International Journal of Research in Medical Sciences
Sharma M et al. Int J Res Med Sci. 2016 Jul;4(7):3020-3023
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20161996

Research Article

Assessment of liver volume with spiral computerized tomography scanning: predicting liver volume by age and height

Madhu Sharma[1], Abhishek Singh[2]*, Shewtank Goel[3], Setu Satani[4], Kavita Mudgil[5]

[1]Department of Radiology, FH Medical College, NH-2, Tundla, Uttar Pradesh, India
[2]Department of Community Medicine, SHKM Govt. Medical College, Mewat, Haryana, India
[3]Department of Microbiology, Teerthanker Mahaveer Medical College and Research Centre, Moradabad, Uttar Pradesh, India
[4]Consultant Radiologist, Global Hospital, Mumbai, India
[5]Department of Ras Shastra and Bhaisajya Kalpana, Smt. Urmila Devi Ayurvedic College and Hospital, Hoshiarpur, Punjab, India

Received: 13 June 2016
Accepted: 20 June 2016

***Correspondence:**
Dr. Abhishek Singh,
E-mail: abhishekparleg@gmail.com

ABSTRACT

Background: Estimation of liver size has critical clinical implication. Precise knowledge of liver dimensions and volume is prerequisite for clinical assessment of liver disorders. Liver span as measured by palpation and USG is prone to inter-observer variability and poor repeatability. The aim was to assess the normal liver volume of healthy adults using spiral computed tomography scans and to observe its relationship with various body indices.
Methods: In this prospective study, all the patients who underwent spiral computed tomography (CT) of the abdomen or thorax in department for conditions unrelated to the hepatobiliary system, during the study period were included. One hundred patients were selected using convenient sampling technique. Study subjects were evaluated clinically and also by laboratory tests. Volume was determined by multiplying the sum of all slices by the 3-D image reconstruction and volume-rendering tool.
Results: Liver volume reciprocally correlated with age (correlation coefficient: r=0.11, p=0.04). Liver volume also correlated with other indices as body height (r=0.12, p=0.02), body weight (r=0.16, p=0.02), BMI (r=0.06, p=0.05) and BSA (r=0.04, p=0.01). Age and body height were found to be good predictors of liver volume (adjusted r2=0.011, F=3.169) and liver volume was best predicted by the following equation: liver volume=672.35+(-8.41x age)+(722.80 x body height).
Conclusions: Liver volume is a reliable index of liver size and measurement of liver volume with spiral CT is useful method. Spiral CT can be utilized for measurement of liver volume for such purpose.

Keywords: Assessment, Liver volume, Spiral CT, Indices, Regression equation

INTRODUCTION

Estimation of liver size has critical clinical implication. Precise knowledge of liver dimensions and volume is prerequisite for clinical assessment of liver disorders and it can facilitate decision making in liver transplant surgery especially to avoid donor-recipient graft mismatch.[1,2] In liver transplantation, pre-transplant liver volume is an independent determinant of the prognosis of graft liver.[3] Overestimation of the donor's SLV may result in excessive hepatic resection leading to liver failure, while underestimation of the recipient's SLV may result in small-for-size graft syndrome.[4] Of several indexes of liver size, liver span and liver volume are important.[5] Liver span (longitudinal diameter) was traditionally used because it can be conveniently measured using palpation and ultrasonography (USG).[6] Liver volume can be measured by USG but it is bounded by some variations due to observer bias. With development of more elaborate imaging methods such as magnetic resonance imaging (MRI), spiral computed tomography, measurement of mass or organ volume has become feasible.[7] The spiral CT images, which can generate 3-D reconstruction images, are particularly accurate in measurement of organ volume.[8]

Considering the complexity of liver shape, liver span alone cannot appropriately represent liver mass. Size of liver is also an important factor when considering surgical correction during liver transplantation and any other liver pathology.[9] Liver span as measured by palpation and USG is prone to inter-observer variability and poor repeatability.[10] There are very few published studies on assessment of liver volume with spiral computerized tomography scanning and predicting liver volume by age and height from India. The present study was therefore conducted to assess the normal liver volume of healthy adults using spiral computed tomography scans. An additional objective of this study was to observe its relationship with various body indices.

METHODS

This prospective study was planned and executed by the Department of Radiology of a tertiary care teaching institution of northern India during 2014-15. All the patients who underwent spiral computed tomography (CT) of the abdomen or thorax in department for conditions unrelated to the hepatobiliary system, during the study period were included in this study. One hundred patients were selected using convenient sampling technique.

The study population comprised of outpatients (OPD) and in-patients (IPD) that required CT examination due to common clinical conditions. After obtaining informed consent from the patients, the medical records and laboratory findings of the patients along with the radiologist's report for each CT examination were studied. Exclusion criteria were subjects who did not give consent, patients unable to comply with procedure, those who had received chemotherapy or on radiotherapy during the two years prior to study or patients with disorder known to affect liver and pregnant females.

Study subjects were evaluated clinically and also by laboratory tests. Data of individuals included in present study was age, sex, body height (BH, measured to the nearest 1 cm) and body weight (BW, measured to the nearest 0.5 kg). Body surface area (BSA) was then calculated using the DuBois and DuBois formula: BSA (m^2)=(BW (in kg) 0.425xBH (in cm)0.725) x 0.007184 and body mass index (BMI) was calculated by-BMI (kg/m^2)=Weight (kg)/(body height (meter)).[2]

CT scans were assessed maintaining a fixed and specified technical configuration while taking CT slices. The CT scan was done in supine position. The thickness of each slice was 10 mm. Estimation of liver volume using CT-Volume of liver was measured using Able 3D Doctor 3.5 (software) in axial CT image.

The liver volume was measured through contiguous slices. The software enabled free hand outlining of the perimetry of liver by digital pen. Investigator trained to recognize the relevant organ boundaries performed all outlining. Inferior vena cava, extra-parenchymal portal vein and the gall bladder were excluded from outline. Hepatic veins and intra-parenchymal portal venous system were included in outlining. Volume was determined by multiplying the sum of all slices by the 3D image reconstruction and volume-rendering tool.

The study adhered to the tenets of the declaration of Helsinki for research in humans. Permission of institutional ethics committee (IEC) was sought before the commencement of the study. All the questionnaires were manually checked and edited for completeness and consistency and were then coded for computer entry. After compilation of the collected data, analysis was done and then results were expressed using appropriate statistical methods.

RESULTS

Data of 100 subjects (62 males and 38 females) was analyzed and included in the present study. Their mean age was 48.33±10.87 years, mean body weight was 62.06±8.84 kg, mean body height was 1.59±0.05 m, and mean BMI was 24.63±3.16 kg/m^2 and mean BSA was 1.58±0.11 m^2 (Table 1).

Table 1: Baseline characteristics of study participants.

	Mean	Standard deviation
Age (years)	48.33	10.87
Height (m)	1.53	0.05
Weight (Kg)	62.06	8.84
BMI (Kg/m^2)	24.63	3.16
BSA (m^2)	1.58	0.11

Maximum liver volume (2,123 cm^3) was in 21-25 years of age group and minimum liver volume (1,022 cm^3) was associated with 66-70 years of age group (Table 2).

In graph plotted between mean age (in different age group) and mean liver volume estimated (in different age group) shows a linear fall in liver volume with advancing age (Figure 1).

Liver volume reciprocally correlated with age (correlation coefficient: r=0.11, p=0.04). Liver volume also correlated with other indices as body height (r=0.12, p=0.02), body weight (r=0.16, p=0.02), BMI (r=0.06, p=0.05) and BSA (r=0.04, p=0.01).

Table 2: Estimated liver volume in different age groups of study subjects.

Age (years)	Liver volume (cm^3)
21-25	2123 cm^3
26-30	1633 cm^3
31-35	1274 cm^3
36-40	1395 cm^3
41-45	1702 cm^3
46-50	1306 cm^3
51-55	1045 cm^3
56-60	1168 cm^3
61-65	1184 cm^3
66-70	1022 cm^3

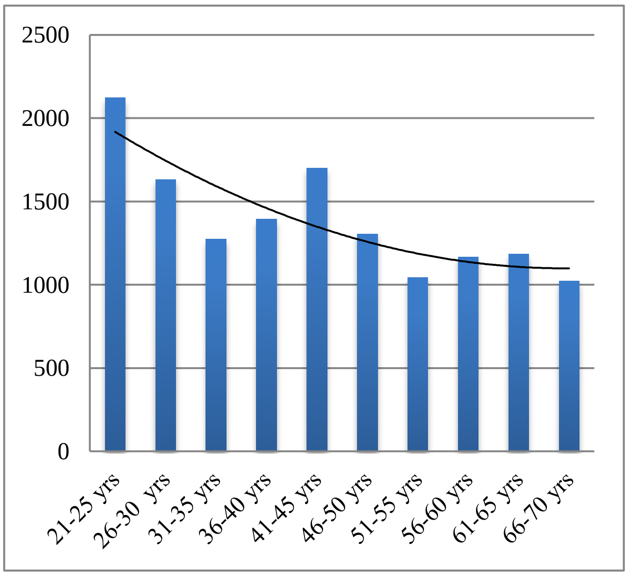

Figure 1: Bar chart showing age group wise estimated liver volume among study subjects.

In males, liver volume showed good reciprocal correlation with age (r=0.24, p=0.02), but in females liver volume correlates more with weight (r=0.21, p=0.03) than age.

On deriving multivariate linear regression formula, age and body height were found to be good predictors of liver volume (adjusted r^2=0.011, F=3.169) and liver volume was best predicted by the following equation: liver volume=672.35+(-8.41xAge)+(722.80xbody height).

DISCUSSION

Organ volume must be related to an individual's age, sex and body habitus for a more precise interpretation of abnormality, for example liver volume is decreased in pathologies leading to fibrosis and consequent shrinkage like cirrhosis of liver.[11] Thus accurate estimation of liver volume is essential prior to living related liver transplant since small for size grafts are known to cause complications and compromised outcome.[12] This study evaluated the normal liver volume in adult Indian subjects by spiral CT.

Another author from India measured the liver weight by post-mortem study whereas the current study was done in living healthy subjects by spiral CT, hence more reliable for surgeons to assess liver volume more precisely in north Indian population.[5]

Henderson et al found that CT volume measurement of the liver correlated well with actual liver volume, with 95% accuracy.[13] In the present study the liver volume was calculated by manual tracing of liver boundary over the abdominal CT scan images. This method was previously suggested as a reliable method.

Another study from south India observed that the mean liver volume in south Indian population to be 1186 cc, which is less than that observed in the current study.[14] It could be due to different body habitus and environment between north Indian and south Indian population. On the other hand, these values were lower than study by Henderson who studied western population but higher than Nakayama who studied Japanese subjects.[4,13] A probable explanation can be given that average Indian body indices lie between a higher western and lower Japanese, body indices.

In this study we observed that liver volume reciprocally correlated with age (correlation coefficient: r=0.11, p=0.04). Liver volume also correlated with other indices as body height (r=0.12, p=0.02), body weight (r=0.16, p=0.02), BMI (r=0.06, p=0.05) and BSA (r=0.04, p=0.01). Another study by Agrawal D et al, is also in concordance with our observations.[15] The results of present study on the relationship between liver volumes with age as well as body height are consistent with those of previous studies.[16] Liver volume was correlated significantly with age, body height, body weight, BMI and BSA, but age showed a relatively greater correlation.

Regarding multivariate linear regression formula, in this study age and body height were found to be good predictors of liver volume (adjusted r^2=0.011, F=3.169) and liver volume was best predicted by the following equation: Liver volume=672.35+(–8.41 x Age)+(722.80 x body height). The result of this study is in agreement with previous study from northern India.[15] That study derived the formula as, liver volume=678.35+(-8.45 x age)+(724.84 x body height).

CONCLUSION

Liver volume assessed with computerized tomography scanning has correlated well with age reciprocally and with body height positively. Thus on the basis of empirical evidences of this study it can be concluded that liver volume is a reliable index of liver size and measurement of liver volume with spiral CT is useful method. Spiral CT can be utilized for measurement of liver volume for such purpose.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Sharma M, Singh A, Goel S, Satani S, Mudgil K. Assessment of liver volume with spiral computerized tomography scanning: predicting liver volume by age and height. Int J Res Med Sci 2016;4:3020-3.