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COMPARISON OF LIVER VOLUMETRY USING MANUAL COMPUTED TOMOGRAPHY VOLUMETRY AND STANDARD LIVER VOLUME FORMULA

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ABSTRACT

Objective: To compare liver volumes measured by manual computed tomography (CT) volumetry with those estimated using a standard liver volume (SLV) formula incorporating body thickness and weight and to assess the accuracy and correlation between the two methods.

Materials and Methods: This was a Descriptive cross-sectional study conducted in the department of Diagnostic Radiology, Doctor's Hospital and Medical Centre, Lahore. This study was carried out for six months from October 2025 to March 2026. A total of 195 adult patients aged 18–65 years undergoing abdominal CT for non-hepatobiliary indications were included using non-probability sampling. Patients with known liver pathology, abnormal liver or renal function tests or contraindications to CT were excluded. CT scans were performed using a 160-slice Toshiba Aquilion Prime scanner. Total liver volume (TLV) was calculated using manual CT volumetry by summation of area method, excluding intrahepatic vessels. Standard liver volume (SLV) was estimated using the formula: SLV = (2 × body thickness + 10 × weight + 190). Data was analyzed using SPSS version 22, and Pearson correlation coefficient (R^2) was used to assess agreement between SLV and CT-derived TLV.

Results: The mean age of patients was 41.47 ± 13.79 years, and mean body weight was 70.69 ± 11.41 kg. A strong positive correlation was observed between SLV and CT-derived TLV ($R^2 = 0.69$, $p < 0.001$). However, SLV consistently underestimated liver volume compared to CT measurements. Stratified analysis showed significant differences across age and weight groups ($p < 0.05$), with increasing discrepancy observed in higher body weight categories.

Conclusion: Although SLV formula demonstrates a strong correlation with CT-derived liver volume, it tends to underestimate actual liver size. CT volumetry remains the most accurate method for liver volume assessment and should be preferred for preoperative evaluation in liver surgery and transplantation while SLV formulas may serve as a convenient alternative in routine clinical settings.

KEYWORDS: Liver volumetry, computed tomography, standard liver volume, liver transplantation, CT volumetry, liver resection.

INTRODUCTION

Liver is considered as one of the most vital organs in the human body. It plays a central role in the metabolism, detoxification as well as synthesis of essential proteins. In clinical practice, accurate measurement of liver volume is important especially in case of liver resection and transplantation. (Olson et al., 2022) Imaging techniques have evolved significantly over the years and computed tomography (CT) has emerged not only as a diagnostic tool for liver pathologies but it is also a reliable method for three-dimensional volumetric analysis. (Castaing et al., 2007) The role of computed tomography has extended beyond its use for liver imaging to include three -dimensional volumetric measurements before resection and transplantation. Volumetric measurements are essential for surgical planning and outcome prediction. (Levesque et al., 2013)

In liver transplantation and hepatic resections, estimation of liver volume is essential to ensure both donor safety and recipient survival. A key parameter is the standard liver volume (SLV) which is considered as the expected liver size based on individual anthropometric characteristics. (Hashimoto et al., 2006) Accurate estimation of SLV is important because it helps to determine the appropriate graft size required to meet the metabolic demands of the recipient. (Tongdee et al., 2013) It is recommended that the graft volume of the recipient's SLV should be approximately 30–40% to ensure adequate liver function post-transplantation. (Inomata et al., 1999)

An imbalance between graft size and recipient requirements can lead to serious complications. A graft that is too small for the recipient may result in small-for-size syndrome. This condition is characterized by impairment in liver function due to insufficient hepatocyte mass. (Sakamoto et al., 2001) This can lead to increased parenchymal cell injury, reduced metabolic and synthetic capacity and poor graft survival. Moreover, transplantation of an excessively large graft into a smaller recipient may result in large-for-size syndrome. (Dogar et al., 2022) Large-for-size syndrome is associated with complications such as vascular compromise, immunological dysfunction and respiratory distress. Therefore, precise liver volume estimation is important to achieve optimal clinical outcomes, improving graft survival and enhancing overall prognosis. (Khalaf et al., 2007)

Liver transplantation is considered the best treatment for patients with end-stage liver disease. Because it not only replaces the diseased organ but may also address underlying conditions such as cirrhosis. Accurate liver volumetry plays an important role in multiple aspects of transplant planning.(Gondolesi et al., 2004) It helps in determining the minimum acceptable liver volume for recipients, assessing donor suitability, ensuring graft safety as well as facilitating appropriate allocation of liver segments. It also assists the surgeons in planning a precise operative strategy to minimize perioperative risks. (Shi et al., 2009)

Standard liver volume has been estimated using mathematical formulas derived from anthropometric parameters such as body weight, height and body surface area. Approximately fifteen different SLV formulas have been proposed in the literature worldwide. (Sandroussi et al., 2009) The existence of numerous formulas reflects the lack of a universally accepted method as each formula demonstrates variable accuracy across different populations. Among these, a relatively simple and practical formula based on CT-measured body thickness and patient weight has been proposed. (Siriwardana et al., 2011) It is expressed as: $(2 \times \text{thickness} + 10 \times \text{weight} + 190)$. (Kiuchi et al., 1999) This formula shows comparatively better predictive performance with an R^2 value of 0.48, which was the highest when compared with the other most often cited formulas. (Kokudo et al., 2015)

Several studies have demonstrated that CT-derived liver volume measurements are generally more accurate than estimates obtained from SLV formulas. (Yoshizumi et al., 2003) In particular, formulas based only on body surface area or body weight shows only moderate predictive capability, with reported R^2 values of approximately 0.46 and 0.49, respectively, when compared with CT volumetry. (Feng et al., 2017) Moreover, population-specific variations further limit the universal applicability of these formulas. A comparative study conducted in a Southeast Asian population found that none of the seven widely used SLV formulas achieved high accuracy. (Selzner et al., 2009) Even the best-performing formulas, developed by FuGui and Poovathumkavadil, showed only moderate correlation with CT-derived liver volumes with a maximum correlation coefficient of 0.74. (Fu-Gui et al., 2009)

There is a growing need to evaluate and compare different methods of liver volume estimation to identify the most reliable method. Manual CT volumetry, although time-consuming is considered a gold standard due to its ability to provide patient-specific and anatomically accurate measurements. (Ma et al., 2017) On the other hand, SLV formulas offer a quicker and more convenient alternative but may lack precision in individual cases. Although many SLV formulas based on body weight and surface area are available, their accuracy varies across populations and they often lack patient-specific precision.(Shirabe et al., 1999)

Therefore, the aim of this study is to compare liver volumes obtained through manual computed tomography volumetry with those estimated using standard liver volume formulas. Recent approaches suggest that CT-based volumetry, especially with added parameters like body thickness may provide more reliable estimates.

MATERIAL AND METHODS

This Descriptive cross-sectional study was carried out in the Department of Diagnostic Radiology, Doctor's Hospital and Medical Centre, Lahore. Th study duration was of 6 months from October 2025 to March 2026. The study was conducted after approval of synopsis from CPSP (Ref No: CPSP/REU/RAD-2022-090-3925 Dated January 15, 2026). A total of 195 patients were included in this study. Non-probability sampling technique was used.

Adults of age 18 to 65 years undergoing abdominal CT scan for non-hepatobiliary indications (e.g., renal donor evaluation, abdominal pain workup) were included. Patients with no known liver pathology, such as fatty liver, liver cirrhosis, or malignancy, confirmed by clinical history and radiological findings were a part of this study. Patients with normal liver function tests (LFTs) at the time of evaluation were enrolled. Both male and female were included in this study.

Patients who were unable to undergo CT scanning, such as pregnant women (confirmed by clinical history or urine pregnancy test, if indicated) and patients with a known allergy to iodinated contrast agents (e.g., urografin) were excluded. Patients with any known liver pathology such as fatty liver, cirrhosis, hepatic tumors, or hepatitis, as identified through clinical history, laboratory findings (e.g., abnormal LFTs), or radiologic signs on CT (e.g., surface nodularity, altered echotexture, liver lesions) were not included. Patients with right heart failure, suspected based on clinical history (e.g., edema, dyspnea) or imaging findings such as hepatic venous congestion on CT were excluded. Patients with deranged renal function (serum creatinine > 1.1 mg/dL) or abnormal liver function tests (elevated ALT, AST, ALP, or bilirubin) were not taken into account.

After approval of synopsis from the Institutional Ethical Review Committee, a total of 195 adult patients meeting the inclusion criteria were prospectively enrolled from the Department of Diagnostic Radiology, Doctors Hospital and Medical Centre, Lahore. All participants underwent abdominal CT scans for clinical indications unrelated to liver pathology. After obtaining written informed consent, each patient's demographic details (age, gender) and body weight were recorded on a pre-designed data collection proforma. All CT scans were performed using the 160-slice Toshiba Aquilion Prime scanner. Initial non-contrast scans were followed by administration of 120–130 mL of non-ionic iodinated contrast at a flow rate of 3.5 mL/sec using an automated injector. Imaging was acquired in triphasic or biphasic sequences, including the portal venous phase, with the following scan parameters: 120 kV, variable mA, automatic collimation, and 1 mm slice thickness.

Total Liver Volume (TLV) was measured from CT images by excluding the intrahepatic blood vessels using the summation of area method. The Standard Liver Volume (SLV) was calculated for each patient using the anthropometric formula: SLV = 2 × body thickness (mm) + 10 × weight (kg) + 190. The primary outcome variable is the accuracy of the SLV formula was assessed by comparing it to the CT-derived TLV.

- Correlation Coefficirnt (R^2) between SLV and TLV.

To minimize bias, all CT scans were performed on the same machine and liver volumetry was conducted by a single experienced radiologist using consistent methodology. Patient demographic and measurement data were recorded by the same trained nurse to avoid inter-observer variation. Effect modifiers, such as age, gender, and body habitus were documented and considered during data analysis to assess their influence on liver volume estimations. Confounding variables (e.g., liver disease, abnormal renal/liver function) were controlled through strict exclusion criteria. All collected data was securely recorded by the principal investigator in the structured proforma for analysis.

Data was analyzed using SPSS version 22.0. Quantitative variables such as age, body weight, CT-derived liver volume and standard liver volume (SLV) were presented as means ± standard deviations. Qualitative variables, such as gender were presented as frequencies and percentages. The primary outcome variable was the correlation of the SLV formula compared to CT-derived liver volume. Pearson correlation coefficient (R^2) was used to evaluate the strength of association between SLV and CT-derived TLV. To assess the influence of effect modifiers such as age, gender, and body weight on the accuracy of SLV estimation, stratification and subgroup analysis were performed. A p-value of < 0.05 was considered as Statistically significant.

RESULT

A total of 195 patients were included in the study. The mean age of participants was 41.47 ± 13.79 years, ranging from 18 to 64 years. The study included both male and female participants, with a slight male predominance: 107 (54.9%) were males and 88 (45.1%) were females. The mean body weight of the study population was 70.69 ± 11.41 kg, indicating a relatively balanced distribution across different body weights. All participants underwent contrast-enhanced computed tomography scans for non-hepatobiliary indications and only those with normal liver morphology and function were included. This careful selection helped minimize confounding factors and allowed for a more accurate comparison between CT-derived liver volumes and standard liver volume estimations.

Table 1: Demographic Characteristics of Study Population (n = 195)

Variable	Mean ± SD / Frequency (%)
Age (years)	41.47 ± 13.79
Weight (kg)	70.69 ± 11.41
Gender	
• Male	107 (54.9%)
• Female	88 (45.1%)

The study population consisted of a balanced distribution of genders with a slight male predominance. The average body weight was within normal adult range.

Table 2: Comparison of CT-Derived Total Liver Volume (TLV) and Standard Liver Volume (SLV)

Variable	Mean ± SD	Minimum	Maximum
CT-derived TLV (mL)	1757.03 ± 327.12	622.2	2888.0
SLV (mL)	1296.33 ± 119.85	890.2	1767.1

CT-derived liver volumes were consistently higher than SLV values calculated using the formula. Thus, indicating a measurable difference between the two methods.

Table 3: Correlation Between SLV and CT-Derived TLV

Variable Comparison	Correlation Coefficient (R)	R^2 Value	p-value
SLV vs CT-TLV	0.83	0.69	< 0.001

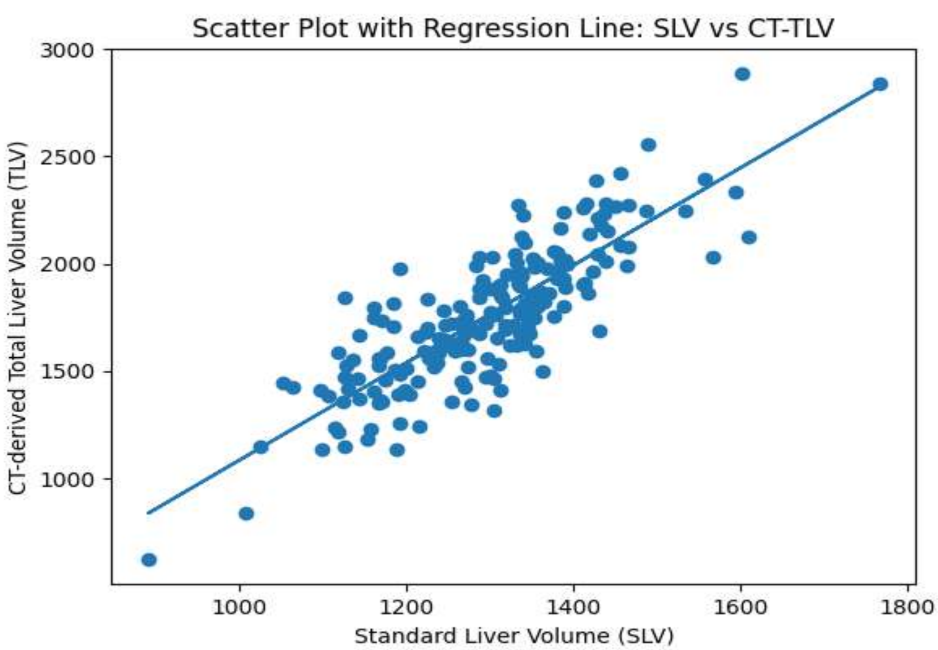
A strong positive correlation (R = 0.83) was observed between SLV and CT-derived TLV. The R^2 value of 0.69 indicates that approximately 69% of the variability in CT liver volume can be explained by the SLV formula. The result was statistically significant ($p < 0.001$).

Table 4: Stratification of Liver Volume by Gender

Gender	Mean CT-TLV (mL)	Mean SLV (mL)
Male	1825.4 ± 310.2	1325.6 ± 115.3
Female	1675.8 ± 298.7	1262.4 ± 110.6

Male participants showed higher liver volumes compared to females in both CT and SLV measurements reflecting expected physiological differences.

Figure: Scatter plot showing correlation between Standard Liver Volume (SLV) and CT-derived Total Liver Volume (TLV).



A scatter plot with regression line showing a strong positive linear relationship between SLV and CT-derived TLV. As SLV increases, CT-TLV also shows a corresponding increase. The regression line indicates a consistent trend, supporting the statistically significant correlation observed in the study ($R^2 = 0.69$, $p < 0.00$

DISCUSSION

Accurate estimation of liver volume is an important component in preoperative planning for liver resection and transplantation. This estimation directly influences donor safety and recipient outcomes. In the present study, a comparison was made between CT-derived total liver volume (TLV) and standard liver volume (SLV) calculated using an anthropometric formula incorporating body thickness and weight. The findings showed a strong positive correlation ($R^2 = 0.69$, $p < 0.001$) between the two methods. However, SLV consistently underestimated liver volume when compared to CT volumetry.

The results of this study are consistent with previous literature which suggests that CT-based volumetric analysis remains the most accurate method for liver volume estimation. A study by Vauthey JN et al. reported that CT volumetry provides precise and reproducible measurements. Thus, making it the gold standard in preoperative liver assessment. (Vauthey et al., 2002) Similarly, Urata K et al. emphasized that although SLV formulas are useful for quick estimation but they often fail to account for individual anatomical variations and lead to discrepancies when compared with imaging-based measurements. (Urata et al., 1995)

In our study, the SLV formula showed a tendency to underestimate liver volume across all subgroups including different age and weight categories. This finding aligns with the work of Heinemann A et al., who demonstrated that anthropometric formulas based solely on body surface area or weight may not fully capture inter-individual variability in liver size. (Heinemann et al., 1999) Furthermore, the increasing rates observed in higher weight groups in our study suggests that body composition plays an important role in liver volume estimation.

Another important finding of this study was the statistically significant difference between CT-derived TLV and SLV across all age groups. Although liver volume showed a slight increase with advancing age, the SLV formula did not proportionately reflect these changes. This observation is supported by findings from Chan SC et al., who reported that population-specific and age-related variations significantly influence liver volume, thereby limiting the universal applicability of standard formulas. (Chan et al., 2006)

The correlation coefficient observed in this study ($R^2 = 0.69$) is higher than that reported in several earlier studies using traditional formulas. For instance, studies evaluating body surface area-based formulas have reported R^2 values ranging from 0.46 to 0.49 (5,6). This suggests that the inclusion of body thickness as a parameter may improve the predictive accuracy of SLV estimation. A study by Yuan et al. also highlighted moderate correlation ($r \approx 0.74$) between SLV formulas and CT volumetry. This further supports the notion that anthropometric formulas while useful are inherently limited. (Yuan et al., 2008)

Despite these improvements, CT volumetry remains superior due to its ability to provide patient-specific, three-dimensional assessment of liver anatomy. It allows exclusion of vascular structures and focal lesions. So it offers a more accurate estimation of functional liver parenchyma. However, manual CT volumetry is time-consuming and requires expertise, which limits its routine use in all clinical settings. In contrast, SLV formulas are simple, quick and cost-effective. This makes them useful for initial screening and decision-making especially in resource-limited settings.

The strengths of this study include a relatively adequate sample size and strict inclusion and exclusion criteria which minimized confounding variables such as underlying liver disease and abnormal biochemical parameters. Additionally, the use of a single CT scanner and a consistent measurement technique helped reduce inter-observer variability.

CONCLUSION

This study demonstrates that although standard liver volume (SLV) formulas show a strong positive correlation with CT-derived liver volumetry but they tend to underestimate actual liver volume when compared with manual CT measurements. The incorporation of body thickness in the SLV formula improves its predictive ability. However, CT-based volumetry remains the most accurate and reliable method for assessing liver volume. Therefore, CT volumetry should be preferred for precise preoperative evaluation in liver surgery and transplantation while SLV formulas may still serve as a useful, quick screening tool in routine clinical practice.

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