의학석사 학위논문

Effect of weight reduction on liver volume in living liver donor with steatosis

지방간을 동반한 생체간이식 공여자에서 체중감량이 간용적에 미치는 영향

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서울대학교 대학원

의과대학 의학과 외과학

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지도교수 이 광 웅

이 논문을 의학석사 학위논문으로 제출함
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서울대학교 대학원
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2023 년 1 월

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Abstract

Effect of weight reduction on liver volume in living liver donor with steatosis

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Purpose

If potential live liver donors are accompanied by steatosis, the donation will proceed after weight reduction. Weight reduction can reduce liver volume, affecting the graft-to-recipient weight ratio. This study aimed to evaluate a decrease in liver volume after weight reduction and analyze the risk factors affecting liver volume reduction.

Materials and methods

From January 2016 to December 2020, we retrospectively reviewed data of 147 potential liver donors with steatosis who participated in a weight reduction program prior to liver transplantation at Seoul National University Hospital.

Results

Ninety-seven (66%) donors underwent donor hepatectomy after weight reduction. After weight reduction, liver volume showed a statistically significant decrease (from 1399.6 ± 315.4 to 1283.6 ± 171.2 ml, $P < 0.05$). There was a more significant reduction in weight (5.8 ± 5.2 vs. 9.4 ± 4.3 %, $P < 0.05$), AST (from 23.5 ± 9.7 to 22.2 ± 18.5 vs. from 27.2 ± 15.8 to 17.7 ± 4.4 U/L, $P < 0.05$), and ALT (from 23.5 ± 9.7 to 22.2 ± 18.5 vs. from 27.2 ± 15.8 to 17.7 ± 4.4 U/L, $P < 0.05$) in the large liver volume reduction (≥10%) group than in the small liver volume reduction group. Risk factors associated with large liver volume reduction, weight reduction (%) and ALT abnormalities were analyzed (odds ratio [OR] = 1.184; 95% CI 1.054-1.329, OR = 5.502; 95% CI 1.660-18.229; all $P < 0.05$). Donors with reductions in large liver volume after weight reduction and graft-to-recipient weight ratio were more likely to have risk factors.

Conclusion

Potential liver donors with 7% or more weight reduction or an ALT abnormality require liver volume/graft-to-recipient weight ratio re-measurement after weight reduction.

Keyword: Steatosis, Weight reduction, Liver volume, Graft to Recipient Weight Ratio, Living donor liver transplantation

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Chapter 1. Introduction

Living donor liver transplantation (LDLT) has become a widely-used treatment for end-stage liver disease and hepatocellular carcinoma that negates the shortage of deceased donors, particularly in Asia countries.[1,2] In LDLT, there are several critical donor-related factors. Graft-to-recipient weight ratio (GRWR) is an essential indicator of relative graft size, which can significantly affect graft survival.[3,4] A GRWR of less than 0.8 is defined as a small-for-size graft (SFSG), which increases the risk of developing small-for-size syndrome (SFSS) that causes encephalopathy, coagulopathy, cholestasis, and ascites.[2,5,6]

On the other hand, hepatic steatosis is an obstacle to donor selection. Macro-vesicular steatosis of above 30% is an absolute contraindication to liver transplantation (LT), and steatosis is one of the main reasons potential donors cannot complete liver donation.[6] However, if a potential liver donor with steatosis attempts to lose weight, steatosis can decrease and LDLT become possible. The success rate of LDLT after weight reduction has been reported to be up to 80% in several studies.[7-9]

Some studies related to bariatric surgery report a correlation between weight reduction and liver volume. In bariatric surgery, weight reduction before surgery can improve surgery time and complications.[10] A low-calorie diet administered before surgery resulted in a significant liver volume reduction of up to 18%, and a

reduction in steatosis.[11,12] After bariatric surgery in patients with non-alcoholic fatty liver disease (NAFLD), a decrease in liver volume of 10 to 20% has been reported after weight reduction.[13] Patients with biopsy-proven non-alcoholic steatohepatitis (NASH) also underwent a decrease in liver volume after weight reduction.[14]

In recent years, a worldwide increase in NAFLD has stimulated the development of diagnostic and treatment options for NASH, a progressive form of this chronic liver disease.[15] Appropriate drug therapy is being developed, and treatment has shown reduced steatosis and improved NASH.[16,17] A study on NAFLD patient dietary treatments found significant decreases in liver span and ALT after treatment in patients with NAFLD.[18] NAFLD is becoming more common in potential liver donors with steatosis; a significant reduction in liver volume is likely in patients with steatohepatitis.

A large GRWR reduction accompanying a decrease in liver volume can have a crucial effect on clinical outcomes in LDLT; however, to the best of our knowledge, the effect of weight reduction on liver volume in LDLT has not been investigated. This study aimed to evaluate a decrease in liver volume after weight reduction in potential liver donors with steatosis, and to analyze the risk factors affecting liver volume reduction.

Chapter 2. Materials and methods

2.1. Study design and Patients

We retrospectively reviewed the medical records of 147 live liver donors who received recommendations for the WR program between January 2016 and December 2021 at Seoul National University Hospital. The study design is illustrated in Figure 1. The donor evaluation process at our center has been previously described in detail.[8] The evaluation process for donors with hepatic steatosis has been classified into three pathways: First, WR was performed after computed tomography (CT) imaging, then magnetic resonance imaging (MRI) was performed, and finally the donor proceeded with liver donation. Second, CT and MRI were simultaneously evaluated, then WR was performed, and finally MR fat fraction for observing steatosis was performed before proceeding with liver donation. Third, CT and MRI were simultaneously evaluated, then WR proceeded and liver donation proceeded without an image study follow-up. This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB no: 2211-057-1377).

2.2. Liver volumetric and steatosis analysis

CT volumetry was measured with Dr. liver® (Virtual Liver Surgery Planning System, Humanopia Inc., Pohang, Korea) using a semi-automatic algorithm for liver extraction.[19,20] MRI volumetry was

measured with Aquarius iNtuition® (Automated preprocessing system, TeraRecon Inc., Durham, USA), which provides automated liver segmentation. Since total liver volume (TLV) was measured, it was performed semi-automatically, and manual slice-by-slice delineation of the liver contours was performed if necessary.[21]

The degree of hepatic steatosis was assessed by MR spectroscopy (MRS), and histological examination was not routinely performed.[22,23]

2.3. Definition of variables and potential risk factors for liver volume reduction

The body weight before WR and after WR at the time of MRI, were measured. WR period, age, sex, height, body mass index (BMI), blood type (ABO), alanine transaminase (ALT) level, aspartate transaminase (AST) level, gamma-glutamyl-transpeptidase (GGT) level, were included in the analysis alongside the following metabolic syndrome factors: hypertension, diabetes mellitus, fasting glucose level, and lipid profiles (total cholesterol, triglycerides, high-density lipoprotein (HDL) cholesterol, and low-density lipoprotein (LDL) cholesterol). Also, TLV before and after WR were measured and estimated, and actual GRWR was analyzed.

A decrease in liver volume of up to 10-20% had been reported in previous studies, so we defined a significant decrease as 10% or more. Significant WR was defined as patients who lost 7% or more of

their total body mass, in consideration of the mean and median values.

In multivariate logistic regression analysis, blood test values were divided into normal and abnormal values, and BMI was divided into normal (BMI<25), obese (25≤BMI<30), and highly obese (BMI ≥30).

2.4. Statistical analysis

Continuous variables were compared using Student's *t*-tests or Mann-Whitney U test. The unpaired t-test was used to compare the difference in mean values before and after WR between the two groups. Multivariate logistic regression using backward stepwise selection was performed using potential risk factors. Pearson's chi-square test was conducted comparing the proportion of patients, and the Kruskal-Wallis test was performed comparing the difference of mean value in subgroup analysis. Statistical significance was set at a P-value of <0.05. Statistical analyses were performed using SPSS 26.0 (IBM Corp., Armonk, NY, USA).

Chapter 3. Results

3.1. Study population

Of the 147 donors who participated in the WR program, ninety-seven (97/147, 66.0%) donors underwent LDLT after WR. Among

these ninety-seven donors, eight donors who underwent LDLT without imaging follow-up after WR were excluded (Figure 1).

3.2. Correlation in liver volume between pre-weight reduction CT and MRI

CT and MRI were both performed before WR in 37 donors. The liver volume measurements were analyzed according to the two modalities (CT and MRI), with no significant difference in TLV between the two (P = 0.385) (Figure 2).

3.3. Patient Characteristics

The mean age was 34.0 ± 11.6 years (range 16-60), and 69 donors were male (69/89, 77.5%). Three donors (3.4%) were receiving medication for hypertension, and two donors (2.2%) had diabetes mellitus. The mean duration of WR was 107.6 ± 128.4 days, and twenty-nine donors (29/89, 32.6%) had a WR period of over 100 days (Table 1).

There were significant decreases in AST, ALT, and GGT levels as well as body weight and BMI after WR. The mean values of fasting glucose level and lipid profiles were within the normal range and were not remeasured after WR. There was a significant decrease in TLV and GRWR after WR (from 1399.6

± 315.4 to 1283.6 ± 271.2 ml, from 1.33 ± 0.31 to 1.14 ± 0.27, all $P < 0.05$) (Table 1).

3.4. Comparison of variables: small vs. large liver volume reduction

We divided the group into large (≥ 10%) and small liver volume reduction (<10%) groups and compared the variables between the two groups after WR. Thirty-eight donors (38/89, 42.7%) showed a large liver volume reduction (Table 2).

There was no significant difference in age and the duration of WR between the two groups. There was a significant difference in BMI decrease (from 26.8 ± 4.1 to 25.2 ± 3.5 vs. from 27.7 ± 3.8 to 25.0 ± 3.0 kg/m^2, $P < 0.05$), as well as in the Δweight (-5.8 ± 5.2 vs. -9.4 ± 4.3%, $P < 0.05$) (Table 2).

In laboratory values, there was a significant difference in AST (from 23.5 ± 9.7 to 22.2 ± 18.5 vs. from 27.2 ± 15.8 to 17.7 ± 4.4 U/L) and ALT (from 31.4 ± 23.6 to 22.1 ± 19.4 vs. from 41.8 ± 25.8 to 19.0 ± 8.7 U/L) decrease between the two groups. There was no significant difference in fasting glucose and lipid panel before WR between the two groups. (Table 2).

3.5. Risk factor analysis of large liver volume reduction (≥10%)

Twenty-seven donors (27/89, 30.3%) had ALT abnormalities (>40 U/L), but AST abnormalities were found in 9 donors (10.1%), and only one donor had an AST abnormality alone. Twenty-three donors (23/89, 25.8%) were diagnosed with hyperlipidemia before WR. The multivariate logistic regression analysis revealed that weight reduction (%, per increase) and ALT abnormality (<40U/L) were independent factors causing large liver volume reduction (≥10%) (odds ratio [OR] = 1.184; 95% CI 1.054-1.329, OR = 5.502; 95% CI 1.660-18.229; all $P < 0.05$) (Table 3).

3.6. Subgroup analysis of liver volume reduction and GRWR changes

Subgroup analysis was performed according to the number of risk factors. The incidence of large liver volume reduction was compared among the four subgroups. Large liver volume reduction rates showed significant differences (23.1, 47.8, 44.4, and 77.8%, $P < 0.05$) (Table 4).

The ΔGRWR was not significantly different between the four subgroups ($P = 0.26$), but there was a significant difference between the subgroups with ALT abnormalities and

without the risk factors. In the group with ALT abnormalities only, the mean GRWR decreased by 0.22 ± 0.11 ($P < 0.05$), and in the group with two risk factors, the mean GRWR decreased by 0.34 ± 0.24 ($P < 0.05$) (Table 4).

Chapter 4. Discussion

In cases of LDLT performed after weight reduction in donors with steatosis, the donor and recipient outcomes were similar to those in donors without steatosis.[7-9] However, in non-transplant clinical settings, several studies suggested that weight reduction decreases liver volume.[10-14] Chen et al. reported that weight reduction reduces liver volume and fat fraction in potential donors,[24-26] but no large-scale studies have been conducted. Our study revealed a decrease in liver volume with weight reduction. Thirty-eight donors in the large liver volume reduction group showed more weight reduction than the donors in the small liver reduction group.

Many studies have suggested indicators that indirectly reflect steatosis, steatohepatitis, and fibrosis in NAFLD patients.[27] Previous studies have suggested that elevated ALT levels are associated with NASH;[28,29] Verma et al. reported ALT level as a predictor of NASH, in which with low sensitivity and high specificity.[30] In our study, elevated ALT improved after weight reduction, and ALT improvement was more significant in the large liver volume reduction group. Of the 89 donors analyzed, 37 (30.3%) had an ALT abnormality before weight reduction, suggesting that these donors

had steatohepatitis before weight reduction. ALT abnormality was found to be a risk factor for significant liver volume reduction in our study.

Before weight reduction in potential liver donors, the presence of fatty liver was determined based on CT evaluation and laboratory results. Our previous study reported an improvement in the degree of fat fraction using MRS before and after weight reduction.[9] In this study, the quantitative degree of steatosis was measured by MRS before weight reduction in only 37 donors. Among thirty-seven donors whose MR fat fraction was measured before and after WR, eight donors with ALT abnormalities had a mean fat fraction of 22.9%; slightly higher than the 17.9% in donors with normal ALT, but with no statistically significant difference. In addition, the fat fraction reduction was 18.8% in the elevated ALT group and 19.1% in the normal ALT group, showing no significant difference.

In our study, 30 donors underwent liver biopsy before LDLT, of which 16 were diagnosed with simple steatosis, and 14 with NASH. All 14 donors' NAFLD activity scores (NAS) were less than 5 points, but the mean value of the 5 NASH donors with abnormal ALTs was higher than that of 9 donors with normal ALTs (3 vs. 2.8). Since this was analyzed in a limited number of patients, it is necessary to compare the correlation with pathological findings and improvement of steatosis through future large-scale studies.

GRWR is important in LDLT because it can affect graft and recipient outcomes.[2-6] We did not remeasure changes in liver volume after the

weight reduction program at our institution. Therefore, when LDLT was performed, there were cases in which the actual GRWR was significantly reduced compared to the initial GRWR. We analyzed the risk factors associated with a significant decrease in liver volume after weight reduction and found weight reduction (%) and ALT abnormality before weight reduction to be risk factors. Where all these risk factors were present, the incidence of significant liver volume reduction was the highest, and the GRWR decrease was considerable, with a mean of 0.34. Even with one risk factor the decrease in GRWR was about 0.2; enough to adversely affect the outcome after liver transplantation. In our study, although there were only 6 cases of small for size grafts after weight reduction, this can lead to catastrophic outcomes after transplantation. Thus, after weight reduction in fatty liver donors with risk factors, remeasurement of liver volume and GRWR are necessary before proceeding with LDLT.

The limitation of this study is that it was a retrospective study with a small sample size. Steatosis was measured before and after weight reduction in 37 donors, and liver biopsy was performed before LDLT in 30 donors. Further large-scale studies are needed in the future. In the liver volumetric analysis, only one researcher performed the measure of TLV with no participation of radiology specialists for validation the measurement. However, this was measured relatively accurately with the development of semi-automated software,

measurement of TLV rather than segmentation, and the implementation of manual contour outlining if necessary.

Chapter 5. Conclusions

In conclusion, in donors with abnormal ALTs or a weight reduction of 7% or more, additional imaging should be performed after weight reduction to examine liver volume changes. Determining whether to proceed with LDLT through the re-predictive value of GRWR is essential in predicting graft and recipient outcomes. On the other hand, donors with these risk factors should undergo surveillance for NAFLD and metabolic syndrome after liver donation.

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국문초록

지방간을 동반한 생체간이식 공여자에서 체중감량이 간용적에 미치는 영향

목적

생체간이식 공여자에서 지방간이 동반된 경우에 체중 감량을 한 후에 공여를 진행하게 된다. 수혜자 체중에 대한 이식 간 중량 비율 (graft to recipient weight ratio, GRWR) 이 0.8 미만일 경우에는 생체 간이식의 성적에 부정적인 영향을 줄 수 있기 때문에 공여자의 체중감량에 따른 이식편의 무게의 변화에 대해 알아보고, 간 용적 감소에 영향을 미치는 위험인자를 분석하고자 하였다.

재료 및 방법

2016 년 1 월부터 2020 년 12 월까지 서울대학교병원에서 간이식 전 체중감량 프로그램에 참여한 147 명의 지방증 간기증 예정자를 대상으로 후향적으로 데이터를 검토하였다.

결과

체중감량을 시행한 후에 간이식을 진행한 공여자는 97 명 (66%) 이였다. 체중감량 후에 간 용적은 통계적으로 유의미하게 감소를 보였다 (1399.6 ±

315.4 에서 1283.6 ± 171.2 ml, $P < 0.05$). 간 용적이 10%이상 감소하는 군에서 체중감량이 간 용적이 적게 감소하는 군에 비해서 더 많은 체중감량을 보였다 (Δ weight(%) −5.8 ± 5.2 vs. −9.4 ± 4.3, $P < 0.05$). 간 용적이 10%이상 감소하는 군에서 AST (23.5 ± 9.7 에서 22.2 ± 18.5 vs. 27.2 ± 15.8 에서 17.7 ± 4.4 U/L, $P < 0.05$), ALT (23.5 ± 9.7 에서 22.2 ± 18.5 vs. 27.2 ± 15.8 에서 17.7 ± 4.4 U/L, $P < 0.05$) 의 감소가 더 유의미하게 많았다. 간 용적이 10% 이상 감소하는 위험인자로 체중감량(%)과 ALT 의 상승 (〉 40 U/L) 이 분석되었다 (상대적위험도 1.184, 95% 신뢰구간 1.054-1.329, $P < 0.05$, 상대적위험도 5.502, 95% 신뢰구간 1.660-18.229] $P < 0.05$). 이러한 위험인자를 가진 공여자가 체중감량 후에 간 용적 감소가 10% 이상인 경우의 발생이 더 많았으며 이에 따른 GRWR 의 감소가 보고되었다.

결론

체중이 7% 이상 감소하거나 ALT 가 상승 되어있는 기증자의 경우 체중 감량 후 추가적인 영상 검사를 시행하여 간 용적 변화를 살펴봐야 한다.

주요어: 지방간 변화, 체중 감량, 간 용적, 이식간-수혜자 체중 비율, 생체 간이식

학 번: 2020-21886

Table 1. Demographics of living liver donor with steatosis before and after weight reduction

Variables	Weight reduction (n=89) Before WR	After WR	*p*-value
Age (years) , mean ± SD	34.0 ± 11.6		
Sex			
Male, n(%)	69 (77.5)		
Female, n(%)	20 (22.5)		
ABO			
A, n(%)	36 (40.4)		
B, n(%)	21 (23.6)		
AB, n(%)	10 (11.3)		
O, n(%)	22 (24.7)		
Underlying disease			
Hypertension (%)	3 (3.4)		
Diabetes (%)	2 (2.2)		
WR duration (days), mean ± SD	107.6 ± 128.4		
Height (cm), mean ± SD	170.6 ± 9.0		
Weight (kg), mean ± SD	79.6 ± 15.4	73.4±13.1	< 0.05
BMI (kg/m2), mean ± SD	27.2 ± 4.0	25.1 ± 3.2	< 0.05
Laboratory finding before WR			
AST (U/L), mean ± SD	25.1 ± 12.7	20.3 ± 14.4	< 0.05
ALT (U/L), mean ± SD	35.8 ± 25.0	20.8 ± 15.7	< 0.05
GGT (U/L), mean ± SD	35.1 ± 29.7	21.1 ± 11.0	< 0.05
Fasting glucose (mg/dl), mean ± SD	101.3 ± 15.9		
Total cholesterol (mg/dl), mean ± SD	171.2 ± 31.5		
LDL (mg/dl), mean ± SD	107.9 ± 25.3		
HDL (mg/dl), mean ± SD	46.7 ± 11.1		
Triglycerides (mg/dl), mean ± SD	107.9 ± 52.3		
Liver volume (ml), mean ± SD	1399.6 ± 315.4	1283.6 ± 271.2	< 0.05
GRWR, mean ± SD	1.33 ± 0.31	1.14 ± 0.27	< 0.05

SD: Standard deviation; WR, weight reduction; BMI, body mass index; AST, aspartate aminotransferase; ALT, alanine aminotransferase; GGT, gamma glutamyl transferase; LDL, low-density lipoprotein; HDL, high-density lipoprotein; GRWR, graft-to-recipient weight ratio

Table 2. Comparison of variables between 2 groups classified on liver volume change

Variables	Small liver volume reduction group (< 10% or increased) (n=51)			Large liver volume reduction group (≥ 10%) (n=38)			*p*-value (between groups)
	Before WR	After WR	*p*-value	Before WR	After WR	*p*-value	
Age (years) , mean ± SD	33.6 ±11.5			34.6±11.7			0.70
WR duration (days), mean ± SD	95.3±115.1			124.0±144.3			0.30
BMI (kg/m2), mean ± SD	26.8 ± 4.1	25.2 ± 3.5	<0.05	27.7 ± 3.8	25.0 ± 3.0	<0.05	<0.05
Δ Weight (%), mean ± SD		-5.8±5.2			-9.4±4.3		<0.05
Liver volume (ml)	1314.6 ± 295.1	1315.3 ± 285.0	0.95	1513.8 ± 309.1	1241.1 ± 248.7	<0.05	<0.05
Δ liver volume (%)		0.4±6.1			-17.7±5.7		<0.05
GRWR	1.29 ± 0.29	1.17 ± 0.27	<0.05	1.40 ± 0.34	1.10 ± 0.26	<0.05	<0.05
Laboratory findings							
AST (U/L), mean ± SD	23.5 ± 9.7	22.2 ± 18.5	0.58	27.2 ± 15.8	17.7 ± 4.4	<0.05	<0.05
ALT (U/L), mean ± SD	31.4 ± 23.6	22.1 ± 19.4	<0.05	41.8 ± 25.8	19.0 ± 8.7	<0.05	<0.05
GGT (U/L), mean ± SD	32.2 ± 21.4	22.4 ± 11.6	<0.05	38.8 ± 38.0	19.3 ± 10.0	<0.05	0.13
Fasting glucose (mg/dl), mean ± SD	102.1±16.8			100.2±14.7			0.58
Total cholesterol (mg/dl), mean ± SD	172.1±32.3			170.1±30.9			0.77
LDL (mg/dl), mean ± SD	104.3±26.3			112.7±23.4			0.12
HDL (mg/dl), mean ± SD	48.4±12.1			44.5±9.1			0.09
Triglycerides (mg/dl), mean ± SD	111.4±63.3			103.2±32.3			0.43

WR, weight reduction; BMI, body mass index; GRWR, graft-to-recipient weight ratio; AST, aspartate aminotransferase; ALT, alanine aminotransferase; GGT, gamma glutamyl transferase; LDL, low-density lipoprotein; HDL, high-density lipoprotein

Table 3. Univariate and multivariate logistic regression analysis for risk factors of significant liver volume reduction (≥ 10%)

	Univariate			Multivariate		
Variables	**B**	**Odds ratio**	***p*-value**	**B**	**Odds ratio**	***p*-value**
Age, years (per increase)	0.007	1.007(0.971-10.45)	0.70			
Sex, male (vs female)	0.121	1.129(0.414-3.075)	0.81			
Weight reduction (%) (per increase)	0.165	1.180(1.061-1.311)	<0.05	0.169	1.184(1.054-1.329)	<0.05
BMI(kg/m2) <25						
vs obesity (25≤BMI<30)	0.845	2.327(0.833-6.504)	0.11			
vs highly obesity (BMI≥30)	0.135	1.144(0.329-3.974)	0.83			
Laboratory finding before WR						
Dyslipidemia (vs absense)	0.281	1.324(0.10-3.437)	0.56			
AST >40 U/L (vs normal)	0.079	1.082(0.270-4.335)	0.91			
ALT >40 U/L (vs normal)	1.435	4.200(1.606-10.982)	<0.05	1.705	5.502(1.660-18.229)	<0.05
GGT >63 U/L (vs normal)	1.059	2.882(0.499-16.634)	0.24			
Fasting glucose < 100 mg/dl						
vs imparing fasting glucose (< 126mg/dl)	0.539	1.714(0.685-4.293)	0.25			
vs diabetes (≥ 126 mg/dl)	-0.041	0.960(0.207-4.462)	0.96			

BMI, body mass index; WR, weight reduction; AST, aspartate aminotransferase; ALT, alanine aminotransferase; GGT, gamma glutamyl transferase

Table 4. Subgroup analysis of liver volume changes and GRWR classified on risk factors

variable	Normal ALT		ALT abnormality (> 40 U/L)		*p*-value
	WR < 7% (n=39)	WR ≥ 7% (n=23)	WR < 7% (n=9)	WR ≥ 7% (n=18)	
Large liver volume reduction ≥ 10%, n(%)	9 (23.1)	11 (47.8)	4 (44.4)	14 (77.8)	< 0.05 c
Δ Liver volume (ml), mean ± SD	-41.6 ± 127.1	-128.0 ± 162.3 a	-157.2 ± 291.2	-241.4 ± 138.4 a, b	< 0.05 d
Δ liver vol (%), mean ± SD	-2.9 ± 9.5	-8.4 ± 11.1	-8.7 ± 10.7	-15.0 ± 8.4 a, b	< 0.05 d
Δ GRWR, mean ± SD	-0.12 ± 0.14	-0.21 ± 0.21	-0.22 ± 0.11 a	-0.34 ± 0.24 a	0.26 d

a. $p < 0.05$ between subgroup 1 by Mann-Whitney U-test

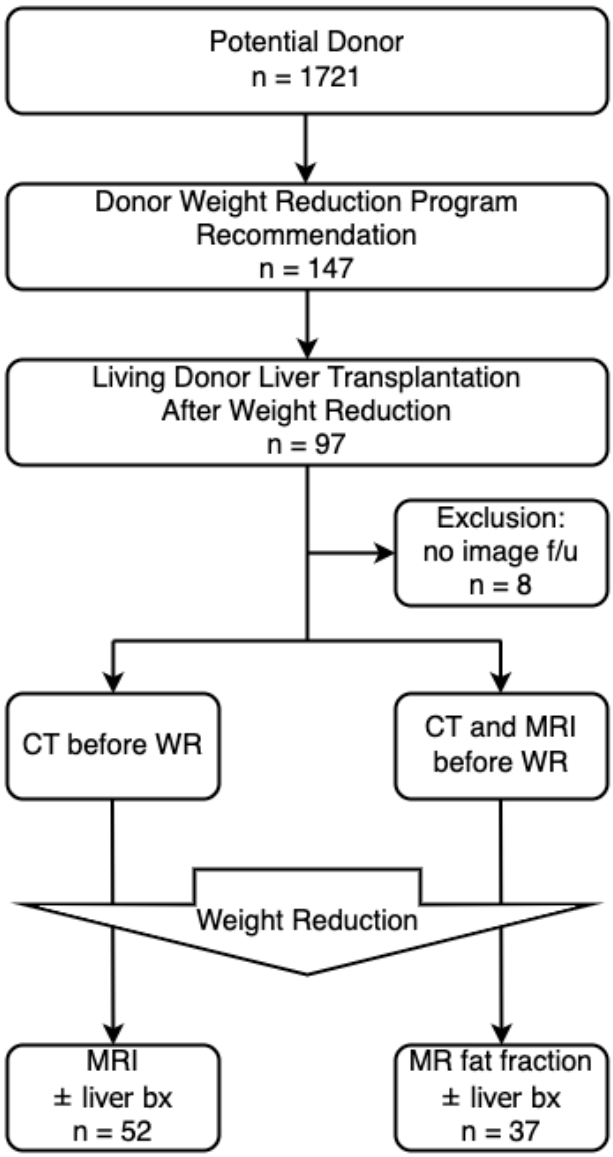
b. $p < 0.05$ between subgroup 2 by Mann-Whitney U-test

c. Statistical significance test was done by Pearson's chi-square test

d. Statistical significance test was done by Kruskal-wallis test

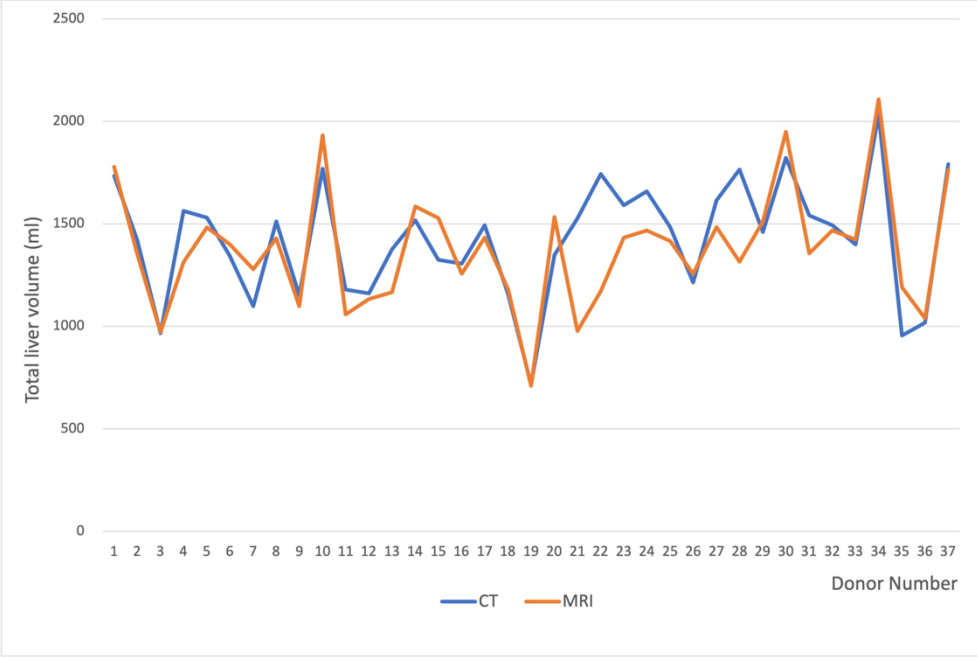
ALT, alanine aminotransferase; WR, weight reduction; GRWR, graft-to-recipient weight ratio

Figure 1. Living liver donor with steatosis work-up flow chart



CT, computed tomography; WR, weight reduction; MRI, Magnetic Resonance Imaging; Bx, biopsy

Figure 2. Correlation in liver volume between pre-weight reduction CT and MRI



CT, computed tomography; WR, weight reduction; MRI, Magnetic Resonance Imaging