ORIGINAL ARTICLE GENERAL SURGERY

NORTH CLIN ISTANB 2018;5(1):1-5
doi: 10.14744/nci.2017.14227

Preoperative evaluation of liver volume in living donor liver transplantation

Adil Baskiran,[1] Aysegul Sagir Kahraman,[2] Ipek Balikci Cicek,[3] Tolga Sahin,[1] Burak Isik,[1] Sezai Yilmaz[1]

[1]Department of General Surgery, Inonu University, Liver Transplantation Institute, Malatya, Turkey

[2]Department of Radiology, Inonu University, Turgut Ozal Medical Center, Malatya, Turkey

[3]Department of Biostatistics and Medical Informatics, Inonu University Faculty of Medicine, Malatya, Turkey

ABSTRACT

OBJECTIVE: The aim of the present study was to retrospectively evaluate the difference between the preoperative estimated volume and the actual intraoperative graft volume determined in donor right hepatectomies and to evaluate the possible effect of age, gender, and body mass index on the difference.

METHODS: A total of 225 donor hepatectomies performed at the center between 2016 and 2017 were evaluated for the study. Left hepatectomies and left lateral segmentectomies were excluded from the analysis. As a result, 174 donor right hepatectomies were included in the study. Volumetric analysis was performed with dynamic hepatic computed tomography (CT), including non-contrast analysis, followed by non-ionic, contrast-enhanced arterial, portal, and hepatic-phase, thin-slice scanning. Volumetric analysis was performed based on the CT images using automatic volume calculating software.

RESULTS: The mean preoperatively estimated graft volume was 800±112 g and the mean intraoperatively measured actual graft volume was 750±131 g. There was a statistically significant difference (p=0.003). Age and body mass index had a significant impact on the discrepancy between the predicted and actual graft volume, while gender did not.

CONCLUSION: A thorough preoperative evaluation of the donor graft volume should be performed in order to prevent donor morbidity and mortality, as well as small-for-size and large-for-size phenomena in the implanted grafts. Physicians working in the field of transplantation should be aware of the fact that a difference of 10% between the predicted and the actual graft volume is usually encountered.

Keywords: Liver; liver transplantation; living donor; radiological investigation; volumetric analysis.

Liver transplantation is the only treatment modality for end-stage liver failure. In countries where cadaveric liver transplantation is rarely performed, living donor liver transplantation (LDLT) has become an alternative route; however, it requires a difficult and attentive initial evaluation. Preoperative volume evaluation is one of these challenging steps, and it is of vital importance for both the donor and the recipient. The ratio of the calculated volume and the weight of the graft should be at least 0.8% in order to protect the recipient from small-for-size phenomena (cellular damage, liver with decreased capacity for metabolism, synthesis, ascites), and the ratio should be <3% to avoid large-for-size phenomena (poor liver perfusion, increased abdominal pressure). The volume of the remaining liver should be at least 30% to protect the donor from life-threatening consequences [1].

In LDLT, the preoperative donor graft volume is often calculated using computed tomography (CT) and automatic volume calculation programs. However, despite technological developments, discrepancies between the preoperative and intraoperative volume measurements are seen. Frericks et al. [2] observed that as the volume

Received: August 02, 2017 *Accepted:* September 07, 2017 *Online:* January 12, 2017

Correspondence: Dr. Adil BASKIRAN. Inonu Universitesi Karaciger Nakli Enstitusu Genel Cerrahi Anabilim Dali Malatya, Turkey.
Tel: +90 422 341 06 06 - 60 14 e-mail: dr.adil.baskiran@gmail.com

ratio increased, so did the margin of error. Preoperative volume calculation is first among the important criteria that determine operative morbidity and mortality. Therefore, as the margin of error in the evaluation decreases, the rate of operative success will also increase.

The aim of this study was to retrospectively compare pre- and intraoperative measurements of graft volume in donors who underwent a right hepatectomy at the Liver Transplantation Institute of Inonü University during a 2-year period, and to determine the effect of age, gender, and body mass index (BMI) on these calculations.

MATERIALS AND METHODS

The data of 225 liver donors who were operated on between 2016 and 2017 were reviewed. Donors who underwent a left hepatectomy or a left lateral hepatectomy were excluded. A total of 174 donors who underwent a right hepatectomy were included in the study.

Preoperative CT images (Somatom Definition, 256x256; Siemens Healthineers, GmbH, Erlangen, Germany) of the patients were used for volumetric evaluation. According to routine dynamic hepatic CT protocol, pre-contrast, thin-slice scanning and non-ionic, contrast-enhanced arterial, portal, and hepatic phase thin-slice scanning were performed. Automatic volume calculation software used the data from the CT images to create estimated measurements. For a right hepatectomy, the liver is divided into lobes with an imaginary line drawn along the midhepatic vein, leaving the midhepatic vein to the donor, and then right liver volume, and remaining liver volume are calculated. The same radiological protocol and volumetric analysis program were used for all of the cases studied. The pre- and intraoperative volumetric measurements were compared, and the effect of BMI, gender, and age on preoperative volume calculations was analyzed. The difference between the preoperative calculations and the intraoperative volumetric measurements is known as the delta (Δ) volume (Fig. 3).

IBM SPSS Statistics for Windows, Version 22.0 software (IBM Corp., Armonk, NY, USA) was used for the statistical analysis, and the data were expressed as median (min-max) or mean±SD. Normal distribution was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The Mann-Whitney U test, Kruskal-Wallis test, Wilcoxon test, eta coefficient, and Spearman correlation coefficient were used, where appropriate. A p value <0.05 was accepted as the level of statistical significance.

RESULTS

Of the total of 174 liver donors, 106 were male and 68 were female, the median age was 28.93 years, the median body weight was 69.7 kg, the median height was 170.7 cm, the median BMI was 23.911 kg/m^2, and the median preoperative liver volume calculated was 779.111 g, while the volume measured intraoperatively was 757.172 g. The demographic data are presented in Table 1.

The difference between the mean preoperative volume value of 800±112 g and the volume measured intraoper-

Table 1. Demographic data of the patients

Variables	Gender	
	Male (n=106)	Female (n=68)
Body mass index (kg/m^2)		
Median (min-max)	22.83 (18.44-30.10)	25.29 (18.14-34.44)
Age (years)		
Median (min-max)	27 (18-45)	28 (18-55)
Actual volume of the extracted graft (g)		
Median (min-max)	760 (530-1195)	704.5 (500-1125)
Preoperative estimated graft volume (g)		
Median (min-max)	800 (500-1000)	770 (450-1300)
Difference in graft volume (g)		
Median (min-max)	-29 (-320-245)	-30 (-205-165)

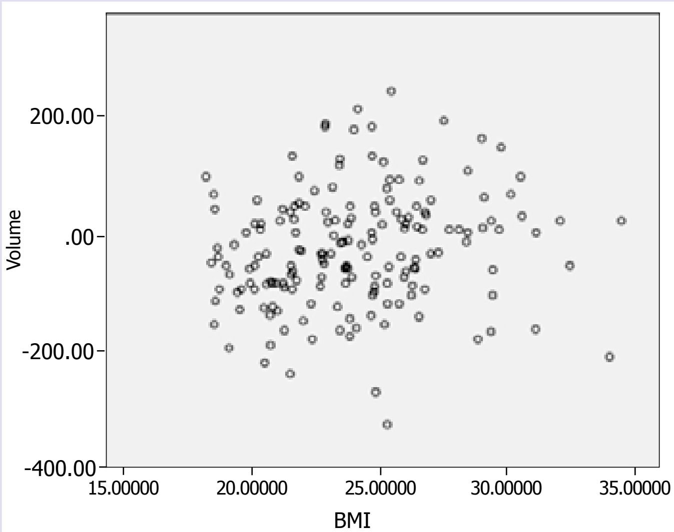

FIGURE 1. The delta volume according to body mass index.
BMI: Body mass index.

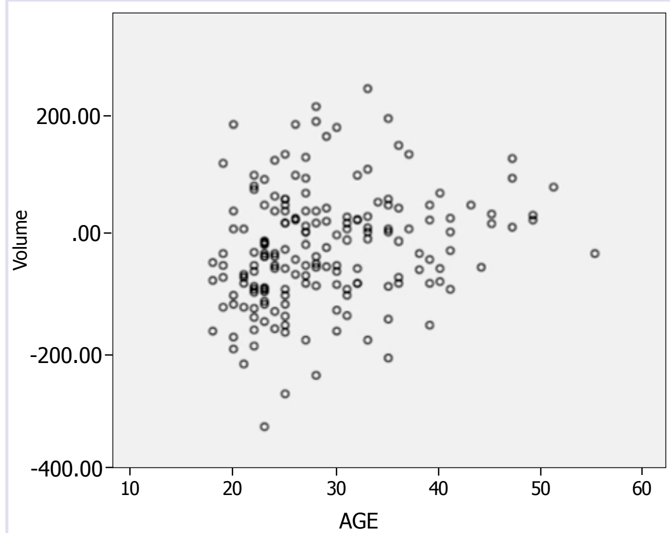

FIGURE 2. The delta volume according to age.

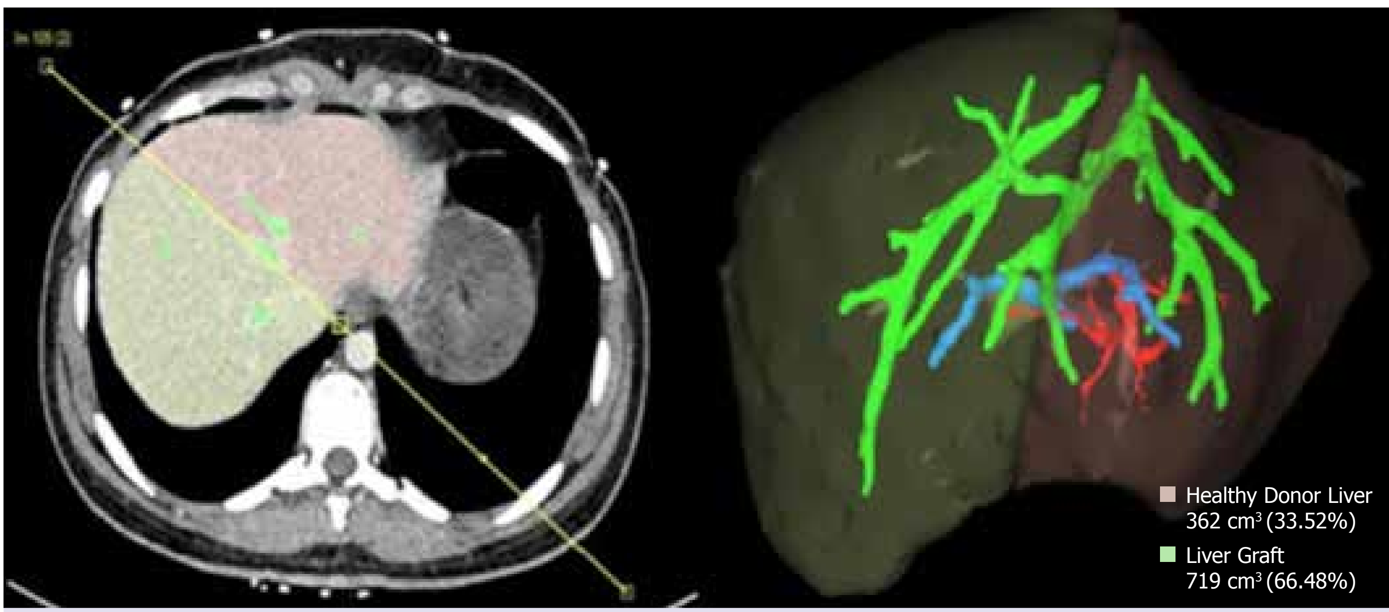

FIGURE 3. Automatic volumeter image of the resection line and hepatic veins

atively of 750±131 g was calculated (p=0.003). A greater difference (delta volume) was observed between the estimated liver volume and the volume of the extracted liver measured intraoperatively in parallel with an increase in BMI (p=0.005; Spearman rho: 0.210) (Fig. 1).

No significant difference was seen in the analysis of volume values based on gender (p=0.08); however, the variance between the preoperative and the intraoperative volume measurement did rise with increase in age (p=0.03; Spearman rho: 0.272) (Fig. 2).

DISCUSSION

Preoperative estimation of the donor liver volume is the most important factor affecting surgical strategy as well as postoperative mortality and morbidity in living donor transplantation. It is important to use no more than 70% of the donor liver volume and that the graft be of the appropriate weight for the recipient [3]. We take extreme care to leave 30% of the total liver volume in the donor and to obtain a volume/weight ratio for the recipient of between 0.8% and 2.9%.

In 1970, Heymsfield et al. [4] were the first to calculate liver volume, and subsequently, many manual and automatic volume calculation programs have been developed. Our clinic utilizes an automatic liver volume calculation program that uses data obtained from CT examinations.

In a study conducted by Paolo R et al. [5], a 20% discrepancy was demonstrated between estimated liver volume and intraoperative measurement of the extracted liver. Frericks et al. [2] emphasized an increased margin of error in living donor liver graft volumes weighing ≥500 g. In our study, a significant increase in delta volume was observed with increasing BMI. Increased BMI or liver volume has been reported to be due to uncalculated or underestimated hepatic blood volume [5].

In a study performed by Li et al. [8], a mean deviation in delta volume of 13.81±8.12% was observed. Although current technological volume assessments subtract the estimated mean blood volume circulating in the liver from the volume of the liver to find the delta volume, a definitive result cannot be obtained, since factors such as the volume of intrahepatic blood during transplantation, age, and heart rate are not evaluated. The cardiovascular performance of the donor, heart rate, hepatic blood flow, and the time of exhalation during the CT examination also affect liver volume measurement [6]. Hwang et al. [9] reported that 100 g of liver tissue contains 29 g of blood. The mean SD of the volumetric assessments performed in our clinic was 5±2.5%. According to the literature, a deviation of some 10% is to be expected in an automatically calculated preoperative volume assessment. Liver volume calculations in donors aged less than 36 years have been reported to be closer to intraoperative measurements [7]. In our study, the delta volume increased with age, which was consistent with other published study results. The primary reason is that as a result of alterations in liver parenchyma with aging, the demarcation line on the liver made during the CT scan cannot be done as accurately, which affects the volumetric analysis.

The line drawn during radiological examination and surgery is one of the most important factors in the measurement of delta volume. The line drawn intraoperatively is determinative in the calculation of liver volume [10]. For a right hepatectomy, the liver is divided into lobes with an imaginary line drawn along the midhepatic vein, leaving the vein on the donor side, and then the volume of the right liver and the remaining liver tissue are calculated. The same radiological protocol and volumetric analysis program were used in all of our cases. Millimetric deviations seen on the tracing of the midhepatic vein may cause great discrepancies in the volumetric assessment. The demarcation line can be seen during the operation after temporary closure of the right portal vein and the right hepatic artery is achieved.

The quantity of blood in the donor's liver, the heart rate of the donor, the time of exhalation during imaging, age, BMI, and the imaginary line drawn along the midhepatic vein during radiological examination affect preoperative volume assessment of the liver graft. The quantity of blood in the liver, the radiologically drawn line dividing the right and left lobes, and the solution used for hepatic perfusion are important factors in the measurement of the delta value.

In conclusion, regardless of technological advances, accurate calculation of delta volume is still a necessary and critical part of LDLT. It is important to keep the delta volume as small as possible, and before deciding on surgery, a 5% to 10% margin of error in radiological measurement should be taken into consideration for both the recipient and the donor.

CONCLUSION

Factors such as the volume of blood passing through the liver during transplantation, cardiovascular performance of the donor, age, body weight, heart rate, and time of exhalation during imaging can affect the measurement of liver volume. Since we cannot measure these parameters during a CT examination, we reduced the preoperatively estimated liver volume by 10% and we obtained values closer to the intraoperatively measured actual liver graft volume. BMI, and age rather than gender of the patients were found affect delta volume.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

Authorship contributions: Concept – A.B.; Design – A.B.; Supervision – A.S.K.; Materials – A.B.; Data collection &/or processing – A.B., I.B.C.; Analysis and/or interpretation – B.I.; Writing – A.B., T.T.S.; Critical review – S.Y.

REFERENCES

1. Mussin N, Sumo M, Lee KW, Choi Y, Choi JY, Ahn SW, et al. The correlation between preoperative volumetry and real graft weight: comparison of two volumetry programs. Ann Surg Treat Res 2017;92:214–20.
2. Frericks BB, Caldarone FC, Nashan B, Savellano DH, Stamm G, Kirchhoff TD, et al. 3D CT modeling of hepatic vessel architecture and volume calculation in living donated liver transplantation. Eur Radiol 2004;14:326–33.
3. Emiroglu R, Coskun M, Yilmaz U, Sevmis S, Ozcay F, Haberal M. Safety of multidetector computed tomography in calculating liver volume for living-donor liver transplantation. Transplant Proc 2006;38:3576–8.
4. Heymsfield SB, Fulenwider T, Nordlinger B, Barlow R, Sones P, Kutner M. Accurate measurement of liver, kidney, and spleen volume and mass by computerized axial tomography. Ann Intern Med 1979;90:185–7.
5. Salvalaggio PR, Baker TB, Koffron AJ, Fryer JP, Clark L, Superina RA, et al. Liver graft volume estimation in 100 living donors: measure twice, cut once. Transplantation 2005;80:1181–5.
6. Radtke A, Sotiropoulos GC, Nadalin S, Molmenti EP, Schroeder T, Lang H, et al. Preoperative volume prediction in adult living donor liver transplantation: how much can we rely on it? Am J Transplant 2007;7:672–9.
7. Yonemura Y, Taketomi A, Soejima Y, Yoshizumi T, Uchiyama H, Gion T, et al. Validity of preoperative volumetric analysis of congestion volume in living donor liver transplantation using three-dimensional computed tomography. Liver Transpl 2005;11:1556–62.
8. Li YC, Hu Y, Zhang MM, Jin XQ, Fan X, Pu CL, et al. Usage of 64-detector-row spiral computed tomography volumetry in preoperative volume prediction in living donor liver transplantation in children. Pediatr Surg Int 2011;27:445–9.
9. Hwang S, Lee SG, Kim KH, Park KM, Ahn CS, Moon DB, et al. Correlation of blood-free graft weight and volumetric graft volume by an analysis of blood content in living donor liver grafts. Transplant Proc 2002;34:3293–4.
10. Lemke AJ, Brinkmann MJ, Schott T, Niehues SM, Settmacher U, Neuhaus P, et al. Living donor right liver lobes: preoperative CT volumetric measurement for calculation of intraoperative weight and volume. Radiology 2006;240:736–42.