	T-tube drainage	Cured
8	59/M	310	T-tube drainage	Waiting for T-tube removal
9	43/M	69	Transhepatic bile duct drainage	Died as a result of sepsis
10	53/M	300	T-tube drainage	Waiting for T-tube removal

TABLE 3. Multivariate analysis for detecting predictors of biliary complications

	Leakage		Stenosis	
	Regression index	*P* value	Regression index	*P* value
GW/SLV	−0.366	0.31	0.007	0.10
Duration	−0.001	0.39	0.0005	0.97
Blood loss/BW	−0.001	0.19	−0.0005	0.49
CIT	−0.0004	0.64	−0.0002	0.77
WIT	−0.001	0.40	0.002	0.11
No. of ducts	−0.077	0.30	0.06	0.40
No. of threads	0.01	0.52	−0.01	0.36
Acute rejection	—	—	0.073	0.41
CMV infection	—	—	−0.0005	0.97

GW, Graft weight; SLV, standard liver volume; BW, body weight of the patients; CIT, cold ischemic time of liver graft; WIT, warm ischemic time of liver graft; CMV, cytomegalovirus.

TABLE 4. Comparison with the previous references

	No.	DDR (%)	Median FUT	Morbidity (%)
Icoz et al., 2003[15]	50	72	15	30
Settmacher 2003[26]	50	76	ND	40
Nakamura 2002[27]	120	34	13	24
Testa, 2000[1]	30	ND	ND	27
Marcos, 1999[28]	25	0	5	24
Present study	81	100	22	32

DDR, Rate of duct-to-duct biliary reconstruction to the whole series; FUT, follow-up term (mo).

tion (2%–24%) (*11–14*). This difference might be because of anatomic variations in bile ducts rather than surgical experience. In cadaveric transplantation, the anastomosis is performed on the intact hepatic duct of the donor and the recipient common bile duct so that only one anastomosis with well-vascularized tissue can be performed (*15*). This is not the case for LDLT, which often necessitates multiple and thin bile duct anastomoses.

In our series, 52% of all the grafts and 57% of the right liver grafts had multiple bile duct orifices. The incidence was comparable to the others (*1*). The poorer outcome might be related to the complicated procedure. Some surgeons performed duct-to-duct anastomosis in selected grafts that would secure a single bile duct anastomosis (*8, 16*). The results of the present multivariate analysis, however, contradicted this presumption. Takatsuki and colleagues (*6*) reported that multiple hepatic ducts were not a significant risk factor for biliary reconstruction. In our technique, the hilar plate was dissected distal to the second-order branch of the bile ducts. The extensive dissection enabled us to overcome the technical difficulty of multiple and widely separated graft bile ducts because the corresponding orifices in the recipient hilar plate could be freely selected.

Wide dissection of the hilar plate might be advantageous for tension-free anastomosis but disadvantageous because of decreased arterial supply to the duct (*17*). The common bile duct, if properly dissected, has its own axial blood supply that is provided mainly by branches of the superior posterior pancreaticoduodenal artery or the right hepatic artery (*18–20*). As in the recipient operation, the bile duct was inevitably dissected from the right hepatic artery, and the arterial supply was provided through connective tissues around the bile duct and the bile duct itself. Meticulous attention must be paid to dissection of the hepatoduodenal ligament, and preservation of axial periductal microcirculation is mandatory for successful biliary reconstruction (*15*). Similarly, the ability to preserve the blood supply to the donor's bile duct requires sharp dissection around the duct (*21*). The use of electrocautery should be avoided. The viability of the bile ducts for donor and recipient should be confirmed by the presence of pulsatile arterial bleeding from the cut ends. The venous drainage system of the duct might be more important. Venous blood enters into the portal venous branch, and the direction of the blood flow is from the caudal to the cranial direction in the upper part of the bile duct. It is unclear whether venous drainage can be maintained after anastomosis.

Transanastomotic external drainage or a T-tube is another concern of LDLT (*15*). Marcos and associates (*22*) reported that the biliary complication rate after routine use of an external drainage tube decreased from 24.% to 13%. A transanastomotic external tube could theoretically help to decrease the intrahepatic biliary pressure caused by edema and consequent partial obstruction of the anastomosis (*1*). The tube can also facilitate a postoperative imaging study; however, its advantage over no stenting and relation with the anastomotic biliary complication has not been clearly shown. In our series, six patients had tube complications, including mislocation and leakage, and one of them underwent reoperation. The complications caused by tubes should not be neglected. In the series of Testa and associates (*1*), stenting of the anastomosis was not routinely performed. Some institutions used a T-tube for decompression (*3, 7*). The randomized, controlled trial of biliary reconstruction in whole liver transplantation (*12*) revealed an increase in the biliary complication rate in the T-tube group. In LDLT, a T-tube will help decompress the bile duct but it will not help prevent stenosis at the anastomotic site. Because in LDLT there are often multiple duct orifices in the graft and a size difference between common bile duct and duct orifice in the graft, it is difficult to put the tip of a T-tube across the anastomotic site.

For surgical repair of stenosis, some authors converted duct-to-duct anastomosis directly to the hepaticojejunostomy for biliary complications (*1, 5, 8, 23*). Another strategy was T-tube insertion in the common bile duct with one arm in the stenotic portion. The surgical revision is technically demanding. The hilar plate of the patient often severely adheres to the hepatic artery or portal vein, and it is difficult to isolate the bile duct safely. In repairs using a T-tube, careful attention must be paid to the appropriate localization of the T-tube under intraoperative cholangiography, allowing for appropriate bile juice drainage. The Kyoto group (*24*) recently reported that 13 of 14 patients were successfully treated with an inside stent. The endoscopic approach is a therapeutic alternative to reoperation (*25*).

CONCLUSION

The results of duct-to-duct anastomosis in 81 patients with at least a 1-year follow-up were reviewed. Long dissection of the recipient hilar plate makes our technique unique and enables a tension-free biliary anastomosis and the ability to overcome the size and number discrepancy between graft and recipient bile ducts. In spite of these advantages, the morbidity rate was 32%, which was not as satisfactory as expected. The present results reveal the necessity for technical modifications to reduce the morbidity rates.

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Prediction of hepatic artery thrombosis by protocol Doppler ultrasonography in pediatric living donor liver transplantation

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Abstract

Hepatic arterial thrombosis (HAT) after liver transplantation is a life-threatening event. Previous reports have suggested that the resistive index (RI) of the hepatic artery predicts HAT. Doppler ultrasonography (US) to measure RI, however, is not routinely performed. The subjects were 70 pediatric patients who underwent living donor liver transplantation (LDLT). Protocol Doppler US was performed once or twice a day for 2 weeks postoperatively and 692 records were examined. Changes in RI values were examined separately in patients with and without HAT complications. The incidence of HAT was 10% (seven of 70). HAT was diagnosed an average of 6.2 days after LDLT. In patients without HAT complications (n = 63), average RI levels at 14 days after LDLT were 0.71 ± 0.1 (records, n = 625). In patients with HAT complications, RI decreased gradually within 2 days before the onset of HAT. RI values of less than 0.6 predicted HAT within 2 days before onset, with 83% sensitivity and 85% specificity. RI during the first 2 weeks after LDLT is a sensitive predictor for HAT. Thrombectomy and reanastomosis should be considered when RI values are less than 0.6 in Doppler US.

Key words: Hepatic artery thrombosis—Living donor—Liver transplantation—Doppler ultrasonography—Resistive index

Hepatic arterial thrombosis (HAT) after liver transplantation is a life-threatening event associated with a high rate of graft loss or death [1]. The incidence of HAT during the first 30 days has been reduced to approximately 5% by recent technical advances [2]. HAT is more common, however, in split or living donor liver transplantation (LDLT) [3].

Although arteriography remains a standard of reference for the diagnosis of HAT, Doppler ultrasonography (US) is a useful diagnostic tool for detecting HAT and the need for urgent revascularization. Rescue of liver graft from HAT depends on its early detection [4]. Protocol postoperative Doppler US appears to be mandatory for early detection [5]. Some studies [6–8] have proposed that decreases in the resistive index (RI) of the hepatic artery might predict HAT. Doppler US is not routinely performed, however, and the indication for Doppler US remains unclear from previous reports. The purpose of our study was to evaluate the significance of RI as a predictor of HAT in protocol Doppler US after pediatric LDLT.

Materials and methods

Seventy-two patients younger than 18 years underwent LDLT procedures at the University of Tokyo from January 1996 to December 2002. Of these, two patients were excluded from the analysis because they died due to simultaneous HAT and portal vein thrombosis. The remaining 70 patients (33 male, 37 female; mean age, 4.6 years) comprised the subjects of this study. The most common indication for LDLT was biliary atresia (n = 61), followed by Wilson disease (n = 2), fulminant hepatic failure (n = 2), cryptogenic cirrhosis (n = 2), and metabolic diseases (n = 1). The remaining two patients had indications for retransplantation. The most commonly used graft was the left lateral sector (n = 50), followed by the left liver (n = 15), right liver (n = 3), and right lateral sector (n = 2).

The operative procedure and postoperative management have been described elsewhere [3]. In brief, the donor and patient hepatic arteries were anastomosed end to end with an

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interrupted suture using 9-0 monofilament under a microscope. Anticoagulant therapy with prostaglandin E1 (0.01 μg/kg per hour) and a protease inhibitor (mesylate gabexate; 1 mg/kg per hour) was administered intravenously just after the operation for 14 days. Antithrombin III concentrates and low-molecular-weight heparin were also used.

Protocol Doppler US was performed once or twice a day for 2 weeks postoperatively with an SSD 2000 or SSD 6500 (Aloka Co. Ltd., Tokyo, Japan). The patencies of the hepatic artery, portal vein, and hepatic vein were assessed. Hepatic artery flow was determined near the porta hepatis. If intrahepatic artery flow was absent, then emergent laparotomy was performed without a confirmatory angiogram. RI ([systolic velocity − diastolic velocity]/systolic velocity) was calculated during each examination.

A total of 692 Doppler US records was collected. Changes in RI values were examined for 2 weeks after LDLT in patients without HAT complications. In patients with HAT complications, changes in RI values were analyzed for 1 week before the onset of HAT. The RI values in patients without HAT, those in patients with HAT within 2 days before the onset, and those in patients with HAT 7 to 2 days before the onset were compared with an unpaired t test. $P < 0.05$ was considered statistically significant. Values were recorded as average ± standard deviation.

Results

Clinical results

The incidence of HAT was 10% (seven in 70). HAT was diagnosed an average of 6.2 days after LDLT. Laparotomy was performed immediately after the diagnosis in each patient. In one patient, thrombus was not apparent but reanastomosis was performed because of anastomotic kinking. In the remaining six patients, a thrombus was detected at the anastomotic site and extended a few millimeters proximally into the reconstructed hepatic artery and was successfully removed. All patients survived the reoperation without retransplantation. One patient died 47 days after LDLT despite successful thrombectomy.

RI levels

In patients without HAT complications (n = 63), RI levels for 14 days after LDLT were 0.71 ± 0.1 (record n = 625; Fig. 1). In patients with HAT complications (n = 7), RI decreased gradually within 2 days before the onset of HAT. RI levels within 2 days before the onset (record n = 28) and those 7 to 2 days before the onset (record n = 39) were 0.52 ± 0.08 and 0.66 ± 0.09, respectively (Fig. 2). There was a significant difference between the two values ($p < 0.001$; Fig. 3).

Ten records in four patients without HAT showed an RI of less than 0.5, recorded on the fourth, fifth, sixth, and ninth days after LDLT. In each patient, the RI level spontaneously

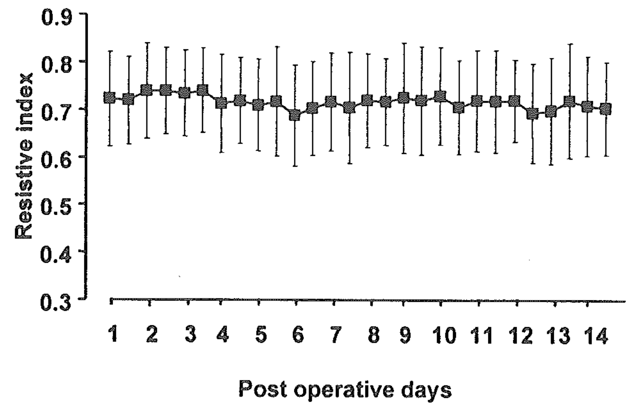

Fig. 1. Changes in RI values in patients without HAT (n = 63). RI was constant around 0.7 during the observation period.

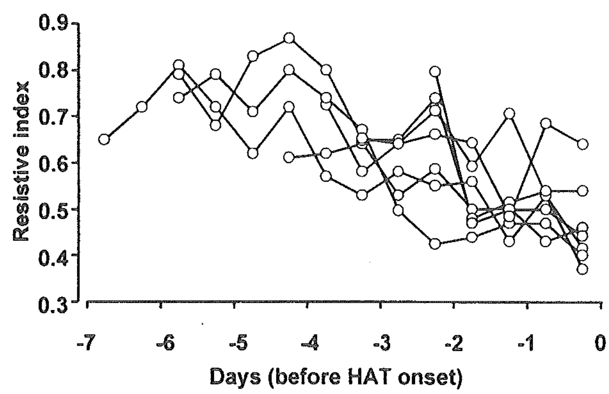

Fig. 2. Changes of RI values in patients with HAT complications (n = 7). RI decreased gradually 2 days before the onset of HAT.

recovered within 12 h. When the threshold was set at 0.6, the sensitivity and specificity of RI for HAT detection were 83% and 85%, respectively (Table 1).

Discussion

RI is a popular parameter that reflects vascular resistance and compliance [9] and is used to characterize the arterial waveform of Doppler US. Dodd and associates [7] emphasized that RI provides excellent screening for the detection of liver graft arterial stenosis or thrombosis. Of the 72 transplant recipients, 42 had normal arteries, 27 had substantial stenoses, and six had thromboses at angiography. Arterial flow was detected using Doppler US in 26 of 27 patients with stenosis, three of six patients with thrombosis, and in all patients with normal angiograms. In patients with HAT and flow detected by Doppler US, only RI was statistically significantly different from that in patients with normal angiograms. Another report [10] concluded that duplex Doppler US is useful for the diagnosis of HAT. In these reports [7,

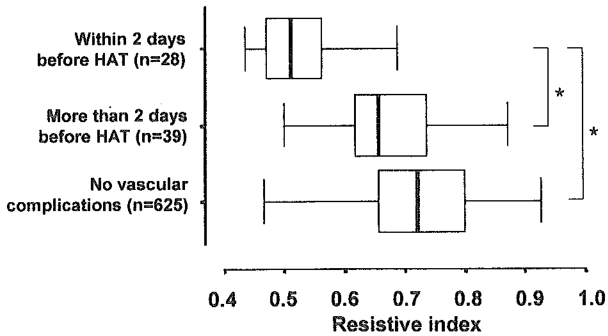

Fig. 3. Distribution of RI values in box-and-whisker plots. In patients with HAT, the RI values 2 days before the onset of HAT were significantly lower than those 2 to 7 days before the onset of HAT or those in patients without HAT. $^*p < 0.001$. n indicates the number of the US records.

Table 1. Sensitivity and specificity for HAT diagnosis for multiple discriminatory thresholds of RI

Threshold	TN	TP	FN	FP	Sensitivity (%)	Specificity (%)
< 0.4	660	1	29	2	3	100
< 0.5	652	13	17	10	43	99
< 0.6	564	25	5	98	83	85

FN, false negative; FP, false positive; HAT, hepatic artery thrombosis; RI, resistive index; TN, true negative; TP, true positive

10], however, Doppler US was not performed routinely and the indications for Doppler US were not clarified.

Recent studies [58] have indicated that protocol Doppler US is useful for early HAT detection. Urgent thrombectomy and revascularization based on the findings of protocol study significantly reduced the rate of late biliary complications and graft loss subsequently complicated by HAT. The present study differed from previous studies in which RI data were consecutively and prospectively collected. Nolten and colleagues [11] reported a qualitative change in the Doppler waveform over time. Although the waveform was initially normal in appearance, it progressed to an absent diastolic flow, dampening of the systolic peak, and, finally, loss of the hepatic arterial signal. The present study confirmed their findings, indicating that RI values of less than 0.6 predict HAT onset within 2 days with 83% sensitivity and 85% specificity.

In summary, we reviewed 692 Doppler US records in 70 pediatric patients. RI was a sensitive predictor for HAT during the first 2 weeks after LDLT. Thrombectomy and reanastomosis should be considered when RI values are less than 0.6 in protocol Doppler US.

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Sharing the Middle Hepatic Vein between Donor and Recipient: Left Liver Graft Procurement Preserving a Large Segment VIII Branch in Donor

Yoji Kishi, Yasuhiko Sugawara, Nobuhisa Akamatsu, Junichi Kaneko, Yuichi Matsui, Norihiro Kokudo, and Masatoshi Makuuchi

There are few reported techniques to minimize the congestion in the donor after left liver graft procuring. If a large tributary of the middle hepatic vein (MHV) draining segment VIII (V8) converges into the root of the MHV in a donor of left liver, this branch should be preserved on the donor side. The volume of congested area when the V8 was ligated was predicted preoperatively by computed tomography (CT) and examined intraoperatively by the clamp test. Postoperative regeneration of the donor liver was evaluated by CT volumetry. This technique was used in 3 cases. The regeneration rate after 3 months of the right paramedian sector was 27, 38, and 8%, and that of the right lateral sector was 31, 63, and 39% in each donor, respectively. No severe complications occurred in the donors. In conclusion, V8 preservation in donors who underwent left liver resection led to satisfactory regeneration both of the right paramedian and lateral sectors and can minimize congestion in remnant liver. (*Liver Transpl 2004;10:1208–1212.*)

A vital issue in living donor liver transplantation (LDLT) is the preservation of a satisfactory blood supply and venous return in both the right and left livers to maximize donor safety and graft function. When splitting the liver along the main portal fissure to procure a hemiliver graft, however, it is practically impossible to maintain complete venous outflow in both, because the middle hepatic vein (MHV) can usually be preserved on only one side. Interruptions of regional venous outflow inevitably cause congestion in the liver. Regional venous outflow disturbances will theoretically disrupt the function of the relevant hepatic parenchyma.[1]

In right liver graft transplantation, various strategies have been reported to reduce the congested area of the right paramedian sector, such as the reconstruction of tributaries of the MHV[2,3] or the use of a right liver graft including the MHV.[4] There are, however, few reported techniques to minimize the congestion in the donor after left liver graft procurement. Here we report a left liver graft without a branch of the MHV tributary that drains the cranial part of the right paramedian sector (V8) to minimize congestion of both the graft and remnant donor liver in left liver graft transplantation.

Abbreviations: CT, computed tomography; LDLT, living donor liver transplantation; MHV, middle hepatic vein; V8, MHV tributary that drains the cranial part of the right paramedian sector.

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Patients and Methods

From February 1996 to September 2003, 240 consecutive LDLTs were performed at our institution. Left liver with caudate lobe graft was used in 91 patients. In every donor, sectional computed tomography (CT) volumetry was performed preoperatively and a left liver with caudate lobe graft was indicated when the volume was over 40% of the recipient standard liver volume.[5]

The indication for procurement of the left liver graft was as follows: CT volumetry of donor liver was performed; a 3-dimensional image was reconstructed from CT using Region Growing software (Version 0.5a; Hitachi Medical, Chiba, Japan); if the volume drained by a V8 branch was large (Fig. 1), a left liver graft without a V8 branch was considered; three donors had a large V8 converging into the root of the MHV, and this branch drained a large part of right paramedian sector and a part of right lateral sector: then a left liver graft was procured, preserving this tributary in the cases reported here; case 1 was a 42-year-old female with hepatic failure due to primary biliary cirrhosis and the left liver was donated by her 42-year-old husband; case 2 was a 37-year-old female with primary biliary cirrhosis and the donor was her 66-year-old father; case 3 was a 14-year-old female with biliary atresia and the donor was her 45-year-old mother.

In the donor operation, MHV tributaries were confirmed by intraoperative ultrasonography. After dissection of the coronary ligament, the confluence of the left and middle hepatic veins was sufficiently exposed. The dissecting line of the

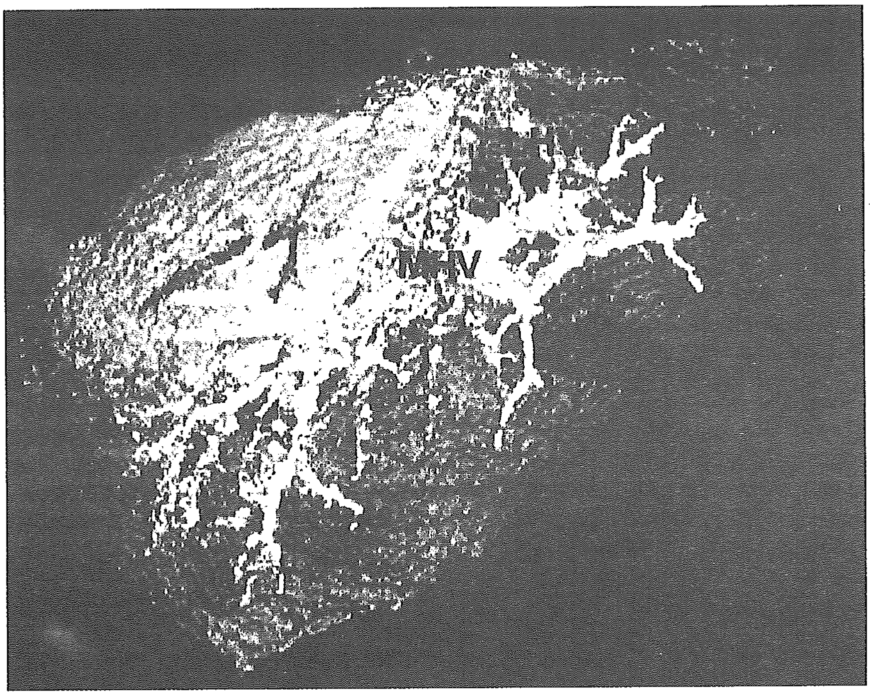

Figure 1. Computer-generated 3-dimensional image of the reconstruction. The red-colored vein indicates a V8 branch that was preserved on the donor side. The area drained by the V8 is shown in light brown. The white line in the left panel shows the dissection line of the hepatic veins. Abbreviations: LHV, left hepatic vein; MHV, middle hepatic vein.

parenchyma was determined according to the demarcation line that appeared by clamping one side of the hepatic artery and portal vein. Dissection of the liver parenchyma was performed using an ultrasonic surgical aspirator (SNP-5000; Aloka, Tokyo, Japan) under Pringle's maneuver.[6,7] During the division of the liver parenchyma, MHV tributaries of more than 5 mm in diameter were preserved using the sling suspension technique.[8] After completion of the parenchymal dissection, the congested area was evaluated as previously described.[9] In brief, after clamping each tributary of the MHV, Doppler ultrasonography was performed to evaluate the portal flow to segment VIII. Subsequently, the right hepatic artery was clamped for a few minutes and the congested area was estimated. When the area of congestion was too large or Doppler ultrasonography indicated reversed portal flow to segment VIII, the MHV was transected proximal to the root of the V8 branch.

The orifice of the hepatic veins of the graft became inevitably separated or became 1 orifice with a septum. Furthermore, the length of the exposed vein was decreased. For easier anastomosis, plasty of the vein orifice on the graft was performed using a cryopreserved deceased donor vein (Fig. 2). To widen the orifice of the superficial branch of the left hepatic vein or that of the MHV, slits were made on the bilateral side of the hepatic vein orifice of the graft. On the recipient side, the venoplasty to make 1 orifice from the left hepatic vein and MHV was performed by the technique described previously.[10] An end-to-end anastomosis was then made between the graft and recipient orifices. The caudate lobe was procured with the left liver and if there were large caudate veins, they were reconstructed.[11]

In recipients, the vascular flow of the graft was checked by Doppler ultrasonography twice a day for the first 14 days and once a week thereafter until hospital discharge. Serum transaminase levels were checked every day for 4 weeks after the operation. In donors, serum transaminase was examined every day for 1 week after the hepatectomy. In both donors and recipients, abdominal CT was performed 3 months after the operation. The regeneration of each sector of the livers was calculated as described elsewhere.[1] The regeneration rates were compared with those of 16 donors who underwent both left hepatectomy with total MHV deprivation and postoperative CT. The Mann-Whitney test was used for the statistical analysis. Measured variables were expressed as range and median. A P value less than .05 was considered significant.

Results

Donors

The operative time and blood loss was 515, 497, and 530 minutes, and 620, 775, and 490 mL, respectively. Postoperatively there were no severe complications to necessitate reoperation. Each donor was discharged on the 12th, 14th, and 16th postoperative day. During the

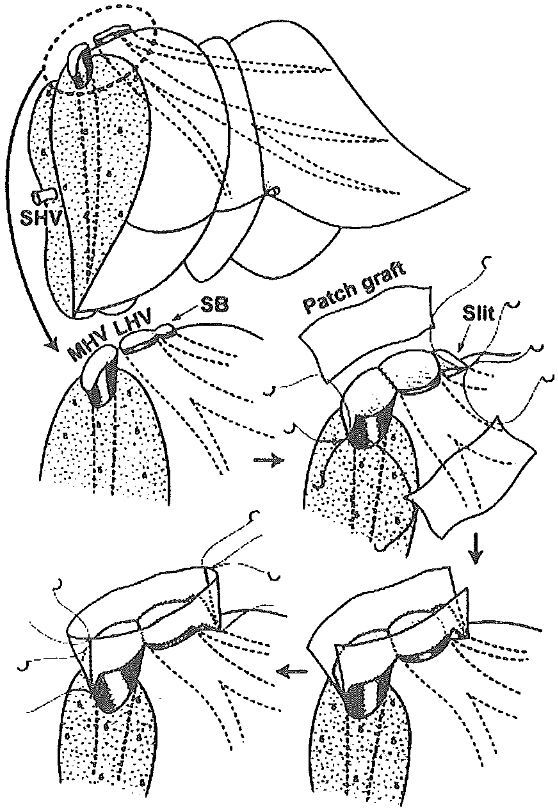

Figure 2. Venoplasty of the stumps using patch grafts. After plasty to make 1 orifice, a slit was made bilaterally to widen the orifice and 2 patches were sutured to the anterior and posterior edges. Each side of the patch was then sutured. The stump was extended and enlarged. Abbreviations: SHV, short hepatic vein; MHV, middle hepatic vein; RHV, right hepatic vein; SB, superficial branch.

3 months after LDLT, comparable regeneration between the right paramedian and lateral sectors was seen in the 3 donors (Table 1).

The regeneration rates of the right paramedian and lateral sector of the 16 donors who underwent left hepatectomy with total MHV deprivation were −20% to 99% (median 3%) and −27% to 118% (median 31%), respectively. There was no significant difference between the 3 cases with V8 preservation and the 16 donors with MHV deprivation in regeneration rate of either the paramedian (P = .12) or lateral (P = .57) sector.

Recipients

The operative time and blood loss of the 3 patients were 880, 955, and 913 minutes, and 4,276, 5,315 and 2,295 mL, respectively. The cold / warm ischemic time of the graft in each case was 106 / 59, 138 / 64, and 150 / 62 minutes, respectively. In Cases 1 and 3, 1 caudate vein was reconstructed. In Case 2, there was no caudate vein with a diameter of more than 5 mm and the reconstruction was not performed. The hospitalization duration after LDLT was 37, 72, and 30 days. During the hospitalization, Doppler ultrasonography revealed a well-maintained triphasic pattern of venous flow and no findings of arterial or portal venous thrombosis in any patient.

Laboratory data indicated that the maximum serum alanine aminotransferase level (376, 314, and 868 IU/L) occurred within the 2nd postoperative day in all cases. In Case 2, a splenectomy was performed simultaneously because of thrombocytopenia. Pancreatic juice leakage occurred postoperatively, but this was treated conservatively by percutaneous drainage, which resulted in a 72-day-long hospitalization. After discharge, no signs of venous stenosis such as persistent abnormal liver function, hypoalbuminemia, ascites, or pleural effusion were observed in either patient.

Discussion

In LDLT, donor safety must be the 1st priority. Preoperative liver volumetry by CT is one of the most important methods for selecting an appropriate donor. Most transplant centers in Western countries choose right liver graft routinely in adult-to-adult LDLT.[12] Right

Table 1. Liver Regeneration in Donors Estimated by Computed Tomography

	RPM			RLS		
Case	Pre (mL)	Post (mL)	RR (%)	Pre (mL)	Post (mL)	RR (%)
1	498	630	27	298	391	31
2	254	351	38	236	386	63
3	462	562	22	243	338	39

Abbreviations: RPM, right paramedian sector; RLS, right lateral sector; Pre, volume on preoperative CT; Post, volume on CT 3 months after LDLT; RR, volume regeneration rate given by (postoperative volume-preoperative volume)/preoperative volume × 100 (%).

liver procuring, however, could impose a higher surgical risk on donors, as reflected by the volume of the residual liver mass.[13] Furthermore, not all donors can provide their right liver.[14] Fan et al.[15] concluded that safe donation was possible only when the estimated residual liver volume was over 30%. Left liver with the caudate lobe can be used as an alternative graft with[12] or without[16] reconstruction of the caudate vein if it is more than 40% of the recipient's standard liver volume.[15]

The MHV usually drains most of the paramedian sector and has a limited role in draining segment IV.[17] For left liver procuring in adult LDLT, the liver parenchyma is usually divided along the right side of the MHV to maintain high graft viability. Although this procedure can cause congestion and atrophy in the paramedian sector of the remnant right liver,[1] congestion is not a significant clinical problem. A compensatory hypertrophy of the right lateral sector may be induced.[18] According to our previous study,[9] in 26% of donors no significant congestion will occur because the regurgitated blood through the right paramedian vein flows into the right lateral vein via intrahepatic venous communication.

There are, however, some anatomic variations of the MHV. A previous report[19] revealed an MHV variation during resection of the right paramedian sector for tumor resection. When a large tributary of the MHV draining segments V and VI was divided, the surface of segment VI became dark purple. To relieve the congestion of segment VI, the MHV tributaries were reconstructed. The MHV sometimes drains a large part of segment VI, in which case, a trunk of the MHV must be preserved on the donor side.[20]

When segment IV is exclusively drained through left hepatic or scissural vein, the present technique will be less relevant. We must note a large interindividual difference in the graft volume regeneration after partial liver transplantation, which might be due to individual anatomical variation in the venous drainage. In the present analysis, we could not clearly show more satisfactory regeneration in the right paramedian sector by V8 preservation. It might be due to the limited number of cases with the present technique.

Another problem with the present technique might include the possible venous graft failure in the long term.[21] Millis et al.[22] reported a 51% complication rate after using cryopreserved vascular graft. Kuang et al.[23] experienced complications including aneurysm, thrombosis, and stricture in 8 of the 9 cryopreserved vein grafts, which were used for portal vein and hepatic arterial interposition. These previous discouraging results indicate that long-term follow-up will be necessary to confirm the feasibility of the technique.

In this report, we propose an option for left liver graft procurement by preserving a large V8. Postoperative CT revealed comparable regeneration of the right paramedian and lateral sectors in donors. Although the indication for the technique is limited by the MHV anatomy, it will minimize liver congestion and can contribute to reducing donor risk.

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Alternatives to the Double Vena Cava Method in Partial Liver Transplantation

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Minimizing graft congestion in partial liver transplantation is important, especially when the graft weight is marginal for the recipient metabolic demand. We prefer the double vena cava technique for reconstructing middle hepatic vein tributaries with thick, short hepatic veins because the technique can reduce the warm ischemic time of the graft and make a wide anastomosis. This technique requires a cryopreserved superior or inferior vena cava. We devised an alternative double vena cava method using iliac or femoral vein grafts and applied it to two right liver transplantation patients. There was no postoperative hepatic venous outflow block in either patient. In conclusion, application of this technique, even in the absence of a suitable vena cava, can help to minimize graft congestion. (*Liver Transpl 2005;11:101–103.*)

Adequate outflow is indispensable for graft function. Hepatic vein reconstruction for adequate outflow, however, is technically demanding in partial liver transplantation because of eventual twisting or compression by the regenerated liver graft.[1] The double vena cava (VC) technique is indicated in a right liver graft if the graft includes major short hepatic veins.[2] Application of this technique, however, depends on the availability of a VC graft. Here we introduce two alternative methods to the double VC technique using venous grafts of smaller diameter.

Patients and Methods

From January 1996 to June 2004, 221 adult patients underwent living donor liver transplantation (LDLT) using a right liver graft at our hospital. The mean follow-up period was 850 days. The indications for LDLT in these patients included hepatitis C virus cirrhosis (n=54), primary biliary cirrhosis (n=50), hepatitis B virus cirrhosis (n=38), fulminant hepatic failure (n=25), cryptogenic cirrhosis (n=17), biliary atresia (n=14), metabolic disorder (n=6), primary sclerosing cholangitis (n=9), and autoimmune hepatitis (n=8). Details regarding the selection criteria and evaluation are described elsewhere.[3,4] All donors and patients provided written informed consent.

Homologous Vein Graft Preparation

Vein grafts were provided by the University of Tokyo Tissue Bank. The preservation and thawing methods have been previously described.[5] In brief, the vein grafts were obtained in a sterile manner from cadavers within 24 hours after cardiac arrest after obtaining informed consent. The specimens were frozen slowly in a programmable freezer at a rate of 1°C/min to -40°C and stored in liquid nitrogen until use. The cryopreservation medium consisted of Rosewell Park Memorial Institute 1640 solution (Whittaker Co., Sydney, Australia), 10% dimethylsulfoxide (Sigma, St. Louis, MO), and .5 g/L cefazolin sodium (Fujisawa, Tokyo, Japan).

For use, the packed vein grafts were placed at room temperature for 7 minutes and immersed gently in 37°C sterile saline for 30 minutes. Thereafter, the vein grafts were picked up from the bag and placed into the Alloflow (Lifenet, Virginia Beach, VA). Finally, they were rinsed with 1 liter of lactated ringer's solution (Lactec G, Ohtsuka Pharmaceutical, Tokyo, Japan).

Right Liver Harvesting

The right liver was harvested as described previously.[4] Briefly, in a basin, the graft was flushed with 1 liter of University of Wisconsin solution through a cannula inserted into the right portal vein. When the graft included major short hepatic veins, including inferior or middle right hepatic veins in the graft, the double VC technique was applied as described previously.[6] Briefly, a cryopreserved VC graft was prepared in a basin. A side hole was made in the wall of the VC, which was anastomosed with the hepatic veins in the graft. With this technique, all hepatic vein trunks of the recipient were sutured at their roots. Then, the inferior VC of the recipient was partially clamped and incised approximately 5 cm longi-

Abbreviations: LDLT, living donor liver transplantation; VC, vena cava.

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