RESEARCH ARTICLE

Computed tomography liver volumetry in living donor liver transplantation: influence of the slice thickness on the volume calculation

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Abstract

Objective: To evaluate the effect of slice thickness on multidetector computed tomography-based preoperative liver volumetry, and to compare the time consumed during volumetry between thin and thick slices.

Method: The retrospective study was conducted at the Pakistan Kidney and Liver Institute and Research Centre, Lahore, Pakistan, and comprised data from September 2022 to January 2023 of patients who underwent donor hepatectomy. Liver volumetry was done on thick 5mm and thin 0.625mm slices, and the consumed time was calculated. The calculated volumes were then compared to the actual per-operative graft volume. Data was analysed using SPSS 20.

Results: Of the 30 donors, 20(66.7%) were males and 10(33.3%) were females. The overall mean age was 26±6.25 years (range: 19-44 years. The mean estimated graft volume on thick slices was 668.57±169.83g compared to 693.70±174.78g on thin slices (p>0.05). The time taken to calculate estimated graft volume on thick slices was 7.29±0.97 minutes compared to 44.07±4.78 minutes on thin slices (p<0.05). The mean actual per-operative graft volume was 632.40±160.03.

Conclusion: There was no significant difference between the volumes calculated on thick and thin slices, but there was significant difference in time taken for volumetry.

Key Words: Multidetector computed tomography-based preoperative liver volumetry, Total liver volume, Graft volume, Actual graft volume, Slice thickness.

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Introduction

End-stage liver disease (ESLD) is a serious condition characterised by liver failure and decompensated cirrhosis, which has high mortality rates. It typically occurs after liver inflammation, leading to fibrosis and scarring, and loss of normal liver functions. The only definitive cure for liver failure is liver transplant surgery, which is commonly performed as living-donor liver transplantation (LDLT) in Pakistan.[1,2]

For LDLT, accurate estimation of liver volume is pivotal to avoid metabolic mismatches between the donor and the recipient, which can result in small-for-size-syndrome or large-for-size-syndrome, and increase the risk of graft rejection.[3] The safety of the donor and the recipient is the most important concern in LDLT. A remnant liver volume of 30-35% of the original liver volume is crucial for the donor's safety, and at least 40% of the standard liver mass or more than 0.8% graft-recipient weight ratio (GRWR) is needed for the recipient. A liver recipient with a GRWR <0.8% has a very low chance of survival.[4] Therefore, it is essential for surgeons to have accurate preoperative measurements with minimal errors.

Preoperative liver anatomy and volume assessment of potential liver donors are usually done using computed tomography (CT) volumetry.[2] Semiautomatic interactive liver volumetry methods are now widely used in clinical practice, where the volume of the liver is calculated by measuring the area of each cross-sectional image by manual correction of tracing of the hepatic contours.[5] The volume is then determined by multiplying the area by the slice thickness and summation of the slice volumes.[6] One factor that can affect the accuracy of preoperative volume calculation is the slice thickness of CT, which can cause partial volume effects.[6,7]

Although volumes calculated from 0.625mm images are expected to be more precise and accurate than those from thicker images about 5mm, more time and effort are required for volume calculation on the basis of 0.625mm images due to the greater number of images to be analysed.[6]

The current study was planned to evaluate the effect of slice thickness on multidetector CT-based preoperative liver volumetry, and to compare the time consumed during volumetry between thin and thick slices.

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Materials and Methods

The retrospective study was conducted at the Pakistan Kidney and Liver Institute and Research Centre, Lahore, Pakistan, and comprised data from September 2022 to January 2023 of patients who underwent donor hepatectomy. After approval from the institutional ethics review board, the sample size was calculated with 95 % level of significance, 10% level of precision, and variation of thick slice from original 71.49. The formula[8] used was:

$$n = \frac{Z^2_{1-\alpha/2}\delta^2}{\varepsilon^2}$$

With the formula, Z1-α/2 was the level of significance (95%), δ was the expected variation in thick group from real (71.4; based on a pilot study, ε was the precision error (10%), and n was the expected sample size (28.08≈30).

The condition of informed consent was waived due to the retrospective design of the study. All the patients who underwent liver resections had triphasic CT evaluation as a part of their pre-surgical planning on a 128-channel multidetector-row CT scanner General Electric (GE) Computed Tomography System Type Revolution EVO 128 slices after injecting 2 ml/kg of iodinated contrast media (Ultravist 370 mgI/mL) at a rate 5.5 ml per second via a power injector system. Preoperative estimated liver volumes were calculated by using a dedicated GE Advantage Workstation which is a semiautomated software for liver volumetry (Volume Viewer 10.5.53, AW server 3.2 Ext.1.2). All healthy livers were included which had been selected for donor hepatectomy. Data of rejected donors with fatty liver and with benign or malignant tumours was excluded.

Two radiologists with >5 years' experience in hepatobiliary imaging performed liver volumetry on thick and thin slices. Portal venous phase was used to mark the liver boundary. Dry volumes of right and left lobes were calculated separately by subtracting portal and hepatic vein volumes (Figure 1).

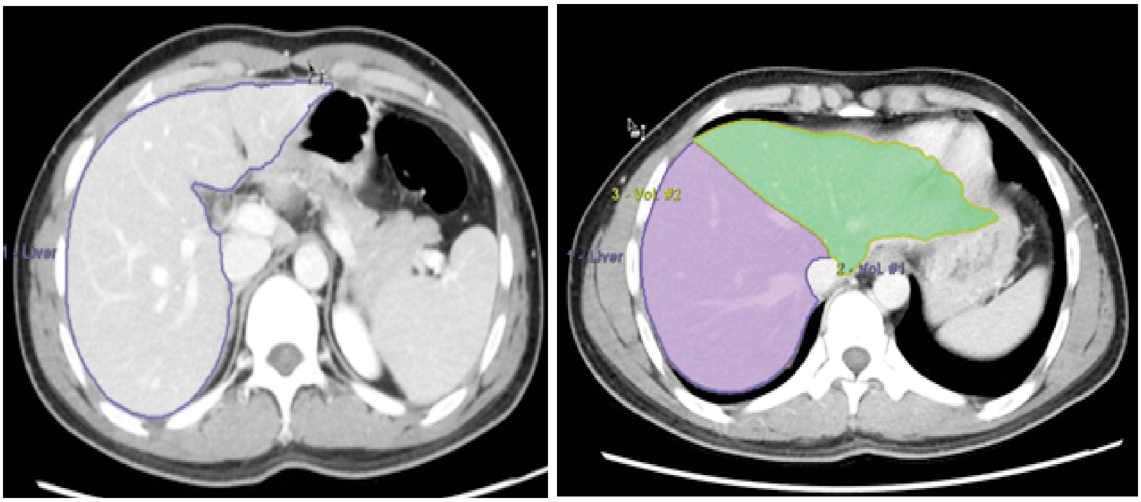

Figure-1: Hepatic contour tracing with manual correction and liver segmentation with virtual cut during computed tomography (CT) volumetry.

Liver volumetry was done on thick 5mm and thin 0.625mm slices, and the consumed time was calculated using a stopwatch. The estimated graft volumes (EGVs) obtained were then compared with actual graft volumes (AGVs) measured immediately after liver resection in the operating theatre (OT). As per the institutional policy, an acceptable difference between EGV and AGV was taken to be 100 g, and this difference was calculated using the formula:

Difference = AGV – (EGV/1.19).[9]

Data was analysed using SPSS 20. The calculated volumes from different slice thicknesses were compared. The differences were analysed statistically with a multiple comparison analysis. A 2-tailed $p<0.05$ value was considered statistically significant. Pearson correlation coefficient (r) was used to study the correlation between EGVs and the time taken for volumetry on both thick and thin slices.

Results

Of the 30 donors, 20(66.7%) were males and 10(33.3%) were females. The overall mean age was 26 years (range:

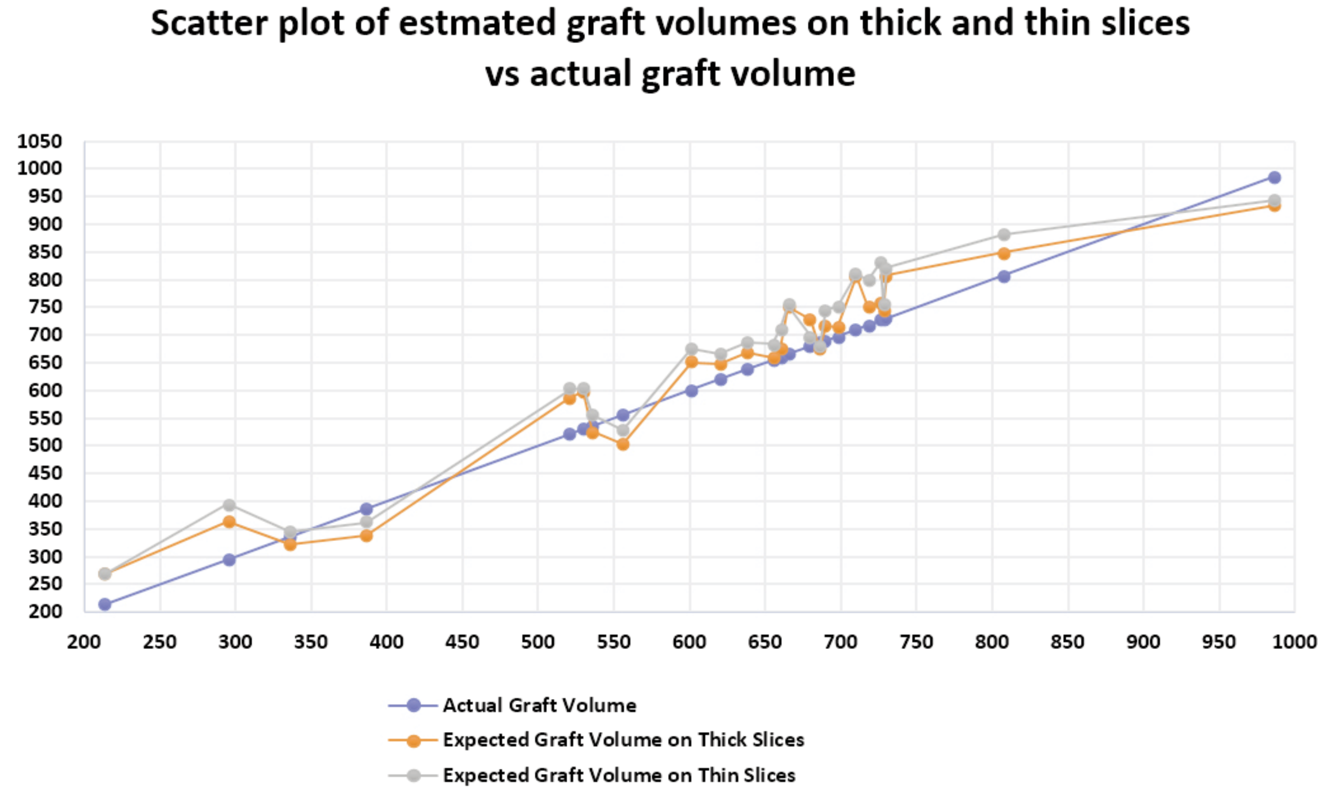

Figure-2: Scatter plot of expected graft volume (EGV) on thick and thin slices compared to actual graft volume (AGV).

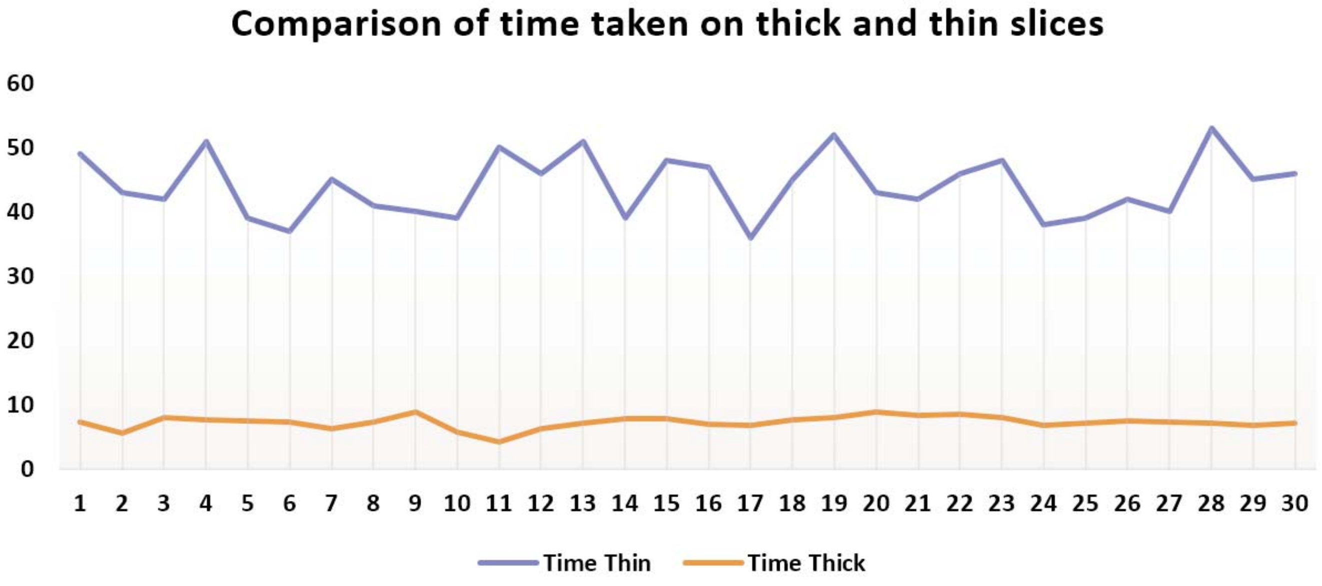

Figure-3: Time measurement between thick and thin slice volumetry.

19-44 years), the median age was 24 and IQR=8.

The mean total liver volumes on thin and thick slices were 1184.1±164.5 gm and 1137.8±165.1 gm respectively. The mean EGV on thick slices was 668.57±169.83g compared to 693.70±174.78g on thin slices. The time taken to calculate estimated graft volume on thick slices was 7.29±0.97 minutes compared to 44.07±4.78 minutes on thin slices. The mean AGV was 632.40±160.03.

Upon assessing variables descriptively, the mean total liver volumes and EGVs on thick and thin slices were not significantly different ($p<0.05$). The mean difference between total liver volumes on thick and thin slices was 46.26 g (SD= 45.46). The mean difference between calculated graft volumes on thick and thin slices was only 25.13 g (SD=20.85). Similarly, the mean difference between estimated graft volume on thin slices (0.625 mm) and actual graft volume and mean difference between estimated graft volume on thick slices (5 mm) and actual graft volume was 61.30 g (SD=54.97) and 36.16 g (SD=47.91) respectively. However, the mean difference between time taken to calculate EGV on thick and thin slices was 37.2±4.8 minutes ($p<0.05$).

Scatter plots showed good agreement between EGVs on thick and thin slices (Figure 2). The difference between time taken for volumetry using thin and thick slices was significantly different (Figure 3).

The correlation coefficient value was positive($r=0.962$) for EGVs on thick and thin slices, and it was negative ($r=-0.59$) for the time taken for volumetry using thin and thick slices.

Discussion

LDLT is the treatment of choice today for ESLD. The two main considerations for LDLT are donor safety, and graft and recipient survival.[10] Therefore, careful selection and detailed evaluation of the donor is critical to providing maximum possible benefit to the recipient.[10-12] For this, all potential donors must undergo multi-step detailed evaluation process, including detailed anatomical study of the liver.[10] CT liver volumetry is an essential part of the donor evaluation protocol, which is done by the radiologists to provide estimated graft volume before considering surgery. The accuracy of these volumes is important to guarantee adequate graft volume to recipient as well as to ensure enough residual liver volume for the donor which should be at least 40% of the standard liver mass, or more than 0.8% GRWR[4]. It is done nowadays using semi-automated interactive liver volumetry method, which involves manual correction of tracing of the hepatic contours.[5,13] This method itself is dependent on various other factors that include volumetry technique, operator's experience, image acquisition parameters, and differential contrast between the surrounding tissues. Another very important and essential parameter is the slice thickness on which this volumetric assessment is performed.[13] Theoretically, and according to the previous research on effects of slice thickness, the precision of estimated volume increases with decreasing slice thickness. However, it also significantly increases the workload on the radiologists. In a volumetric study, effect of slice thickness was observed and significant increase in estimated liver volume was reported when slice thickness was decreased[6]. Considering the resultant increased workload of radiologists and surgeons, 5mm slice thickness was considered acceptable for volumetry if 5% error was permissible[6]. To the best of our knowledge, only one dedicated study has been conducted to measure the time taken for volumetry on thick and thin slices.[14]

In the current study, most of the volumes were within the permissible margin of error accepted by the institutional policy on both thick and thin slice volumetry except for a few outliers that were out of range for both thick and thin slices; 3 EGVs on thin slices and 4 EGVs on thick slices. Therefore, there was no significant difference in the accuracy of EGVs on thick and thin slice volumetry when compared to AGV. The observed over- or under-estimation of volumes cannot be explained only by the effect of slice thickness. Other causes of error include under-estimation of the blood volume in intrahepatic vessels.[15-17] This is explained by the fact that actual graft collapses with no blood flowing through the vessels before anatomosis.[14] Another possible explanation is the difference of actual surgical plane of dissection versus the plane drawn by radiologists during volumetry, partial volume effects, drawing of contour and segmentation or the examination technique.[14,18-20] Since these differences are almost the same for thick and thin slices, if the huge difference of consumed time (44±4.7 min on thin slices vs 7.2±0.9 min on thick slices) is kept in mind, it would be reasonable to adopt thick slice volumetry without any unacceptable compromise on accuracy. Apart from saving time, it can decrease huge amount of workload on the radiologists.

The current study has a few limitations. The sample size was relatively small, and comprised both left and right lobe graft estimations in a single study. These need to be studied separately to know the effects of slice thickness on right lobe and left lobe grafts estimation. The study included slice thickness of 0.625mm and 5mm, while slice thickness of 2.5mm could also be included to further observe the differences and consider the best possible slice thickness in terms of both precision and required time.

Conclusion

The estimated graft volumes calculated on thin 0.625mm and thick 5mm slices did not differ significantly. Considering the required precision of the calculated volume and the significant reduction of the operator time needed for volumetric measurements, a 5-mm slice thickness appeared to be the preferred slice thickness for CT volumetry.

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TF: Data acquisition, analysis, drafting.
MSR: Conception of idea and design, data acquisition.
SK: Intellectual input.
TM: Final approval.
FI: Data acquisition and interpretation.
SZ: Critical analysis.