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Donor morbidity in right and left hemiliver living donor liver transplantation: the impact of graft selection and surgical innovation on donor safety

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Summary

This study investigated adequate liver graft selection for donor safety by comparing postoperative donor liver function and morbidity between the right and left hemilivers (RL and LL, respectively) of living donors. Between April 2006 and March 2012, RL (n = 168) and LL (n = 140) donor operations were performed for liver transplantation at Kyoto University Hospital. Postoperative hyperbilirubinemia and coagulopathy persisted in RL donors, whereas the liver function of LL donors normalized more rapidly. The overall complication rate of the RL donors was significantly higher than that of the LL donors (59.5% vs. 30.7%; $P < 0.001$). There were no significant differences in severe complications worse than Clavien grade IIIa or in biliary complication rates between the two donor groups. In April 2006, we introduced an innovative surgical procedure: hilar dissection preserving the blood supply to the bile duct during donor hepatectomy. Compared with our previous outcomes (1990–2006), the biliary complication rate of the RL donors decreased from 12.2% to 7.2%, and the severity of these complications was significantly lower. In conclusion, LL donors demonstrated good recovery in postoperative liver function and lower morbidity, and our surgical innovations reduced the severity of biliary complications in living donors.

Introduction

The first living donor liver transplantation (LDLT) using the left lateral segment was performed for a paediatric recipient in 1988 [1]. After the first successful case was reported in 1990 [2], LDLT in children became accepted worldwide within a few years. LDLT has emerged as an alternative method for reducing the waiting period and the mortality of patients on the waiting list [3,4]. Given the success of paediatric liver transplantation (LT) and the unavailability of deceased donor organs, Japanese LT surgeons extended the indications for LDLT to adult patients, and the first successful LDLT using a left hemiliver (LL) graft in an adult patient was performed [5]. LL grafts subsequently became common for use in adult patients.

The first LDLT using a right hemiliver (RL) graft in a child was performed at our institution [6], and because an inferior graft survival rate with smaller grafts [less than a graft-to-recipient weight ratio (GRWR) of 0.8%] was reported [7], the transplantation of RL grafts in adult patients has rapidly expanded as a standard procedure worldwide.

Donor safety is the first priority in LDLT, and among the most important complications of donor surgery are biliary complications, including bile leakage and biliary stricture. Our previous study reported that biliary complications occurred more frequently in RL donations than in LL donations and that the severity was also greater in RL donations [8]. Hence, in April 2006, we introduced a surgical procedure to avoid biliary complications in donor surgery. We also modified our graft selection criteria. We introduced minimum dissection of the bile duct at the hilus to preserve the blood supply to the bile duct. The GRWR was reduced from 0.8% to 0.6% as a new graft selection criterion; LDLT using an LL graft subsequently increased in our institution.

This study aimed to evaluate the usefulness of this new surgical procedure and to report on the donor morbidity with RL and LL liver transplantation by comparing the postoperative liver function and complication details between the two groups.

Patients and methods

Donors and grafts

Between April 2006 and March 2012, 429 consecutive LTs [411 LDLT, 16 deceased donor liver transplantations (DDLTs) and two domino LTs] were performed at Kyoto University Hospital. Of the 411 living donors, 168 underwent a donor operation for an RL graft with (n = 11) or without (n = 157) the middle hepatic vein (MHV), and 140 underwent a donor operation for an LL graft with (n = 76) or without (n = 64) the caudate lobe. In this study, donors of the lateral segment, extended lateral segment, mono segment and posterior segment were excluded from the analysis. The donor and graft demographic data, duration of surgery, intraoperative blood loss, postoperative hospital stay, liver function test and complications/morbidity were evaluated. As a postoperative liver function test, serial changes in serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), total bilirubin (T-Bil) and prothrombin time–international normalized ratio (PT-INR) were measured in the peripheral blood on postoperative days (PODs) 1, 2, 3, 5, 7, 10, 14, 21 and 28.

This study was approved by the Ethics Committee of Kyoto University and was conducted in accordance with the Declaration of Helsinki of 2000.

Donor and graft selection

Potential donors underwent blood tests, including blood counts, blood chemistry, infection analyses, tumour markers, blood type determination, human leucocyte antigen typing and mixed lymphocyte reaction assays. Nonalcoholic steatohepatitis (NASH) was evaluated using the homoeostatic model assessment index. For all potential donors, multidetector-row computed tomography (CT) imaging was performed to detect hepatic anatomical variations and to evaluate the donor's whole liver volume, graft volume and remaining donor liver volume. Instead of a needle biopsy of the donor liver, the liver-to-spleen CT attenuation value ratio (L/S ratio) was used in our institution to assess steatosis of the liver. The L/S ratio indicates the grade of hepatic steatosis. The optimal L/S ratio to predict more than 30% hepatic steatosis is 1.1 [9]. Since November 2002, HepaVision2 (MeVis, Bremen, Germany), which is software specifically developed for image analysis and risk analysis of the liver, was used to estimate the graft volume and congestive volume in the graft [10]. Using raw data obtained from multislice CT, various anatomic sites can be visualized, and volumetry of the portal and venous regions can be performed. Conventional volumetry, including whole liver volume, RL volume with or without MHV, LL volume and remnant liver volume, was calculated. To assess the biliary tree, routine magnetic resonance cholangiopancreatography (MRCP) was performed.

Our graft selection criteria were modified in April 2006; the GRWR minimum was reduced from 0.8% to 0.6%, and LL became the first choice for the graft whenever feasible. The RL was considered when the GRWR of the LL was <0.6%. However, if the remnant liver volume was <30% of the total liver volume, the person was excluded as a donor candidate.

Surgical procedure for the donor operation

The donor operation was performed as described previously [11,12]. Briefly, under general anaesthesia, a thorough laparotomy was performed. After a retrograde cholecystectomy, a catheter was inserted into the cystic duct for intraoperative cholangiography. Depending on the type of liver graft donation, the right or left portal vein and the right or left hepatic artery were isolated, and the demarcation line was noted by temporally clamping the graft's side vessels. Liver parenchymal transection was performed using the Cavitron Ultrasonic Surgical Aspirator (CUSA system, Valleylab Inc., Boulder, CO, USA) and bipolar electrocautery without inflow occlusion prior to cutting the hepatic duct. The cutting line of the hepatic duct was carefully determined based on intraoperative cholangiography using a static X-ray film unit. After parenchymal transection was initiated, hilar dissection was performed without dissection of the pericholedochal tissue to preserve the blood supply around the hepatic duct. The hepatic duct within the hilar plate was separated with fine scissors, and the stumps of the remnant hepatic duct were meticulously closed with 6–0 polydioxanone absorbable monofilament sutures. To ensure the absence of bile leakage and stricture, a cholangiogram was performed again. Systemic administration of heparin was performed following complete parenchymal transection. Thereafter, the hepatic artery, portal vein and hepatic vein were cut sharply. All the grafts were perfused ex situ via the portal vein with a histidine-tryptophan-ketoglutarate solution (Custodiol; Chemie GmbH, Alsbach-Hahnlein, Germany).

Modifications of the surgical procedure in the donor operation

We modified the surgical procedure in the donor surgery as follows. Since April 2002, a biliary decompression tube has been placed through the cystic duct into the residual bile duct to prevent bile leakage from the bile duct stump in donors with difficulty in hepatic duct end closure. Since June 2004, abdominal drainage has been reduced to bile duct drainage only, except in donors at high risk for biliary complications based on the intraoperative findings. Since April 2006, parenchymal transection has been started before cutting the hepatic duct, and we have introduced the method of hilar dissection during parenchymal transection. This procedure minimizes the dissection of the bile duct, thus preserving the blood supply to the bile duct of both the graft and the remnant liver.

Definition of the grade of postoperative donor complications

Postoperative donor complications were graded according to the Clavien classification [13]. Complications worse than Grade IIIa were recognized as major complications. Hyperbilirubinemia was defined as serum total bilirubin levels >3 mg/dl at POD 7 without coagulopathy.

Statistical analysis

All the values are presented as the means and standard deviations for each group. Categorical variables were compared with the chi-square test or Fisher's exact test. The statistical analyses of the groups at each time point were tested with 2-way analysis of variance and Bonferroni's *post hoc* test. For the patient survival analysis, the Kaplan–Meier method with the log-rank test was used. P values <0.05 were considered statistically significant. The analysis was performed using GRAPHPAD PRISM software version 5 (GraphPad Software, La Jolla, CA, USA).

Results

Changes in graft types

Figure 1 demonstrates the changes in the numbers of LDLT graft types since April 2006. After the introduction of the new modified graft selection criteria, LDLT using LL grafts gradually increased. Since 2009, the frequency of LL grafts has become nearly equal to that of RL grafts.

Donor demographics

The demographic data of the RL and LL donors are summarized in Table 1a. Regarding the donor and graft characteristics, there was no significant difference in the gender distribution or donor age between the RL and LL donors. The mean body weight and body mass index of the LL donors were significantly higher than those of the RL donors. Regarding the donor operative outcomes, the duration of surgery and blood loss were comparable between the RL and LL donors. We administered no homologous blood transfusions to donors of either graft type. No significant difference was found in the postoperative hospital stay between the RL and LL donors.

Postoperative liver function test

There were no significant differences in the peak serum AST or ALT levels between the RL (324 ± 193 IU/l and 325 ± 161 IU/l, respectively) and LL (289 ± 136 IU/l and 339 ± 150 IU/l, respectively) donors. However, the peak serum T-Bil level was significantly higher in the RL donors (4.3 ± 1.8 mg/dl) than in the LL donors (2.6 ± 2.1 mg/dl) ($P < 0.05$).

Figure 2a and b show the postoperative serial changes in the serum T-Bil and PT-INR levels, respectively. The RL donors presented a significant increase in serum T-Bil during the week after donor surgery ($P < 0.05$) (Fig. 2a). Moreover, the PT-INR was significantly higher in the RL donors at PODs 1, 2, 3 and 5 than that in the LL donors ($P < 0.05$) (Fig. 2b). Essentially, liver damage persisted longer in the RL donors than in the LL donors.

Donor complications

No donor mortality or life-threatening complications were observed in the 308 living donor hepatectomies during this study period. The donor complications are shown in Table 2. The overall complication rate of the RL donors (59.5%) was significantly higher than that of the LL donors (30.7%) ($P < 0.001$). The rates of biliary complications in the RL and LL donors were 7.1% and 5.0%, respectively (P = NS). Regarding the complications in the RL donors, there were 12 biliary complications, including 11 instances of bile leakage (6.5%) and one biliary stricture (0.6%). The number of bile leakage and biliary stricture occurrences in the LL donors was 5 (3.6%) and 2 (1.4%), respectively. Regarding the rate of each biliary complication, there were no significant differences between the donors. The mean time to the occurrence of bile leakage in the 11 RL and 5 LL donors was 10.7 and 12.0 days, respectively. One biliary stricture in an RL donor occurred 33 days after donor surgery. Two LL donors were diagnosed as having biliary strictures 47 and 118 days after surgery.

Regarding nonbiliary complications, intra-abdominal fluid collection had the highest incidence in the RL donors, occurring in 26 (15.5%) donors and significantly more often than in the LL donors (2.1%) ($P < 0.001$). Moreover,

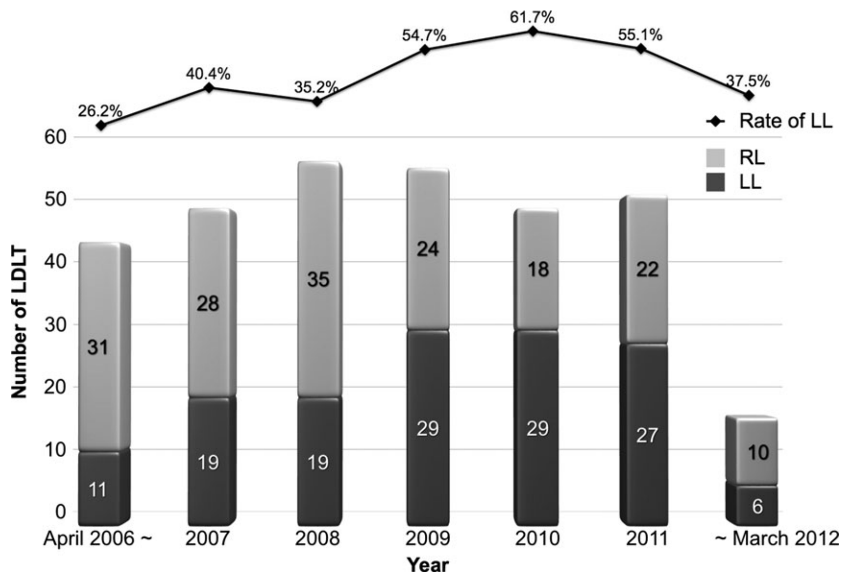

Figure 1 Changes in the numbers of graft types. Modified graft selection criteria were introduced in 2006; the use of LL grafts for LDLT has increased compared with RL grafts.

Table 1. (a) Donor and graft demographic data. (b) Comparison of recipients by graft type.

Variables	RL (n = 168)	LL (n = 140)	*P* value
(a)			
Gender (M/F)	75/93	50/90	0.130
Age (year)	43.9 ± 12.6	42.8 ± 11.4	0.452
Body weight (kg)	58.7 ± 10.5	63.7 ± 11.2	<0.001*
BMI (%)	21.9 ± 2.8	22.8 ± 2.9	0.009*
Actual graft volume (g)	667 ± 106	417 ± 85	<0.001*
GRWR (%)	1.02 ± 0.21	0.87 ± 0.25	<0.001*
Duration of operation (min)	406 ± 82	420 ± 77	0.135
Blood loss (g)	345 ± 224	338 ± 257	0.799
Hospital stay (day)	17.7 ± 29.4	14.6 ± 7.0	0.196
(b)			
Gender (M/F)	155/53	40/100	<0.0001*
Recipient age (year)	50.8 ± 12.9	44.1 ± 18.5	0.0003*
Recipient body weight (kg)	67.2 ± 11.5	50.2 ± 11.4	<0.0001*
Recipient MELD score	17.6 ± 7.5	19.0 ± 8.9	0.2524

*$P < 0.05$.

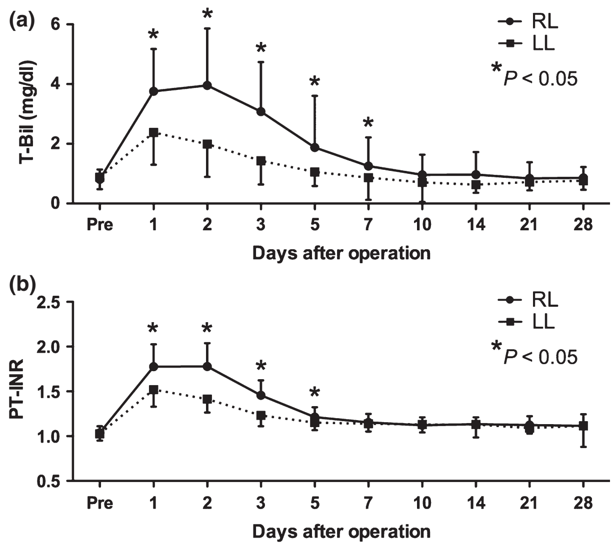

Figure 2 Postoperative serial changes in serum T-Bil and PT-INR levels. (a) The serum T-Bil levels of the RL graft donors were significantly higher than those of the LL graft donors 1 week after donor surgery ($P < 0.05$). (b) PT-INR levels were significantly higher in the RL graft donors at PODs 1, 2, 3 and 5 than in the LL graft donors ($P < 0.05$).

the rate of hyperbilirubinemia was notably higher in the RL donors (2.4%) than in the LL donors (0.7%); however, this difference was not significant. The highest incidence of complications in the LL donors involved skin wound problems, which occurred more frequently in the LL donors (11.4%) than in the RL donors (6.0%); however, this difference was not significant. No significant differences were found in other abdominal complications. Two venous thromboses, including one hepatic venous thrombosis and one portal venous thrombosis, occurred in the RL donors. These two donors with venous thromboses were diagnosed via postoperative CT scan, and the thrombi were detected in the MHV and the stump of the right portal vein, respectively. These thrombi disappeared after anticoagulant therapy, and these two donors were discharged without any further complications.

Regarding extra-abdominal complications, pleural effusion occurred significantly more frequently in the RL donors (5.4%) than in the LL donors (0.7%) ($P < 0.05$).

Table 2. Comparison of donor complications.

	RL (n = 168)	LL (n = 140)	P value
All complications	100 (59.5%)	43 (30.7%)	<0.001*
Biliary complications	12 (7.1)	7 (5.0)	0.484
Bile leakage	11 (6.5)	5 (3.6)	0.307
Biliary stricture	1 (0.6)	2 (1.4)	0.593
Other abdominal complications			
Fluid collection	26 (15.5)	3 (2.1)	<0.001*
Skin wound problem	10 (6.0)	16 (11.4)	0.101
Small bowel obstruction	1 (0.6)	2 (1.4)	0.593
Intra-abdominal abscess	2 (1.2)	–	0.503
Drug-induced hepatotoxicity	4 (2.4)	7 (5.0)	0.360
Massive ascites	3 (1.8)	–	0.254
Hyperamylasemia	3 (1.8)	1 (0.7)	0.629
Hyperbilirubinemia	7 (4.2)	1 (0.7)	0.076
Gastritis/intractable ulcer	1 (0.6)	–	1.000
Venous thrombosis	2 (1.2)	–	0.503
Extra-abdominal complications			
Pleural effusion	9 (5.4)	1 (0.7)	0.025*
Atelectasis	1 (0.6)	1 (0.7)	1.000
Pneumothorax	1 (0.6)	–	1.000
Pulmonary embolism	–	1 (0.7)	0.455
Fever of unknown origin	5 (3.0)	1 (0.7)	0.226
Others	13 (7.7)	2 (1.4)	0.014*

*$P < 0.05$.

There were no significant differences in other extra-abdominal complications.

Postoperative complication grade

The postoperative complication grades of the RL and LL donors are shown in Table 3. In the RL donors, the complication rates of Grades I and II were 22.0% and 23.2%, respectively. Regarding major complications, the incidence of Grade IIIa complications was 14.3%; no complications worse than Grade IIIb occurred during this study period. The 24 Grade IIIa complications included nine biliary complications, six cases of intra-abdominal fluid collection, two skin wound problems, two intra-abdominal abscesses, four pleural effusions and one pneumothorax. Of the 11 RL donors with bile leakage, endoscopic nasobiliary drainage was necessary in 3 (1.8%) donors (Grade II), and percutaneous drainage of the bile was performed in 8 (4.8%) donors (Grade IIIa). Moreover, endoscopic retrograde biliary drainage was necessary for 1 (0.6%) biliary stricture (Grade IIIa).

The complication rates of Grades I, II and IIIa were 13.6%, 8.6% and 7.9%, respectively, in the LL donors. Regarding major complications, 11 Grade IIIa complications (six biliary complications, three skin wound problems, one small bowel obstruction and one pulmonary embolism) occurred. A Grade IIIb complication occurred in only 1 (0.7%) LL donor. In this donor, reoperation (hepaticojejunostomy) was necessary for delayed biliary stricture 7 months after donor surgery.

Table 3. Complication grades of RL and LL donors.

	I	II	IIIa	IIIb
All complications				
RL	37 (22.0%)	39 (23.2%)	24 (14.3%)	–
LL	19 (13.6%)	12 (8.6%)	11 (7.9%)	1 (0.7%)
Biliary complications				
RL	–	3 (1.8%)	9 (5.4%)	–
LL	–	–	6 (4.3%)	1 (0.7%)

	Complication rate	P
Severe complications above grade III		
RL	14.3% (24/168 cases)	0.15
LL	8.6% (12/140 cases)	

The complication rate of RL donors was Grade IIIa and was comparable with that of LL donors (P = 0.15). During this study period, no Grade IV or V complications were experienced.

Comparison of biliary complications in RL donors during different periods

Table 4 shows the biliary complication rate and major complication rate in the RL donors according to different periods. The biliary complication rate in the RL donors decreased from 14.2% (Period 1: June 1990 to March 2002) to 12.9% (Period 2: April 2002 to March 2006). During this study period (Period 3: April 2006 to March 2012), the overall biliary complication rate of RL donors was 7.1%, which was significantly lower than that during Period 1. The major complication rate showed a tendency to decrease over time, but there were no significant differences among the three periods.

Comparison of recipients by graft type

The recipients' characteristics and the model for end-stage liver disease (MELD) score are summarized in Table 1b. Significant differences were found in recipient gender distribution, age and body weight. The MELD scores of the

Table 4. Biliary complications in RL donors according to period.

Period	Biliary complication rate (%)	P	Major complication rate (%)
June 1990 to March 2002	14.2	0.03	16.6
April 2002 to March 2006	12.9		17.8
April 2006 to March 2012	7.1		14.3

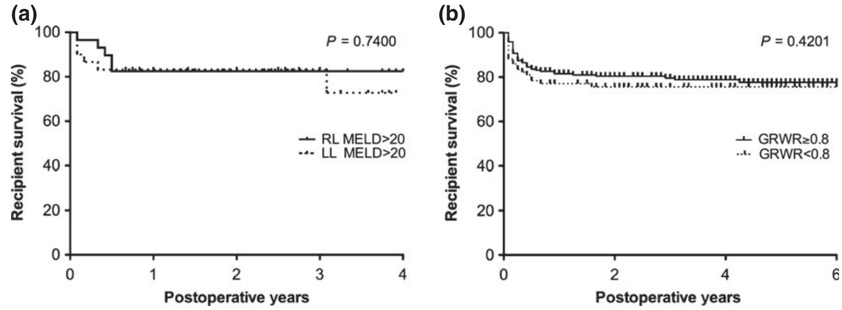

Figure 3 Comparison of recipient survival according to MELD score and GRWR. (a) Survival rate of recipients with MELD scores >20 was comparable between RL and LL graft recipients. (b) The log-rank test found no statistically significant differences in survival rate of recipients with GRWR ≥0.8 and those with GRWR <0.8.

RL and LL recipients were 17.6 ± 7.5 and 19.0 ± 8.9, respectively. Figure 3a shows that the survival rate of the LL recipients with MELD scores >20 was comparable with that of the RL recipients ($P = 0.7400$). Moreover, as shown in Fig. 3b, there was no significant difference in the survival rate between recipients with a GRWR <0.8% and those with a GRWR ≥0.8% ($P = 0.4201$).

Discussion

In LDLT, the safety of the donor is the ultimate priority. However, we experienced the first instance of donor death in Japan in 2003, which resulted from liver failure caused by RL graft donation and NASH. Trotter reported 13 living liver donor deaths that were 'definitely' related to donor surgery [14]. Similarly, Ringe identified 33 living liver donor deaths, including 21 deaths related to the surgical procedure. Of these 21 deaths, at least 14 cases involved RL graft donation. They concluded that the incidence of donor death was 0.1–0.3% and likely reached 0.5% when using an RL graft for adult-to-adult LDLT [15]. Therefore, the selection of graft type is very important for donor safety.

We previously reported on the surgery-related morbidity in LDLT, in which multivariate analysis demonstrated that RL donation was an independent risk factor for complications in these donors [8]. Recently, the feasibility and usefulness of LL grafts for adult-to-adult LDLT have been reported [16,17]. The safety of LL grafts for adult-to-adult LDLT was compared with that of RL grafts. Moreover, the outcomes of LL grafts in LDLT were not inferior to those of RL grafts in LDLT. However, small-for-size syndrome (SFSS) occurred more often in LL graft LDLT than in RL graft LDLT.

There are still many debates regarding the relationship between the MELD score and post-transplant outcomes. Theoretically, a high MELD score is associated with poor patient and graft survival following LT. Hayashi reported that there was no correlation between the 1-year survival rate and the MELD score [18]. Although Li reported that MELD score emerged as an independent risk factor for SFSS, they also reported that the 1- and 3-year survival and postoperative complication rates were similar between recipients with high MELD scores and those with low MELD scores [19,20]. RL grafts are recommended for recipients with MELD scores >20 [21], yet the present study showed that LL grafts were feasible for recipients with MELD scores >20, with a survival rate comparable with that of RL grafts (Fig. 3a). In addition, our recent study indicated that pretransplant sarcopenia and the absence of perioperative nutritional therapy were independent risk factors for post-transplant mortality in patients undergoing LDLT, whereas the MELD score is not [22]. However, the recipient's pretransplant general condition (MELD, portal hypertension, renal dysfunction, pretransplant diabetes mellitus, etc.) is a risk factor affecting recipient and graft survival [21,23,24]. Thus, we may modify our graft selection criteria in the future.

We modified our graft selection criteria and introduced new recipient portal pressure control in 2006. The lower limit for GRWR was reduced to 0.6%. Regarding the recipient's portal pressure, our previous study showed that a final portal pressure <15 mmHg was an important factor for better outcomes in adult-to-adult LDLT using smaller grafts [25]. The present study demonstrated that the recipient survival rate was comparable between patients with a GRWR <0.8% and those with a GRWR ≥0.8% (Fig. 3b). Therefore, we believe that small grafts can be safely available via portal pressure control without SFSS, and LDLT using an LL graft has been increasingly used in our institution since 2006 (Fig. 1).

Our study showed that the overall complication rate of RL donors was significantly higher than that of LL donors and that Clavien grade II and IIIa complications occurred significantly more frequently in RL donors than in LL donors. Additionally, LL donors showed significantly better improvement in serum T-Bil and PT-INR levels. Our study demonstrated that LL donors could achieve earlier liver function recovery after donor hepatectomy than RL donors. This result was due to a sufficient remnant liver volume. Hyperbilirubinemia and coagulopathy persisted in RL donors. Because the early recovery of postoperative liver function can contribute to donor safety, LL grafts offer significant advantages in donor safety compared with RL grafts. Essentially, LL grafts offer significant advantages in postoperative liver regeneration. Previously, we had primarily performed RL graft donor surgeries in LDLT, and we reported several studies on donor morbidity in RL and LL grafts [8,26,27]. Based on our experience in donor surgery, our donor surgery procedure and postoperative management have been continuously modified and improved in the effort to reduce severe donor morbidity. The team experience of each organ transplant centre is believed to be the most critical factor in reducing donor morbidity; living donor morbidity after liver donation has been strongly correlated with the experience of the centre [28,29].

Biliary complications remain among the most common problems associated with LDLT, and the rate of these complications has been reported to range from 0% to 38.6% [30]. Table 5 shows the biliary complications and compares the RL donors with the LL donors; our previous reports are included [8,16,26,31–35]. Nearly all centres have reported that the overall biliary complication rate was higher in the RL donors than in the LL donors. Anatomic variations in the biliary tract might significantly contribute to the higher biliary complication rate in the RL donors. The anterior and posterior segmental branches of the right hepatic duct (RHD) often diverge immediately proximal to the bifurcation of the RHD and left hepatic duct (LHD). Therefore, the RHD must be cut within a few millimetres of the bifurcation. Furthermore, RL grafts often have multiple biliary orifices, whereas LL grafts usually have a single orifice. RL grafts also have larger biliary stamps than LL grafts, which result in a higher incidence of biliary leakage among RL donors.

The hilar plexus is a set of communicating arcade vessels that bridge the right and left hepatic arterial systems, and it is located within the hilar plate. The blood supply to the RHD arises from both the right hepatic artery and the hilar plexus. The LHD is supplied by a plexus that is continuous with the plexus at the confluence of the RHD and the common bile duct. Therefore, dissection of the hilar plate and hepatic artery can easily destroy the communicating arcade of the hilar bile duct. Minimizing the dissection of the hepatic artery and portal vein is important to avoid damage to the arterial plexus and to ensure that the surrounding tissues remain attached to the common and branched hepatic ducts. The high hilar dissection technique during recipient hepatectomy might contribute to reducing the biliary complications by preserving adequate blood supply to the bile duct [36]. We have applied this hilar dissection technique in donor hepatectomy since April 2006.

According to a previous study from our institution, the biliary complication rate in RL donors decreased from 18.6% [26] to 14.5% [27]. In 2010, Iida updated our published experiences and reported that the incidence of biliary complications in RL donors from April 2002 to March 2006 decreased to 12.9% [8]. During this study period (April 2006 to March 2012), the overall biliary complication rate of RL donors was 7.1%, and we did not experience complications worse than Clavien grade IIIb in the RL donors. We believe that surgical refinements and innovations, especially in the dissection of the bile duct, have assisted in reducing the incidence of biliary complications.

Although the biliary complication rate of the LL donors was lower than that of the RL donors, the Clavien grade IIIb complication of biliary stricture occurred in only one LL donor. This previously reported donor had a trifurcated portal vein and a rare biliary anomaly [37]. When rare biliary anatomy is observed in the LL, precise preoperative identification of the biliary anomalies is essential.

Table 5. World reports of biliary complications in living donors for liver transplantation.

First author (reference)	Year	Institute	Number of donor (RL:LL)	Number of biliary complication		Biliary complication rate (%) (RL:LL)
				Bile leakage (RL:LL)	Biliary stricture (RL:LL)	
Fujita [23]	2000	Kyoto, Japan	43:99	8:3	N/A	18.6:3.0
Lo [28]	2003	Multicenter, Asia	561:334	34:8	6:0	7.1:2.4
Hwang [29]	2006	Seoul, Korea	591:571 (*89)	3:2	5:0	1.4:0.4†
Shio [30]	2008	Kyoto, Japan	434:297 (*237)	43:5	9:3	11.1:2.4†
Taketomi [16]	2009	Fukuoka, Japan	69:137	3:2	4:2	10.1:2.9
Iida [8]	2010	Kyoto, Japan	500:762 (*493)	53:36	8:2	12.2:4.9†
Kousoulas [31]	2010	Hanover, Germany	36:51 (*47)	1:3	N/A	2.8:5.9†
Shin [32]	2012	Seoul, Korea	698:129 (*108)	N/A	N/A	2.0:0.9†
Present study	2014	Kyoto, Japan	168:140	11:5	1:2	7.1:5.0

N/A, not applicable.
*The number of lateral segment.
†The number of lateral segment graft.

Therefore, we routinely perform preoperative MRCP and intraoperative cholangiography with a static X-ray film unit in all live donors to prevent biliary complications. We should undertake continuous efforts to improve the surgical technique in an effort to reduce biliary complications.

In conclusion, our study demonstrated superior recovery of postoperative liver function and lower morbidity in LL donors compared with RL donors. Moreover, the survival rate of the LL recipients was comparable with that of the RL recipients, even in high-risk recipients with MELD scores >20. The biliary complication rate has gradually decreased due to surgical innovations regarding hilar dissection. To reduce morbidity in living donors, further surgical technique refinements and careful postoperative management are necessary. An LL graft is recommended as the first choice in LDLT, given adequate portal pressure modulation.

Authorship

JI: Participated in analysing the data and writing the paper. TI, MM, TU, SY, TH, KO, YF, AM and TK: Participated in collecting the data and performing the surgery. SU: Participated in creating the research design and performing the surgery.

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