Effect of graft size matching on pediatric living-donor liver transplantation at a single center

Jun-Jie Li1 | Cai-Hua Zu2 | Shi-Peng Li3 | Wei Gao1 | Zhong-Yang Shen1 | Jin-Zhen Cai1

1Department of Liver Transplantion, Oriental Organ Transplant Center, Tianjin First Central Hospital, Tianjin, China
2Department of Gastroenterology, Zhengzhou Yi He Hospital Affiliated to Henan University, Zhengzhou, China
3Department of General Surgery, Jiaozuo People’s Hospital, Xinxiang Medical University, Jiaozuo, China

Correspondence
Jin-zhen Cai, MD, and Zhong-yang Shen, MD, Department of Liver Transplantion, Organ Transplant Center, Tianjin First Central Hospital, Tianjin, China.
Emails: drcaijinzhen@yeah.net; zhongyangshen@vip.sina.com

Funding information
National Science Foundation of China, Grant/Award Number: 81170443, 81670600 and 81700556; Tianjin Health Bureau of Science and Technology, Grant/Award Number: 2014KY08; National Key Clinical Specialty Construction Project of Organ Transplantation Department, Grant/Award Number: 2015DFG31850; International S&T Cooperation Program of China; Tianjin Clinical Research Center for Organ Transplantation Project, Grant/Award Number: 15ZXLC5Y00070

Abstract
We retrospectively analyzed 252 patients with end-stage liver disease who had undergone LDLT from January 2009 to September 2015. Of these, 25 had a GRWR of <2.0% (Group A), 204 had a GRWR of ≥2.0% or <4.0% (Group B), and 23 had a GRWR ≥4.0% (Group C). The three GRWR groups demonstrated similar characteristics, except for recipient age and recipient BMI. The overall 1-, 2-, and 3-year graft survival rates were 95.1%, 93.5%, and 93.5%, respectively. However, among the three groups, graft survival rates at 1 year, 2 years, and 3 years were significantly different (P = .0009). Hepatic artery stenosis/thrombosis was more frequently observed in Group C than in Groups A and B (P = .001). Wound infection was also more frequently observed in Group C than in Group A and B (P = .002). However, intestinal fistula/bile leakage/biliary-enteric anastomotic fistula was more frequently observed in Group A than in Groups B and C (P = .001). In addition, reoperation more frequently occurred in Group A and C than in Group B (P = .001). Recipients with a GRWR between 2.0% and 4.0% had significantly better graft survival rates.

KEYWORDS
graft-to-recipient weight ratio, living-donor liver transplantation, patient and graft survival rates, pediatric

1 | INTRODUCTION

The first living-donor liver transplantation (LDLT) procedure was performed in 1988 as a life-saving procedure for a 4-year-old girl with terminal advanced liver failure due to biliary atresia.1 After the first successful LDLT in 1989, this revolutionary procedure was gradually accepted.2 Due to the scarcity of organs available for deceased-donor transplantation, LDLT has seen great progress in terms of patient experience and techniques, as well as pre-, peri-, and post-transplant management.3-5 Ueda et al reported that patient and graft survival rates after pediatric LDLT in a large cohort of children at their center were similar to the survival rates for cadaveric liver transplantation. Patient survival at 1, 5, and 10 years was 84.6%, 82.4%, and 77.2%, respectively, and the corresponding findings for graft survival were 84.1%, 80.9%, and 74.5%.6 After nearly 30 years of development, LDLT has become an effective therapy for children with end-stage liver disease.7-9 The majority of the recipients received LDLT for biliary atresia (BA), because the size of the abdominal cavity in cirrhotic baby seems to be different from metabolic and ALF children.10 Various factors, including the graft-to-recipient weight ratio (GRWR), should be initially assessed to determine their influence on graft survival and outcomes. Kasahara et al11 reported that recipients under 1 year of age (296 recipients) who received grafts with a GRWR >4.0% exhibited significantly
reduced patient survival due to problems associated with large-for-size grafts. Another study suggested that a GRWR between 1.9% and 5.8% would not cause noticeably adverse events for infantile LDLT recipients $\leq 8$ kg. Recent studies have shown the effect of the GRWR on liver transplantation; therefore, the optimal range of the GRWR for pediatric LDLT should be determined. This study aimed to assess graft survival and outcomes according to the GRWR and to calculate the optimal range of the GRWR.

## METHODS

### 2.1 Selection of recipients and donors

Two hundred and fifty-two children (age $\leq 18$ years) who had undergone LDLT due to end-stage liver disease from January 2009 to September 2015 at Tianjin First Central Hospital were enrolled in this study. The recipients were categorized into three groups: patients with a GRWR $<2.0\%$, patients with a GRWR $\geq2.0\%$ or $<4.0\%$, and patients with a GRWR $\geq 4.0\%$. During the same study period, 93 deceased-donor liver transplants were performed in children, including 15 split liver transplants and one reduced-size liver transplant, and these patients were excluded from this study.

All donors were confirmed to be volunteers and had given signed informed consent. Living donors were screened by the hospital ethics review board; their relationship with the recipients was determined, and the following medical evaluations were performed: (i) gender, age, height, weight, and body mass index (BMI) determination; (ii) laboratory tests to determine blood type, liver function, kidney function, hepatitis virology, and HIV status; and the syphilis unheated serum reagin test; (iii) abdominal computed tomography (CT), ultrasound, and magnetic resonance imaging; (iv) analysis of total liver volume and volume of the left lateral lobe (IQQA-Liver, EDDA Technology, Princeton, NJ, USA); (v) liver biopsy when ultrasound and CT scanning revealed the presence of fatty liver; and (vi) evaluation of donor biliary anatomy using intraoperative repeated real-time cholangiography or preoperative magnetic resonance cholangiography.

### 2.2 Clinical data collection

Patients were analyzed for graft survival and reviewed regarding recipient factors (age, gender, BMI, model for pediatric end-stage liver disease [PELD] score, and diseases after LDLT) and operative factors (cold ischemic time, warm ischemic time, operation time, and estimated blood loss). In addition, postoperative complications were evaluated, including postoperative bleeding, vascular or biliary problems, pulmonary infection, sepsis, wound infection, seizure disorders, and reexploration.

### 2.3 Donor and recipient surgery

We performed piggyback liver transplantation without venovenous bypass in all of the recipients. Biliary tract reconstruction was performed via a Roux-en-Y choledochojunostomy in all patients. Intraoperative color Doppler ultrasonography was performed to assess blood flow velocity and pattern after vascular reconstruction and during abdominal wall closure. Techniques used for abdominal closure were identical among recipients in different groups, and primary closure of the abdominal wall was achieved in all recipients.

### 2.4 Medication and immunosuppression protocol

The immunosuppressant basiliximab (10 mg intravenous infusion) was administered intraoperatively and on postoperative day 4. Methylprednisolone was administered at a dose of 10 mg/kg (intravenous infusion) after reperfusion of the grafts, followed by 1-2 mg/kg 4 times daily for the first day, with tapering to 1 mg/kg once daily on day 6. From day 7, methylprednisolone was taken orally and discontinued at the end of the first 3-12 months after LDLT. Tacrolimus (0.1 mg/kg) was administered via a nasogastric tube 36 hours after transplantation, with dose adjustment to maintain trough blood levels at 8-10 ng/mL during the first month and then at 5-8 ng/mL thereafter. Some patients were also treated with mycophenolate mofetil (250 mg twice daily, orally), which was withdrawn at 3-6 months postoperative. Hepatic artery thrombosis was controlled by intravenous infusion of heparin, while the patients were in the intensive care unit; they were then switched to oral warfarin, with dose adjustment to maintain the prothrombin time at approximately twofold longer than that of the controls.

### 2.5 Follow-up

The surviving children were followed up in the clinic weekly during the first 3 months after LDLT, biweekly from 4 to 6 months postoperative, monthly from the seventh to the 12th month, and every 3 months thereafter. The following tests were performed at each follow-up visit: height, body weight, serum liver tests, renal function tests, serological concentration of immunosuppressive agents, serological cytomegalovirus (CMV) tests, and Epstein-Barr virus (EBV) tests. Abdominal sonography was performed every 3 months during the first 2 years and annually thereafter. All recipients were followed until death, graft loss, or December 2015.

### 2.6 Statistical analysis

Statistical analyses were performed using commercially available software (SPSS version 23.0; SPSS Inc, Chicago, IL, USA). Categorical data are presented as numbers with percentages, and continuous data are presented as the means $\pm$ SD or medians with a range, depending on the normality of the distribution. Clinical variables were analyzed using the chi-square test or Fisher’s exact test for categorical data, and the Kruskal-Wallis $H$ test was used for continuous data. The cumulative survival curves for patients and grafts were plotted using the Kaplan-Meier method, and curves were compared...
using the log-rank test. \( P \)-values < .05 were considered statistically significant.

3 | RESULTS

3.1 | Recipients and donors

Between January 2009 and September 2015, 252 children were examined, including 129 boys and 123 girls, and the median age at the time of transplant was 7.0 months (ranging 4.0-205.0 months). The study also included 105 men and 137 women, with a median age of 30.0 years (ranging 23.0-55.6 years). The baseline characteristics for the three groups are shown in Table 1. The original liver diseases of the patients are listed in Table 2. The recipient gender and PELD score and the donor age, gender, and BMI were not different among the groups. However, the recipient age and BMI were significantly higher in Group A than in Groups B and C \( (P < .0001) \). Twenty-five (9.9%) patients had a GRWR <2.0% (Group A), 204 (81.0%) had a GRWR ≥2.0% or <4.0% (Group B), and 23 (9.1%) had a GRWR ≥4.0% (Group C). The median GRWRs among the three groups were 1.60% for Group A, 2.75% for Group B, and 4.33% for Group C. The minimum GRWR was 0.75%, and the maximum GRWR was 5.24%. The GRWR was significantly different among the groups \( (P < .0001) \).

3.2 | Operative characteristics

In 249 cases, the left lateral segment (II and III) was harvested. In two donors, the left lobe (II-IV) was removed along with the middle hepatic vein, and in the remaining two donors, the right lobe was harvested. In terms of operative factors, no significant differences were observed regarding cold ischemic time, warm ischemic time, operation time, and estimated blood loss (Table 3).

3.3 | Postoperative complications and laboratory changes

The postoperative complications after LDLT in the three groups are listed in Table 4. The incidences of postoperative portal vein stenosis/thrombosis, hepatic venous outflow tract obstruction, pulmonary infection, sepsis, seizure disorders, and PTLD were not different among the groups. However, the incidences of hepatic artery stenosis/thrombosis and wound infection were more significant in Group C than in the other groups \( (P = .001 \) and .002). In contrast, biliary complication (intestinal fistula/bile leakage/biliary-enteric anastomotic fistula) rates were somewhat higher in Group A recipients. It is also noteworthy that Group A and C recipients underwent more reoperations than Group B recipients.

Laboratory changes such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), total bilirubin (TB), and albumin (ALB) levels within 28 days after LDLT were compared among recipients in the three groups. The serial changes of the above indicators

| Table 1 | Clinical characteristics of recipients and donors according to GRWR |
|---------|-------------------------------------------------------------------|
| Characteristics | GRWR | <2% (25) | ≥2%, <4% (204) | ≥4% (23) | P-value |
| Recipient | Age (mon) | 24.0 (5.0,205) | 7.0 (4.0,78.0) | 6.0 (5.0,11.0) | <.0001 |
| | Gender (M/F) | 13/12 | 107/97 | 9/14 | .484 |
| | Body weight (kg) | 17.8 ± 12.9 | 7.7 ± 1.8 | 15.4 ± 2.3 | <.0001 |
| | BMI | 19.8 ± 5.7 | 17.4 ± 2.7 | 15.4 ± 2.3 | <.0001 |
| | PELD score | 16.7 ± 5.2 | 15.9 ± 7.4 | 16.3 ± 2.9 | .312 |
| | Kasai surgery | 6 (24.0%) | 53 (26.0%) | 4 (17.4%) | .661 |
| Donor | Age (yr) | 34.3 (22.3,55.6) | 30.0 (20.4,54.6) | 31.1 (20.3,48.5) | .14 |
| | Gender (M/F) | 12/13 | 82/122 | 11/12 | .638 |
| | BMI | 22.9 (18.3,33.3) | 22.1 (15.6,32.8) | 22.6 (18.6,29.6) | .260 |
| | Graft type | Living-donor | Living-donor | Living-donor | - |
| | Graft weight (g) | 230.3 ± 101.6 | 269.8 ± 47.5 | 222.0 ± 43.0 | .0005 |
| | GRWR (%) | 1.6 (0.75%, 1.98%) | 2.75 (2.00%, 3.96%) | 4.33 (4.11%, 5.24%) | <.0001 |

BMI, body mass index; PELD, pediatric end-stage liver disease model.

| Table 2 | Original liver diseases of the patients |
|---------|--------------------------------------|
| Diagnoses | GRWR | <2% (25) | ≥2%, <4% (204) | ≥4% (23) | Total |
| Biliary atresia | 21 | 198 | 23 | 242 |
| Liver cirrhosis | 1 | 5 | 0 | 6 |
| Metabolic disorder | 1 | 1 | 0 | 2 |
| Fulminant hepatic failure | 1 | 0 | 0 | 1 |
| Budd-Chiari syndrome | 1 | 0 | 0 | 1 |
are shown in Figure 1. The baseline levels of serum ALT, AST, TB, and ALB were similar among the three groups before LDLT. Compared to Groups A and B, the apparent values of ALT and AST in Group C recipients were higher during the first week. Serum TB clearance in Group A recipients was delayed during the first 3 days after LDLT. However, a difference in serum ALB was not observed among the three groups. Furthermore, the above four indicators reached normal levels within 2 weeks after LDLT.

**DISCUSSION**

The GRWR is a useful index to evaluate the graft and patient survival rate, as well as outcomes of LT patients. When the GRWR was less than 0.8%, patients suffered from encephalopathy, coagulopathy, and cholestasis and had poor graft survival.\(^{13,14}\) Moon et al\(^{15}\) showed that donor age was the only significant risk factor for poor graft survival in LDLT, and a graft with a GRWR <0.8% can be used safely when a recipient is receiving the graft from a donor younger than 44 years. In a study by Seung DL et al,\(^{16}\) 317 patients underwent LDLT and were categorized into three groups by GRWR, the authors concluded that a GRWR lower than 0.7% is safe and does not require portal pressure modulation in adult-to-adult LDLT using the right lobe under favorable conditions, including a low model for end-stage liver disease score. In patients with a GRWR >2.5%, the rate of respiratory failure was higher than the rates of other postoperative complications.\(^{17}\) The aforementioned research mainly examined the effect of the GRWR in adult liver transplantation. We found that when the GRWR was less than 1%, the patient survival rate was lower, likely due to enhanced parenchymal cell injury and reduced metabolic and synthetic capacity. However, the negative impact of large-for-size grafts was less pronounced in this study. Another limitation of the study is that adult and pediatric patients were not separately analyzed.\(^{13}\)

Obviously, anatomical and physiological characteristics of the liver differ between children and adults. We acknowledge that liver volume per body weight decreases with the growth of children.\(^{18}\) The data corroborate a large variation in the size of liver segments, even in healthy living donors. Therefore, precise measurement of a donor’s liver by CT volumetry is essential before operating. Due to limited data, a reasonable range of the GRWR for pediatric LDLT remains unknown. Our data clearly demonstrated that recipients with a GRWR ranging from 2.0% to 4.0% showed positive results. Whether serum ALT and AST levels were higher in recipients with a GRWR greater than 4.0% during the first week after LDLT remains to be determined. The fact that the serum TB level was higher in recipients with a GRWR <2.0% during the first 3 days after LDLT may be related to the reduced metabolic and synthetic capacity.

In a study of 47 pediatric cases, it was demonstrated that graft size matching is not necessarily a serious problem for living-related

---

**TABLE 3** Operative characteristics of recipients

| Variables                        | GRWR | P-value |
|----------------------------------|------|---------|
| Cold ischemic time (min)         | <2%  | ≥2%, <4%| ≥4%   |
|                                  | (25) | (204)  | (23)  |
| Warm ischemic time (min)         | 61.2 ± 25.6 | 65.3 ± 16.7 | 63.2 ± 22.7 | .357 |
| Operation time (min)             | 490.2 ± 97.7 | 450.8 ± 82.3 | 462.7 ± 105.4 | .265 |
| EBL (mL)                         | 363.3 ± 178.5 | 308.0 ± 192.6 | 326.5 ± 243.9 | .200 |

EBL, estimated blood loss.

**TABLE 4** Postoperative complications of recipients according to GRWR (n, %)

| Variables                                   | GRWR | P-value |
|---------------------------------------------|------|---------|
| Portal vein stenosis/thrombosis             | <2%  | ≥2%, <4%| ≥4%   |
|                                             | (25) | (204)  | (23)  |
| Hepatic artery stenosis/thrombosis          | 3 (12.00%) | 15 (7.35%) | 4 (17.40%) | .209 |
| Hepatic venous outflow tract obstruction     | 0 (0%) | 1 (0.49%) | 4 (17.40%) | .001 |
| Intestinal fistula/bile leakage/             | 1 (4.00%) | 2 (0.98%) | 0 (0%) | .471 |
| biliary-enteric anastomotic fistula         | 5 (20.00%) | 9 (4.41%) | 2 (8.70%) | .019 |
| Pulmonary infection                          | 6 (24.00%) | 31 (15.19%) | 6 (26.09%) | .284 |
| Sepsis                                       | 2 (8.00%) | 3 (1.47%) | 1 (4.35%) | .085 |
| Wound infection                              | 1 (4.00%) | 1 (0.49%) | 3 (13.04%) | .002 |
| Seizure disorders                            | 1 (4.00%) | 1 (0.49%) | 1 (4.35%) | .345 |
| PTLD                                         | 1 (4.00%) | 1 (0.49%) | 0 (0%) | .345 |
| Reoperation                                  | 5 (20.00%) | 5 (2.45%) | 3 (13.04%) | .001 |

GRWR, graft-to-recipient weight ratio; PTLD, post-transplant lymphoproliferative disorders.
partial liver transplants with a GRWR ranging from 0.61% to 6.0% with respect to blood supply, tissue oxygenation, and metabolic capacity, as long as the liver graft is anatomically fit to the recipient. Furthermore, the authors also reported that living-related partial liver transplantation for small infants with relatively large grafts can be performed successfully when blood flow to the graft is ensured. Shunt ligation should be performed as needed by duplex Doppler sonography. In addition, the authors speculated that living-related partial liver transplantation for adolescents or adults with relatively small grafts can be performed successfully when early regeneration is ensured.19

A recent study reported that when infant recipients weighed ≤8 kg and had a GRWR within the range of 1.9% and 5.8%, no noticeable adverse events occurred. However, it was speculated that a reduction in the graft mass should still be considered an applicable strategy for select cases.12

A report by Bonatti et al highlighted two major complications that resulted from transplanting a graft that is too large. The first is inadequate perfusion of the liver, resulting in graft dysfunction, and the second is abdominal wall closure, which can cause graft compression or diaphragmatic splinting and can result in respiratory complications. Temporary abdominal closure using a silastic patch is advisable in such cases.20 The study showed that reduction in the left lateral segment (LLS) was considered when the estimated GRWR of the LLS of the donor was >4.0%. In one case, when the GRWR was >4.0% and the ratio of thickness (the ratio of the maximum thickness of the LLS to the anteroposterior diameter in the recipient’s abdominal cavity) was <1.0, non-anatomically reducing LLS was considered. In another case, when the GRWR was >4.0% and the ratio of thickness was ≥1.0, a segment 2 graft was considered.21 In contrast, several studies maintain that the GRWR should be at least 1% in pediatric LDLT. However,
intestinal fistula/bile leakage/biliary-enteric anastomotic fistula was more frequently observed in the recipients with GRWR <2%, and small-for-size syndrome may occur. Then, small-for-size syndrome can induce biliary endothelial injury, resulting in biliary complications. Another possibility may be that the number of patients with less can affect the statistical accuracy. With the development of surgical techniques, auxiliary LT compensation for insufficient initial function of small-for-size grafts has been gradually established.

Some limitations were present in this study. The first limitation is its retrospective nature and the fact that we enrolled a large portion of BA patients. BA is the main diagnosis leading to LT in children. When diagnosed early in life, a Kasai portoenterostomy (Kasai-PE) can prevent or postpone LT. When properly performed, the Kasai procedure can postpone LT and positively affect outcomes. Having a K-PE and having not performed a Kasai-PE had the same effect in patient and graft survival; however, a previous Kasai-PE can increase post-LT complications as biliary complications and bowel perforations. In China, Kasai surgery has not been popularized, and the experience of each center is insufficient. Meanwhile, the incidence of cholangitis after Kasai is high in China, so the efficacy of Kasai is not same as that of foreign countries. Even so, we transplant, doctors still recommend patients to undergo Kasai surgery first. Second, selection bias might have influenced the outcomes. Third, we did not determine a safe lower and upper limit in our study. Fourth, the recipients with a GRWR less than 2% were inevitably older, which possibly affected the patient outcomes, but we did not take this into consideration.

In conclusion, the GRWR in pediatric LDLT is a major risk factor that affects graft survival. We recommend a GRWR between 2.0% and 4.0% as the optimal range. This study has the potential to provide clinical evidence for the donor selection process. However, a more comprehensive investigation of the safe lower and upper limits of GRWR is required.

ACKNOWLEDGEMENTS

The study was supported by National Science Foundation of China (81170443, 81670600, 81700556), Tianjin Health Bureau of Science and Technology fund (2014KY08), National Key Clinical Specialty Construction Project of Organ Transplantation Department (2013544), International S&T Cooperation Program of China (2015DFG31850).

CONFLICTS OF INTEREST

No conflicts of interest in any form existed.

AUTHORS’ CONTRIBUTIONS

Jin-zhen Cai and Zhong-yang Shen: Conceptualized and designed the study; Jun-jie Li and Cai-hua Zu: Participated in collection, analysis, and interpretation of the data and drafted the article; Jin-zhen Cai, Shi-peng Li, Wei Gao, Jun-jie Li, and Cai-hua Zu: Offered important data or suggestions for this work and revised the manuscript critically for intellectual content; Jun-jie Li and Cai-hua Zu: Contributed equally to this work.

ETHICAL APPROVAL

All living donors were required to pass through the Institutional Review Board of Tianjin First Center Hospital.

ORCID

Jin-Zhen Cai http://orcid.org/0000-0001-5414-1050

REFERENCES

1. Raia S, Nery JR, Mies S. Liver transplantation from live donors. Lancet. 1989;2:497.
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;322:1505-1507.
3. Tanaka K, Uemoto S, Tokunaga Y, et al. Surgical techniques and innovations in living related liver transplantation. Ann Surg. 1993;217:82-91.
4. Makuchii M, Kawasaki S, Noguchi T, et al. Donor hepatectomy for living related partial liver transplantation. Surgery. 1993;113:395-402.
5. Milis JM, Cronin DC, Brady LM, et al. Primary living-donor liver transplantation at the University of Chicago: technical aspects of the first 104 recipients. Ann Surg. 2000;232:104-111.
6. Ueda M, Oike F, Ogura Y, et al. Long-term outcomes of 600 living donor liver transplants for pediatric patients at a single center. Liver Transpl. 2006;12:1336-1336.
7. Devictor D, Tissieres P. Pediatric liver transplantation: where do we stand? Where are we going? Expert Rev Gastroenterol Hepatol. 2013;7:629-641.
8. Emre S, Uzman V, Rodriguez-Davalos M. Current concepts in pediatric liver tumors. Pediatr Transplant. 2012;16:549-563.
9. Kelly DA, Bucuvalas JC, Alonso EM, et al. Long-term medical management of the pediatric patient after liver transplantation: 2013 practice guideline by the American Association for the Study of Liver Diseases and the American Society of Transplantation. Liver Transpl. 2013;19:798-825.
10. Kasahara M, de Ville DGJ. Reducing left liver lobe grafts, more or less? Don’t throw out the baby with the bath water. Pediatr Transplant. 2015;19:815-817.
11. Kasahara M, Sakamoto S, Umeshita K, Uemoto S. Effect of graft size matching on pediatric living-donor liver transplantation in Japan. Exp Clin Transplant. 2014;12(Suppl 1):1-4.
12. Wan P, Li Q, Zhang J, et al. Influence of graft size matching on outcomes of infantile living donor liver transplantation. Pediatr Transplant. 2015;19:880-887.
13. Kluchi T, Kasahara M, Uryuhara K, et al. Impact of graft size mismatching on graft prognosis in liver transplantation from living donors. Transplantation. 1999;67:321-327.
14. Dahm F, Georgiev P, Clavien PA. Small-for-size syndrome after partial liver transplantation: definition, mechanisms of disease and clinical implications. Am J Transplant. 2005;5:2605-2610.
15. Moon JI, Kwon CH, Joh JW, et al. Safety of small-for-size grafts in adult-to-adult living donor liver transplantation using the right lobe. Liver Transpl. 2010;16:864-869.
16. Lee SD, Kim SH, Kim YK, Lee SA, Park SJ. Graft-to-recipient weight ratio lower to 0.7% is safe without portal pressure modulation in right-lobe living donor liver transplantation with favorable conditions. Hepatobiliary Pancreat Dis Int. 2014;13:18-24.
17. Levesque E, Duclos J, Ciaccio O, Adam R, Castaing D, Vibert E. Influence of larger graft weight to recipient weight on the post-liver transplantation course. Clin Transplant. 2013;27:229-247.
18. Noda T, Todani T, Watanabe Y, Yamamoto S. Liver volume in children measured by computed tomography. Pediatr Radiol. 1997;27:250-252.
19. Tanaka A, Tanaka K, Tokuka A, et al. Graft size-matching in living-related partial liver transplantation in relation to tissue oxygenation and metabolic capacity. *Transpl Int*. 1996;9:15-22.

20. Bonatti H, Muiesan P, Connelly S, et al. Hepatic transplantation in children under 3 months of age: a single centre’s experience. *J Pediatr Surg*. 1997;32:486-488.

21. Sakamoto S, Kanazawa H, Shigeta T, et al. Technical considerations of living donor heptectomy of segment 2 grafts for infants. *Surgery*. 2014;156:1232-1237.

22. Neto JS, Feier FH, Bierrenbach AL, et al. Impact of Kasai portoenterostomy on liver transplantation outcomes: a retrospective cohort study of 347 children with biliary atresia. *Liver Transpl*. 2015;21:922-927.

How to cite this article: Li J-J, Zu C-H, Li S-P, Gao W, Shen Z-Y, Cai J-Z. Effect of graft size matching on pediatric living-donor liver transplantation at a single center. *Clin Transplant*. 2018;32:e13160. [https://doi.org/10.1111/ctr.13160](https://doi.org/10.1111/ctr.13160)