ASTR

ORIGINAL ARTICLE
pISSN 2288-6575 • eISSN 2288-6796
https://doi.org/10.4174/astr.2024.107.2.91
Annals of Surgical Treatment and Research

# Multivariable linear model for predicting graft weight based on 3-dimensional volumetry in regards to body weight change of living liver donor: an observational cohort study

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**Purpose:** The purpose of this study is to build a prediction model for estimating graft weight about different graft volumetry methods combined with other variables.
**Methods:** Donors who underwent living-donor right hepatectomy from March 2021 to March 2023 were included. Estimated graft volume measured by conventional method and 3-dimensional (3D) software were collected as well as the actual graft weight. Linear regression was used to build a prediction model. Donor groups were divided according to the 3D volumetry of <700 $cm^3$, 700–899 $cm^3$, and ≥900 $cm^3$ to compare the performance of different models.
**Results:** A total of 119 donors were included. Conventional volumetry showed $R^2$ of 0.656 ($P < 0.001$) while 3D software showed $R^2$ of 0.776 ($P < 0.001$). The $R^2$ of the multivariable model was 0.842 ($P < 0.001$) including for 3D volume ($\beta = 0.623$, $P < 0.001$), body mass index ($\beta = 7.648$, $P < 0.001$), and amount of weight loss ($\beta = -7.252$, $P < 0.001$). The median errors between different models and actual graft weight did not differ in donor groups (<700 and 700–899 $cm^3$), while the median error of univariable linear model using 3D software (122.5; interquartile range [IQR], 61.5–179.8) was significantly higher than multivariable-adjusted linear model (41.5; IQR, 24.8–69.8; P = 0.003) in donors with estimated graft weight ≥900 $cm^3$.
**Conclusion:** The univariable 3D volumetry model showed an acceptable outcome for donors with an estimated graft volume <900 $cm^3$. For donors with an estimated graft volume ≥900 $cm^3$, the multivariable-adjusted linear model showed higher accuracy.
**[Ann Surg Treat Res 2024;107(2):91-99]**

**Key Words:** Liver transplantation, Liver graft, Three-dimensional volumetry, Volumetry

## INTRODUCTION

Liver transplantation (LT) is a lifesaving procedure for patients with end-stage liver disease as well as malignancies such as hepatocellular carcinoma. However, due to a shortage of organ donations, many patients who require LT will not receive a donated liver unless their physical condition deteriorates significantly. To overcome this disproportionate supply and demand of organs, many countries are developing living-donor LT programs. Preoperative volumetric assessment is vital for the proper selection of a donor for the right recipient to ensure a successful LT [1-6]. While many centers developed their own protocol for volumetric assessment, our center maintained its protocol for measuring the cross-sectional area and calculating the volume using a conventional picture archiving and communication system (PACS) by transplant clinicians.

**Received** March 5, 2024, **Revised** May 31, 2024, **Accepted** June 1, 2024

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Over time, many new technologies have been developed, and 3-dimensional (3D) technology has also been introduced for volumetric assessment. While preoperative volumetric assessment shows high accuracy when comparing it to the actual graft weight, there are still cases where the estimated volume differs from the graft weight. Additionally, some donors undergo weight reduction before surgery to reduce steatosis of the graft, which can lead to the graft being reduced compared to the initial estimated size [7-9]. Therefore, we designed this study to build a multivariable linear regression model for predicting graft weight based on CT volumetry combined with other potential factors that can increase the accuracy of prediction.

## METHODS

This study was approved by the Institutional Review Board (IRB) of Samsung Medical Center in Seoul, Korea (No. SMC 2023-09-049). The need for informed consent from the participants was waived by the IRB due to the retrospective nature of the study.

The main objective of this study is to compare preoperative estimated volumes obtained through conventional methods performed by transplant clinicians, and 3D software performed by biomedical graphic artists to the actual graft weight, and further build a prediction model that can be used, especially when there is a body weight change of the donor. This will involve adjusting variables, such as weight change during the preparation period and other characteristics that are relevant, to create a multivariable prediction model. The secondary objective is to analyze the data further and identify the best cutoff point, which can be used to apply different prediction models for graft weight estimation.

### Patients and data

The study included living donors who underwent living-donor right hepatectomy for LT from March 2021 to March 2023. Demographic data of the donors, such as sex, age, height, and weight were collected, along with preoperative volumetric assessment data obtained from both transplant clinicians and 3D software. The body weight measured at the time of the CT scan, the actual body weight measured at the time of liver donation, and the actual graft weight measured at the time of LT were also recorded.

### Donor evaluation

Donors underwent evaluation to determine their eligibility for living liver donation based on specific criteria, including a minimum graft-recipient weight ratio of 0.8%, a minimum remnant liver volume of 30%, absence of liver parenchymal disease, including moderate steatosis, and no contraindication for major hepatectomy. To measure liver volume, the PACS system (GE Healthcare) and Microsoft Excel were used to measure each cross-sectional area by transplant clinicians who were in fellowship training. Since 2019, our center adopted various 3D software for surgical planning of LT and liver resection. For measuring 3D volumetry, Mimics Medical (Materialise), 3D slicer (https://www.slicer.org), and the beta version of AcroXeR LiverAIz viewer (SurgicalMind, Inc. and LiverAIz, Inc.) were used, and the process was started from March 2021. After developing an auto-segmentation model for living liver donor CT based on a 3D U-Net model, automated inference was implemented initially and was later edited by professional biomedical artists [10,11]. For donor evaluation, the portal phase or delayed phase of multiphasic CT angiography was used where both the portal vein and hepatic vein are well recognizable. After 3D reconstruction of the liver parenchyma, portal vein, and hepatic vein, the liver parenchyma was divided into right and left based on specific principles: the division line is based on portal inflow, the division line meeting the inferior vena cava ends between the groove of the right hepatic vein and middle hepatic vein, the division line meeting the hilum ends between the hilar bifurcation of the right portal vein and left portal vein, and the division line of the paracaval caudate lobe is in the middle of the inferior vena cava. The volume was measured after excluding the intrahepatic portal vein and hepatic vein (Fig. 1).

### Statistical analysis

Comparisons between preoperative volumetry by conventional method, 3D software and actual graft weight were performed. The accuracy was calculated by dividing the difference between the estimated volume to graft weight by the estimated volume. To build a prediction model of predicting the graft weight based on preoperative data including preoperative volumetry multivariable linear regression model was used. To further delineate which model is the best fit for specific groups, donors were divided into 2 groups based on the prediction model with superior results showing less error. Donor groups were further divided into 3 groups according to the 3D volumetry of <700 $cm^3$, 700–899 $cm^3$, and ≥900 $cm^3$. The median error between different models to actual graft weight was compared using Mann-Whitney tests. Two-sided P-values of <0.05 were used to indicate statistical significance. Statistical analyses were performed with IBM SPSS Statistics ver. 26.0 (IBM Corp.).

## RESULTS

During the study period, 119 donors were included for living-donor right hepatectomy and measured for both conventional volumetry and 3D volumetry. Table 1 shows the baseline

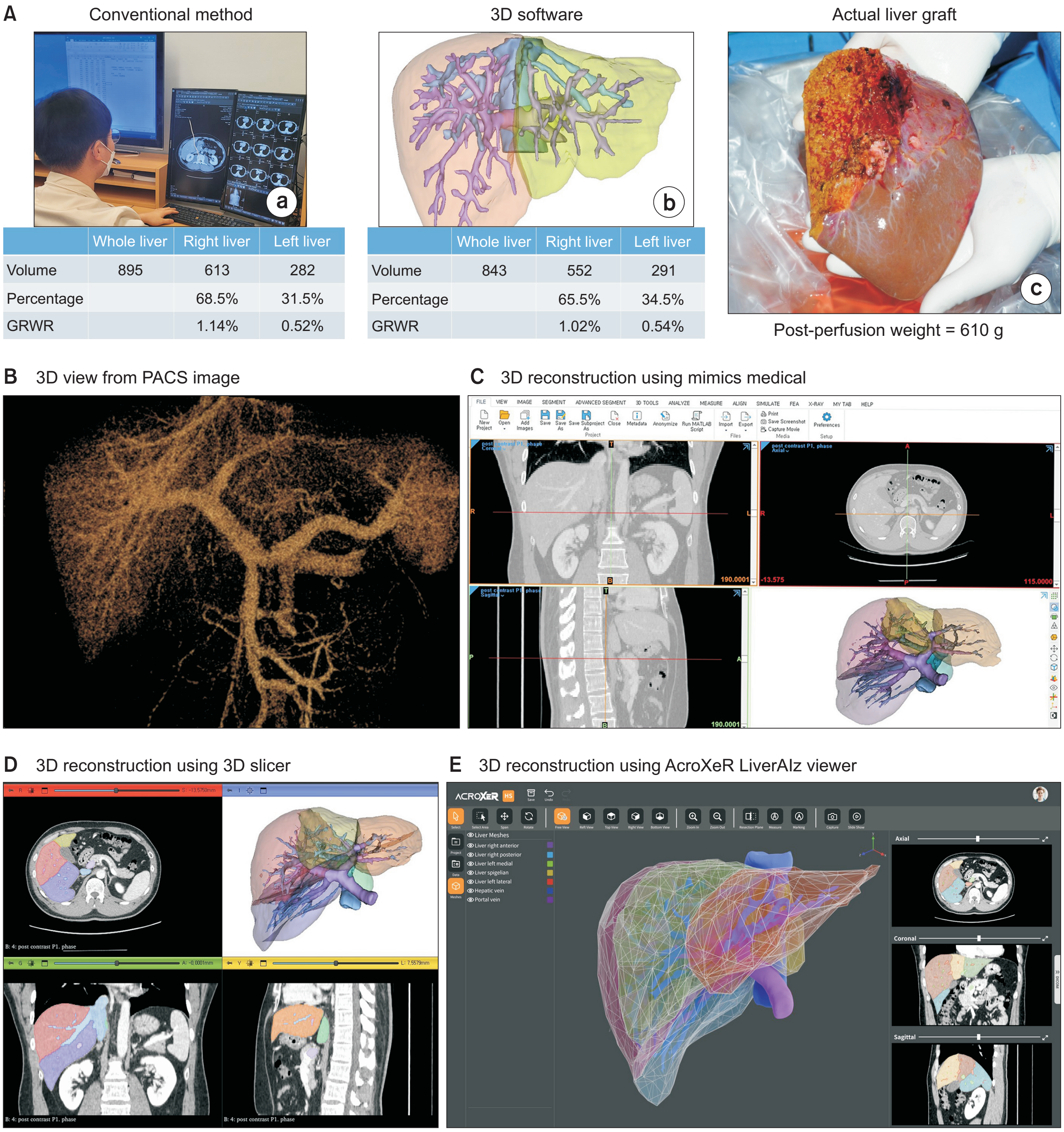



**Fig. 1.** Different methods for measuring the estimated graft volume. (A) a: The conventional method involved the transplant surgeon measuring the liver's cross-sectional area using picture archiving and communication system (PACS) and Microsoft Excel. b: A biomedical artist created a 3-dimensional (3D) model using 3D software and calculated the volume through the software. c: The actual graft was weighed intraoperatively after preservation solution perfusion. (B) While the 3D view obtained from the PACS image shows a hazy and indistinguishable view, additional edits using (C) Mimics Medical (Materialise), (D) 3D Slicer (https://www.slicer.org), and (E) beta version of AcroXeR LiverAIz viewer (SurgicalMind, Inc. and LiverAIz, Inc.) show a well-distinguishable 3D view with volumetric information. GRWR, graft-to-recipient weight ratio; PACS, picture archiving and communication system.

characteristics of the donors. Female donors were slightly more than male donors (65 females to 54 males, 54.6%). The mean age was 38.2 ± 12.9 years. Mean weight at CT acquisition and at the time of operation were 67.0 ± 12.8 kg and 66.5 ± 12.5 kg, respectively. Donors with weight change less than 1 kg, 1–2.9 kg, 3–4.9 kg, and >5 kg were 59 (49.6%), 40 (33.5%), 9 (7.6%), and

11 (9.2%), respectively.

The mean volumes measured using the conventional method for whole, right, and left were 1,178 ± 252 $cm^3$, 775 ± 170 $cm^3$, and 403 ± 101 $cm^3$, respectively. The mean volumes measured using 3D volumetry for whole, right, and left were 1,198 ± 257 $cm^3$, 783 ± 179 $cm^3$, and 415 ± 104 $cm^3$, respectively. The mean graft weight was 742 ± 132 g, and the graft-recipient-weight ratio was 1.10% ± 0.24%. Median macrosteatosis and microsteatosis were 3% (interquartile range [IQR], 1%–5%) and 1% (IQR, 1%–5%), respectively. The mean accuracies of conventional method and 3D software were 0.91 ± 0.08 and 0.92 ± 0.07.

**Table 1.** Baseline characteristics and volumetry of living right liver donors calculated by different methods

| Characteristic | N |
|---|---|
| No. of patients | 119 |
| Sex | |
| Male | 54 (45.4) |
| Female | 65 (54.6) |
| Age (yr) | 38.2 ± 12.9 |
| Height (cm) | 166.6 ± 8.4 |
| Weight at CT acquisition (kg) | 67.0 ± 12.8 |
| Weight at operation (kg) | 66.5 ± 12.5 |
| Body mass index at operation ($kg/m^2$) | 23.8 ± 3.4 |
| Weight change (kg) | |
| <1.0 | 59 (49.6) |
| 1.0–2.9 | 40 (33.5) |
| 3.0–4.9 | 9 (7.6) |
| >5.0 | 11 (9.2) |
| CT volumetry by conventional method ($cm^3$) | |
| Whole liver | 1,178 ± 252 |
| Right liver (%) | 775 ± 170 (65.6 ± 4.8) |
| Left liver (%) | 403 ± 101 (34.1 ± 4.0) |
| CT volumetry by 3D software ($cm^3$) | |
| Whole liver | 1,198 ± 257 |
| Right liver (%) | 783 ± 179 (65.4 ± 4.7) |
| Left liver (%) | 415 ± 104 (34.6 ± 4.7) |
| Graft weight (g) | 742 ± 132 |
| Graft-recipient-weight ratio (%) | 1.10 ± 0.24 |
| Macrosteatosis (%) | 3 (1–5) |
| Microsteatosis (%) | 1 (1–5) |
| Accuracy of conventional method | 0.91 ± 0.08 |
| <1.0 kg (n = 59) | 0.91 ± 0.07 |
| 1.0–2.9 kg (n = 40) | 0.91 ± 0.08 |
| 3.0–4.9 kg (n = 9) | 0.91 ± 0.06 |
| >5.0 kg (n = 11) | 0.86 ± 0.10 |
| Accuracy of 3D software | 0.92 ± 0.07 |
| <1.0 kg (n = 59) | 0.92 ± 0.07 |
| 1.0–2.9 kg (n = 40) | 0.92 ± 0.06 |
| 3.0–4.9 kg (n = 9) | 0.93 ± 0.05 |
| >5.0 kg (n = 11) | 0.87 ± 0.10 |

Values are presented as number only, number (%), mean ± standard deviation, or median (interquartile range).
3D, 3-dimentional.

## Multivariable linear regression prediction models

In Table 2, different linear regression models were tested. The univariable linear model using conventional volumetry for predicting graft weight showed $R^2$ of 0.656 ($P < 0.001$) with a coefficient of 0.631 ($P < 0.001$) for estimated volume and a constant of 253 ($P < 0.001$). When only donors with a weight change of less than 3 kg were included, $R^2$ showed 0.678 ($P < 0.001$) with a coefficient of 0.719 ($P < 0.001$) for estimated volume and a constant of 194 ($P < 0.001$).

The univariable linear model using 3D software volumetry for predicting graft weight showed $R^2$ of 0.776 ($P < 0.001$) with a coefficient of 0.651 ($P < 0.001$) for estimated volume and a constant of 232 ($P < 0.001$). When only donors with a weight change of less than 3 kg were included, $R^2$ showed 0.806 ($P < 0.001$) with a coefficient of 0.710 ($P < 0.001$) for estimated volume and a constant of 192 ($P < 0.001$).

The multivariable linear regression model was built using 3D volumetry alongside body mass index and the amount of weight loss. The $R^2$ was 0.842 ($P < 0.001$). The coefficients for 3D volume, body mass index, and amount of weight loss were 0.623 ($P < 0.001$), 7.648 ($P < 0.001$), and –7.252 ($P < 0.001$). The constant was 75.5 ($P = 0.035$).

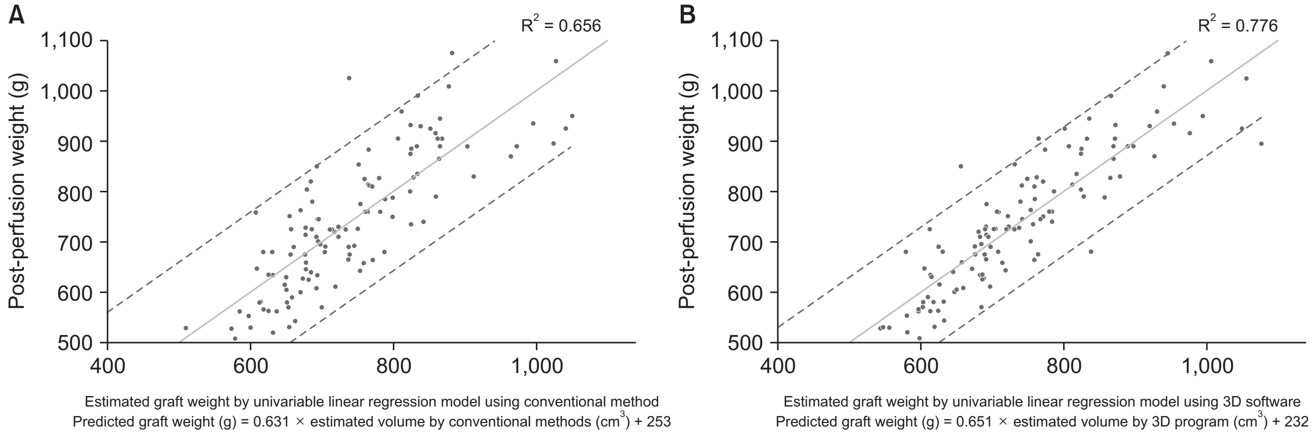
*Predicted graft weight (g) = 0.623 × estimated volume by 3D program ($cm^3$) + 7.648 × body mass index ($kg/m^2$) – 7.252 × amount of weight loss (kg)*

Fig. 2 demonstrates the accuracy of 3 different models for predicting actual liver graft weight.

**Table 2.** Linear regression models for predicting actual graft weight based on donor characteristics and estimated volumes

| Variable | $R^2$ | P-value | β | P-value | Constant | P-value |
|---|---|---|---|---|---|---|
| Conventional method (n = 119) | 0.656 | <0.001 | 0.631 | <0.001 | 253 | <0.001 |
| Among weight change <3 kg (n = 99) | 0.678 | <0.001 | 0.719 | <0.001 | 194 | <0.001 |
| 3D software (n = 119) | 0.776 | <0.001 | 0.651 | <0.001 | 232 | <0.001 |
| Among weight change <3 kg (n = 99) | 0.806 | <0.001 | 0.710 | <0.001 | 192 | <0.001 |
| Adjustment with 3D software (n = 119) | 0.842 | <0.001 | | | | |
| 3D volume | | | 0.623 | <0.001 | | |
| Body mass index | | | 7.648 | <0.001 | | |
| Amount of weight loss | | | –7.252 | <0.001 | | |
| Constant | | | | | 75.5 | 0.035 |

3D, 3-dimentional.



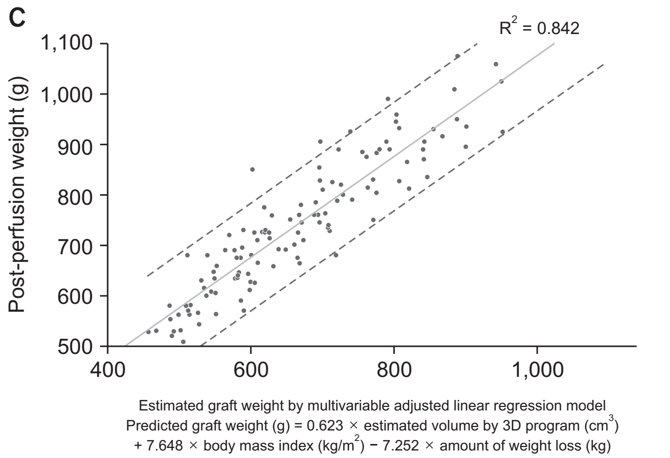




**Fig. 2.** Scatter plot between different graft weight estimation models and actual graft post-perfusion weight. (A) Estimated graft weight by univariable linear regression model using conventional method. (B) Estimated graft weight by univariable linear regression model using 3-dimensional (3D) software. (C) Estimated graft weight by multivariable linear regression model including 3D software, body mass index and amount of weight loss.

## Comparison between groups showing better prediction by different models

Since 3D software showed higher $R^2$ compared to the conventional method, the univariable linear regression model using 3D software was compared with the multivariable-adjusted model. After prediction errors were compared between the 2 models with actual graft weight, donors were divided into 2 groups where 3D software showed better prediction (n = 46), and where adjusted multivariable model showed better prediction (n = 72). One patient with the same error between the 2 different models was excluded from this analysis (Table 3).

There were no differences regarding sex (P = 0.313), age (P = 0.610), height (P = 0.141), weight at operation (P = 0.969), and body mass index (P = 0.253) between the 2 groups. There was also no difference in the initial body weight (P = 0.742) between the 2 groups. Although the 3D software group showed median weight gain (–0.15; IQR, –0.63 to 0.8) while the multivariable-adjusted model group showed median weight loss (0.3; IQR, –0.6 to 1.7) during the preparation period, there was no statistical difference between the 2 groups (P = 0.167). The median duration between CT acquisition and LT was similar between the 2 groups (P = 0.347), as well as the median MRI fat fraction (P = 0.522). There were significant differences regarding 3D volumetry measured by 3D software. The whole liver volume was significantly larger in the multivariable-adjusted group (1,242 ± 291 cm$^3$ *vs.* 1,130 ± 175 cm$^3$, P = 0.010). While right liver volume was also larger in the multivariable-adjusted group (815 ± 200 cm$^3$ *vs.* 735 ± 130 cm$^3$, P = 0.010), there was no difference in the left liver volume between the 2 groups (394 ± 83 cm$^3$ *vs.* 427 ± 114 cm$^3$, P = 0.072). The proportion of donors who lost weight during the preparation period did not show a significant difference between the 2 groups (P = 0.137).

## Comparison of median errors between the 2 models according to 3-dimensional volumetry

Table 4 shows the comparisons of median errors between the 3D software prediction model, multivariable-adjusted model, and actual graft weight according to the 3 groups divided by 3D volumetry. There were no differences in the median errors between the 3D software prediction model and actual graft weight and multivariable-adjusted model and actual graft weight in the 2 groups with 3D volume of <700 cm$^3$ (37.0 [IQR, 10.1–62.5] *vs.* 27.9 [IQR, 13.6–53.2], P = 0.274) and 700–899 cm$^3$ (39.0 [IQR, 22.5–77.8] *vs.* 34.0 [IQR, 19.5–57.1], P = 0.773). However, the median error between the 3D software prediction

**Table 3.** Comparison of different donor groups divided by better prediction method of different linear regression models

| Variable | Donor group | | P-value |
|---|---|---|---|
| | 3D software (n = 46) | 3D software with adjustment (n = 72) | |
| Sex | | | 0.313 |
| Male | 18 (39.1) | 35 (48.6) | |
| Female | 28 (60.9) | 37 (51.4) | |
| Age (yr) | 39.0 ± 13.1 | 37.7 ± 12.8 | 0.610 |
| Height (cm) | 165.1 ± 7.5 | 167.5 ± 8.9 | 0.141 |
| Weight at operation (kg) | 66.5 ± 12.9 | 66.4 ± 12.5 | 0.969 |
| Body mass index (kg/m$^2$) | 24.3 ± 3.7 | 23.6 ± 3.2 | 0.253 |
| Initial body weight (kg) | 66.5 ± 12.4 | 67.3 ± 13.2 | 0.742 |
| Weight loss (kg) | –0.15 (–0.63 to 0.8) | 0.3 (–0.6 to 1.7) | 0.167 |
| Weight loss (%) | –0.2 (–0.8 to 1.2) | 0.5 (–0.1 to 2.7) | 0.223 |
| Duration between CT and LT (mo) | 2.5 (1.5–3.6) | 2.6 (2.0–3.4) | 0.347 |
| MRI fat fraction | 4.4 (3.4–6.0) | 3.8 (2.9–6.9) | 0.522 |
| CT volumetry | | | |
| Whole liver volume (cm$^3$) | 1,130 ± 175 | 1,242 ± 291 | 0.010 |
| Right liver volume (cm$^3$) | 735 ± 130 | 815 ± 200 | 0.010 |
| Proportion (%) | 65.1 ± 5.0 | 65.6 ± 4.5 | 0.552 |
| Left liver volume (cm$^3$) | 394 ± 83 | 427 ± 114 | 0.072 |
| Proportion (%) | 34.9 ± 5.0 | 34.4 ± 4.5 | 0.525 |
| Weight change | | | 0.137 |
| Weight gain | 26 (56.5) | 30 (41.7) | |
| No change | 1 (2.2) | 3 (4.2) | |
| Weight loss | 19 (41.3) | 39 (54.2) | |

Values are presented as number (%), mean ± standard deviation, or median (interquartile range).
3D, 3-dimentional; LT, liver transplantation.

**Table 4.** Comparisons of prediction accuracy of univariable linear regression model of 3D software and multivariable-adjusted linear regression models in donor groups divided by estimated graft volume

| 3D volumetry (cm$^{3)}$) | Median error between | | P-value | Mean error of 3D software – error of adjusted model[a)] | P-value |
|---|---|---|---|---|---|
| | 3D software and actual graft weight | Adjusted model and actual graft weight | | | |
| <700 (n = 41) | 37.0 (10.0–62.5) | 27.9 (13.6–53.2) | 0.274 | 7.6 ± 31.1 | >0.999 (*vs.* 700–899 cm$^3$)<br><0.001 (*vs.* ≥900 cm$^3$) |
| 700–899 (n = 48) | 39.0 (22.5–77.8) | 34.0 (19.5–57.1) | 0.773 | 7.5 ± 40.2 | >0.999 (*vs.* <700 cm$^3$)<br><0.001 (*vs.* ≥900 cm$^3$) |
| ≥900 (n = 30) | 122.5 (61.5–179.8) | 41.5 (24.8–69.8) | 0.003 | 84.5 ± 100.7 | <0.001 (*vs.* <700 cm$^3$)<br><0.001 (*vs.* 700–899 cm$^3$) |

Values are presented as median (interquartile range).
3D, 3-dimentional.
[a)]When error of 3D software is higher, the number is positive. When error of adjusted model is higher, the number is negative.

model and actual graft weight was significantly higher compared to the median error between the multivariable-adjusted model and actual graft weight (122.5 [IQR, 61.5–179.8] *vs.* 41.5 [IQR, 24.8–69.8], P = 0.003).

Table 4 also shows the mean value for the error of 3D software subtracted by the error of the multivariable-adjusted model. When the mean values of the 3 different donor groups were compared, the donor group with 900 cm$^3$ showed significantly higher values compared to the <700 cm$^3$ group and 700–899 cm$^3$ group (both, P < 0.001). However, there was no difference between the <700 cm$^3$ group and 700–899 cm$^3$ group (P > 0.999). Fig. 3 shows the mean value of the error of 3D software subtracted by the error of the multivariable-adjusted model for 3 different donor groups divided by 3D volumetry.

## DISCUSSION

LT as a solution for liver failure and hepatocellular carcinoma can guarantee a remarkable outcome for those who need the

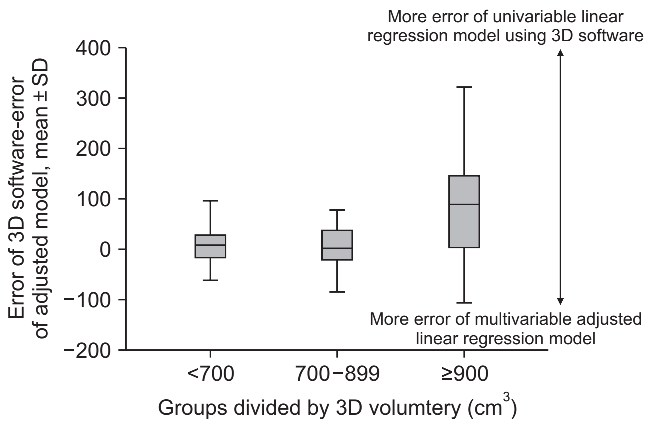



**Fig. 3.** The mean ± standard deviations (SD) for error of 3-dimensional (3D) software subtracted by error of multivariable-adjusted model for 3 different donor groups divided by 3D volumetry. As the box and whisker plot approaches the positive value, it suggests that the univariable linear model using 3D software exhibits more error. Conversely, when the plot approaches the negative value, it suggests that the multivariable-adjusted linear regression model shows more error.

procedure. However, since organ donation from deceased donors does not meet the requirement, living-donor LT is performed. The size of partial graft from living donors should be large enough for recipients for successful LT. When the size of the graft is smaller than the metabolic demand of the recipient, small-for-size syndrome can occur, and this can lead to the loss of both the recipient and graft. The usual cutoff of graft-recipient weight ratio for preventing small-for-size syndrome is 0.8%. However, as experience accumulated with small-sized liver grafts, even smaller liver grafts with lower graft-recipient weight ratio are successfully performed [12]. For detailed preoperative planning, a precise estimation of liver graft volume is required [13-17].

This study aimed to compare the accuracy of preoperative volumetry to actual graft weight and develop a prediction model to adjust for any differences between volume and weight. Initially, we compared 2 volumetry methods: the conventional method, performed by various surgeons using a PACS system and Excel, and the 3D volumetric assessment, conducted by only 3 biomedical artists. The 3D method yielded a higher $R^2$ of 0.776, likely due to its detailed surgical plane and the ability to divide the right and left lobes with a 3D view.

However, since our center did not routinely check follow-up CT scans for donors who underwent weight reduction, the volumetry for those donors could be incorrect; therefore, we adjusted the model using body mass index and the amount of weight reduction. This multivariable-adjusted model had an $R^2$ of 0.842, with the remaining error potentially due to other factors, such as differences in the actual surgery performed by the surgeon and the inability to identify periphery branches of the portal vein.

The most important finding of this study was that we built 2 prediction models that can be used for graft weight estimation. When the estimated graft volume is less than 900 $cm^3$, the univariable linear regression model with 3D volumetry shows a comparable outcome with the multivariable-adjusted model. This means that an univariable regression model can be used for donors whose estimated volume was less than 900 $cm^3$. However, when the estimated graft volume is equal to or larger than 900 $cm^3$, the multivariable-adjusted model showed higher predictability. This is possibly due to a higher probability of overweight donors in those donor groups, which may lead to weight reduction of both the donor and graft liver. Therefore, the multivariable-adjusted model is recommended for donors with an estimated graft weight equal to or larger than 900 $cm^3$.

The main reason for comparing and building a prediction model was to change the donor evaluation process from the conventional method to 3D software. Currently, 3D modeling is only done for donors who are confirmed to undergo donation. The potential donors who undergo CT for eligibility are evaluated by the conventional method. This process increases the workload of transplant surgeons in their fellowship training. Eventually, our center is planning to introduce a deep learning model for auto-segmentation of the liver anatomy for the donor evaluation process. The present study will be the baseline data which will be compared to the auto-segmentation model in the future.

The 3D modeling of the liver is becoming more popular for liver surgeons [6,14,16-22]. The 3D reconstructed image can enhance the anatomical understanding of the surgeon for preoperative planning. This can also be useful for intraoperative navigation by comparing the operative field to the pre-constructed 3D image. Another merit of using 3D reconstruction comes from the precise application of volumetric assessment. This study focused on volumetric assessment of the donor where graft weight is vital for the success of LT. Currently, there are several software that can measure 3D liver volume. The difference comes not from the accuracy of the volume measurement but from the user interface. The finding that 3D software showed better prediction ($R^2$ = 0.806) compared to the conventional method, which did not use 3D software ($R^2$ = 0.678), emphasizes the usefulness of using these softwares in clinics. Besides the prediction model, the accuracy of the volume compared to the actual graft weight was higher in the 3D software (0.92 ± 0.07) compared to the conventional method (0.91 ± 0.08). The key difference between the 2 methods is that conventional method can be affected by human error and inter-observer variations. Summating the cross-sectional area can have errors when the predicted transection plane is different from the actual surgical plane. However, 3D modeling for volumetry and surgical planning is currently not covered by the national medical insurance in Korea. There is an urgent need for change regarding applying this technology in the clinical field.

The limitation of this study is that this study only included Korean donors with right lobe donation. To apply this model to other types of populations, external validation is required. While the right liver graft was analyzed, the remnant left liver volume was not evaluated for accuracy. This can only be done if CT scans are obtained right after surgery, which is unnecessary for the donor. The number of cases included is 119, which is not many. However, as the data accumulate, the prediction model can become more accurate. The usefulness of developing these models is also an issue. To help clinicians, more effort should be made to find unmet needs and develop solutions. While the prediction model was especially useful for predicting donors who underwent weight reduction, a question can be raised since those donors' liver grafts are already large enough that the surgeons need not be concerned about the actual graft weight. Graft weight predictions for small donors will be more valuable compared to big donors.

Currently, donor data are prospectively accumulated in the center's registry. Therefore, the accuracy of such models will increase in the future. Due to the development of artificial intelligence modeling using 3D U-Net, automated 3D segmentation can be done [10,11]. To minimize human labor for 3D modeling, an automated 3D modeling algorithm is applied in actual clinical practice for volumetric assessment.

To summarize, despite some limitations, our study demonstrated that 3D volumetric assessment can be used with acceptable outcomes for predicting graft weight of the right liver in donors. Specifically, for donors with an estimated graft volume of less than 900 $cm^3$, the univariable linear regression model can be used with high accuracy. For donors with an estimated graft volume equal to or larger than 900 $cm^3$, the multivariable-adjusted linear regression model including 3D volume, body mass index, and amount of weight loss can be used with high accuracy.

## ACKNOWLEDGEMENTS

### Fund/Grant Support

This research was supported by a grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (RS-2023-KH135171), the Basic Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2023R1A2C2005946) and Future Medicine 2030 Project of the Samsung Medical Center (SMX1230771).

### Conflict of Interest

No potential conflict of interest relevant to this article was reported.

### ORCID iD

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