American Journal of Transplantation 2006; 6: 2672–2679
Blackwell Munksgaard

doi: 10.1111/j.1600-6143.2006.01528.x

Living Donor Liver Transplantation for Biliary Atresia: A Single-Center Experience with First 100 Cases

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The aim of this study is to present our institutional experience in living donor liver transplantation (LDLT) as a treatment for end-stage liver disease in children with biliary atresia (BA). A retrospective review of transplant records was performed. One hundred BA patients (52 males and 48 females) underwent LDLT. The mean follow-up period was 85.5 months. The mean age was 2.4 years. The mean preoperative weight, height, and computed GFR were 12.2 kg, 82.5 cm, and 116.4 ml/min/1.73 m^2, respectively. Twenty-seven patients were below 1 year of age, and 49 patients were below 10 kg at the time of transplantation. Ninety-six had had previous Kasai operation prior to transplant. The mean recipient operative time was 628 min. The mean recipient intraoperative blood loss was 176 ml. Thirty-five did not require blood or blood component transfusion. The left lateral segment (64) was the most common type of graft used. There were 27 operative complications which included 3 reoperations for postoperative bleeding, 9 portal vein, 4 hepatic vein, 4 hepatic artery, and 7 biliary complications. There was one in-hospital mortality and one retransplantation. The overall rejection rate was 20%. The overall mortality rate was 3%. The 6-month, 1-year and 5-year actual recipient survival rates were 99%, 98% and 98%, respectively.

Key words: Extrahepatic biliary atresia, liver transplantation, outcome

Abbreviations: BA, biliary atresia; CHD, congenital heart disease; ELLS, extended left lateral segment; cGFR, calculated glomerular filtration rate; LDLT, living donor liver transplantation; LL, left lobe; LLS, left lateral segment; LT, liver transplantation; OLT, orthotopic liver transplantation; RL, right lobe

Received 13 April 2006, revised 24 June 2006, revised and accepted for publication 17 July 2006

Introduction

Biliary atresia (BA) is the most common cause of chronic cholestasis in infants and children, occurring in 1: 8000–1: 20 000 live births (1–5). There is an increased incidence in the Pacific rim and a predominance in Orientals (4). This obstructive cholangiopathy leads to early development of secondary biliary cirrhosis (2,3). The prognosis of untreated BA is poor with reported median survivals of <2 years. The Kasai hepatoportoenterostomy has improved the outcome of BA patients, particularly if performed on children <90 days old (6). However, 67% of these patients will develop chronic liver disease and almost all will require liver transplantation (LT) before reaching adulthood. The general approach is that Kasai procedure has now become a bridge to LT (7–9).

BA is the most common indication for pediatric LT, representing at least 50% of all pediatric cases (10). In our center, BA comprises around 80% of all pediatric LT cases. Numbers of children waiting for orthotopic liver transplantation (OLT) have increased due to progress in medical treatments and success of OLT in the last 10 years (11). However, there is still a shortage of organ donation. Living donor liver transplantation (LDLT) was developed to alleviate organ shortage due to a markedly limited deceased donor organ graft supply, and to decrease mortality while on the waiting list (12).

Few series have focused on the results of pediatric LDLT for BA only (13–15). Recent large studies report on pediatric OLT for BA combine the results of deceased donor grafts, split-liver grafts, reduced-size grafts and LDLT (5,16–18). Furthermore, the data concerning long-term outcome in these children, including schooling, and renal and metabolic functions due to long-term immunosuppression, is not available. Data on the live donor are also lacking. The present study is aimed at reviewing our experience in LDLT for BA, including recipient and donor characteristics, and analyzing the results as well as long-term outcome in these children.

Patients and Methods

From June 1994 to September 2005, 237 LDLT were performed at the Chang Gung Memorial Hospital-Kaohsiung Medical Center, Taiwan. One

hundred twenty-four (124) were pediatric LDLT. One hundred (100) of these pediatric LDLT were for BA. The records of these BA patients and their follow-up were retrospectively analyzed and included recipient and donor demographic data, operative outcome, coexisting medical conditions, type of graft, complications, and long-term outcome. The mean follow-up period was 85.5 months (range, 6–141).

Operative technique

The authors' techniques of donor left and right graft hepatectomy and recipient total hepatectomy in LDLT have been described in detail previously (19,20). The graft consisted of the left lateral segment (LLS, segments 2, 3), an extended left lateral segment (ELLS, segments 2, 3, part of 4), left lobe (LL, segments 2, 3, 4), or right lobe (RL, segments 5, 6, 7, 8). If needed, graft hepatic vein venoplasty (21) was performed. Triple recipient venoplasty was done in patients receiving an LLS, ELLS, or LL (19); whereas right hepatic vein orifice widening was done in patients receiving an RL. The size of these venoplasty openings was adjusted to measure wider than the graft hepatic vein. Assuring the correct orientation of the graft and recipient vessels, the graft hepatic vein was anastomosed to the recipient hepatic vein triple venoplasty opening with the inferior vena cava cross-clamped (19). Veno-venous bypass was not used. The graft was reperfused after completion of portal vein anastomosis followed by hepatic artery reconstruction under microsurgical techniques. Extreme care to prevent air and particulate embolism in the cava was done by flushing the graft with lactated Ringer's solution before completion of hepatic vein and portal anastomoses. Duct-to-jejunum Roux-en-Y biliary reconstruction was completed and the falciform ligament was reconstructed in left-side grafts. Intraoperative color flow Doppler ultrasound was performed to check vascular flow patterns and velocities after vascular reconstruction, and before and after abdominal closure.

Anesthesia management

The anesthesia management was according to protocol by the Department of Anesthesiology (22), which included complete preoperative evaluation of the cardiovascular system, and intraoperative maintenance of normothermia, normal blood ionized calcium and pH. Blood loss, ascites, and intraoperative transudate loss were primarily replaced with 5% albumin and crystalloids to maintain a central venous pressure of around 10 cm H_2O. Red blood cell transfusion was not given for hemoglobin higher than 8.0 g/dL and as long as the intravascular volume was sufficient to maintain normal hemodynamics.

Immunosuppression

From the start of our LDLT program in 1994, the immunosuppression included cyclosporine (Novartis, Basel, Switzerland), azathioprine (GlaxoWellcome, Auckland, New Zealand), and steroid. For cyclosporine, the conventional trough levels (C_0) monitoring was adapted until January 2002. At that time, the target C_0 levels were 300–400 ng/mL during the first postoperative month, 100–200 ng/mL for up to 1 year, and approximately 100 ng/mL or less thereafter.

Since January 2002, C_2 monitoring was adapted. The C_2 concentrations were aimed at 800–1200 ng/mL during the first 6 months, 640–960 ng/mL for up to 1 year, and 480–720 ng/mL thereafter. In the latter course, there were no specific target levels. The dose of cyclosporine and its adjustments were based on the results of liver function test. As much as possible, the aim was for the lowest possible dose where liver function test results can be maintained at acceptable normal or near normal levels.

When our deceased donor LT program started in 1984, the available cyclosporine was the nonmicroemulsified form which had erratic GI absorption. Azathioprine (2 mg/kg/day started intraoperatively, reduced to 1 mg/kg/day after 2 weeks, and discontinued by 6 months posttransplantation) was added to potentiate immunosuppression. This protocol was adapted when the LDLT program started in 1994. With the introduction of the microemulsified cyclosporine (Neoral, Novartis, Basel, Switzerland), we have decreased the length of time of azathioprine usage to 3–6 months.

The steroid arm of the triple drug immunosuppression was started as methylprednisolone administered at an initial dose of 20 mg/kg intravenously during the operation. On postoperative day 1, the dosage was 3 mg/kg/day; and gradually reduced daily until 0.5 mg/kg/day by postoperative day 6. The oral dose was tapered to a maintenance dose of 2.5–5 mg/day. During the latter follow-up period, this maintenance dose was given every other day and gradually tapered by prolonging the interval. Steroids were eventually discontinued at a time point exceeding 6 months after transplantation.

Mycophenolate (Roche, Basel, Switzerland) was used in recipients whose indications included (a) more potent immunosuppression was desirable, (b) renal-sparing benefits, and (c) to decrease the dose of calcineurin inhibitor required. All rejections were biopsy-proven and managed with intravenous pulse methylprednisolone (10 mg/kg/body weight), and an increase in the dose of the current immunosuppression or switched to tacrolimus (Fujisawa, Osaka, Japan), and/or adding mycophenolate.

Follow-up

After discharge, the recipients were monitored in the Department of Surgery Liver Transplantation Unit of the Chang Gung Memorial Hospital, Kaohsiung. Six (6) foreign patients were monitored in their respective country (Philippines); and updates on these recipients were made through correspondence with the attending physician in that country. Long-term outcome was analyzed in the subgroups of children ($n = 41$, 5-year survival; $n = 20$, 7-year survival; $n = 9$, 10-year survival) who had reached at least 5 years of follow-up after LDLT. Medical records included height, weight, serum liver function tests (albumin, AST, ALT, alkaline phosphatase, gamma glutamyl transpeptidase, bilirubin), renal function (blood urea nitrogen, creatinine, calculated glomerular filtration rate (cGFR) by the Counahan formula (23)), cholesterol, triglycerides, glucose, uric acid, hepatitis surveillance and complete blood count. School performance and employment were inquired.

Statistical analyses

Patient survival was defined as the time period between transplantation and February 2006 or patient death. Graft survival was defined as the period between transplantation and February 2006 where graft failure or loss either by retransplantation or death was reported. Data were presented as mean $\pm$ SD, and median as appropriate. SPSS Advanced Module Statistic (SPSS, Chicago, IL) was used to analyze data. Mann-Whitney test and 2-tailed test were used to analyze relationships between the presence of congenital heart disease (CHD), age and recipient extubation time. A p value of <0.05 was considered significant. Actual 6-month, 1-year, 5-year and 10-year survival rates were determined.

Results

Recipient and donor characteristics

There were 52 boys and 48 girls. Twenty-seven (27) patients were below 1 year, and 49 patients were below 10 kg at the time of LDLT. Ninety-six (96) patients had Kasai operation prior to LDLT. The mean Child-Turcotte-Pugh score was 9; and the median United Network for Organ Sharing (UNOS) score was 3. Table 1 showed the demographic data based on pretransplant body weight of the 100 recipients. The more commonly associated nongastrointestinal

Table 1: Preoperative demographic characteristics based on recipient body weight before transplant (n = 100)

Characteristic	<10 kg (n = 49)	>10 kg (n = 51)	Total
Age[1]	1 year 8 months (6 months–2 year 8 months) Median: 1 year	4 year 4 months (1 year 1 month–19 year 3 months) Median: 2 year	2 year 5 months (6 month–19 year 3 months)
Height	69.4 cm (61.0–82.7 cm) Median: 65 cm	93.7 cm (73.0–161.7 cm) Median: 80 cm	81.6 cm (61.0–161.7 cm)
Weight	7.9 kg (5.1–9.6 kg) Median: 9 kg	16.4 kg (10.0–53 kg) Median: 10.5 kg	12.2 kg (5.1–53 kg)
CTP Score	9.7 (7–13)	8.4 (5–13)	9 (5–13)
PELD Score	17.6 (1–43)	8.1 (1–19)	12.8 (1–43)
Median UNOS score	2B	3	3
Preoperative creatinine^{+}	0.34 (0.1–0.8)	0.37 (0.2–0.7)	0.35 (0.1–0.8)
Preoperative cGFR[2]	112.9 (32.8–320.7)	118.7 (47.8–331)	116.4 (32.8–331)
Previous Kasai operation	47	49	96

CTP, Child-Turcotte-Pugh; PELD, Pediatric Model for End-Stage Liver Disease; UNOS, United Network for Organ Sharing; cGFR, calculated glomerular filtration rate.

[1]Twenty-seven patients below 1 year age.

[2]cGFR = mL/min/1.73 m^2 = (0.43 × height in cm)/serum creatinine in mg/dL; $^{+}$12 patients with pretransplant renal dysfunction (10 in the <10 kg, 2 in the >10 kg).

medical conditions pretransplant included CHD (n = 20), intrapulmonary shunting (n = 13), polysplenia syndrome (n = 2), and hepatopulmonary syndrome (n = 1).

The donors included mothers (n = 61), fathers (n = 30), grandparents (n = 5), aunts (n = 2) and cousins (n = 2). The most common type of graft used was the LLS (n = 64). The other types of grafts used included an ELLS (n = 29), RL without middle hepatic vein (n = 4), LL (n = 2), and LL with middle hepatic vein (n = 1). Graft venoplasty was done in 14 LLS, 5 ELLS and 1 LL grafts.

Operative outcome

Table 2 summarized the recipient operative outcomes. Thirty-five (35) of the recipients did not require blood transfusion. Veno-venous bypass was not used in any recipient. Gore-Tex^{R} patch was required to close the abdomen in three recipients (LDLT 52, LDLT 68, LDLT 69). A total of

Table 2: Operative outcome based on recipient body weight (n = 100)

Outcome	<10 kg (n = 49)	>10 kg (n = 51)	Total
Cold ischemia	50.1 min (17–104 min)	62.3 min (27–144 min)	57.3 min (17–144 min)
Warm ischemia	42.0 min (29–56 min)	42.0 min (26–59 min)	42.0 min (26–59 min)
Total operative time	558.9 min (427–811 min)	669.7 min (423–1180 min)	628 min (423–1180 min)
Blood loss	178.2 mL (10–850 mL)	174.1 mL (13–1210 mL)	176 mL (10–1210 mL)
Pack red cell transfusion[1]	165.9 g (0–490 g)	75.2 g (0–720 g)	120.3 g (0–720 g)
Graft venoplasty	11	9	20
Graft-to-recipient weight ratio[2]	3.4 (2.1–5.1)	2.1 (0.91–4.29)	2.7 (0.91–5.1)
Required Gore-Tex^{R} abdominal wall closure	3	0	3
Operative complications	16	11	27
In-hospital mortality	1	0	1

[1]Thirty-five recipients did not require blood or blood product transfusion.

[2]Eight recipients with ratio >4.

Table 3: Operative and other complications based on recipient body weight

	<10 kg	>10 kg	Total
A. Operative complications (n = 27)			
Reoperation for bleeding	1	2	3
Portal vein complication[1]	7	2	9
Hepatic vein complication[2]	2	2	4
Hepatic artery complication[3]	1	3	4
Bile duct complication[4]	3	4	7
Total	14	13	27
B. Other major complication (n = 27)			
Recurrent variceal bleeding	5	2	7
GI perforation	2	2	4
Intestinal obstruction 2^0 postoperative adhesions	0	3	3
Posttransplant lymphoproliferative disorder	2	1	3
De novo hepatitis B infection	2	1	3
Idiopathic thrombocytopenic purpura	1	1	2
Acute renal failure	1	0	1
Intracerebral hemorrhage	1	0	1
Infectious mononucleosis	0	1	1
Jackson-Pratt drain fracture	0	1	1
Prolonged ascites	1	0	1
Total	15	12	27
C. Other minor complication (n = 7)			
Hirsutism	1	3	4
Gingival hyperplasia	1	2	3
Total	2	5	7

[1]Five patients detected intraoperatively with redo, four patients underwent reoperation.
[2]One patient underwent balloon dilatation and stenting, three patients underwent balloon dilatation.
[3]Three patients detected intraoperatively with redo, one patient underwent reoperation.
[4]Five patients underwent reoperation, one retransplant.

27 operative complications occurred. Table 3 showed the breakdown of operative complications. One (1) graft was lost due to early portal vein thrombosis (LDLT 94). Intraoperative color flow Doppler ultrasound was used to demonstrate flow and pulsatility following vessel anatomoses for early detection of possible vascular complications. There were no perioperative cardiac complications despite having CHD as the most commonly associated nongastrointestinal medical condition pretransplant. There was no difference in the length of extubation time among CHD recipients with BA when compared to non-CHD recipients with BA. Of the 27 operative complications, 13 underwent reoperations. There was 1 in-hospital mortality (LDLT 94); and 1 retransplantation (LDLT 4).

Table 4 summarized the donor operative outcomes. There was no mortality in the donors. There were three donor complications. One (1) donor developed bile leak which spontaneously abated; another donor developed biloma and was successfully treated by percutaneous drainage. The third donor developed biliary stricture and required a Roux-en-Y biliary reconstruction. This latter donor had had a history of gallbladder disease and laparoscopic cholecystectomy prior to donation.

Table 4: Donor characteristics and operative outcome (n = 100)

Characteristic	Outcome
Gender	Male-32; female-68
Mean age	32 years (20–57 years)
Mean donor body weight	59.7 kg (34–90.3 kg)
Mean graft weight	287.9 g (172–832 g)
Mean graft-to-recipient weight ratio	2.7 (0.91–5.1)
Mean intraoperative blood loss	66.4 mL (10–280 mL)
Mean postoperative hospital stay	7 days (5–30[1] days)
Donor complications[2]	3

[1]Thirty days incurred as postoperative hospital stay for a foreign donor who underwent reoperation for a biliary complication.
[2]All biliary complications; one required reoperation.

Table 5 summarized the recipient and donor operative outcomes based on the type of graft used. There were no statistical differences in the subgroups except that LL donors had had more intraoperative blood loss.

Complications after transplantation

The other postoperative complications included recurrent variceal bleeding, gastrointestinal perforation, gut obstruction secondary to postoperative adhesions, posttransplant lymphoproliferative disease, and de novo hepatitis B infection. Table 3 showed the breakdown of other complications. One (1) recipient (LDLT 151) died of posttransplant lymphoproliferative disease. The minor complications were due to dose-related cyclosporine use. The adverse effects abated with a decrease in the cyclosporine dose.

Survival and rejection

All surviving recipients were studied until February 2006, with a mean follow-up of 85.5 months (range, 6–141). There were 3 deaths. One (1) recipient died (survival, 1.4 months) as in-hospital mortality due to early portal vein thrombosis (LDLT 94), another recipient (LDLT 4) developed secondary cirrhosis due to intrahepatic biliary stricture and recurrent cholangitis episodes. The cause of intrahepatic biliary stricture remained unknown as all vascular reconstructions were patent. This transplantation and complication occurred during the program's early experience with LDLT. The management was percutaneous transhepatic bile duct drainage and repeated dilatation/stenting of the strictures. With these nonoperative treatments, this recipient survived for 6 years. During the first retransplantation using a deceased donor left lobe graft, hepatic artery thrombosis occurred intraoperatively which was detected by routine Doppler ultrasound. A re-do of the hepatic artery was performed. However, 8 days later, the patient developed portal vein thrombosis and massive gastrointestinal bleeding which required an emergency reretransplantation. This was the only retransplantation case in this series. The third mortality (LDLT 151) died after 8.8 months due to posttransplant lymphoproliferative disease.

Table 5: Operative outcome based on type of living donor graft used (n = 100)

Characteristic	LL (n = 3)	LLS (n = 64)	ELLS (n = 29)	RL (n = 4)
Cold ischemia	49 min	51 min	67.2 min	69.8 min
Warm ischemia	37.3 min	38.4 min	44.3 min	35.3 min
Total recipient operative time	582 min	580 min	688 min	673 min
Recipient blood loss	361.7 mL	154.7 mL	110 mL	721.3mL
Recipient packed red cell transfusion	145 g	132.5 g	21.8 g	720 g
Recipient operative complications	0	17	10	0
Graft weight	317.7 g	273.1 g	278 g	663.3 g
Graft venoplasty	1	14	5	0
Donor blood loss	183.3 mL	63.4 mL	66.7 mL	95 mL
Donor complications	0	1	1	1

LL, left lobe; LLS, left lateral segment; ELLS, extended left lateral segment; RL, right lobe.

The overall actual recipient survival rates at 6 months, at 1, 5 and 10 years were 99%, 98%, 98% and 90%, respectively. The over-all graft survival at 1, and 5 years was 98% (as graft loss due to portal vein thrombosis in LDLT 96, and recipient loss due to posttransplant lymphoproliferative disorder in LDLT 151). Nineteen recipients (19, 20%) had had episodes of acute cellular rejection (mild, moderate, severe). There was no steroid-resistant rejection, and muromonab CD3 (OKT3) had been not used. Similarly, there was no chronic rejection case.

Long-term outcome after LDLT

Of the 100 recipients, 41 had reached >5 years post-LDLT. Of these 41, 20 had reached at least 7 years, and 9 had reached at least 10 years. Data concerning growth showed that at 1-year postoperative standpoint, despite belonging to below 50th percentile pretransplant, the height-for-age and weight-for-age among the transplanted BA children greatly improved after operation and comparable to those non-BA children.

There were 12 patients with pretransplant impaired renal function. Ten (10) of these patients belonged to the <10 kg body weight group pretransplant. The renal dysfunction in these 12 patients improved posttransplant; and only 2 patients remained with renal impairment after transplant. Despite having a cGFR <65 mL/min/1.73 m^2, these two patients showed improvement in their renal function from baseline cGFR after transplant (LDLT 78 cGFR pretransplant 45.9, posttransplant 64.3; LDLT 142 cGFR pretransplant 32.8, postransplant 52.7).

The cGFR showed a significant 2-peak decrease at 6-months and 2-years after transplant, respectively [105.7 mL/min/1.73 m^2 (43.0–331.0) vs. 86.0 mL/min/1.73 m^2 (28.1–174.2) at 6 months; vs. 83.7 mL/min/1.73 m^2 (39.0–139.6) at 2 years]. Eleven (11, 27%) recipients developed new onset renal dysfunction 6 months posttransplant. Significantly, 29% and 24.4% of the recipients were with renal dysfunction at 6 months and 2 years posttransplant, respectively, when compared to the 9.8% who had renal dysfunction pretransplant.

When the long-term renal function among patients who were surviving >5 years posttransplant was investigated, it was found that only 2 of 11 patients who developed new onset renal dysfunction at 1 year post transplant remained with renal dysfunction until the 7th year. Improvement in the cGFR was noted after the 5th posttransplant year, and with further significant improvement on the 7th year (Table 6). Persistent arterial hypertension requiring medication was not seen in any recipient. There were no significant differences in the preoperative, and 1- and

Table 6: Long-term renal function after living donor liver transplantation for biliary atresia (n = 41)

Characteristic	Years posttransplant						
	Pre-LTx n = 41	6 month n = 41	1st year n = 41	2nd year n = 41	5th year n = 41	7th year n = 20	9th year n = 8
Mean height (cm)	89.9	90.8	91.4	111.5	130.5	138.9	151.2
Mean serum creatinine (mg/dL)	0.4	0.6	0.6	0.6	0.6	0.7	0.8
Mean cGFR	105.7	86	86.2	83.7	106.7	94	87.1
% of recipients[1] with renal dysfunction[2]	9.8% (4)	27% (11)	14.6% (6)	24.4% (10)	4.9% (2)	10% (2)	25% (2)

LTx, liver transplant; cGFR, calculated glomerular filtration rate [cGFR = mL/min/1.73 m^2 = (0.43 × height in cm)/serum creatinine in mg/dL].
Included only were those recipients who were surviving >5 years.
[1]Eleven (27%) recipients developed new onset renal dysfunction 6 months posttransplant.
[2]Renal dysfunction is defined as cGFR <65 mL/min/1.73 m^2 body surface area.

5-year postoperative levels of cholesterol, triglyceride, uric acid, and fasting blood glucose. Immunosuppression was based upon cyclosporine as primary immunosuppressive agent in the majority of the recipients in the long-term (92 cyclosporine, 4 tacrolimus, 1 no immunosuppression).

Among the 97 survivors, 47 (48%) were pre-elementary school age. Among the pre-elementary school age children, 21 were attending regular kindergarten. Thirty-three (33) were attending regular elementary school, 16 were in high school, and 1 was in college level.

Discussion

We have reported a 98% real-time survival rate at 5 years following LDLT for BA. This result compares favorably with the 90% pediatric LT survival rate reported by Wallot (24) which also took into account those who survived at least 3 months after the primary OLT. However, when compared to specific outcome for BA after OLT where reported rates range between 78% (7,15) at 5 years and 82% (5,17) at 10 years, the result of our LDLT series is much improved.

Survival after transplant depends on several factors such as status of the recipient including urgency of operation, graft quality, and difficulty of operation. High blood loss index is a correlating factor with poor patient survival (25,26), particularly in case of BA (26). Our recipient mean blood loss was 176 mL and 35% did not require blood or blood product transfusion perioperatively. The intraoperative blood loss was measured as the sum of the amount of blood in the suction bottle and the weight of blood in the surgical swabs. We used the commercially available ACCU-MEASURE^R RECEPTAL^R Accurate Measurement Device 250 mL suction receptacle (Abbott Laboratories, North Chicago, IL) to measure the amount of blood in the suction bottle. This receptacle is calibrated at 5 mL per unit measure.

The central venous pressure levels were generally maintained at 10 cm H_2O during the course of the transplantation, except during the anhepatic phase when the levels were lower because of the decrease in venous return as a result of total cross-clamping of the inferior vena cava; and we do not use veno-venous bypass even in older children. Our limit for red blood cell transfusion was 8.0 g/dL. Under conditions of normovolemia and an adequate response of the cardiorespiratory system, acute dilution of blood will enhance the venous return to the heart and thereby improve total and capillary blood flow significantly. An increase in flow rate seen with hematocrits between 25% and 30% is not only able to compensate fully for the diminished oxygen content of the blood but also helps prevent thromboembolic complications through improvement of its rheologic properties and viscosity (27).

In difficult intraoperative situations such as poor portal vein and/or hepatic vein flows, and difficult abdominal wall closure that compromise vascular flow velocities, we have used Foley catheter (28,29) to reposition the graft in situations where the portal or hepatic vein flow is insufficient due to graft malposition. We have also used Broviac^R catheter inserted into the inferior mesenteric vein where heparinized saline is infused to augment insufficient portal inflow where malpositioning of the graft is not a problem (i.e. resulting from small hypoplastic or sclerotic portal vein due to recurrent cholangitis pretransplant and pretransplant portal vein thrombosis). Polytetrafluoroethylene patch (Gore-Tex^R) was used to approximate the anterior abdominal fascia in situations where the abdomen is too tight to close such that it compromises vascular flow (30). We have used Gore-Tex^R patch to close the abdomen in three recipients in this series. The graft weight-to-recipient weight ratio was >4 in all recipients and all were <10 kg at the time of transplantation. Further, early detection of vascular complications is prompted by use of color flow Doppler ultrasound intraoperatively and during postoperative follow-up thereby increasing graft salvage.

The relationship between recipient survival and donor age is controversial; but cold ischemia time has also been pointed out as a factor that affects graft and recipient survival (26,31,32). Living donor liver grafts have reduced cold ischemia time (12). In our series, in contrast with other series (5,15), we did not find any relationship between donor age, cold and warm ischemia time, total operative time, and type of live donor graft used with regards to poor recipient outcome. The presence of coexisting nondecompensated CHD also did not increase recipient operative morbidity and mortality.

It is interesting to note that in the <10 kg group there were more pretransplant renal impairment (10 vs. 2 in >10 kg, significant), more operative complications (16 vs. 11 in >10 kg, not significant), and more portal vein complications (7 vs. 2 in >10 kg, significant). The amount of red blood cell transfusion was also higher in the <10 kg group than the >10 kg group. The vascular complications can be explained by the observation that smaller patients tend to have smaller caliber portal veins added to the fact that most of these vessels were sclerotic due to recurrent cholangitis.

We have no case of steroid-resistant rejection or chronic rejection in this series. All rejections in this series responded to bolus(es) of intravenous methylprednisolone (10 mg/kg), an increase in the dosage of current immunosuppression, and/or adding mycophenolate. OKT3 was not used in any patient in this series.

The improvements in medical and surgical treatments in pediatric LT including advances in immunosuppression have improved patient survival. With these advances, focus has now been shifted to quality of life assessments and low or drug-free immunossupression. It has been reported

that chronic liver diseases in children did not influence linear growth and sexual development after OLT (33). However, other series report that prolonged use of steroids, age at time of OLT, and degree of initial growth delay are risk factors of growth failure in children after OLT (34–36). Our findings concerning somatic growth in BA children after LDLT, although done only within a 1-year timeframe, did not differ in the assessments of Burdelski (37), and Fouquet (5) where post-OLT children have regained the difference in growth in height and weight compared with nontransplanted children. Renal function based on the cGFR was adequate in a majority of the group. Despite development of new renal dysfunction in a few recipients and a decrease in the cGFR during the first 6 months to 2 years in about a quarter of recipients, renal function improved with decrease in the dose of immunosuppression and stabilized in the long-term. Our results are in accordance with observed findings reported by Fouquet (5) in BA children after OLT. The 2-peak decrease in cGFR occurring at 6 months and 2 years post-LDLT may be explained by the fact that most rejections occur within the 1st year post-LDLT in this series prompting a reincrease in the immunosuppression required. Metabolic disturbances were also not documented in our series. One (1) recipient (LDLT 1) who developed posttransplant lymphoproliferative disorder 5 years post-LDLT is currently alive and well, and immunosspression-free and steroid-free for the past 6 years.

Although 27% of our recipients are currently below 3 years old, the levels of academic achievement based on scholastic records among the transplanted children were not mentally deficient and were comparable with the normal population. A limitation in this assessment is that we did not use a particular neurodevelopmental checklist to survey over-all mental capability. Scholastic and psychosocial status development must be evaluated further over a longer period of time.

With regards to donor outcome, all donors are back to their predonation activities of daily living. One (1) left-side graft donor had a hepatic duct stricture that required a Roux-en-Y hepaticojejunostomy. This donor had a history of laparoscopic cholecystectomy prior to liver graft donation. This experience prompted us to modify our indications for intraoperative cholangiography when procuring a left-side graft. Initially, we have three indications when to do an intraoperative cholangiography. These indications are preoperative magnetic resonance cholangiography showing (1) the bile ducts branching within 1 cm from the confluence, (2) right sectoral bile duct draining into the left hepatic duct and (3) presence of bile duct trifurcation. This morbidity led us to add a fourth indication—(4) history of biliary surgery. In procuring a right-side graft, intraoperative cholangiography is routine (38).

In summary, our results show that outcome after LDLT for BA is characterized by a 98%, 98% and 90% actual recipient survival rate at 1, 5 and 10 years, respectively, and low donor morbidity. This improved survival is based on judicious preoperative donor and recipient selection, meticulous surgical technique, immediate detection and prompt intervention of complications, and keen postoperative surveillance.

Acknowledgment

This work was partly supported by program project grant NHRI-EX 93-9228SP from the National Health Research Institutes, Taiwan.

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