

Assessment of Liver Volume with Spiral Computerized Tomography scanning in North Indian Adults

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Abstract

AIM: To evaluate the normal liver volume in north Indian population by using spiral computerized tomography. **METHODS:** CT data of 337 patients (176 males, 161 females) was prospectively evaluated. Body parameters (body height, body weight, body surface area and body mass index) and laboratory data were collected. After data processing, the volume of liver was assessed. **RESULTS:** The mean liver volume was found to be $1445.20 \pm 329.18 \text{ cm}^3$. Liver volume best correlated with age ($p < 0.05$, correlation coefficient: $r = 0.13$) and correlation with body height was 0.10 and with other parameter as body weight, BMI and BSA was respectively ($p < 0.05$) 0.05, 0.08 and 0.09. **CONCLUSION:** The Liver volume assessed with computerized tomography scanning has correlated well with age reciprocally and with body height positively.

INTRODUCTION

Estimation of liver size has important clinical implication. A thorough knowledge of liver dimensions and volume is prerequisite for clinical assessment of liver disorders & it can facilitate decision making in liver transplant surgery^[1-10] especially to avoid donor-recipient graft mismatch.

Of several indexes of liver size, liver span and liver volume are important. Liver span (longitudinal diameter)^[11] was traditionally used because it can be conveniently measured using palpation^[12] and ultrasonography (USG). However, considering the complexity of liver shape, liver span alone cannot appropriately represent liver mass. Additionally, liver span as measured by palpation and USG is prone to inter-observer variability and poor repeatability. Few studies have explained that palpation and percussion provide vague evidence of liver enlargement^[13, 14].

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, 15] on one hand and in all the space occupying lesions leading to the increase in the size of liver like tumors of the liver on the other hand. Size of liver is also an important factor when considering surgical correction during liver transplantation and any other liver pathology^[3, 8, 9, 16-18].

In liver transplantation, pre-transplant liver volume is an independent determinant of the prognosis of graft liver. Living donor liver transplantation (LDLT) has been used to alleviate the shortage of available liver donors. Accurate estimation of the standard liver volume (SLV) of the living donor and recipient is crucial. 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, 5, 16, 19, 20].

Liver volume can be measured by USG^[21, 22], but it is bounded by some variations due to observer bias^[23]. 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. The spiral CT images which can generate 3-D reconstruction images are particularly accurate in measurement of organ volume.

In present study, normal liver volume of healthy adult north Indian population has been estimated by using spiral computed tomography scans and its relationship with various body indices^[1, 24-26] has been statistically calculated.

MATERIAL AND METHODS

Patient Selection- In this prospective study, 337 individuals aged between 21-70 years were evaluated clinically and also by laboratory tests. There were 161 males and 176 females.

These were individuals of different ethnic background belonging to northern India who underwent spiral computed tomography (CT) of the abdomen or thorax in department of radiodiagnosis, Chhatrapati Shahuji Maharaj Medical University, (erstwhile King George’s Medical College), Lucknow, India for conditions unrelated to the hepatobiliary system, during December 2006 and July 2007.

The patient’s population comprised of outpatients and inpatients 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 reviewed.

Individuals who did not give consent, patients unable to comply with procedure, those who had received chemotherapy or radiational therapy during the two years prior to study or patients with disorder known to affect liver and pregnant females were excluded from the study.

Clinical Data- 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:

$$BSA (m^2) = [BW (in kg)^{0.425} \times BH (in cm)^{0.725}] \times 0.007184$$

and body mass index (BMI) was calculated by -

$$BMI (kg/m^2) = Weight (kg) / [Body height (meter)]^2$$

CT scans (GE Medical System, USA, and model name – CT/e) were evaluated in 337 subjects 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. All outlining were performed by a single investigator (DA) trained to recognize the relevant organ boundaries.(figure:1) 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.

(figure:2)

Figure 1

Figure 1: Showing tracing of liver boundary on CT image

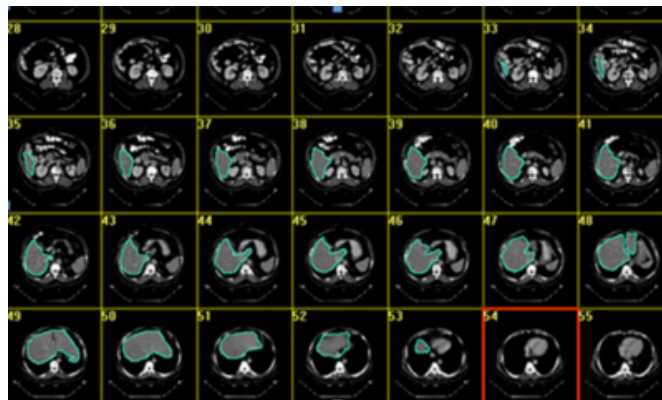
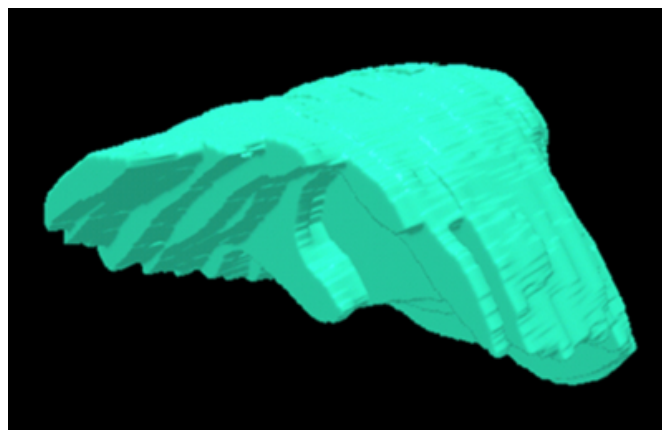


Figure 2

Figure 2 : 3D liver image constructed from CT image slices



Statistical Analysis - The results have been presented as mean ± SD. All values were recorded on a Microsoft excel spreadsheet. Data analysis was performed using Microsoft excel 2007. Mean and standard deviation of the liver volume was calculated and correlation was obtained between liver volume and different body indices.

RESULTS

A total of 337 subjects (176 males, 161 females) native of north India were included in the present study. Their mean age was 49.39 years (21- 70 years), mean body weight was 63.10 kg (41 – 87 kg), mean body height was 1.58 m (1.42 – 1.76 m), and mean BMI was 25.27 kg / m² (13.86 – 35.88 kg/ m²), and mean BSA was 1.64 m² (1.34 – 1.98 m²) (Table 1).

Table- 1 Mean ± SD of various parameters included in study

Figure 3

Figure 2 : 3D liver image constructed from CT image slices

Parameters	Mean ±SD
Age (years)	49.34 ± 11.99
Height (m)	1.57 ± 0.06
Weight (kg)	63.10 ± 9.77
BMI ^a (kg/m ²)	25.27 ± 3.46
BSA ^b (m ²)	1.64 ± 0.13

^a BMI, Body mass index; ^b BSA, body surface area

Mean liver volume was estimated to be 1,445.20 cm³ ± 329.18 cm³ (1,209.72 – 1,680.68 cm³). Liver volume reciprocally correlated with age (correlation coefficient: r = 0.13, p < 0.05). Liver volume also correlated with other indices as body height (r = 0.10, p < 0.05), body weight (r = 0.05, p < 0.05), BMI (r = 0.08, p < 0.05) and BSA (r = 0.09, p < 0.05). Statistical analysis shows that liver volume is related more significantly with age than body height. The correlation of other body indices (body weight, BMI and BSA) with liver volume was weaker.

Mean liver volume observed in different age group has been shown in table – 2 and figure – 3. It demonstrates that maximum liver volume (2,321 cm³) was in 21-25 years of age group and minimum liver volume (1,149 cm³) was associated with 66-70 years of age group. In scatter diagram (figure-4) 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 4

Table- 2 Estimated Liver volume in different age groups

Age Group (in years)	Liver volume (cm ³)
21-25	2,321
26-30	1,372
31-35	1,236
36-40	1,393
41-45	1,507
46-50	1,503
51-55	1,430
56-60	1,260
61-65	1,281
66-70	1,149

Figure 5

Figure 3: Bar chart showing estimated liver volume in different age group

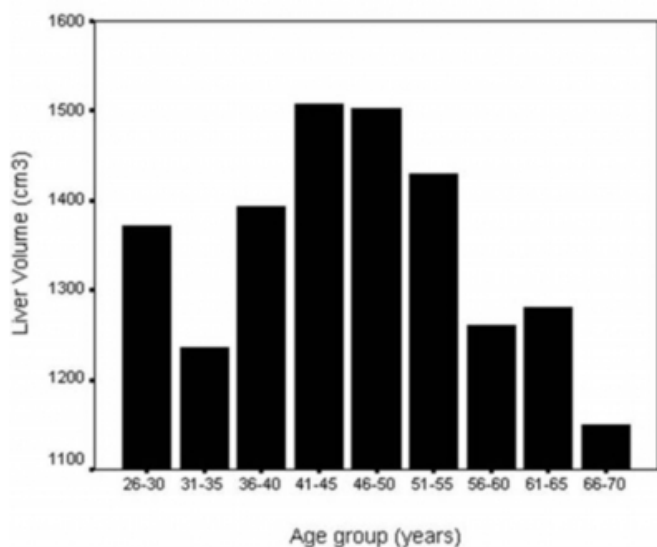
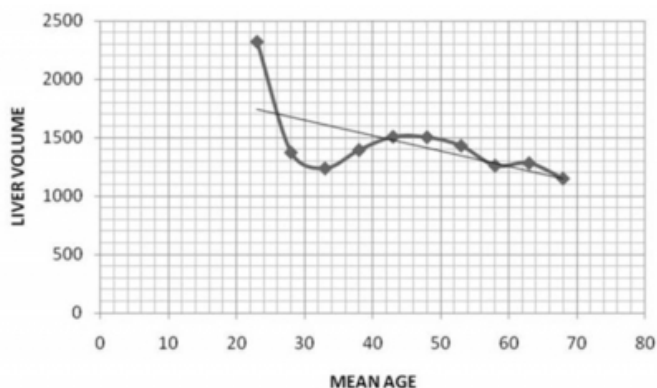


Figure 6

Figure 4: Scatter diagram showing relationship of mean liver volume with mean age in different age group



In males (n=161) mean liver volume observed was 1,511 cm³ and in females (n=176) was 1,287 cm³. In male, liver volume showed good reciprocal correlation with age (r = 0.21, p < 0.05), but in females liver volume correlates more with weight (r = 0.14, p < 0.05) than age.

Using multivariate linear regression, we found age and body height to be good predictor of liver volume (adjusted r² = 0.015, F = 3.485) and liver volume was best predicted by the following equation: Liver Volume = 678.35 + (- 8.45 x Age) + (724.84 x body height).

DISCUSSION

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^[27]. Graft volume to SLV ratio of 30% or less and graft to recipient body weight ratio of less than 0.8 are associated with increased morbidity, and impaired graft and patient survival post transplant^[20,28, 29].

The present study assessed the normal liver volume in adult north Indian population prospectively by spiral CT. Statistically age correlated reciprocally where as body height related positively with liver volume. Since computerized tomography is non-invasive, user friendly, reliable so it was chosen as a means to assess the liver volume.

Various past studies have assessed liver dimensions and volumes by USG and CT^[21, 23-26] in living and also by post mortem study directly.

Some of the researchers who used ultrasonography^[14] have reported great differences in the liver volume; in their study and they revealed the need of a more reliable method. Some researcher^[8, 25] established the usefulness of three dimensional computed tomography of liver before donor hepatectomy.

Singh et al. (1999)^[11] and See Ching et al. (2006)^[30] measured the liver weight by post-mortem study and Cao et al. (2007)^[31], Schiano et al. (2000)^[9] and Zhu et al. (1999)^[32] conducted the study on cirrhosis and malignant liver, where as the present 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.

Soyer et al. (1992)^[33], Schiano et al. (2000)^[9], Henderson et al. (1981)^[25] have shown that CT volume measurement of the liver coorelated well with actual liver volume, they reported 95% accuracy. 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 by Emiroglu et al. (2000)^[1], Simon et al. (2007)^[34], Satau et al. (2006)^[17].

It has been conclusively proven that age and gender are independent determining factors of liver size. In this study, mean liver volume was 1,445.20 ± 329.18 cm³ (in male - 1,511 cm³, female - 1,287 cm³). Chandramohan et al.(2007)^[35] reported that the mean liver volume in south Indian population to be 1186 cc, which is less than that observed in the present study. It may be due to different body habitus and environment between north Indian and south Indian

population. In comparison with researches in western population by Henderson^[25], Kamel^[37], liver volume was lower in present study and higher than Japanese and Chinese population which were conducted by Nakayama^[6]. Lemke^[19], See^[30], Zhu^[32], Wang^[37], Fu-guil^[38], this may be due to the fact that because the average Indian body indices lie between a higher western and lower Japanese, Chinese body indices.

Most of the studies have been performed in the western population, some also in Asians, but there is lack of normogram for liver volume in north Indian population. Normal body parameters, including organ size show racial variations. Hence, it is not rational to extrapolate the normal liver volume data of western adult population to Indian population.

The results of present study on the relationship between liver volumes with age as well as body height are consistent with those of previous reports. Liver volume was correlated significantly with age, body height, body weight, BMI and BSA, but age showed a relatively greater correlation^[34, 39, 40].

Limitation of this study is that we couldn't compare the liver volume with real size of liver. However it is already proved that contiguous CT slice examination is an objective and reliable method to measure the liver volume^[34].

In conclusion, liver volume is a reliable index of liver size and measurement of liver volume with spiral CT is useful method. Hence spiral CT facilitates measurement of liver volume and enable us to use it in clinical field.

References

1. Emiroglu R, Coskun M, Yilmaz U, Sevmis S, Ozcay F, and Haberal M. Safety of multidetector computed tomography in calculating liver volume for living-donor liver transplantation. *Transplant Proc.* 2006 Dec;38(10):3576-8.
2. Harada N, Shimada M, Yoshizumi T, Suehiro T, Soejima Y, and Maehara Y. A simple and accurate formula to estimate left hepatic graft volume in living-donor adult liver transplantation. *Transplantation.* 2004 May 27;77(10):1571.
3. Hiroshige S, Shimada M, Harada N, Shiotani S, Ninomiya M, Minagawa R, Soejima Y, Suehiro T, Honda H, Hashizume M, and Sugimachi K. Accurate preoperative estimation of liver-graft volumetry using three-dimensional computed tomography. *Transplantation.* 2003 May 15; 75(9):1561-4.
4. Kazuhiro Ogasawara, Yoshie Une, Yasuaki Nakajima, and Junichi Uchino. The significance of measuring liver volume using computerized tomography images before and after hepatectomy. *Surgery Today: Springer Tokyo, 1994; ISSN: 1436-2813, Vol 25 No.1:pp43-48.*
5. Khalaf H, Shoukri M, Al-Kadhi Y, Neimatallah M, and Al-Sebayel M. Accurate Method for Preoperative Estimation of the Right Graft Volume in Adult-to-Adult Living Donor Liver Transplantation. *Transplant Proc.* 2007 Jun;39(5):1491-5.
6. Nakayama Y, Li Q, Katsuragawa S, Ikeda R, Hiai Y, Awai K, Kusunoki S, Yamashita Y, Okajima H, Inomata Y, and Doi K. Automated hepatic volumetry for living related liver transplantation at multisection CT. *Radiology* 2006 Sep;240(3):743-8.
7. Radtke A, Sotiropoulos GC, Nadalin S, Molmenti EP, Schroeder T, Lang H, Saner F, Valentin-Gamazo C, Frilling A, Schenk A, Broelsch CE, and Malagó M. Preoperative volume prediction in adult living donor liver transplantation: how much can we rely on it? *Am J Transplant.* 2007 Mar;7(3):672-9.
8. Satou S, Sugawara Y, Tamura S, Kishi Y, Kaneko J, Matsui Y, Kokudo N, and Makuuchi M. Three-dimensional computed tomography for planning donor hepatectomy. *Transplant Proc.* 2007 Jan-Feb;39(1):145-9.
9. Schiano TD, Bodian C, Schwartz ME, Glajchen N, and Min AD. Accuracy and significance of computed tomographic scan assessment of hepatic volume in patients undergoing liver transplantation. *Transplantation.* 2000 Feb 27;69(4):545-5.
10. Uslu Tutar N, Kirbaş I, Oztürk A, Sevmiş S, Kayahan Ulu EM, Coşkun M, and Haberal M. Computed tomography volumetric follow-up of graft volume in living related liver recipients. *Transplant Proc.* 2007 May;39(4):1175-7.
11. Singh V, Singh K, Singh D, Nain CK, and Sodhi L. Liver span and weight in health and disease. *Trop Gastroenterol.* 1999 Apr-Jun;20(2):73-4.
12. Kirk RM. Clinical assessment of liver enlargement?. *Indian J Gastroenterol* 2004;23:163-164.
13. Joshi R, Singh A, Jajoo N, Pai M, and Kalantri SP. Accuracy and reliability of palpation and percussion for detecting hepatomegaly: a rural hospital-based study. *Indian J Gastroenterol.* 2004 Sep-Oct;23(5):163-4.
14. Zoli M, Magalotti D, Grimaldi M, Gueli C, Marchesini G, and Pisi E. Physical examination of the liver: is it still worth it? *Am J Gastroenterol.* 1995 Sep;90(9):1428-32.
15. Lin XZ, Sun YN, Liu YH, Sheu BS, Cheng BN, Chen CY, Tsai HM, and Shen CL. Liver volume in patients with or without chronic liver diseases. *Hepatogastroenterology.* 1998 Jul-Aug;45(22):1069-74.
16. Sakamoto S, Uemoto S, Uryuhara K, Kim Id, Kiuchi T, Egawa H, Inomata Y, and Tanaka K. Graft size assessment and analysis of donors for living donor liver transplantation using right lobe. *Transplantation.* 2001 May 27; 71(10):1407-13.
17. Satou S, Sugawara Y, Matsui Y, Kaneko J, Kishi Y, Imamura H, Kokudo N, and Makuuchi M. Preoperative estimation of right lateral sector graft by three-dimensional computed tomography. *Transplant Proc.* 2006 Jun;38(5):1400-3.
18. Yuan Y, Song B, Wu B, Xu J, Li YC. Research on relationship between preoperative CT volumetry of donor's liver and intraoperative weight measurement of liver for living related liver transplantation. *Sichuan Da Xue Xue Bao Yi Xue Ban.* 2007 Jun;38(3):526-8.
19. Lemke AJ, Brinkmann MJ, Pascher A, Steinmüller T, Settmacher U, Neuhaus P, and Felix R. Accuracy of the CT-estimated weight of the right hepatic lobe prior to living related liver donation (LRLD) for predicting the intraoperatively measured weight of the graft. *Rofo.* 2003 Sep;175(9):1232-8.
20. Kalayoglu M, D'Alessandro A M, Sollinger Hw, Hoffman RM, Pirch JD, Belzer FO. Experience with reduce size liver transplantation. *Surg Gynecol Obstet* 1990;171:139-47.
21. Carr D., JG Duncan. Liver volume determination by

- ultrasound: a feasibility study. *The British Journal of Radiology*, 1976; Vol 49, Issue 585: 776-778.
22. Kaya Sarac, Ramazan Kutlu, Cengiz Yakinci, Yasar Durmaz, Tamer Baysal, and Onsal Ozgen. Sonographic Evaluation of Liver and Spleen Size in School-Age Children. *Turk J Med Sci* (2000); 30: 187-190.
23. Niederau C., Sonnenberg A., Muller J.E., Erckenbrecht J.F., Scholten T. and Fritsch. W.P. Sonographic measurement of the normal liver, spleen, pancreas, and portal vein. *Radiology*, 1983; Vol 149. pp 537-540.
24. Geraghty EM , Boone JM, McGahan JP, and Jain K.: Normal organ volume assessment from abdominal CT. *Abdom Imaging*. 2004 Jul-Aug;29(4):482-90. Epub 2004 Mar 18.
25. Henderson JM, Heymsfield SB, Horowitz J, and Kutner MH. Measurement of liver and spleen volume by computed tomography. *Radiology* 1981;141:525-527.
26. Heymsfield SB, Fulenwider T, Nordlinger B, Barlow R, Sones P, and Kutner M. Accurate measurement of liver, kidney, and spleen volume and mass by computerized axial tomography. *Ann Intern Med* 1979; 90:185-187.
27. Kiuchi T, Kisharaha M, Uryuhara k, Inomata Y, Uemota S, Asonuma K, et al. Impact of graft size mismatching on graft prognosis in liver transplantation from living donors. *Transplantation* 1999;67:321-7.
28. Urata K, Kawasaki S, Matsunami H, Hashikura Y, Ikegami T, Ishizone S, et al. Calculation of the child and adult standard liver volume for liver transplantation. *Hepatology* 1995; 21:1317-21.
29. Higashiyama H, Yamaguchi T, Mori K, Nakono Y, Yokoyama t, Takeuchi T, et al. Graft size assessment by preoperative computed tomography in living related partial liver transplantation. *Br J Surg* 1993;80:489-92.
30. See Ching Chan, Chi Leung Liu, Chung Mau Lo, Banny K Lam, Evelyn W Lee, Yik Wong, and Sheung Tat Fan. Estimating liver weight of adults by body weight and gender. *World J Gastroenterol* 2006 April 14;12(14): 2217-2222.
31. Cao J , Yang A, Long XY, Liu H, Cao JN, and Li H. CT hepatic volume measurement combined with CT perfusion imaging in evaluating the hepatic functional reserve. *Zhong Nan Da Xue Xue Bao Yi Xue Ban*. 2007 Jun,32(3): pp 422-6.
32. Zhu J , Leng X, Dong N, Qi G, and Du R. Measurement of liver volume and its clinical significance in cirrhotic patients. *Zhonghua Wai Ke Za Zhi*. 1999 Feb;37(2):110-2.
33. Soyer P, Roche A, Elias D, Levesque M. Hepatic metastases from colorectal cancer: influence of volumetric analysis on surgical decision making. *Radiology* 1992;184:695-7.
34. Simon A.W.G.Dello, Ronald M. van Dam, Jules J.G. Slangen, Marcel C.G. van de Poll, Marc H.A. Bemelmans, Jan Willem W.M.Greve et al. liver volumetry plug and play: Do it yourself with Image J. *World J Surg* (2007)31; 2215-2221.
35. Chandramohan A., Eapen A, Govil S, Govil S, and Jeyaseelan V. Determining standard liver volume: Assessment of existing formulae in Indian population. *Indian J Gastroenterol* 2007;26:22-25.
36. Kamel IR , Kruskal JB, Warmbrand G, Goldberg SN, Pomfret EA, and Raptopoulos V. Accuracy of volumetric measurements after virtual right hepatectomy in potential donors undergoing living adult liver transplantation. *AJR Am J Roentgenol*. 2001 Feb;176(2):483-7.
37. Wang XF, Li B, Lan X, Yuan D, Zhang M, Wei YG, Zeng Y, Wen TF, Zhao JC, Yan LN (2008). Establishment of formula predicting adult standard liver volume for liver transplantation, *Zhonghua Wai Ke Za Zhi*. 2008 Aug 1;46(15):1129-32.
38. Fu-Gui L, Lu-Nan Y, Bo L, Yong Z, Tian-Fu W, Ming-Qing X, Wen-Tao W, Zhe-Yu C.(2009) Estimation of standard liver volume in Chinese adult living donors. *Transplant Proc*. 2009 Dec;41(10):4052-6.
39. George W Rylance, Terence A Moreland, Michael D Cowan, David C Clark (1982), Liver volume estimation using ultrasound scanning: *Arch Dis Child* 1982;57:283-286 doi:10.1136/adc.57.4.283
40. Wynne HA, Cope LH, Mutch E, Rawlins MD, Woodhouse KW, James OF. The effects of age upon liver volume and apparent liver blood flow in healthy man. *Hepatology* 1989;9:297-301.

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