Pure Laparoscopic Versus Open Right Hepatectomy in Living Liver Donors: Graft Weight Discrepancy

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Background: Accurate volumetric evaluation of donors’ livers before surgery is crucial for successful living-donor liver transplantation. However, there are few studies on the volumetric evaluation in the recently popularized pure laparoscopic donor hepatectomy method, in contrast to the number of studies for conventional donor hepatectomy. We aimed to analyze the difference between estimated graft weight and actual graft weight in pure laparoscopic donor right hepatectomy (PLDRH) and conventional donor right hepatectomy (CDRH) procedures.

Material/Methods: The medical records of 612 donors who underwent right hepatectomy in living-donor liver transplantation between January 2014 and December 2020 were retrospectively reviewed. The CDRH group targeted patients from January 2014 to October 2015, and the PLDRH group targeted patients from March 2016 to December 2020.

Results: There were 119 and 376 donors who underwent CDRH and PLDRH, respectively. Although there was no significant difference in the estimated graft weights (P=0.994) and actual graft weights (P=0.489) between the groups, the estimated graft weights were significantly higher than the actual graft weights in both groups. However, the estimated graft weight and actual graft weight showed linear correlations in both the CDRH (r=0.81, P<0.001) and PLDRH (r=0.76, P<0.001) groups, with the CDRH group having greater linearity.

Conclusions: The estimates of graft weight were similar between the 2 groups. However, since the actual graft weight tended to be smaller in the PLDRH group, this should be considered before surgery.

Keywords: Hepatectomy • Laparoscopy • Liver Transplantation • Living Donors

Abbreviations: AGW – actual graft weight; CDRH – conventional donor right hepatectomy; DAA – direct-acting antiviral agents; EGW – estimated graft weight; GRWR – graft-to-recipient weight ratio; HCC – hepatocellular carcinoma; HCV – hepatitis C virus; LDLT – living-donor liver transplantation; MELD – Model for End-stage Liver Disease; NAFLD – non-alcoholic fatty liver disease; NASH – non-alcoholic steatohepatitis; PLDH – pure laparoscopic donor hepatectomy; PLDRH – pure laparoscopic donor right hepatectomy; SFSS – small-for-size syndrome

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Background

Liver transplantation is currently considered the criterion standard treatment for patients with end-stage liver disease. The use of living-donor liver transplantation (LDLT) in particular is increasing worldwide owing to its advantages [1]. Its faster transplantation route has alleviated deficiencies in organs from deceased donors and reduced mortality in patients awaiting liver transplantation [1].

However, accurate volumetric determination, which is necessary for an accurate remnant liver volume and graft-to-recipient weight ratio (GRWR), is crucial for the safety of both the donors and recipients [2]. While a remnant liver volume of 30-35% of the original volume is required for donor safety, recipients need at least 40% of the standard liver volume or a 0.8% GRWR [3].

With the recent increase in liver transplantation, as well as the development of new surgical techniques and increased experience among surgeons, pure laparoscopic donor hepatectomy (PLDH) has emerged to satisfy donors’ cosmetic and functional needs. As several studies have confirmed its feasibility and safety, more centers are beginning to use PLDH [4-6]. However, compared to conventional donor hepatectomy, little attention has been paid to volumetric evaluation in PLDH.

Since the initiation of PLDH program in November 2015, our center performed more than 400 cases of PLDH, most of which were right hepatectomies. The aim of this study was to analyze the difference between the estimated graft weight (EGW) and actual graft weight (AGW) in pure laparoscopic donor right hepatectomy (PLDRH), and to compare the correlation between the EGW and AGW with that in conventional donor right hepatectomy (CDRH). This may be one of the largest studies to compare graft weights between PLDRH and CDRH procedures.

Material and Methods

Study Design and Patients

This retrospective study analyzed graft weight discrepancies according to surgical methods in LDLT. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Institutional Review Board of the Seoul National University Hospital (IRB no. 2111-097-1272).

A total of 612 living donors who underwent right hepatectomy between January 2014 and December 2020 at the Seoul National University Hospital (Seoul, South Korea) were enrolled in our study. Donors who underwent extended right hepatectomy were excluded from the study. We divided the patients into 2 groups: the CDRH group, comprising 144 patients who underwent conventional open surgeries between January 2014 and October 2015, and the PLDRH group, comprising 431 patients who underwent PLDH from March 2016 to December 2020. Donors who underwent hepatectomy between these 2 periods were excluded. Donors who underwent laparoscopy-assisted CDRH and CDRH after the standardization of PLDRH were also excluded. Finally, 119 donors from the CDRH group and 376 donors from the PLDRH group were included in the data analysis (Figure 1).

CT Volumetric Protocol

All LDLT donors underwent preoperative imaging evaluation with multidetector row helical computed tomography (CT) according to the standard protocol for multiphasic liver CT imaging (reconstruction section thickness, 2.5-3 mm). The EGW was measured using 3D CT image reconstruction software (Dr. Liver; Humanopia Co., Ltd., Pohang-si, South Korea). The surgical team measured the EGW along the planned surgical plane. Gallbladder, blood, and other vascular and biliary structures were excluded during the calculation of liver volume. The density value was set at 1.00 g/mL.

Figure 1. Study design.
Actual Graft Weight Measurement

After the liver graft was resected, it was washed out with HTK solution (Custodiol, Kohler Pharma GmbH, Alsbach, Germany) through the main branches at the hilum and cooled to 4°C for preservation. Once the intrahepatic liquid turned clear, the graft weight was measured using a calibrated electronic laboratory scale.

Statistical Analysis

Results are expressed as mean±standard deviation (SD) for continuous variables and absolute numbers (percentage) for categorical variables. The t test was used to compare continuous variables. The chi-square test or Fisher’s exact test was used to compare categorical variables. The Pearson correlation coefficient was used to analyze discrepancies between the EGW and AGW for both the CDRH and PLDRH groups. Linear regression analysis was used to compare the correlations of EGW and AGW between the 2 groups. Statistical significance was set at P<0.05. Data analysis was performed using SPSS version 21 (SPSS, Inc., Chicago, IL, USA).

Results

We retrospectively reviewed the baseline characteristics and operative outcomes of 495 living donors. The results are summarized in Table 1. The donors in the PLDRH group were slightly younger than those in the CDRH group (36.5±12.7 vs 33.6±10.8 years; P=0.026). Donors in the PLDRH group had more bile duct anomalies, which were evaluated by preoperative radiological imaging (41.5% vs 30.3%; P=0.028), but less anomalies in the right inferior hepatic vein (42.3% vs 58.5%; P=0.002). The PLDRH group had a longer operative time (260.9±66.1 vs 237.5±48.1 minutes; P=0.001); warm ischemia time (13±18 vs 4±4 minutes; P=0.001), defined as the time from hepatic artery ligation to liver removal; and bench work time (59.2±20.6 vs 43.1±18.6 minutes; P=0.001) than the CDRH group. However, the PLDRH group had less blood loss (257.8±194.6 vs 300.8±167.1 ml; P=0.020) and a shorter length of hospital stay (7.2±2.4 vs 8.5±1.8 days; P=0.001) than the CDRH group. ΔAST% (1244.7±512.9 vs 958.0±430.6; P=0.001), defined as 

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\frac{\text{peak AST} - \text{preoperative AST}}{\text{preoperative AST}} \times 100
\]

, ΔALT% (1548.5±788.9 vs 1100.9±546.3; P=0.001) and Δbilirubin% (847.2±497.8 vs 657.9±389.6; P=0.001), both of which were calculated using the same formula as that for ΔAST%, were all higher in the PLDRH group than in the CDRH group. Regarding postoperative hemoglobin (Hb) levels, there was no difference in the lowest hemoglobin level, but ΔHb% showed a marginal significance, which suggests that the PLDRH group had a small change in Hb levels (20.4±7.1 vs 21.6±5.1; P=0.051). The 2 groups showed no differences in donor sex, BMI, ABO compatibility, abdominal surgery history, preoperative blood tests, or the proportion of donors with diabetes mellitus and hepatitis B virus core antibody. There were no significant differences in postoperative complications. The median follow-up duration was 1499 (25-2836) days in the CDRH group and 757 (10-2052) days in the PLDRH group.

The recipients’ baseline characteristics are summarized in Table 2. The recipients in the PLDRH group were older (55.7±10.9 vs 53.2±12.4 years; P=0.038) and heavier (65.6±11.6 vs 61.5±12.5 kg; P=0.001) than the CDRH group. There were also differences in the underlying etiology (P=0.019) and real GRWR (1.2±0.3 vs 1.1±0.3; P=0.031) between the 2 groups. There were no differences in the recipients’ sex, model for end-stage liver disease (MELD) scores, Child–Pugh scores, estimated GRWR, or proportion of recipients with hepatocellular carcinoma (HCC). The lengths of postoperative hospital stay and rates of major complications, defined as complications with a Clavien–Dindo classification over grade III [7], were similar between the 2 groups (Table 3). However, the rates of early (within 30 days after LDLT) and late (after 30 days) major biliary complications were higher in the PLDRH group compared to the CDRH group.

There were no significant differences between the CDRH and PLDRH groups in terms of EGW (792.3±169.9 vs 7r2.2±171.3 g; P=0.994) or AGW (712.5±142.0 vs 722.9±138.5 g; P=0.489). (Table 1). The means of EGW and AGW were 790.5±172.5 g and 715.1±141.6 g in the CDRH group and 792.7±171.2 g and 722.9±138.5 g in the PLDRH group, respectively. The EGW was higher than the AGW in both groups (P<0.001). However, there was a significant correlation between the EGW and AGW in both groups (r=0.81, P=0.001 in the CDRH group and r=0.76, P<0.001 in the PLDRH group), with the CDRH group showing a higher linear correlation than the PLDRH group (r=0.66, P<0.001 versus r=0.58, P<0.001) (Table 4, Figure 2).

Discussion

Since PLDRH was first performed in 2010 [8], it has been performed by experienced surgeons and teams worldwide [9]. Our center previously reported its feasibility and safety based on 300 PLDRH procedures performed from 2016 to 2018 [10]. Accurate graft size is an important factor in liver transplantation that is necessary for donor evaluation and the prevention of small-for-size syndrome (SFSS) in recipients [2]. However, some studies have shown that estimations of graft weight using CT differ from the actual weights [11,12]. Moreover, graft discrepancies in PLDRH have not been fully evaluated. Our study showed that the EGW was significantly higher than AGW in both the CDRH and PLDRH groups (P<0.001 in both
Table 1. Baseline characteristics and operative outcomes of liver donors who underwent CDRH and PLDRH.

| Variables                        | CDRH (n=119) | PLDRH (n=376) | P value |
|----------------------------------|--------------|---------------|---------|
| Sex                              |              |               | 0.857   |
| Male                             | 72           | 224           |         |
| Female                           | 47           | 152           |         |
| Age, years                       | 36.5±12.7    | 33.6±10.8     | 0.026   |
| BMI, kg/m²                       | 23.3±3.1     | 23.8±3.3      | 0.105   |
| DM                               | 2 (1.7)      | 1 (0.3)       | 0.145   |
| HTN                              | 9 (7.6)      | 12 (3.2)      | 0.039   |
| ABO compatibility                |              |               | 0.102   |
| Compatible                       | 104 (87.4)   | 304 (80.9)    |         |
| Incompatible                     | 15 (12.6)    | 72 (19.1)     |         |
| Abdominal OP history             | 24 (20.5)    | 63 (16.8)     | 0.358   |
| Missing                          | 2            | 1             |         |
| Preoperative blood tests         |              |               |         |
| Hb, g/dL                         | 14.8±1.4     | 14.7±1.4      | 0.397   |
| Total bilirubin, mg/dL           | 0.5±0.3      | 0.5±0.3       | 0.468   |
| AST, IU/L                        | 16.6±3.3     | 16.8±3.6      | 0.559   |
| ALT, IU/L                        | 15.8±6.7     | 15.9±7.3      | 0.871   |
| CT graft variation               | 90 (75.6)    | 267 (71)      | 0.327   |
| Bile duct                        | 36 (30.3)    | 156 (41.5)    | 0.028   |
| Portal vein                      | 23 (19.3)    | 70 (18.6)     | 0.863   |
| Hepatic artery                   | 5 (4.2)      | 11 (2.9)      | 0.552   |
| Right inferior hepatic vein      | 70 (58.8)    | 159 (42.3)    | 0.002   |
| Operative time, minutes          | 237.5±48.1   | 260.9±66.1    | <0.001  |
| Warm ischemia time, minutes*     | 4±4          | 13±18         | <0.001  |
| Missing                          | 7            | 7             |         |
| Bench work time, minutes         | 43.1±18.6    | 59.2±20.6     | <0.001  |
| Missing                          | 9            | 14            |         |
| Blood loss, mL                   | 300.8±167.1  | 257.8±194.6   | 0.020   |
| Missing                          | 0            | 2             |         |
| Fatty change, %                  |              |               |         |
| Macrovesicular                   | 2.6±2.6      | 2.0±2.9       | 0.066   |
| Microvesicular                   | 1.8±2.0      | 1.4±2.9       | 0.170   |
| Missing                          | 5            | 4             |         |
| Graft weight, g                  |              |               |         |
| Estimated graft weight           | 792.3±169.9  | 792.2±171.3   | 0.994   |
| Missing                          | 2            | 0             |         |
| Actual graft weight              | 712.5±142.0  | 722.9±138.5   | 0.489   |
Table 1 continued. Baseline characteristics and operative outcomes of liver donors who underwent CDRH and PLDRH.

| Variables               | CDRH (n=119) | PLDRH (n=376) | P value |
|-------------------------|--------------|---------------|---------|
| Missing                 | 6            | 1             |         |
| HBcAb                   | 13 (11)      | 65 (17.3)     | 0.101   |
| Missing                 | 1            | 1             |         |

Postoperative blood tests

| Variable               | CDRH          | PLDRH         | P value |
|------------------------|---------------|---------------|---------|
| Hb, g/dL               | 11.6±1.3      | 11.7±1.4      | 0.702   |
| ΔHb%**                 | 21.6±5.1      | 20.4±7.1      | 0.051   |
| Total bilirubin, mg/dL | 3.6±1.8       | 4.2±2.0       | 0.004   |
| Δbilirubin%***         | 657.9±389.6   | 847.2±497.8   | <0.001  |

AST, IU/L

| Variable               | CDRH          | PLDRH         | P value |
|------------------------|---------------|---------------|---------|
| Peak                   | 170.5±59.4    | 222.3±92.4    | <0.001  |
| ΔAST%*                 | 958.0±430.6   | 1244.7±512.9  | <0.001  |
| ALT, IU/L              |               |               |         |
| Peak                   | 170.0±67.2    | 232.5±91.0    | <0.001  |
| ΔALT%**                | 1100.9±546.3  | 1548.5±788.9  | <0.001  |

Hospital stays, days

| Variable               | CDRH          | PLDRH         | P value |
|------------------------|---------------|---------------|---------|
| 8.5±1.8                |               | 7.2±2.4       | <0.001  |

Postoperative complications###

| Variable               | CDRH          | PLDRH         | P value |
|------------------------|---------------|---------------|---------|
| 5 (4.2)                |               | 27 (7.2)      | 0.249   |
| Minor                  | 2 (1.7)       | 10 (2.7)      | 0.739   |
| Hyperbilirubinemia     | 2 (1.7)       | 4 (1.1)       | 0.634   |
| Wound                  | 0             | 3 (0.8)       | 1.000   |
| Fluid                  | 0             | 1 (0.3)       | 1.000   |
| Ascites                | 0             | 1 (0.3)       | 1.000   |
| HV narrowing           | 0             | 1 (0.3)       | 1.000   |
| Others                 | 0             | 1 (0.3)       | 1.000   |
| Major                  | 3 (2.5)       | 19 (5.1)      | 0.243   |
| Bleeding               | 0             | 2 (0.5)       | 1.000   |
| Infection(anti)        | 2 (1.7)       | 11 (2.9)      | 0.743   |
| Others                 | 1 (0.8)       | 8 (2.1)       | 0.694   |

Data are given as mean±SD or n (%). BMI – body mass index; DM – diabetes mellitus; HTN – hypertension; Hb – hemoglobin; AST – aspartate aminotransferase; ALT – alanine aminotransferase; CT – computed tomography; HBcAb – hepatitis B core antibody; HV – hepatic vein.

* Warm ischemia time was defined as the time from hepatic artery ligation to the time when the liver was removed.
** ΔHb% = ([preoperative Hb – postoperative Hb]/preoperative Hb)×100.
*** Δbilirubin% = ([preoperative bilirubin – postoperative bilirubin]/preoperative bilirubin)×100.
* ΔAST% = ([preoperative AST – postoperative AST]/preoperative AST)×100.
** ΔALT% = ([preoperative ALT – postoperative ALT]/preoperative ALT)×100.
### Major complications were defined as a Clavien-Dindo grade ≥3.
Factors that affect the accuracy of the EGW include the fact that the blood volume may not have been completely excluded during volume measurements [2,13]. Although the Dr. Liver program, which was used for volumetry, excludes the volume of vascular and biliary structures, it is difficult to completely exclude the blood volume of the peripheral vessels. The difference between the actual surgical transection plane and the radiological transection plane may also have contributed to overestimation of the EGW [3,14]. Moreover, previous studies reported that an organ-preserving solution can cause dehydration of the graft due to its osmolarity [15,16], leading to a reduction in the AGW and an overestimation of the EGW. Although the EGW was higher than the AGW, there was a significant correlation between the 2. The correlation coefficient (r) was 0.814 in the CDRH group and 0.759 in the PLDRH group, both of which indicate a strong positive correlation. However, the coefficient was slightly higher in CDRH group. Similarly, the R² value, which shows a linear relationship between the 2 variables, was slightly higher in the CDRH group. The higher discrepancy in the PLDRH group may be due to the use of clips and staplers during PLDRH surgery, whereas the vasculature and bile ducts are incised and sutured during CDRH. The use of clips and staplers takes up space, and thus the division point will be more inclined toward the graft than expected [17].

Although there may be other factors that affect the graft weight [3,18,19], there are no large-scale studies investigating these factors and their effects. We analyzed the donor and recipient characteristics to see if there were differences between the PLDRH and CDRH groups, and investigated their influence on the graft weight. Donor age was lower in the PLDRH group. This may be due to PLDRH being preferred for cosmetic purposes and providing a better quality of life [5,10,20]. Thus, the number of young people, especially young women, opting for PLDRH is increasing. Since the donors were young, the number of patients with hypertension seemed to be smaller due to fewer underlying diseases. Kayashima et al [16] suggested that younger donors can develop more capillary vascular beds, which can lead to an increase in the EGW and vulnerability to dehydration. However, the difference was minimal in our study (36.5 vs 33.6 years), and the influence of donor age was reduced in our study by using the HTK solution as the organ perfusion solution, which has a lower osmolarity than the UW (University of Wisconsin) solution that was used in previous studies.

### Table 2. Baseline characteristics of CDRH and PLDRH recipients.

| Variables          | CDRH (n=119) | PLDRH (n=376) | P value |
|--------------------|--------------|---------------|---------|
| Sex                |              |               | 0.398   |
| Male               | 79 (66.4)    | 265 (70.5)    |         |
| Female             | 40 (33.6)    | 111 (29.5)    |         |
| Age, years         | 53.2±12.4    | 55.7±10.9     | 0.038   |
| Body weight, kg    | 61.5±12.5    | 65.6±11.6     | 0.001   |
| Underlying etiology|              |               |         |
| HBV                | 68 (57.1)    | 206 (54.8)    | 0.022   |
| HCV                | 17 (14.3)    | 26 (6.9)      | 0.013   |
| Others             | 37 (31.1)    | 158 (42.0)    | 0.033   |
| HCC                | 71 (59.7)    | 224 (59.6)    | 0.986   |
| MELD               | 15.5±7.6     | 14.1±6.1      | 0.075   |
| Child-Pugh         | 8.1±2.5      | 7.7±2.4       | 0.120   |
| Missing            | 0            | 3             |         |
| estimated GRWR     | 1.3±0.3      | 1.2±0.3       | 0.105   |
| Missing            | 1            | 0             |         |
| real GRWR          | 1.2±0.3      | 1.1±0.3       | 0.031   |
| Missing            | 6            | 1             |         |

Data are given as mean±SD or n (%).
| Variables                        | CDRH (n=119) | PLDRH (n=376) | P value |
|----------------------------------|--------------|---------------|---------|
| Hospital stay, days              | 26.1±37.3    | 21.6±20.4     | 0.205   |
| Early major complications        | 35 (29.4)    | 104 (27.7)    | 0.711   |
| Intra-abdominal bleeding         | 14 (11.8)    | 31 (8.2)      | 0.244   |
| Hepatic artery problems          | 2 (1.7)      | 5 (1.3)       | 0.676   |
| Portal vein problems             | 5 (4.2)      | 7 (1.9)       | 0.171   |
| Hepatic vein problems            | 5 (4.2)      | 7 (1.9)       | 0.121   |
| Biliary problems                 | 3 (2.5)      | 36 (9.6)      | 0.013   |
| Intra-abdominal fluid collection | 2 (1.7)      | 13 (3.5)      | 0.529   |
| Wound problems                   | 2 (1.7)      | 9 (2.4)       | 1.000   |
| Cardiac problems                 | 1 (0.8)      | 5 (1.3)       | 1.000   |
| Pulmonary problems               | 5 (4.2)      | 8 (2.1)       | 0.320   |
| Gastrointestinal problems        | 4 (3.4)      | 3 (0.8)       | 0.061   |
| Lymphatic problems               | 1 (0.8)      | 0             | 0.240   |
| Primary nonfunction              | 1 (0.8)      | 0             | 0.240   |
| Sepsis                           | 2 (1.7)      | 8 (2.1)       | 0.494   |
| Neurological problems            | 0            | 1 (0.3)       | 1.000   |
| Kidney problems                  | 0            | 1 (0.3)       | 1.000   |
| Others                           | 0            | 6 (1.6)       | 0.344   |
| Late major complication          | 46 (38.7)    | 174 (46.3)    | 0.145   |
| Intra-abdominal bleeding         | 2 (1.7)      | 11 (2.9)      | 0.743   |
| Hepatic artery problems          | 1 (0.8)      | 1 (0.3)       | 0.423   |
| Portal vein problems             | 1 (0.8)      | 10 (2.7)      | 0.473   |
| Hepatic vein problems            | 2 (1.7)      | 10 (2.7)      | 0.739   |
| Biliary problems                 | 26 (21.8)    | 141 (37.5)    | 0.002   |
| Intra-abdominal fluid collection | 7 (5.9)      | 27 (7.2)      | 0.625   |
| Wound problems                   | 1 (0.8)      | 1 (0.3)       | 0.423   |
| Cardiac problems                 | 0            | 4 (1.1)       | 0.577   |
| Pulmonary problems               | 5 (4.2)      | 15 (4.0)      | 1.000   |
| Gastrointestinal problems        | 6 (5.0)      | 7 (1.9)       | 0.092   |
| Bone problems                    | 1 (0.8)      | 0             | 0.240   |
| Kidney problems                  | 0            | 1 (0.3)       | 1.000   |
| Sepsis                           | 7 (5.9)      | 17 (4.5)      | 0.547   |
| Neurological problems            | 2 (1.7)      | 5 (1.3)       | 0.676   |
| Others                           | 4 (3.4)      | 20 (5.3)      | 0.386   |
| Retransplantation                | 1 (0.8)      | 2 (0.5)       | 0.563   |

Data are given as mean±SD or n (%).
There were more bile duct anomalies in donors in the PLDRH group than there were in the CDRH group. This may be due to the absence of selection criteria for liver anatomy at our center. Although there were few right inferior hepatic vein variations in donors in the PLDRH group, there were still no clear selection criteria. Anatomical variations between the 2 groups were well handled during the surgery. The fact that there was no difference in postoperative complications between the 2 groups demonstrates this.

The underlying etiologies of the recipients were different between the 2 groups. Since the development of direct-acting antiviral agents (DAAs) for hepatitis C virus (HCV), hepatitis C can now be cured and the number of liver transplantations due to HCV has been decreasing [21]. However, with the worldwide increase in alcohol consumption, alcoholic liver disease has increased [22]. Non-alcoholic fatty liver disease (NAFLD) and non-alcoholic steatohepatitis (NASH) have also increased due to the rising prevalence of diabetes and metabolic syndromes [23,24]. As the recipients in the PLDRH group included more recent patients, the number of recipients with HCV-related liver diseases decreased was lower, while other etiologies, including alcoholic liver disease, NAFLD, and NASH, were higher in the PLDRH group. However, recipient etiology did not significantly affect graft weight.

The recipients in the PLDRH group were older and heavier than those in the CDRH group. As population aging continues and surgical techniques develop, recipients’ ages have also increased. In addition, the mean BMI was higher due to changes in eating habits and obesity. Studies have demonstrated that older and heavier people have a poor prognosis in LDLT [25-27]. This may allow operators to cut out more grafts, but the actual graft weight was smaller. In addition, there were only small differences in age or weight between the 2 groups. Therefore, differences in recipient age and weight did not seem to confound the results.

This study also confirmed the general characteristics of PLDRH. The operative time, warm ischemia time, and bench work time were significantly longer, and the blood loss was lower in the PLDRH group, as previously reported [10,28,29]. Laparoscopic procedures are known to have a learning curve [17,30], with the operative time gradually decreasing with the accumulation of the center’s experience. Thus, the mean operation time of PLDRH was 260.9 minutes in this study, which was shorter than the PLDRH group.

Table 4. Mean estimated graft weights and actual graft weights of CDRH and PLDRH groups.

| Variables         | CDRH (n=119) | PLDRH (n=376) | P value |
|-------------------|--------------|---------------|---------|
| Estimated graft weight | 792.3±169.9 | 792.2±171.3 | 0.994   |
| Missing | 2 | 0 |
| Actual graft weight | 712.5±142.0 | 722.9±138.5 | 0.489   |
| Missing | 6 | 1 |

Data are given as mean±SD.

There were more bile duct anomalies in donors in the PLDRH group than there were in the CDRH group. This may be due to the absence of selection criteria for liver anatomy at our center. Although there were few right inferior hepatic vein variations in donors in the PLDRH group, there were still no clear selection criteria. Anatomical variations between the 2 groups were well handled during the surgery. The fact that there was no difference in postoperative complications between the 2 groups demonstrates this.

The underlying etiologies of the recipients were different between the 2 groups. Since the development of direct-acting antiviral agents (DAAs) for hepatitis C virus (HCV), hepatitis C can now be cured and the number of liver transplantations due to HCV has been decreasing [21]. However, with the worldwide increase in alcohol consumption, alcoholic liver disease has increased [22]. Non-alcoholic fatty liver disease (NAFLD) and non-alcoholic steatohepatitis (NASH) have also increased due to the rising prevalence of diabetes and metabolic syndromes [23,24]. As the recipients in the PLDRH group included more recent patients, the number of recipients with HCV-related liver diseases decreased was lower, while other etiologies, including alcoholic liver disease, NAFLD, and NASH, were higher in the PLDRH group. However, recipient etiology did not significantly affect graft weight.

The recipients in the PLDRH group were older and heavier than those in the CDRH group. As population aging continues and surgical techniques develop, recipients’ ages have also increased. In addition, the mean BMI was higher due to changes in eating habits and obesity. Studies have demonstrated that older and heavier people have a poor prognosis in LDLT [25-27]. This may allow operators to cut out more grafts, but the actual graft weight was smaller. In addition, there were only small differences in age or weight between the 2 groups. Therefore, differences in recipient age and weight did not seem to confound the results.

This study also confirmed the general characteristics of PLDRH. The operative time, warm ischemia time, and bench work time were significantly longer, and the blood loss was lower in the PLDRH group, as previously reported [10,28,29]. Laparoscopic procedures are known to have a learning curve [17,30], with the operative time gradually decreasing with the accumulation of the center’s experience. Thus, the mean operation time of PLDRH was 260.9 minutes in this study, which was shorter than
that reported in our previous study [10]. Postoperative blood test results were different between the 2 groups. The peak bilirubin and ∆bilirubin%, peak AST and ∆AST%, and peak ALT and ∆ALT% of the donor were all higher in the PLDRH group than those in the CDRH group. ∆Hb% tended to be lower in the PLDRH group (P=0.051). Although postoperative peak bilirubin, AST levels, and ALT levels were higher, hospital stay duration was shorter in the PLDRH group. This result also corresponds with the findings of our previous studies [10,17,31]. The recipient outcomes are also in accord with those reported in our previous study [10]. The postoperative outcomes, including hospital stay, complications, and rate of retransplantation, were similar between the PLDRH and CDRH groups. However, the rates of both early and late major biliary complications were higher in the PLDRH group than in the CDRH group. This can be explained by a larger number of bile duct anomalies, as well as longer operative time, warm ischemia time, and bench work time, in the PLDRH group compared to the CDRH group.

To the best of our knowledge, this is one of the largest studies to evaluate graft weight discrepancy in patients who underwent PLDRH. However, this study has several limitations. First, the results of this study were from a single center; thus, it may be difficult to generalize our results to other centers. In addition, since this was a retrospective study, there may be a selection bias, such as underreported postoperative complications. Second, there are some factors that may have affected graft weight that have not been fully considered. For instance, Hiroshige et al [15] reported that liver grafts were gradually dehydrated by the organ perfusion solution. Further studies measuring the weight of the liver graft at each step of the back-table procedure are required. Third, the ratio of graft volume (GV) to standard liver volume (SLV), which is another concept used to evaluate graft size for a recipient, was not considered in this study [32,33]. Urrata et al demonstrated that the conversion ratio for liver weight and liver volume was 1.12 g/mL, rather than 1.0 g/mL [34]. Furthermore, Toshima et al reported that a recipient’s BMI or physique should be considered (BMI >30 or ≤30 kg/m²) when calculating GV/SLV, to better predict actual SFSS [33]. Considering that our LDLT protocol is based on GRWR with a minimum acceptance of 0.8%, the concept of GV/SLV was not included in the present study. Further studies should include this concept, the actual outcomes according to GV/SLV, and finally, the impact of PLDRH on GV/SLV compared to CDRH.

**Conclusions**

Graft weight was overestimated in both the PLDRH and CDRH groups. Although the difference between the 2 groups was not substantial, the AGW tended to be smaller in the PLDRH group, which should be taken into account when performing PLDRH.

**Declaration of Figures’ Authenticity**

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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