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Assessment of Role of Computed Tomography Volumetry in Preoperative Evaluation of Liver Volume in Living Donor Liver Transplantation

Mohamed Ibrahim Taema[1], Mohamed Mohsen Tolba Fawzi[2], Aya Mohamed Abd El-Rhim Ali*[1], Mohamed Moataz Al-Fawal[1]
Departments of [1]Radiodiagnosis, and [2]National Hepatology and
Tropical Medicine Research Institute Faculty of Medicine, Zagazig University, Egypt
***Corresponding author:** Aya Mohamed Abd El-Rhim Ali, **E-Mail:** ayaboraey@yahoo.com **Mobile:** (+20) 01069946457,

ABSTRACT

Background: It has been frequently utilized in liver transplantation surgeries to determine the liver's preoperative computed tomography volumetry (CTV) to avoid issues that may arise from graft size and residual liver volume. **Objective:** Liver transplantation in Zagazig University Hospitals was studied to determine the accuracy of the estimation of graft size using manual and automated interactive software. **Patients and Methods:** Eighteen patients; with age range from 21 to 42 years (mean age 30.4 years) and gender distribution of 6 females (33.3%) and 12 males (66.7%). The outpatient clinic of liver transplantation at the National Hepatology and Tropical Medicine Research Institute in Cairo, Egypt, directed all patients to the Radiology Department. All patients had computed tomography volumetry. **Results:** Differences in graft size between preoperative and actual graft measurements had an average volume of 21.7+33.65 cm^3 and between the pre-op and actual graft volumes, the mean difference was 51.96+33.65 cm^3 (range 4-131 cm^3). Mean estimated graft-to-recipient weight ratio (GRWR) was (1.1±.2) and mean actual GRWR was (1.1±.3). Correlation between estimated GRWR and actual GRWR was statistically significant. A significant association was found between mean preoperative volume and total volume of the graft. The findings were statistically significant. **Conclusion:** For determining the volume of preoperative grafts, CT volumetry is a reliable method that was found to be highly correlated with the actual graft volume.

Keywords: Computed tomography volumetry, Liver transplantation.

INTRODUCTION

End-stage liver failure can only be treated by a liver transplant. Living donor liver transplantation (LDLT) has emerged as an option to cadaveric liver transplantation in areas where it is uncommon. However, this procedure necessitates a lengthy and meticulous initial evaluation. Preoperative volume appraisal is one of these difficult steps, and it is of critical relevance to both the donor and the recipient alike. Accordingly, the graft's volume to weight ratio should be at least 0.8% in order to avoid small-for-size problems (cellular damage, liver with limited capacity to perform metabolic processes or synthesize new blood cells, and ascites, poor liver perfusion, increased abdominal pressure). To avoid life-threatening complications for the donor, the residual liver capacity must be at least 30 percent larger **[(1)].** If the liver graft is excessively large, it might cause liver necrosis and slow wound healing, which can have a devastating effect on the recipient (large-for-size) **[(2)].**

As long as the donor does not have steatosis or any kind of liver disease, a 30-percent remnant liver volume for an adult donor is regarded the minimum criterion for transplantation to proceed **[(3)].** A donor's pre-existing liver condition can have an impact on the graft function and survival in addition to its size, which is a relevant consideration. Steatosis of the liver is a typical occurrence in industrialized countries and can have a substantial impact on surgical outcomes in the transplantation process **[(4)].**

A thorough understanding of intrahepatic vascular and biliary anatomy is necessary for accurate liver volume assessment. An accurate measurement of the donor liver volume necessitates thorough familiarity with the surgical process. Important anatomical differences that could affect surgical methods should be addressed **[(5)].** There are only 55.61% of people who have the usual anatomy of the hepatic arterial. The left gastric artery can be used to substitute the left hepatic artery, and the superior mesenteric artery can be used to replace the right hepatic artery, in addition to auxiliary hepatic arteries on the right or left **[(6)].**

The predicted volume and graft weight acquired by CTV have a strong agreement **[(7)].** **Nakayama *et al.* [(8)]** reported that the mean weight of an adult liver was (881.1± 249.8 g), while mean volume of liver was (956.99± 280.1 cm^3).

CT scans and computer systems that automatically calculate donor graft volume are frequently used in the preoperative planning of LDLT. Nevertheless, despite advances in technology, variations in volume assessments between preoperative and intraoperative procedures continue to be observed **[(9)].**

Liver anatomy and the size of potential donor organs are currently assessed preoperatively using CT-volumetry **[(8)].** CT-volumetry can be utilized following clinical assessments of the optimal graft size (e.g., using the "graft weight to body weight ratio") to find the most suitable liver segments for donation **[(10-11)].**

A radiologist typically sums up the liver area on each axial slice of a CTV using manual contour tracing of the hepatic outlines. The basic optical mouse is frequently used for contour tracing. A freehand electromagnetic pen tablet has been used to trace the liver margins in novel ways **[(12,13)].** Both procedures are equally accurate and precise. With the freehand electromagnetic pen contour-tracing method, the

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average segmentation time per patient is greatly reduced. However, manual procedures are time-consuming and need a lot of attention from the operator. Automated and semi-automated methods of volumetric measurements have been offered to further speed up the process and avoid tiresome processes [8, 12-14].

In this study, liver transplantation in Zagazig University Hospitals was studied to determine the accuracy of the estimation of graft size using manual and automated interactive software.

SUBJECTS AND METHODS

Eighteen patients; with age range from 21 to 42 years (mean age 30.4 years) and gender distribution of 6 females (33.3%) and 12 males (66.7%). All patients were referred to the Radiology Department from the outpatient clinic of liver transplantation at National Hepatology and Tropical Medicine Research Institute in Cairo, Egypt.

Ethical consent:

Once all participants had signed informed consent forms and submitted them to the Zagazig University Research Ethics Committee, the study was approved (ZU-IRB#8061). The Helsinki Declaration released by the World Medical Association was adhered to for human testing.

Inclusion criteria: Age group: from 21 to 50 years, both sexes, and any healthy donor with no acute or chronic disease after subjecting to complete history taking and proper examination

Exclusion criteria: Steatosis patients, lack of liver capacity, liver space occupying lesions (SOL), unfavorable anatomical variants, and pregnant or lactating females.

All patients had to go through the followings:

- History taking and clinical provisional diagnosis.
- The subjects' age, gender, height, weight as well as body mass index (BMI) (kg/m^2 considered as BMI up to 25: Non obese and BMI > 25: Obese) were all noted down and analysed. The results were then compared.
- Kidney function test.
- Radiological investigations: computed tomography volumetry.

Technique of CT volumetry:

CT scans were performed on all individuals. VCT (Volume Computed Tomography) Toshiba, gantry rotation period 0.06 seconds, and table speed of 15 milliliters per rotation were used in the scanning procedure. At 120 kV, the X-ray tube current was 280-300 mA. Prior to the examination, all patients were instructed to fast for six to eight hours before the procedure can take place. Adequate hydration was maintained for at least three hours before the examination so that the stomach and intestines were filled with water, allowing for proper subtraction procedures and visualization of target vessels.

During examinations, patients were taught how to hold their breath if necessary to ensure their compliance. Sustained supine position on CT table with patient's arms resting comfortably above the head was called "Headfirst."

An 18–20-gauge catheter was inserted into a superficial vein in the ante-cubital fossa, or the dorsum of the hand, to administer intravenous fluids. An anterior-posterior image was obtained for one scout. A lack of parenchymal blood supply, infection, or biliary dilatation could be seen using pre- and post-contrast imaging. We took our pre-contrast images in the following manner: the slices were taken at 10-mm thickness; the slices were taken at 6-mm pitch; and the sections were taken at 15-ml per rotation on the table. At 120 kV, the X-ray tube current was 280-300 mA. It was done after the maximum of 150 ml of contrast material was given to the patient at a flow rate of 5 ml/s. A low osmolality, non-ionic contrast media was utilized

The gantry rotated at a speed of 0.6 seconds and the table rotated at a speed of 15 ml per revolution to perform helical CT at a nominal section thickness of 10 mm. At 120 kV, the X-ray tube current was 280-300 mA.

At 10 mm, the nominal thickness of a segment, sections were recreated. The exam lasted a total of 70.5 seconds. Images were reconstructed with a 10 mm slice thickness and a 10 mm slice spacing were used to compute volume. Extrahepatic portal vein and inferior vena cava were manually eliminated from volume analysis, along with bigger fissures, gall bladder and hepatic ligamentum teres. We used the middle hepatic vein (MHV) as a landmark to guide our hepatectomy in a craniocaudal path, stretching from the gallbladder fossa to the portal bifurcation. Section I (caudate lobe) was usually spared. The volume of the liver's right and left lobes, with and without MHV, was summed.

Intraoperative graft volume measurement: Weighting the graft immediately after resection provided the true liver volume.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS), version 20, was used to execute analyses on the data collected. The mean, median, standard deviation, and range were used to summarise the quantitative data. Qualitative data were represented as frequency and proportions. Spearman's correlation coefficient and Percent error ratio were calculated. P value < 0.05 was considered significant.

RESULTS

The characteristics of the studied subjects are shown in table 1.

Table (1): Characteristics among studied group

Age (years)	Studied donors (n=18)	
Mean ± SD	30.4 ± 6.1	
Median	30.5	
Min. – Max.	21.0 – 42.0	
Sex	**Studied donors (n=18)**	
	No.	%
Male	12	66.7
Female	6	33.3
Variables	**Studied donors (n=18)**	
Weight (kg): Mean ± SD Median Min. – Max.	74.6 ± 7.3 75.5 56.0 – 87.0	
Height (cm): Mean ± SD Median Min. – Max.	170.0 ± 7.6 170.0 156.0 – 182.0	
BMI (kg/m^2): Mean ± SD Median Min. – Max.	26.1 ± 3.5 25.1 20.6 – 33.0	
Whole liver volume (cm) **Mean ± SD** **Median** **Min. – Max.**	1469.8 ± 205.8 1431.0 1100.0 – 1850.0	
Weight of recipients (kg) **Mean ± SD** **Median** **Min. – Max.**	76.1 ± 13.5 73.5 55.0 – 105.0	

Correlation between estimated GRWR and actual GRWR was statistically significant. There was a high association between the preoperative volume and the final graft volume **(Table 2).**

Table (2): Estimated graft-to-recipient weight ratio, and intraoperative graft weight in the study.

Intraoperative graft weight (gm)	Studied sample (n=18)	
Mean ± SD Median Min. – Max.	790.4 ± 162.0 802.5 542.0 – 1150.0	
Actual graft-to-recipient weight ratio Mean ± SD Median Min. – Max.	1.1 ± 0.3 0.99 0.79 – 1.8	
Correlation between CTV estimated and intraoperative graft weight in the study		
Spearman's correlation	r	P
	0.75	**<0.001**
Correlation between estimated and actual graft-to-recipient weight ratio in the study		
Spearman's correlation	r	P
	0.66	**0.003**

The mean error ratio in our study was 4.4 ± 13.6% **(Table 3).**

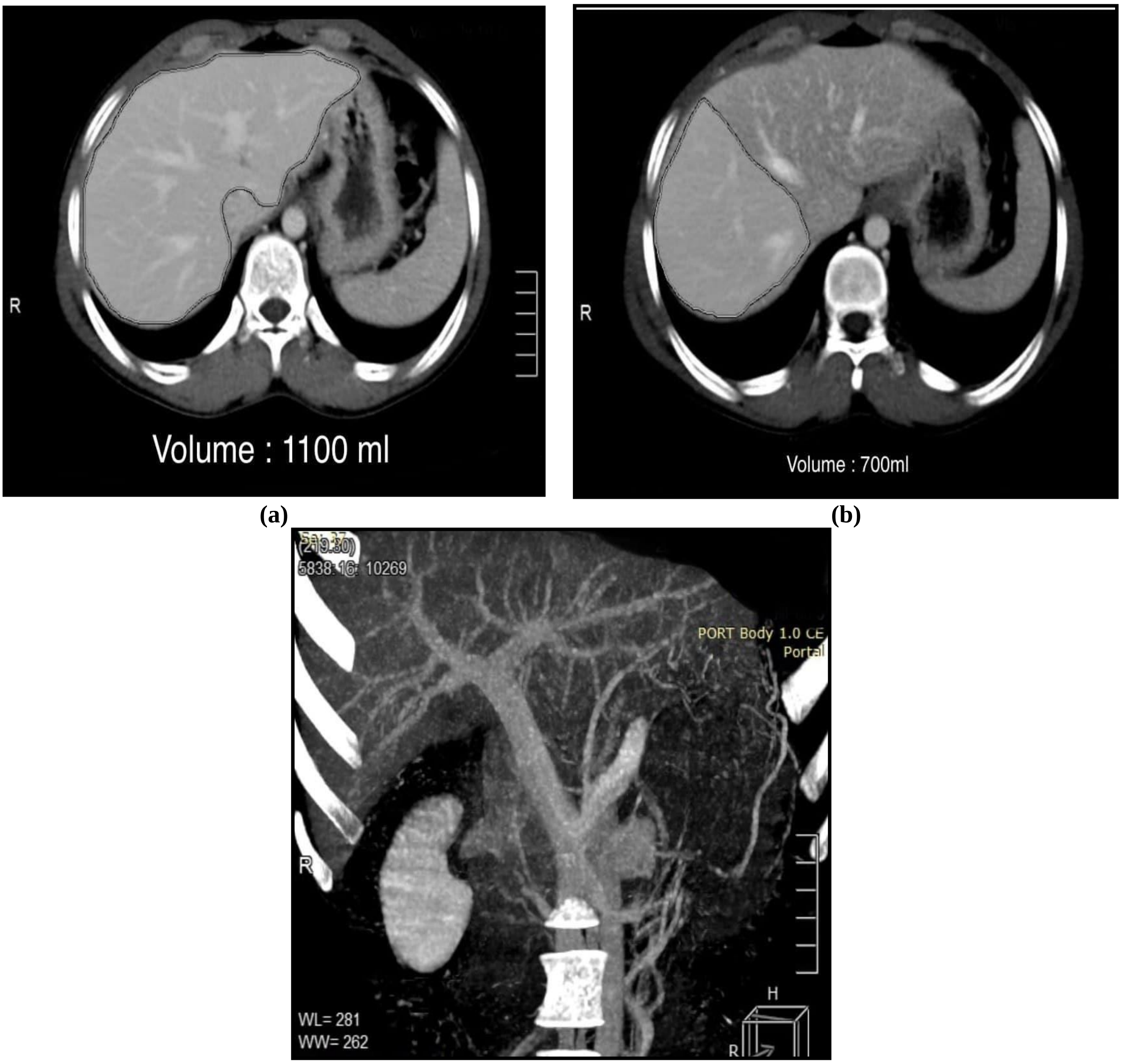
Table (3): Percentage error ratio in the study

Percentage error ratio	Studied sample (n=18)
Mean ± SD	4.4 ± 13.6
Median	1.7
Min. – Max.	-24.7 – 31.6

Computed tomography volumetry was overestimated in 50 % of the studied subjects **(Table 4).**

Table (4): Accuracy of computed tomography volumetry in the study

Types of graft	Studied sample (n=18)	
	No.	%
Underestimation	7	38.9
Accurate estimation	2	11.1
Overestimation	9	50.0



(a) (b)

(c)

Figure (1): 31-year old female donor with BMI of 23.9 and recipient weight 72 K, she had no history of chronic diseases or previous operation, a) Axial CT cut of the abdomen post contrast (portal phase) shows estimated whole liver volume=1100 gm with exclusion of the IVC (b) Estimated right lobe volume=700 gm (without MHV) and resection line (c) CT portography maximum intensity projection (MIP) portal vein is seen patent with normal contrast enhancement, no occluding thrombus or filling defect, normal branching (Right and left) and no sign of portal hypertension (portal vein seen average caliber with no collaterals). Actual intraoperative =595 gm. Estimated GRWR= 0.91. Actual GRWR=0.79.

DISCUSSION

When hepatic illness has progressed to its last stages, the only option left is liver transplantation. There is a shortage of cadaveric liver, which is why living donor liver transplantation (LDLT) is a surgical technique in which healthy donors donate a piece of their liver to compatible recipients so as not to affect the vascular and metabolic needs of the remaining liver [(15)].

In adults, a right hepatectomy is done, while a left hepatectomy is done in children. The size of the graft and the amount of residual liver volume in the donor are the two most critical factors in determining the success of the transplant. Because of the increased metabolic demands of the recipient, a tiny graft may lead to hepatic dysfunction, including hyperbilirubinemia, ascites, and portal hypertension. As an alternative, big grafts might cause anatomical problems, such as inadequate blood flow, difficulty in abdominal closure, and unfavorable vessel orientation [(15)].

However, if the remaining parenchyma of the donor's liver is functionally normal, the recipient can survive if the donor's liver mass is at least 40% of the recipient's or the graft-to-receiver body weight ratio is larger than 0.8 percent. In order to avoid problems with transplant size and remaining liver volume, it is critical that the liver volume of possible living donors be correctly determined [(15)].

Our study was conducted on 18 patients who underwent right lobe liver transplantation; 6 (33.3%) females and 12 (66.7%) males with mean age of (30±6.1), mean BMI (26.1± 3.5), mean height (170 ±7.6), mean weight (74.6± 7.3), mean estimated whole liver (1469.8±205.8), and mean weight of the recipient was (76.1± 13.5). 61.11% donors had BMI<25 and 38.89% donors had BMI> 25. According to **Sharma *et al.*** [(15)] 55.1 percent of donors had a BMI of 25 or less, while 44.9 percent of donors had a BMI of 25 or more, and preoperative (p 0.001) and intraoperative transplant volume and BMI were highly correlated (p 0.001).

According to **Sharma *et al.*** [(15)], there were 816.5+142.5 g preoperative liver volumes, and 812.1+136.2 g intraoperative liver volumes. In our study, however, the intraoperative liver weight was 790.4+162.0 g, whereas the preoperative liver weight was 816.5+142.5 g. However, according to their investigation, they concluded that the volume difference between preoperative and actual graft volume was 21.7+33.65 cm^3 whereas our study indicated that it was 51.96+33.65 cm^3 (range 4-131 cm^3). Mean estimated GRWR was (1.1±0.2) and mean actual GRWR was (1.1±0.3). Correlation between estimated GRWR and actual GRWR was statistically significant. The mean error ratio was 6.59+4.623 %. While the mean error ratio in our study was 4.4 ± 13.6%.

An excellent association was found between mean preoperative volume and total volume of the graft. The findings were statistically significant (r=0.75, p <0.001) in our study and it is close to **Erbay *et al.*** [(16)] and **Emiroglu *et al.*** [(17)]. **Sharma *et al.*** [(15)] reported that mean preoperative volume showed an excellent association with final volume. This is contrary to the findings of the authors, who found a correlation coefficient of 0.98. The findings are statistically significant. (r=0.902, p<0.01).

Goja *et al.* [(18)] observed overestimation more frequently than underestimation, and in **Sharma *et al.*** [(15)] study there were 30 (57.7%) occurrences of underestimate and 22 (42.3%) cases of overestimation of liver volume among the 52 cases studied. **Raj *et al.*** [(19)] according to their study, wider pieces of grafts tend to overestimate the volume of grafts, whereas thinner sections are more accurate (0.625 mm). Slice thickness, according to **Hori *et al.*** [(20)], is only responsible for an inaccuracy of up to 5%. Using a slice thickness of 10 millimeters may have contributed to overestimation in our 18 cases. According to our study underestimation occurred in seven cases (38%), while overestimation occurred in nine cases (50%) and accuracy occurred in two situations (11.1%).

Mussin *et al.* [(1)] found that 55.1 percent of patients in the manual volumetry group had a minimal change (less than 15%) and 44.9 percent of patients had a substantial difference (more than 15%). Only one patient (5.6 percent) had an error ratio of more than 15 percent in our investigation. In contrast to the surgeons, we performed hepatectomy along a straight resection line parallel to the MHV in our research. This tiny gap in results could have been caused by the difference between linear and curved lines.

CONCLUSION

Using CT volumetry to estimate preoperative graft volume was found to be a reliable method that accurately predicted preoperative graft volume and showed excellent agreement with actual graft volume.

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