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ORIGINAL ARTICLE

Donor outcome and liver regeneration after right-lobe graft donation

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Summary

Sufficiently detailed information on donor safety and the liver regeneration process following right-lobe living donation has been unavailable, so we evaluated donor outcome and liver regeneration in 13 males and 14 females (39.0 ± 14.8 years old) who provided 27 right-lobe grafts without the middle hepatic vein. Preoperative total liver volume (TLV), graft volume, and postoperative changes in residual liver volume (RLV) were measured by volumetric computed tomography. Histological steatosis of the liver was graded as none, minimal (≤10%), and mild (11–30%). The median follow-up period was 337 days. Estimated graft volume and actual graft weight were linearly correlated ($Y = 177.85 + 0.795X$, $R^2 = 0.812$, $P < 0.0001$). Graft-to-recipient weight ratio was 1.08 ± 0.19%. Four donors had postoperative complications, but they resolved in response to conservative treatment. Postoperative hospital stay was 15.2 ± 5.5 days. Peak liver enzyme values were significantly higher in donors with mild steatosis ($n = 7$) than without steatosis ($n = 16$) ($P < 0.05$). Donor RLV was 40.8 ± 6.6% of original TLV at surgery, 79.8 ± 12.0% by 6 months, and 97.2 ± 10.8% by 12 months. At 3 months the liver of the older donors (≥50 years) had grown significantly more slowly than in younger donors (70.4 ± 9.2% vs. 79.3 ± 9.6%, $P = 0.0391$). In conclusion, right hepatectomy without middle hepatic vein of living donors is a safe procedure with acceptable morbidity, and the residual liver regenerated to its preoperative size by 1 year. However, meticulous care should be taken in donors with liver steatosis and aged donors.

Introduction

Living-donor liver transplantation (LDLT) was first used in 1988 to treat children because of the severe shortage of pediatric donors [1]. After the first success [2], LDLT using a left lateral segment became widely accepted as a treatment of choice for end-stage liver disease in pediatric patients. LDLT has now become an accepted alternative for any patients waiting for cadaveric liver transplantation, especially in countries like Japan where cadaveric organ harvesting is very limited. After expansion of the indication of LDLT for adult populations by using left-lobe grafts, small-for-size grafts with relatively high morbidity remained a significant barrier to more widespread use [3]. The subsequent evolution of LDLT has led to its applicability to right-lobe donation with good initial results [4,5]. Right-lobe grafts are now commonly used in many LDLT programs, because the right lobe represents approximately 60% of the entire liver volume, and provides sufficient viable tissue for many adult recipients of average size. Although LDLT using right-lobe grafts is rapidly being accepted worldwide, donor safety should be the top priority. The undisputed disadvantage of LDLT is the risk of serious complications or death in an otherwise healthy donor, but published complication rates in right-lobe living donors have differed widely from programs to

program [6–10], and there is still no standardized method for reporting surgical outcome. As a result, sufficiently detailed information on donor safety is not yet available, and controversy has been remaining. Moreover, few studies on regeneration of the residual liver in the living donor have been reported [6,7,10–12], and little is known about the long-term process of liver regeneration in right-lobe living donors.

In the present study, we evaluated our experience with regard to donor outcome and liver regeneration after donor surgery harvesting the right-lobe for use as a graft.

Patients and methods

Donors

Between March 2002 and November 2003, 38 consecutive LDLTs were carried out in Mie University Hospital, Japan, after obtaining the approval of the Ethics and Indications Committee of Mie University, and the 27 donors who donated their right lobe without the middle hepatic vein were enrolled in this study. The 11 donors who were excluded consisted of three who donated right-lobe grafts with the middle hepatic vein, two who donated left-lobe grafts with the middle hepatic vein, and six who donated the left lateral segment graft. The ages of the donors ranged from 18 to 62 years. In terms of their relationship to the recipient, the donors consisted of 10 spouses (one husband and nine wives), 10 offspring (eight sons and two daughters), three sisters, one father, one grandson, one cousin, and one son-in-law. Significant medical history consisted of hypothyroidism, hypertension with diabetes mellitus, gastric ulcer and well-controlled depression in one donor each. There were three donors with a history of abdominal surgery, and the procedures consisted of appendectomy in three and gynecological surgery in one. One donor was ABO incompatible with her recipient.

Donor selection

Donor candidates were limited to blood relatives up to the third degree and the spouse, or equivalent of the recipient, if they manifested a strong desire to donate part of their liver of their own free will. After first obtaining their informed consent, donor candidates were medically screened by means of blood tests, abdominal ultrasonography (US), and tests for general anesthesia. Final candidates were examined for vascular anomalies by 5-mm slice volumetric computed tomography (CT) with three-dimensional images, and biliary sytem was evaluated by three-dimensional drip infusion cholangiography (DIC)-CT. The total liver volume (TLV), graft volume and residual liver volume (RLV) of the donors were calculated by CT volumetric analysis. Graft-to-recipient weight ratio (GRWR) was estimated using graft volume instead of the actual graft weight (estimated GRWR = graft volume/recipient body weight × 100). The CT of the liver for volume determination was performed as described elsewhere [13]. Briefly, the scheduled graft and the whole liver were traced on 5-mm CT slices, and areas enclosed were calculated and integrated.

Selection criteria for donors were, in principle, age 20–60 years, healthy, ABO compatible, estimated GRWR >1.0%, and estimated RLV (preoperative estimated TLV – estimated graft volume) >30% of TLV. Each application for LDLT was submitted to the Ethics and Indications Committee of our University, and Committee discussed the applications with regard to donor safety and the indications of the recipients. The Committee gave its final approval to perform the transplant only after interviewing the potential donor and her or his family. The donor was informed that she or he could withdraw at any time.

Pretransplant evaluation of the donor

The pretransplant evaluation of the anatomy of the donor's liver was based on Doppler US and CT scan and did not include angiography or endoscopic retrograde cholangiopancreatography. In one emergency case the preoperative CT scan was omitted because the equipment was not available. The liver was evaluated for steatosis by US and CT alone, and preoperative liver biopsy was not routinely performed. Donor candidates who were suspected of having steatosis were placed on a diet and exercise program, and their candidacy was evaluated again at a later date. To prevent postoperative pulmonary emboli, all candidates were screened by US for deep vein thrombi of lower extremities before surgery.

Donor surgery

The surgical procedure used in the donors has been described in detail elsewhere [5,14]. Briefly, after the abdomen was entered, a liver biopsy specimen was collected to evaluate for hepatic steatosis. Before parenchymal transection of the liver, the right lobe was mobilized, and the short hepatic veins were transected except right inferior hepatic veins of significant size. Short hepatic veins along the left side of inferior vena cava were left intact. After dissection and isolation of the vessels at the hepatic hilum, the transection plane was determined by referring to the demarcation line obtained by temporary clamping of the right portal branch and right hepatic artery. The transection line was then marked by electrocautery on the surface of the liver just to the right of the demarcation line. After releasing the clamps of hepatic blood flow,

parenchymal transection was carried out without any interruption of the hepatic blood flow. Intraoperative cholangiography prior to transection of right hepatic duct was omitted when the anatomy of biliary system was clearly demonstrated by preoperative three-dimensional DIC-CT. Parenchymal transection was started at the liver edge and proceeded down to the bile duct, and after transecting the right hepatic duct at its bifurcation, the parenchymal transection was continued cranially toward the right hepatic vein. The grafts were flushed with histidine–tryptophan–ketoglutarate solution *ex situ* via the portal vein, and then weighed on the back-table and preserved in the same solution. Graft weight was considered equivalent to its volume, because the specific gravity of the liver is similar to that of water. Before closing the abdomen, intraoperative cholangiography was performed to test for bile leakage with clamping of common bile duct at the supraduodenal portion.

Postoperative care

After surgery the donors were cared for in a surgical recovery room. Early oral nutrition was encouraged, and progressed as tolerated. Postoperative pain was managed by routine epidural infusion of analgesics. As the prevention and early detection of deep vein thrombosis is one of the most important points in postoperative care of living donors, an intermittent pneumatic compression device was used during surgery and the early postoperative period until the donor was ambulatory. Serial Doppler US of the deep veins was performed postoperatively, and intravenous heparin, 10 000 units daily, was given after removal of the epidural catheter until the donor became ambulatory.

Postoperative evaluation of graft and liver regeneration

The ratio of graft size to recipient body weight was evaluated by using actual GRWR (actual graft weight/recipient body weight × 100). Estimated-actual %RLV of donors immediately after donation was calculated as: estimated-actual %RLV = (preoperative estimated TLV − actual graft weight)/preoperative estimated TLV × 100. Postoperative liver regeneration is expressed as a percentage of the original TLV based on follow-up CT liver volume measurements. Follow-up CT volumetry was performed 7, 14, 30, 90, 180, and 360 days postoperatively on 23, 22, 22, 22, 17, and 7 donors respectively.

Evaluation of the degree of steatosis

All liver biopsy specimens were examined histologically. The specimens were classified into three groups based on the degree of macrovesicular steatosis observed: none (0% steatosis), minimal (≤10%), and mild (11–30%).

Evaluation of postoperative liver functions and complications

Postoperative changes in liver function test values were analyzed in relation to donor age, histological degree of steatosis of the liver, and estimated-actual %RLV. The donors were also assessed for postoperative complications during and after the initial hospital stay. The follow-up periods of the donors ranged from 134 to 666 days (median 337).

Statistical analysis

Values are expressed as mean ± SD. Variables were compared by using the unpaired Student's *t*-test, and statistical significance was defined as $P < 0.05$. All statistical analyses were performed using the Stat View 5.0 software package for Macintosh (SAS Institute Inc., Cary, NC, USA).

Results

Liver volumetry and graft profiles

Preoperative CT volumetric analyses and postoperative graft profiles are summarized in Table 1. Estimated graft volume ranged from 476.0 cm^3 to 1064.8 cm^3, and actual graft weight ranged 460 to 1180 g. The values for estimated graft volume and actual graft weight showed a positive linear correlation ($Y = 177.85 + 0.795X$, $R^2 = 0.812$, $P < 0.0001$). Preoperative estimated GRWR, calculated using estimated graft volume instead of actual graft weight, ranged from 0.79 to 1.89%, and in one case it was <0.8%. All of the actual GRWR values were >0.8%. Preoperative estimated %RLV, defined as (estimated

Table 1. CT volumetric analysis and graft profile.

Preoperative ($n = 26$)	
Estimated TLV (cm^3)	1145.8 ± 199.7 (806.1–1694.9)
Estimated graft volume (cm^3)	721.0 ± 129.0 (476.0–1064.8)
Estimated %RLV	37.0 ± 4.1 (25.4–44.3)
Estimated GRWR (%)	1.16 ± 0.25 (0.79–1.89)
Postoperative ($n = 26$)	
Actual graft weight (kg)	679.4 ± 144.4 (460–1180)
Estimated-actual %RL	40.8 ± 6.6 (27.2–51.4)
Actual GRWR (%)	1.08 ± 0.19 (0.83–1.57)

Values are expressed as mean ± SD. Numbers in parentheses indicate range.

TLV, total liver volume; RLV, residual liver volume; GRWR, graft-to-recipient weight ratio; Estimated % RLV = (TLV − estimated graft volume)/TLV × 100; Estimated-actual %RLV = (TLV − actual graft weight)/TLV × 100.

TLV − estimated graft volume)/estimated TLV × 100, ranged from 25.4% to 44.3%. Two donors had a preoperative estimated %RLV below 30%. The actual transection lines in both donors were intentionally shifted to the right, and as a result their postoperative estimated-actual %RLV, calculated by actual graft weight instead of preoperative estimated graft volume, was more than 30%. Finally, only one donor, a donor with a preoperative estimated %RLV of 33.8%, had estimated-actual %RLV of 27.2% postoperatively.

Histological examination of the liver biopsy specimen during surgery revealed minimal (≤10%) and mild (11–30%) macrovesicular stestosis in 4 and 7, respectively, of the 27 grafts. None of the grafts exhibited histological steatosis of >30%.

Surgery and complication

Surgical factors related to the harvesting procedure in the 27 donors and the postoperative complications are summarized in Table 2. The patients with complications consisted of three males and one female, and they ranged in age from 18 to 54 years old (32.8 ± 15.6 years). They required a significantly longer postoperative hospital stay than the other donors (25.0 ± 7.4 days vs. 13.5 ± 2.8 days, $P < 0.0001$), but all of them recovered in response to conservative treatment. None of the donors with a significant medical history experienced a recurrence or exacerbation postoperatively. All donors are being followed, and they are alive and well.

Postoperative liver function

Changes in postoperative liver function test values are shown in Fig. 1. The values for aspartate aminotransferase (AST), alanine aminotransferase (ALT), and prothrombin time international normalized ratio (PT-INR) of all of the donors peaked on postoperative day (POD) 1 or 2, and rapidly returned to within the normal range by 1 month. The serum total bilirubin (T-Bil) values also peaked on POD 1 or 2, and they were all below 5 mg/dl, except in one case with a peak value of 9.8 mg/dl. That patient was a 55-year-old male with a body height of 173 cm, body weight of 85 kg, and normal preoperative liver function test values. His preoperative estimated TLV was 1458 ml and actual graft weight was 840 g. Right hepatectomy was performed uneventfully with an intraoperative blood loss of 616 ml. Postoperative estimated-actual RLV was calculated at 42.4% of original TLV. His T-Bil value increased to 9.8 mg/dl on POD 2 after the peak liver enzymes values (AST 844 IU/l, ALT 628 IU/l) occurred on POD 1, and the histological examination of his liver had revealed mild macrovesicular steatosis (up to 30%). The T-Bil values of all donors, including this donor, decreased to within the normal range within 1 month. The postoperative peak liver function tests values were analyzed in relation to donor age (<50 years, ≥50 years), intraoperative blood loss (<500 ml, 500–1000 ml, >1000 ml), estimated-actual %RLV (<40%, ≥40%), and histological degree of macrovesicular steatosis of the liver (none, minimal, mild). The results showed that only histological degree of steatosis affected the postoperative peak AST and ALT values, which were significantly higher in the donors with mild macrovesicular steatosis than in those without steatosis (AST; $P = 0.0380$, ALT; $P = 0.0166$). However, there were no significant differences in postoperative peak T-Bil and PT-INR value according to degree of macrovesicular steatosis in the liver (Table 3).

Table 2. Operative results ($n = 27$).

Operation time (min)	365.7 ± 71.9 (225.0–551.0)
Blood loss (ml)	822.2 ± 572.1 (175–1597)
Blood transfusion	
Autologous	6
Heterologous	0
Postoperative complications	
Bile leakage	1
Persistent fluid collection with fever	1
Duodenal ulcer	1
Fever of unknown origin	1
Hospital stay (days)	15.2 ± 5.5 (9–34)

Values are expressed as mean ± SD or numbers of cases. Numbers in parentheses indicate range.

Postoperative liver regeneration

The residual liver of the donors was 40.8 ± 6.6% of original TLV immediately after right hepatectomy, i.e. at time 0. The residual liver grew rapidly, resulting in an increase to 61.6 ± 10.8% and 68.3 ± 9.4% of original TLV by 1 week and 2 weeks, respectively, after surgery. Thereafter, the liver volume gradually increases to 79.8 ± 12.0% and 97.2 ± 10.8% of original TLV by 6 months and 12 months, respectively, after the donation.

Postoperative changes in liver regeneration of donors were compared according to donor age (<50 years, ≥50 years), gender (male, female), intraoperative blood loss (<500 ml, 500–1000 ml, >1000 ml), estimated-actual %RLV (<40, ≥40%), and histological degree of macrovesicular steatosis of the liver (none, minimal, mild). The results showed no significant differences in liver regeneration according to any of these factors except donor age. Postoperative changes in liver volume according to donor age are shown in Fig. 2. The mean liver volume 90 days following donation by donors 50 years of age or older was significantly lower than in younger donors

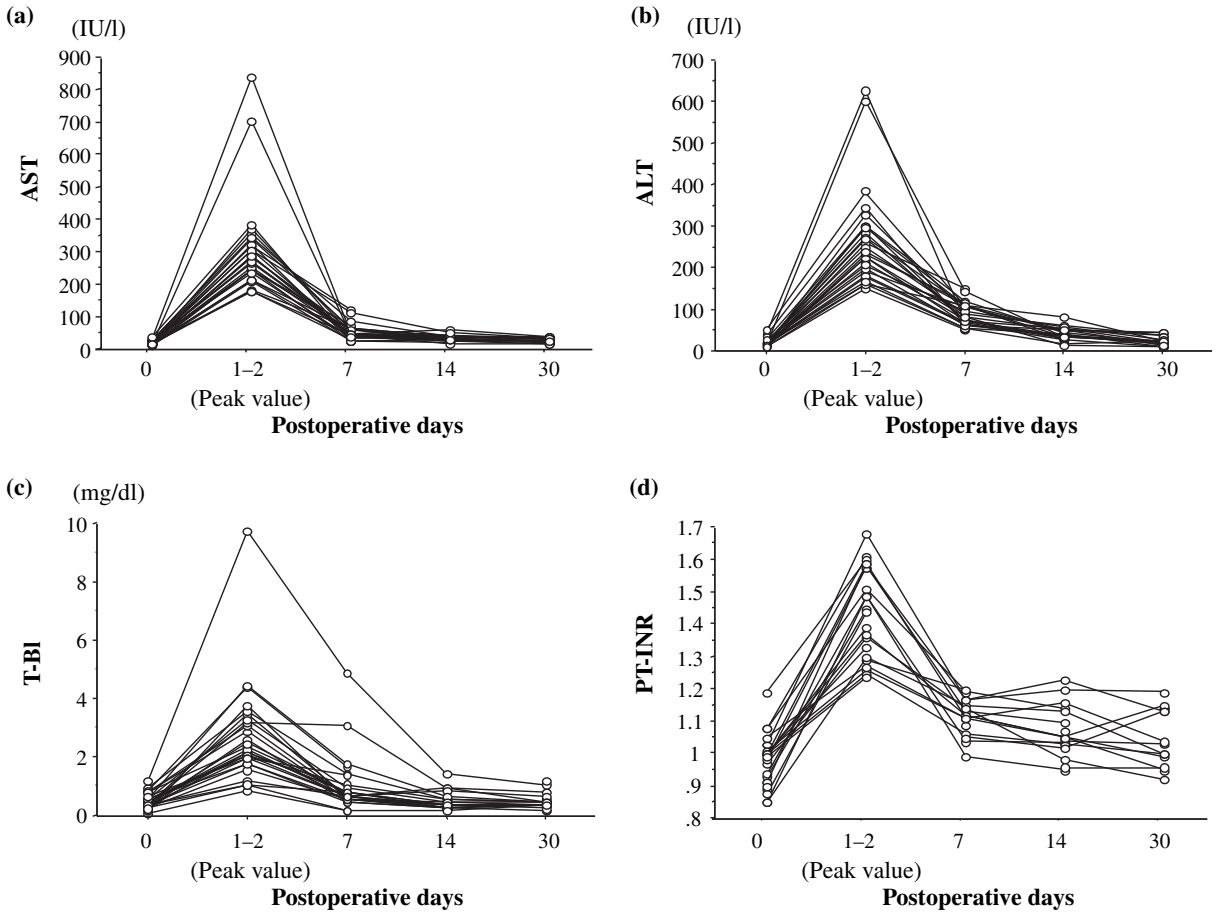

Figure 1 Changes in postoperative liver function test values. (a) Aspartate aminotransferase (AST); (b) alanine aminotransferase (ALT); (c) total bilirubin (T-Bil); (d) prothrombin time international normalized ratio (PT-INR).

Table 3. Histological degree of steatosis and postoperative liver function test values.

	Postoperative peak values (mean ± SD)			
	T-Bil (mg/dl)	AST (IU/l)	ALT (IU/l)	PT-INR
Total ($n = 27$)	2.74 ± 1.71	312.5 ± 146.9	270.0 ± 116.3	1.44 ± 0.14
Degree of steatosis				
None (0%) ($n = 16$)	2.69 ± 1.07	277.8 ± 124.4	233.1 ± 106.4	1.46 ± 0.15
Minimal (≤10%) ($n = 4$)	2.00 ± 0.56	282.3 ± 46.6	252.8 ± 46.2	1.42 ± 0.15
Mild (11–30%) ($n = 7$)	3.27 ± 2.99	423.4 ± 187.2*	364.3 ± 122.7**	1.39 ± 0.11

*$P = 0.0380$ versus none, **$P = 0.0166$ versus none.

(70.4 ± 9.2% of original TLV vs. 79.3 ± 9.6% of original TLV, $P = 0.0391$), and it was still lower at 180 postoperative days, but the difference was not statistically significant (73.4 ± 9.5% of original TLV vs. 84.3 ± 12.0% of original TLV, $P = 0.0655$).

Discussion

The LDLT was initially introduced to overcome shortage of organs for pediatric patients, and the evolution of the modality has led to right-lobe living donation for adult-to-adult liver transplantation. Furthermore, an extended right liver graft, including the trunk of middle hepatic vein, was devised by the Hong Kong group [15]. However, the safety criteria for right-lobe donation should be strict. The harvesting of the middle hepatic vein with a right-lobe graft allows an optimal venous drainage for the recipient but can also have adverse effects for the donor. The operative risk of right-lobe donation is considered higher than for donation of other types of liver grafts,

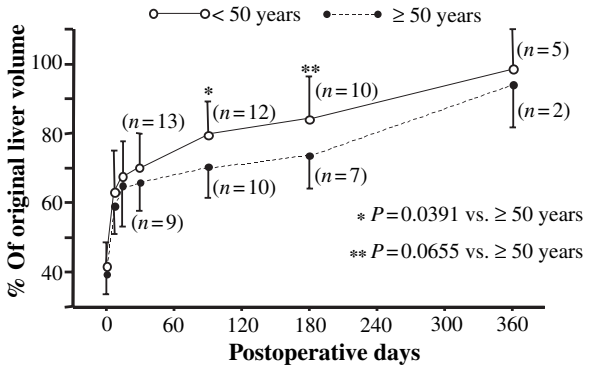

Figure 2 Changes in residual liver volume by age after right hepatectomy for living donation. The percentages of original liver volume at postoperative day 0, 7, 14, 30, 90, 180, and 360 are expressed as mean ± SD.

because the liver volume remaining in the donor is smaller. Indeed, Surman [16,17] reported that eight donor deaths had occurred worldwide after partial-liver donation. Three of these deaths had occurred in the United States, and two of the three were right-lobe donors. The mortality rate of living donors has been reported to be 0.8% in Europe [18] and 0.2% in the United States [19]. The Japanese Liver Transplantation Society reported no perioperative donor deaths among the total of 1853 living liver donors operated in 48 Japanese centers between November 13, 1989 and April 11, 2002 [20]. However, on May 4, 2003, the first death of living donor who donated the right-lobe with middle hepatic vein occurred in Japan[21], and donor safety committee of the Japanese Liver Transplantation Society made an inspection of this donor. Consequently, the donor was diagnosed as nonalcoholic steatohepatitis (NASH) and the RLV was too small (around 25% by estimation), and the committee proposed the avoidance of NASH as living donor and the volume guarantee of residual donor liver as more than 30% by estimation. Recent studies of right-lobe donors have reported morbidity rates that included minor complications of 18–40.5% [6–10], and bile leakage has been found to be more frequent in right-lobe donors than after left-sid procedures [20,22]. We instituted a LDLT program in March 2002 and have performed 27 right-lobe donations without middle hepatic vein. There was no donor who died or received heterologous blood transfusion. Four donors experienced minor postoperative complications, but all of them resolved in response to conservative treatment without any surgical intervention. In the present study, three donors who donated right-lobe with middle hepatic vein were excluded, because of small number and short postoperative follow-up periods, but all of them had uneventful postoperative course. According to the results of this, right hepatectomy without middle hepatic vein from living donors is a safe procedure with acceptable morbidity, however, living donor surgery requires greater care when the right-lobe is being donated.

In previous studies on postoperative changes in liver function test values following liver donation by living adults, the peak AST, ALT, and T-Bil values were found to be higher in right-lobe donors than left-lobe donors [22]. Moreover, the liver enzyme and T-Bil values of right-lobe donors on POD 1 have been reported to be significantly higher in older donors, donors with smaller RLV, and donors with macrovesicular steatosis of the liver [8,13]. In the present study, however, only one of these factors, steatosis of the liver, had a significant influence on the postoperative peak values of AST and ALT. Although one of the donors in our series who had mild macrovesicular steatosis of the liver had a peak postoperative T-Bil value of 9.8 mg/dl, his preoperative data, operative factors, and RLV were all within the averaged range in our series. It is well known that implantation of cadaveric livers with severe fatty infiltration (>60%) is frequently associated with early hepatic dysfunction and an increased incidence of primary nonfunction. A more recent study showed that even 30% steatosis negatively affected graft and recipient survival in cadaveric transplantation [23]. In contrast to the cadaveric grafts, Hayashi *et al.* [24] and Soejima *et al.* [25] reported that moderate (up to 50% or 60%) fatty liver grafts from living donors was followed by graft and recipient survival comparable with that obtained with normal control liver grafts because of the shorter duration of cold preservation of the graft. They also reported the absence of any specific postoperative complications in the donors related to the steatosis of the liver [24,25]. However, a retrospective study after major hepatic resection for benign or malignant liver disease showed that postoperative liver failure occurred in 9% of even the patients with no more than 30% steatosis [26]. The results of our study suggested that even mild steatosis of the liver could be a risk factor of right hepatectomy from living donors.

There have been numerous studies on the liver regeneration after hepatic resection for benign and malignant tumors, but few studies have characterized the process of liver regeneration in living donors. To the best of our knowledge, Kawasaki *et al.* [11] were the first to report on the liver regeneration in donors and recipients. They measured regeneration by CT volumetry after LDLT with a left lateral segment or left-lobe graft in a small series of four pediatric patients and their donors, and reported that the residual liver of the donors tended to grow more slowly than the grafted liver in the recipient throughout the first postoperative year. By contrast, Marcos *et al.*

[12] reported on liver regeneration in right-lobe living donors by volumetric magnetic resonance imaging. They found that the liver of most donors regenerated rapidly during the first week and had almost completely regenerated within 60 days after surgery. Moreover the time course of the liver regeneration did not differ significantly between the donors and recipients. More recent studies have reported different results. Pomfret *et al.* [10] reported that maximum growth of the residual liver occurred within 1 month after right-lobe donation, and was followed by gradual increases in volume throughout the rest of the first postoperative year, whereas the mean volume of the residual liver in the donors had increased to only 83.4% of the preoperative original volume by 1 year. Ghobrial *et al.* [6] and Pascher *et al.* [7] reported a similar time course of liver regeneration, with the liver volume of the donors reaching 80–85% of its original volume by 1 year. The time course of liver regeneration during the first 6 months after surgery in our series was similar to their findings, and the volume of the residual liver had regenerated to 97.2% of the original liver volume by 1 year after donation. The difference in our results may be attributable to the smaller number of cases at 1 year in our series. Thus, it may require at least 1 year after donation for the liver of right-lobe donors to attain its original volume.

Normal liver regeneration is a complicated process that depends on the activation of more than 100 genes and involvement by numerous growth factors, cytokines, and transcriptional factors, and the mechanisms controlling liver regeneration are not yet sufficiently understood. There has been no consensus as to factors that have a significant impact on the process of liver regeneration in right-lobe donors. Marcos *et al.* [12] reported that volume of the residual liver affects the duration of the regeneration process, with a smaller initial liver volume prolonging the course. Pomfret *et al.* [10] reported finding no effect of donor age, body mass index, operative blood loss, or perioperative liver function test values on liver regeneration, but that liver regrowth was slower in female donors than in male donors. In our study, the residual liver of the donors 50 years or older had grown significantly less at 3 months than in those under 50 years old, but gender, intraoperative blood loss, RLV, and steatosis of the liver had no influence on the rate of liver regeneration. These results may be attributable to the fact that the LDLT programs used similar donor selection criteria, which generally exclude high risk donors, i.e. older donors, donors with severe steatosis, and donors in whom the residual liver would be expected to be small.

In conclusion, our LDLT program showed that right hepatectomy without middle hepatic vein in healthy living donors is a safe procedure with acceptable morbidity and that the residual liver regenerated to its preoperative size volume by 1 year after donation. However, right-lobe living donor surgery requires more meticulous care, especially in donors with steatosis of the liver and aged donors.

References

1. Raia S, Nery JR, Mies S. Liver transplantation from live donors. *Lancet* 1989; **21**: 497.
2. Strong RW, Lynch SV, Ong TH, Matsunami H, Koido Y, Balderson GA. Successful liver transplantation from a living donor to her son. *N Engl J Med* 1990; **322**: 1505.
3. Kiuchi T, Kasahara M, Uryuhara K, *et al.* Impact of graft size mismatching on graft prognosis in liver transplantation from living donors. *Transplantation* 1999; **67**: 321.
4. Marcos A, Fischer RA, Ham JM, *et al.* Right lobe donor liver transplantation. *Transplantation* 1999; **68**: 798.
5. Inomata Y, Uemoto S, Asonuma K, *et al.* Right lobe graft in living donor liver transplantation. *Transplantation* 2000; **69**: 258.
6. Ghobrial RM, Saab S, Lassman C, *et al.* Donor and recipient outcomes in right lobe adult living donor transplantation. *Liver Transpl* 2002; **8**: 901.
7. Pascher A, Sauer IM, Walter M, *et al.* Donor evaluation, donor risk, donor outcome, and donor quality of life in adult-to-adult living donor liver transplantation. *Liver Transpl* 2002; **8**: 829.
8. Ito T, Kiuchi T, Egawa H, *et al.* Surgery-related morbidity in living donor of right-lobe graft: lesson from the first 200 cases. *Transplantation* 2003; **76**: 158.
9. Malago M, Testa G, Frilling A, *et al.* Right living donor transplantation: an option for adult patients. Single institution experience with 74 patients. *Ann Surg* 2003; **238**: 853.
10. Pomfret EA, Pomposelli JJ, Gordon FD, *et al.* Liver regeneration and surgical outcome in donors of right-lobe liver grafts. *Transplantation* 2003; **76**: 5.
11. Kawasaki S, Makuuchi M, Ishizone S, Matsunami H, Terada M, Kawarazaki H. Liver regeneration in recipients and donors after transplantation. *Lancet* 1992; **339**: 580.
12. Marcos A, Fisher RA, Ham JM, *et al.* Liver regeneration and function in donor and recipient after right lobe adult to adult living donor liver transplantation. *Transplantation* 2000; **69**: 1375.
13. Sakamoto S, Uemoto S, Uryuhara K, *et al.* Graft size assessment and analysis of donors for living donor liver transplantation using right lobe. *Transplantation* 2001; **71**: 1407.
14. Tanaka K, Uemoto S. Principles and technique of living donation of the liver. In: Bucheler E, Nicolas V, Broelsch CE, Rogiers X, Krupski G, eds. *Diagnostic and Interventional Radiology in Liver Transplantation.* Berlin Heidelberg: Springer-Verlag, 2003: 37–46.

15. Lo CM, Fan ST, Liu CL, *et al.* Adult-to-adult living donor liver transplantation using extended right lobe grafts. *Ann Surg* 1997; **226**: 261.
16. Surman OS. The ethics of partial-liver donation. *N Engl J Med* 2002; **346**: 1038.
17. Surman OS. Transplantation of right hepatic lobe. *N Engl J Med* 2002; **347**: 615.
18. Broelsch CE, Malago M, Testa G, Valentin Gamazo C. Living donor liver transplantation in adults: outcome in Europe. *Liver Transpl* 2000; **6** (Suppl. 2): S64.
19. Brown RS, Russo MW, Lai M, *et al.* A survey of liver transplantation from living adult donors in the United States. *N Engl J Med* 2003; **348**: 818.
20. Umeshita K, Fujiwara K, Kiyosawa K, *et al.* for the Japanese Liver Transplantation Society. Operative mortality of living liver donors in Japan. *Lancet* 2003; **362**: 687.
21. Akabayashi A, Slingsby BT, Fujita M. The first donor death after living-related liver transplantation in Japan. *Transplantation* 2004; **77**; 634.
22. Fujita S, Kim I-D, Uryuhara K, *et al.* Hepatic grafts from live donors: donor morbidity for 470 cases of live donation. *Transpl Int* 2000; **13**: 333.
23. Marsman WA, Wiesner RH, Rodriguez L, *et al.* Use of fatty donor liver is associated with diminished early patient and graft survival. *Transplantation* 1996; **62**: 1246.
24. Hayashi M, Fujii K, Kiuchi T, *et al.* Effects of fatty infiltration of the graft on outcome of living-related liver transplantation. *Transplant Proc* 1999; **31**: 403.
25. Soejima Y, Shimada M, Suehiro T, *et al.* Use of steatotic graft in living-donor liver transplantation. *Transplantation* 2003; **76**: 344.
26. Behrns KE, Tsiotos GG, DeSouza NF, Krishna MK, Ludiwig F, Nagorney DM. Hepatic steatosis as a potential risk factor for major hepatic resection. *J Gastrointest Surg* 1998; **2**: 292.