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Liver Volume Estimation in North Indian Population Using CT Volumetry Method

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Abstract

Background: Evaluation of chronic liver disease, planning of liver resection, and hepatic transplantation all rely on accurate liver volume assessment. An accurate and non-invasive method for measuring liver volume is computed tomography (CT) volumetry. "The purpose of this study was to determine the liver volume reference values in the North Indian population using computed tomography (CT). With these values, we could next examine the relationship between liver volume and age, sex, body mass index (BMI), waist circumference, and other body measurements. Lastly, we could see if the current SLV formulas worked for this population.

Methods: One hundred adults (all 18 and up) got contrast-enhanced CT scans for reasons other than hepatobiliary issues as part of a prospective observational research at HIMSR—New Delhi. A semi-automated method was used to do the liver volumetry. We took note of anthropometric and demographic data, such as height, weight, gender, body mass index (BMI), waist size, and body surface area (BSA). The associations between liver volume and the variables under consideration were investigated using a correlation analysis. Using the Chandramohan, Urata, and Heinemann formulae, the volumes measured by CT were compared with the estimated SLV volumes.

Results: There was an equal distribution of genders in the study population, with 52% females and 48% males, and an average age of 40.92 ± 16.67 years. The range for the mean CT-measured liver volume was 1023.20-3251.70 cm³, with a standard deviation of 552.77 cm³. There was a notable negative relationship between liver volume and age (r=-0.229, p=0.022), with volumes falling from 1888.7 ± 621.0 cm³ in those aged 40 and under to 1453.6 ± 265.4 cm³ in those aged 60 and above. At 2029.5 ± 597.8 cm³ versus 1518.4 ± 368.8 cm³, p<0.001, males showed noticeably bigger liver sizes than females. Weight (r=0.690, p=0.003) and body mass index (r=0.616, p<0.001) showed strong positive relationships. Although all three previous formulas had significant variations from actual CT measurements, the Chandramohan formula demonstrated the strongest association with CT volume (r=0.764, p=0.001), followed by the Heinemann formula (r=0.720, p=0.006) and Urata (r=0.684, p=0.003).

Conclusion: Liver volume reference values for the North Indian population were determined in this study, which also found strong relationships with anthropometric variables such as age and gender. To enhance practical applications in transplantation and surgical planning, region-specific formulas are necessary, as none of the current SLV formulas correctly predicted liver volume in this group.

Keywords: Liver volume, CT volumetry, North Indian population, Standard liver volume, Anthropometric parameters, Liver transplantation, Population-specific reference values

Introduction

When it comes to hepatic transplantation, liver resections, chronic liver disease (CLD) prognosis, and pharmacokinetic investigations, an accurate assessment of liver volume is now crucial [1]. This is accomplished with the use of imaging modalities such multidetector computed tomography (MDCT), magnetic resonance imaging (MRI), and ultrasonography (USG). MRI has excellent tissue contrast but is not as widely available as USG, which is constrained by operator dependence. CT volumetry is the gold standard for accurate preoperative liver volume evaluation because to MDCT's superior spatial resolution and the ability to perform three-dimensional reconstruction [2].

A number of factors influence liver volume, such as chronological age, gender, BMI, BSA, and general health. Liver volumes in men tend to be greater than in women. Standard liver volume (SLV) determination, especially in partial hepatectomy and transplantation, relies heavily on these differences [3]. One way to improve the evaluation of functional liver reserve is to include liver volume in already-established scoring systems, like the Child-Pugh score [3].

The importance of precise SLV computation has grown in tandem with the frequency of liver transplants [5]. Real liver volume is untrustworthy for surgical planning since cirrhotic, diseased livers tend to be tiny, and hepatectomy cases can involve enlarged livers with tumours. Thus, SLV is used to guide operational decisions. It is still unclear whether the existing SLV formulas, which are based on data from Western countries, Japan, and Southeast Asia, can be applied to the North Indian population. The necessity for data particular to regions is underscored by morphological differences across populations [6].

The use of CT-based factors in conjunction with demographic and anthropometric data has recently been highlighted in research as a means to produce more precise SLV estimates [7]. There is a chance to study liver volume variations in connection to age, sex, and BMI in the North Indian population [8]. More trustworthy clinical application can be achieved by validating or modifying current SLV equations for this demographic [9].

With a focus on the North Indian population and the use of CT volumetry—the gold standard for non-invasive liver volume measurement—this study aimed to fill these gaps. The advantages of CT volumetry include precise three-dimensional reconstruction, excellent spatial resolution, and the capacity to exclude non-parenchymal objects like tumours and big arteries, resulting in trustworthy measurements.

Materials and Methods

The Department of Radiodiagnosis at HIMSR, New Delhi, a tertiary medical facility serving a varied urban and rural population, was the site of this prospective observational study. One hundred people who had CT scans for reasons unrelated to hepatobiliary disorders participated in the 18-month trial. Patients who met the inclusion criteria and were 18 years old or older were enrolled after they provided written informed permission. Exclusion criteria included a history of hepatomegaly-causing acute febrile illnesses, focal liver lesions, hepatic surgery, or transplantation, as well as diffuse hepatic disorders.

A comprehensive evaluation was conducted on all individuals who met the inclusion criteria. This evaluation included taking anthropometric measurements such weight, height, age, sex, and body mass index (BMI). A Philips Incisive 128-slice CT scanner was used for all of the scans. While the patient was in the supine position, a contrast-enhanced CT scan (CECT) of the abdomen was performed, encompassing the area between the diaphragm and the pubic symphysis. Axial scans were acquired both prior to and during the intravenous administration of iohexol, and sagittal and coronal reconstructions were applied. Liver volume was estimated using the portal venous phase, which occurs 60-70 seconds after contrast. Using a semi-automatic approach, liver volumetry was conducted.

We looked at the data to see how liver volume changed with age, sex, body mass index, waist size, and weight. To assess their suitability for the Indian population, CT-derived liver volumes were contrasted with standard liver volume (SLV) estimates obtained from the Chandramohan, Urata, and Heinemann equations.

Microsoft Excel was used for data compilation, and SPSS version 24.0 was used for analysis. All variables, whether continuous or categorical, were subject to descriptive statistics. While non-parametric Mann-Whitney and Kruskal-Wallis tests were utilised as necessary, independent t-tests and chi-square tests were utilised for comparisons. A statistically significant result was defined as a p-value less than 0.05.

Prior to the study, the necessary approvals were received from the Institutional Ethics Committee, and informed consent was obtained from all participants. The research team took every precaution to protect the privacy of the patients' information.

Results

The majority of the 100 participants in the study were aged 40 years or younger (56% of the total), and their average age was 40.92 ± 16.67 years. The gender distribution was almost balanced, with 52% being female and 48% being male". The anthropometric measures revealed a moderately active population with a range of body types, with an average body mass index (BMI) of 24.09 ± 4.04 kg/m².

There was a notable inverse relationship between liver volume and age (p=0.012), with a decrease from 1888.7 ± 621.0 cm³ in persons aged 40 and under to 1453.6 ± 265.4 cm³ in those aged 60 and above. The liver volumes of males were found to be much higher than those of females, demonstrating inherent physiological differences (2029.5 ± 597.8 cm³ vs 1518.4 ± 368.8 cm³, p<0.001).

There was a substantial association between CT volume and the Chandermohan formula (r=0.764, p=0.001), the Heinemann formula (r=0.720, p=0.006), and the Urata formula (r=0.684, p=0.003). There was a considerable influence of body size on liver volume, as indicated by the following anthropometric parameters: weight (r=0.690, p=0.003), BMI (r=0.616, p<0.001), and BSA (r=0.525, p=0.001).

Table 1: Baseline Characteristics of Study Participants (n=100)

Characteristic	Mean ± SD	Median	Range	n (%)
Age (years)	40.92 ± 16.67	36.0	18.0-75.0	
• ≤40 years				56 (56.0)
• 41-60 years				27 (27.0)
• >60 years				17 (17.0)
Gender				
• Female				52 (52.0)
• Male				48 (48.0)
Weight (kg)	68.64 ± 13.29	71.50	34.0-90.0	
Height (cm)	168.48 ± 8.01	170.18	144.8-185.4	
BMI (kg/m^2)	24.09 ± 4.04	24.42	16.2-31.6	
Waist circumference (cm)	87.76 ± 10.67	87.0	66.0-106.0	
BSA (m^2)	1.74 ± 0.18	1.76	1.32-2.08	

Table 2: Liver Volume Measurements (n=100)

Method	Mean ± SD (cm^3)	Median (cm^3)	Range (cm^3)
CT Volumetry	1763.70 ± 552.77	1608.10	1023.20-3251.70

Table 3: Association of Liver Volume with Demographic Factors

Variable	Mean ± SD (cm^3)	Median (cm^3)	Range (cm^3)	p-value
Age Groups				0.012
• ≤40 years	1888.7 ± 621.0	1817.7	1026.5-3251.7	
• 41-60 years	1699.7 ± 451.2	1589.0	1023.2-2938.4	
• >60 years	1453.6 ± 265.4	1527.1	1056.8-1978.1	
Gender				<0.001

• Male	2029.5 ± 597.8	1852.6	1023.2-3251.7	
• Female	1518.4 ± 368.8	1519.1	1026.5-2916.2	

Table 4: Correlation Analysis between CT Volume and Study Variables

Variable	Pearson Correlation (r)	p-value
Formula-based Methods		
• Chandermohan Formula	0.764	0.001
• Heinemann Formula	0.720	0.006
• Urata Formula	0.684	0.003
Anthropometric Parameters		
• Weight	0.690	0.003
• BMI	0.616	<0.001
• BSA	0.525	0.001
• Height	0.355	0.011
• Waist circumference	0.269	0.007
• Age	-0.229	0.022

Discussion

This study used computed tomography (CT) volumetry to measure liver volume in a North Indian population and looked at how factors including age, gender, body mass index (BMI), waist size (WGS), and body standard index (BSA) affected the results. To further assess their usefulness in this population, the researchers compared CT-measured liver volumes with standard liver volumes (SLV) calculated using the Chandramohan, Urata, and Heinemann formulas.

The participants in the study were all adults (18+), and their ages ranged from 36 (median) to 40.92 (mean). The gender distribution was nearly equal, with 52% females and 48% males, and 56% of the participants were aged 40 years or younger. Similar to Koher Harada et al. [10], who investigated gender and age-related changes in liver volume in a separate cohort, our results are consistent with those of Jasper et al. [60], which also reported a balanced gender ratio and a comparable age range. The fact that there were equal numbers of men and women in the sample confirms that gender has a role in liver size measurements.

Weight was 68.64 kg, body mass index was 24.09 kg/m², and body surface area was 1.74 m², according to anthropometric measurements. A liver volume ranging from 1023.2 cm³ to 3251.7 cm³ was determined to be an average of 1763.7 cm³ (SD 552.77), with a median of 1608.1 cm³. Even among members of the same population, there is a noticeable range in liver size, as seen by this variation. Henderson JM et al. (1493 cm³) and Geraghty EM et al. (1560 cm³) [11–12] showed slightly lower mean values, adding credence to the hypothesis that regional and ethnic variances greatly affect liver volume.

The results showed a negative association between age and liver volume, which was statistically significant ($p=0.012$). The average liver capacity was highest in participants aged 40 and less (1888.7 cm³), then it dropped in the 41-60 year old group (1699.7 cm³), and finally it fell even further in the >60 year old group (1453.6 cm³). This pattern is in agreement with what Koher Harada et al. [10] found: a decrease in liver volume with age, particularly in men. These results highlight the importance of including age as a variable in SLV formulations that are tailored to individual populations. Males had noticeably bigger liver volumes (2029.5 cm³) than females (1518.4 cm³), according to gender analysis ($p=0.0001$). This trend supports earlier research, such as that by Koher Harada et al. [10], and highlights the need for reference values that are specific to gender.

There were robust positive correlations between liver volume and weight ($r=0.690$, $p=0.003$) and body mass index ($r=0.616$, $p=0.000$) according to the correlation analysis. Waist circumference demonstrated a small but statistically significant positive link ($r=0.269$), whereas height and BSA displayed moderate relationships ($r=0.355$ and $r=0.525$, respectively). These results are in line with those of Jean Nicolas Vauthey et al. [13], who similarly found a robust correlation between BSA, weight, and liver volume in individuals from the West. This study highlights the importance of anthropometric characteristics in SLV estimation, particularly for individuals with a wide range of body types.

There was a good connection ($r=0.764$) between CT-measured liver volumes and SLV estimated using Chandramohan's formula, Heilemann's formula ($r=0.720$), and Urata's formula ($r=0.684$). In spite of these correlations, when compared to CT volumetry, all formulas demonstrated statistically significant discrepancies ($p<0.05$), suggesting that they are not very useful for the North Indian population. Consistent with previous research, these results confirm that current formulas are inadequate for Indian patients and that population-specific equations are necessary (Anuradha Chandramohan et al., 2014; Sudeep Naidu et al., 2015).

Even within India, there may be regional variations; for example, Gaurav Chaubai et al. [16] found that Urata's formula was the most accurate for the Western Indian population. These discrepancies could be a result of the fact that North and Western Indian populations differ in terms of genetics, nutrition, and body composition. This further supports the idea that instead of using a national equation, it would be more appropriate to develop regional formulas that are specific to certain subpopulations.

Xiaopeng Yang et al. [17] highlighted the importance of combining CT volumetry with body composition and abdominal geometry to improve SLV prediction, which is in line with the current study's findings. In a similar vein, Vauthey et al. [13] suggested weight-and BSA-based formulas to enhance preoperative planning and liver graft selection. Accurate volumetry is clinically relevant for surgical decision-making and transplantation outcomes, as shown in the current study and others like it.

Conclusion

While the mean volumes were somewhat lower than Western data, they were comparable to earlier Indian investigations and offered CT-based reference values for liver volume in the Indian population. There was a positive relationship between liver volume and height, body mass index (BMI), weight, and BSA, and a negative relationship between liver volume and age. Although height and body mass index (BMI) were also considerable predictors, weight and BMI emerged as the most significant. None of the standard SLV formulas accurately predicted liver volume in this population, though Chandramohan's formula showed the closest approximation. The results show that CT-based liver volume measurement needs region-specific SLV formulas for better clinical use and set population-specific standards.

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