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Original Research Article

Reliability of CT volumetry as a tool to calculate the preoperative donor liver volume: Correlation with the intraoperative graft weight in living donor liver transplantation (LDLT)

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ABSTRACT

Introduction: Liver transplantation has become an ideal management for end stage liver diseases. The preoperative volumetric assessment of donor liver is an important factor in determining the surgical strategy and in predicting post operative donor and recipient mortality and morbidity. CT has high spatial and contrast resolution and provides comprehensive parenchymal vascular and volumetric preoperative evaluation of donor undergoing live donor liver transplant and its accuracy can be established by comparing it with the intraoperative actual graft volume.

Materials and Methods : 52 patients who underwent donor right hepatectomy were included in the study and underwent CT scanning during the period from July 2017 to June 2019. Manual tracing of CT volumetry was done for calculating liver volume. The actual liver volume is obtained by weighing the graft immediately after resection. The difference between preoperative CT volume and intraoperative graft weight was defined as a percentage error ratio, which was classified as overestimation (+) and underestimation (-).

Results: In 28 (53.8%) cases, right lobe liver grafts obtained including MHV, whereas in 24(46.2%) cases right liver lobe grafts obtained excluding MHV. The mean preoperative liver volume calculated was 816.5+ 142.5g, while the mean volume measured intraoperatively was 812.6 g + 136.8g. The mean volume difference between preoperative and actual graft volume was 51.96+33.65cm^3(range 4-131cm^3). The mean error ratio was 6.59+4.623%. 30(57.7%) cases had underestimation, whereas 22(42.3%) cases had overestimation of liver volume. The mean preoperative volume had a good correlation with actual graft volume.

Conclusion: The present study concludes that CT volumetry accurately predicted preoperative graft volume and showed excellent correlation with actual graft volume.

1. Introduction

Liver transplantation is the treatment of choice for end-stage hepatic diseases. Living donor liver transplantation (LDLT) is a surgical procedure performed to meet the shortage of available cadaveric liver in which healthy donors donate a part of their liver to compatible recipients such that it does not significantly compromise the vascular and metabolic needs of the left over portion of the liver.[1] Right hepatectomy is performed in adults whereas left hepatectomy is performed in pediatric age group. The most important factor responsible for the success of the transplant is the size of the graft and the remnant liver volume in the donor. A small graft may not meet the metabolic demands of the recipient resulting in impaired liver functions such as hyperbilirubinemia, prolonged prothrombin time (PT), ascites and portal hypertension. Conversely, a large graft is associated with anatomical complications causing poor perfusion of the graft, difficulty in abdominal closure

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and unfavourable orientation of the vessels.[1–3] Minimum graft volume of 40% of recipient's liver mass or graft-to-recipient body weight ratio of more than 0.8% is considered sufficient to provide adequate functional hepatocytes to the recipient whereas liver remnant volume of 30-40% of total is adequate for the donor to survive if remnant parenchyma is functionally normal. Therefore, it is essential that liver volume is measured accurately in potential living donors to avoid complications arising due to graft size and remnant liver volume.[4,5]

Hence preoperative estimation of liver volume is essential for successful outcome. Ultrasound has not universally shown success for 3D evaluation of the liver mainly because of limitations due to variable reproducibility of the examination depending on the examiner.[6] The quality of MRI images is often degraded by motion artefacts precluding precise assessment.[6] At present, CT volumetry is the most preferred method for preoperative volumetric assessment of the liver because CT has high spatial and contrast resolution.

CT volumetry is traditionally been performed by manual tracing of the liver boundary and summation of the liver area on individual axial section. At our institute, we also used manual CT volumetry which is still the most widely used method for liver volumetry due to its accuracy.[4–6] Still there are conflicting datas about CT Volumetry regarding its accuracy in estimation of graft volume. This study intends to correlate the results of CT volumetry with the intraoperative weight of liver graft in patients undergoing Living Donor Liver Transplantation(LDLT).

2. Materials and Methods

2.1. Data Extraction

Subject source were the patients admitted in BLK Super speciality Hospital, Pusa Road, New Delhi for liver transplant in Liver transplant unit and Radiodiagnosis department during the duration of July 2017 to June 2019. The prospective study design consisted of 52 donors who came for liver transplantation with age ranging from 18 years to 49 years with mean age 30years and gender distribution of 21 females (40.4%) and 31 males (59.6%). Patients with significant steatosis, inadequate liver volume, liver SOL and unfavourable anatomical variants were not included in the study.

3. Method of Evaluation

The approval of research protocol by the local ethics committee was taken and after taking informed consent from all the patients, procedure of doing CT scan was explained accordingly. Relevant clinical and family history was taken. Parameters like the age (years), sex, weight(kg), height(cm) and BMI(kg/m2 taken as BMI < 25- Non obese, BMI > 25- Obese)were taken.

CT Scanning was performed with 64 slice Lightspeed VCT (Volume Computed Tomography)– GE Healthcare. Imaging protocol on MDCT consists of obtaining non-contrast images through the liver parenchyma, followed by CT angiography in the arterial, portal, and hepatic venous phases. CT angiographic images obtained after intravenous administration of 100-120 ml of non ionic contrast agent Iohexol 350 (Omnipaque) at a flow rate of 4 ml/s using real time bolus tracking. Volumetry is calculated manually with images reconstructed with 5 mm slice thickness and slice interval of 5 mm. All major vessels such as the extrahepatic portal vein in the area of porta hepatis and inferior vena cava as well as larger fissures, gall bladder and the hepatic ligamentum teres were manually excluded from the volume analysis. We performed hepatectomy in a craniocaudal direction using the middle hepatic vein as a landmark and extending along the gallbladder fossa anteriorly and the portal bifurcation posteriorly. The caudate lobe (segment I) is typically spared. Total liver volume, right and left lobe volume including and excluding MHV is calculated. In present study, 28(53.8%) right liver lobe grafts obtained including MHV, whereas 24(46.2%) grafts obtained excluding MHV (Figure 1)

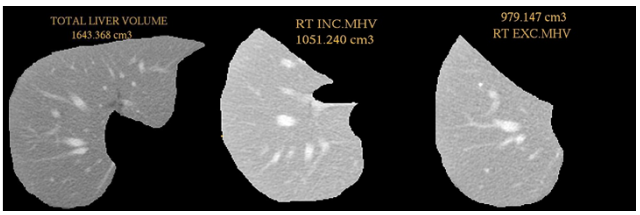

Fig. 1: CT Volumetry images representing TLV, RT+MHV and RT-MHV respectively

3.1. Intraoperative graft volume measurement

The actual liver volume is obtained by weighting the graft immediately after resection.

3.2. Statistical Analysis

The difference between preoperative CT volume (A) and intraoperative graft weight (B) was defined by a percentage error ratio= (A-B)/B *100.

(+) error percentage=overestimation, (-) error percentage = underestimation.

The graft recipient weight ratio (GRWR) estimated using CT volume, intraoperative weight and recipient weight. The normal range we considered in our study is 0.8-2.9%.

The statistical significance of categorical variables with outcome was determined by using Pearson's chi-square/ Fisher Exact test. The statistical significance was taken as $p < 0.05$. The data was analysed with SPSS statistical software version 22.0.

4. Results

The mean preoperative liver volume (A) calculated was 816.5+ 142.5g, while the volume measured intraoperatively (B) was 812.6 g + 136.8g. The mean volume difference between preoperative and actual graft volume was 51.96+33.65cm^3(range 4-131cm^3). The mean error ratio was 6.59+4.623%.

The mean preoperative volume had a good correlation with actual graft volume. The results being statistically significant.(r=.902, p<0.01)(Diagram 1).

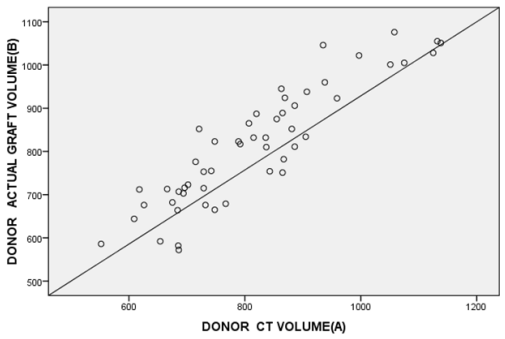

Diagram 1: Correlation between donor CT volume and actual graft volume

The mean preoperative right lobe liver volume (A) in male and female donors was 812+ 140.56 and 822+148.47g, respectively, while the mean right lobe volume measured intraoperatively (B) in male and female was 810.6 g + 131.123g and 816.14 g + 148.142g respectively. In present study, gender didn't have any significant correlation with preoperative (p=0.801) and intraoperative graft volume (p=0.481).

The mean preoperative liver volume (A) in age<20 years, 21-30 years, 31-40 years and >40 years was 737.86g, 799.86g, 904.08g and 795g, respectively, while the mean volume measured intraoperatively (B) was 754.86g, 797.76g, 895.15g and 780g respectively. In present study, age didn't have any significant correlation with preoperative (p=0.270) and intraoperative graft volume (p=0.390).

In present study, 55.1% donors had BMI<25 and 44.9% donors had BMI> 25. The mean preoperative liver volume (A) in BMI < 25 and >25 was 761.74g and 884.95g, respectively, while the mean volume measured intraoperatively (B) in BMI < 25 and >25 was 767.96g and 871.18g respectively. In present study, BMI have significant agreement with preoperative (p<0.001) and intraoperative graft volume (p=0.001).

The overall measured mean error ratio was 6.59+4.623%. 30 (57.7%) cases had underestimation, whereas 22(42.3%) cases had overestimation of liver volume (Diagram 2).

In our study 2 patients had graft recipient weight ratio <0.8 and no patient had graft recipient weight ratio >3%. However, no complications of small-size graft developed in those 2 patients.

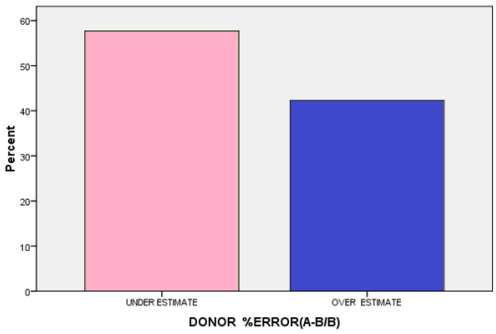

Diagram 2: Percentage of Over/Underestimation.

5. Discussion

CT has high spatial and contrast resolution and provides comprehensive parenchymal vascular and volumetric preoperative evaluation of donor undergoing live donor liver transplant.[7] In present study, the mean preoperative volume had a good correlation with actual graft volume. The results being statistically significant. (r=.902, p<0.01). Some studies have reported a correlation coefficient of 0.898 between the preoperative and actual graft volume.[1,2] Some studies have reported an error ratio of 10% to 20%.[8–10] In our study, the mean error ratio was 6.59+4.623%.

Goja et al[11] have reported overestimation more than underestimation. In present study, 30 (57.7%) cases had underestimation, whereas 22(42.3%) cases had overestimation of liver volume. Raj et al[12] reported that thinner slice had a good correlation with graft volume than a thicker sections, where thicker sections tend to underestimate the graft volume compared to thinner sections (0.625mm). Hori et al[13] suggested that a maximum of 5% error can be attributed to slice thickness. In our study we have used 5mm slice thickness likely contributing to underestimation.

Baskiran et al[10] reported that age and BMI had a significant impact on the error percentage while gender did not. In present study, donor's age and gender didn't have any significant agreement with error percentage (p=0.500, 0.523 respectively) and overestimation or underestimation (p=0.881,0.740 respectively). While BMI have significant agreement with error percentage (p=0.030) but it didn't have any significant agreement with overestimation or underestimation separately (p=0.740).

Mussin et al[9] classified the error ratio as minimal difference (<15%) and big difference (>15%), in which 55.1% patients in manual volumetry group had minimal difference and 44.9% patients had big difference. In our study 48 (92.30%) patients had error ratio <15% and 4 (7.7%) had error ratio >15%. In our study we have done hepatectomy using a linear imaginary resection line along

the MHV while the surgeons used a curvilinear resection line. The discrepancy between linear and curvilinear line could have resulted in that small variation in results.

Hwang et al[14] reported that 100 gm of liver contained 20gm of blood. Kim et al[15] reported that percentage of blood volume varies from 6.5% to 19.8%. In our study we have used manual method so we could not subtract all intrahepatic blood volume whereas intraoperatively, graft volume is measured blood free, this could have resulted in overestimation in our results.

6. Conclusion

The present study concludes that CT volumetry for preoperative graft volume assessment is a reliable tool and it accurately predicted preoperative graft volume and showed excellent correlation with actual graft volume and suggested that BMI has significant agreement with preoperative and intraoperative graft volume as well as with percentage error ratio. Age and gender did not have any significant correlation with graft volume , error percentage, over- and underestimation.

7. Recommendations

CT must be used routinely in LDLT patients for pre-operative assessment of liver volume. However, we recommend use of thinner slices instead of thick sections, although it is time consuming but it can significantly reduce the error percentage ratio. We would also like to recommend the use of curvilinear resection line on CT volumetry simulating the surgical incision, which can decrease magnitude of overestimation and underestimation.

8. Acknowledgement

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9. Source of Funding

None.

10. Conflict of Interest

None.

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