

Normal Splenic Volume Assessment on CT in 426 Adults

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ABSTRACT

Objective: The purpose of this study was to determine the normal splenic volume on computed tomography in Thai adult patients at Siriraj Hospital.

Methods: The width (W), length (L), thickness (T) and splenic volume were obtained from 426 patients who underwent CT for various indications. The relationship between splenic volume and age, gender and body habitus were also examined.

Results: The average splenic volume (S Vol) was $124.1 \pm 51.8 \text{ cm}^3$, ranging from 27.60 to 430.85 cm^3 . Correlation between splenic volume and age, height, weight and BMI were significant (age: $r = -0.151$, $p < 0.001$; height: $r = 0.187$, $p < 0.001$; weight: $r = 0.248$, $p < 0.001$ and BMI: $r = 0.159$, $p < 0.05$). Splenic volume correlated well with all the linear measurements, especially with the splenic length. The formulae S Vol (in cm^3) = $19.6 + 0.5 (L \times W \times T)$ and S Vol (in cm^3) = $-40.3 + 21.4L$ were derived and can be used to estimate the splenic volume.

Conclusion: Two formulae of splenic measurement indexes were derived with good correlation which can be satisfactorily used in order to estimate splenic volume in routine practice.

Keywords: Normal splenic volume, splenic volume assessment

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INTRODUCTION

Splenomegaly is an important clinical scenario resulting from primary splenic disease or secondary to other related diseases such as portal hypertension. Owing to variable normal splenic size from patient to patient, the measurement of splenic volume appears to be a useful method for assessing the normal spleen. In regular practice, splenic enlargement on computed tomography (CT) is diagnosed on the basis of subjective or crude criteria. The product of the width, thickness and length of the spleen (the so-called "splenic index") has also been proposed as an indicator for evaluating splenic size on CT.¹

Previous studies reported the difference between the average splenic volumes in the Japanese populations and North American populations.² The propose of this study was to determine the volume of the normal spleen by CT in Thai adult patients at Siriraj Hospital and its variations in relation to age, gender and body habitus.

MATERIALS AND METHODS

Patient selection criteria

One thousand and two hundred Thai adult patients (age ≥ 18 years) who underwent abdominal CT for various conditions from January to December 2008 were selected. Ethics committee approval was obtained. No informed consent was necessary for this retrospective study.

To develop a study group, we used the following exclusion criteria: (a) clinical or laboratory evidence of infection; (b) lymphohematogenous disorders; (c) immunological conditions such as connective tissue disease and storage disease; (d) liver diseases including portal hypertension; (e) cardiac or renal failure; (f) history of splenic injury or splenectomy (g) any splenic related diseases

Therefore the CTs of 426 Thai adult patients were included with age ranging from 18-98 years [56.07 ± 15.78 years (mean \pm standard deviation)]. There were 195 males (mean age, 57.42 ± 16.19 ; range, 18 - 90 years) and 231 females (mean age, 54.93 ± 15.36 ; range, 19 - 98 years). One hundred and sixty three patients (38.26%) had follow up CT examination for benign conditions such as liver hemangioma, liver cyst, renal angiomyolipoma, adrenal adenoma, renal stone and myoma uteri. One hundred and seven patients (25.12%) had CT examination due to palpable abdominal mass or abdominal pain. Seventy eight patients (18.31%) underwent CT angiography for vascular diseases. Twenty three patients (5.4%) were healthy donors

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for kidney transplantation. Twenty three patients (5.4%) were screened for metastatic disease in patients with known primary carcinomas of breast, colon, lung, renal cell carcinoma and cervix. Twenty two patients (5.16%) were check ups and 6 (2.35%) patients with history of abdominal injury.

CT techniques

CT examinations were performed in the Department of Radiology, Siriraj Hospital by LightSpeed MDCT (General Electric Medical Systems, Milwaukee, WI) or a SOMATOM definition 64 Scanner (Siemens Medical Solution, Erlangen, Germany) at 1-1.5 mm slice interval.

Image analysis

We measured the maximal width, length and thickness of the spleen with the technique previously described by Schlesinger et al.³ Maximal splenic width (W), defined as the longest diameter on any transverse section; the thickness (T), defined as the thickness at the midpoint of the long axis of the spleen on the section with the maximal width; splenic length (L) was assessed by multiplying the section thickness by the number of consecutive sections containing an images of the spleen (Fig 1).

Splenic volume was calculated by drawing the line of the entire splenic surface on each image and made a volume measurement with interpolation by using computer software (Fig 2).

Anthropometric data, including height and body weight, were collected for each patient. The body mass index (BMI) was calculated using the equation: BMI = weight (kg)/height (m)².

Splenic volume and linear measurements of the spleen were related to each other and to the age, height, weight, and BMI of the patients, employing Pearson's correlation coefficient. The splenic volume of men was compared with those of women in the age groups utilizing the student's *t*-test.

Calculations of the splenic volume using linear measurements, in order to determine a convenient method for assessing splenic volume in regular practice, were also performed.

Statistical analysis was performed using the SPSS statistical package version 17.0.



Fig 1. Example of measurement of the maximal width (W) and thickness (T) of the spleen at midpoint of section where width was determined.

RESULTS

The mean splenic volume was 124.1 cm³ with a standard deviation (SD) of 51.8 cm³. The volume of the spleen ranged from 27.60 to 430.85 cm³.

The average volume of the spleen was higher in males (134.2 ± 52.5 cm³) than in females (115.6 ± 49.8 cm³) (Table 1), with statistical significance (95% confidence interval = 8.6 to 28.1, *p*<0.001). There was a general decrease in spleen size as age increased (Table 2).

The mean splenic width, length and thickness were 8.5 ± 1.40 (ranging 4.23-13.94), 7.68 ± 1.60 (ranging 3.4 to 14.5), and 3.33 ± 0.73 (ranging 1.95 to 6.86) cm, respectively. The splenic volume correlated well with statistical significance (*p*<0.001) with all the linear measurements (length: *r* = 0.662, *p*<0.001; width: *r* = 0.642, *p*<0.001, and thickness: *r* = 0.584, *p*<0.001) (Fig 3).

Two formulae to assess the splenic volume (splenic measurement index) were derived.

Among the unidimensional indexes, the splenic length (L) showed the best correlation with the splenic volume using this formula:

$$S \text{ Vol (in cm}^3\text{)} = -40.3 + 21.4L$$

Among the multidimensional indexes, the formula to calculate splenic volume (S Vol) was:

$$S \text{ Vol (in cm}^3\text{)} = 19.6 + 0.5 (L \times W \times T)$$

Coefficient of determination (R²) of unidimensional indexes and multidirectional indexes were 43.8% and 78.6%, respectively.

There were 292 patients whose height ranged from 142 to 192 cm (mean 162.15 ± 9.07 cm), and 289 patients whose body weight ranged from 36 to 98 kg (61.36 ± 11.89 cm). The BMI of 234 patients was 23.61 ± 4.2 kg/m², with a range from 15.19 to 39.82 kg/m². The rest of the patients had no available data.

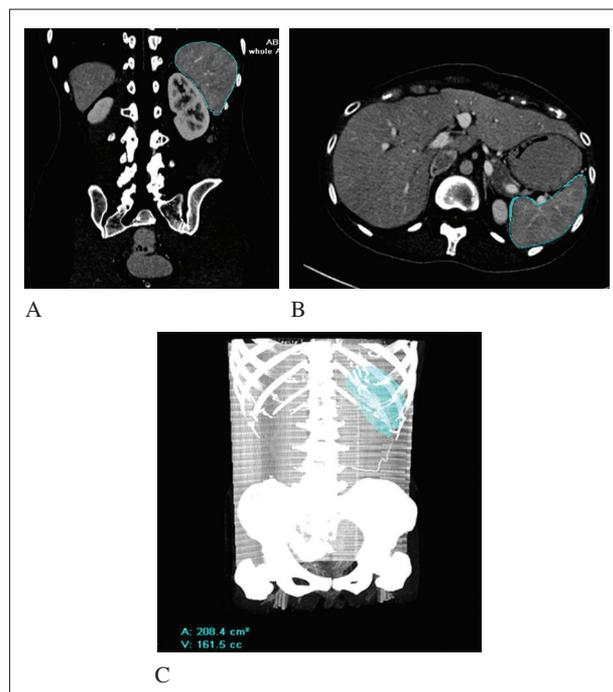


Fig 2. Example of splenic volume measurement. Coronal CT section (A), axial CT section (B) and three-dimensional reconstruction image of the spleen (C), the computer software calculated the volume of the spleen.

TABLE 1. Splenic volume with gender.

Gender	N	Splenic volume (cm ³)	
		Mean ± SD	Range
M	195	134.2 ± 52.5	30.45-430.85
F	231	115.6 ± 49.8	27.60-301.40
Total	426	124.1 ± 51.8	27.60-430.85

SD=standard deviation

Correlations between splenic volume and age, height, weight and BMI were significant (age: $r = -0.151$, $p < 0.01$; height: $r = 0.187$, $p < 0.01$; weight: $r = 0.248$, $p < 0.01$ and BMI: $r = 0.159$, $p < 0.05$) (Fig 4).

DISCUSSION

The spleen is the essential visceral abdominal organ which is affected by splenic diseases itself and other systemic diseases. Splenomegaly is one of the clinical manifestations, which is frequently determined by visual assessment instead of accurate measurement techniques. Among many imaging modalities including conventional radiography, sonography, nuclear scintigraphy and CT, CT is considered a reliable method and plays a major role for assessing the volume of the spleen.^{4,5}

Cools et al¹ and Schlesinger et al³ found that the splenic volume in adults correlated best with the product of LxWxT (at the midpoint of the long axis on the section of the maximum width). Therefore, we chose to use this product to calculate the estimated splenic volume in this study.

In our study, the average splenic volume (mean ± SD) was 124.1 ± 51.8 cm³ for 426 Thai adult patients, ranging from 27.6 to 430.85 cm³. Splenic volume could be calculated using the unidimensional or multidimensional indexes. Correlation to the splenic volume was better for the multidimensional indexes ($R^2=78.6\%$).

The average splenic volume in this study was quite similar to two previous studies in the Japanese populations; Kaneko et al.,⁶ reported a mean splenic volume of 112 ± 40 cm³ for 150 patients. Harris et al² reported the overall splenic volume was 127.4 ± 62.9 cm³ for 230 Japanese patients, ranging from 22 to 417 cm³.

Our results were in accordance with a study by Bezerra et al.,⁷ in 249 adult patients, they studied the unidimensional measurements and the best correlation to volume were splenic length and width. Correlation was better for the multidimensional indexes.

The mean splenic volume in this study was smaller than that obtained in three previous studies in North American subjects. Henderson et al.,⁵ proposed a mean spleen

TABLE 2. Splenic volume by age.

Age (years)	N	Splenic volume (cm ³)	
		Mean ± SD	Range
18-30	36	156.6 ± 67.1	89.80-430.85
31-40	46	131.5 ± 44.8	52.20-244.25
41-50	57	127.9 ± 46.9	53.05-233.10
51-60	112	118.1 ± 44.8	40.30-231.55
61-70	100	119.5 ± 56.0	38.85-336.55
71-80	58	121.6 ± 52.7	30.45-264.00
>80	17	98.2 ± 34.4	27.60-166.35
Total	426	124.1 ± 51.8	27.60-430.85

SD=standard deviation

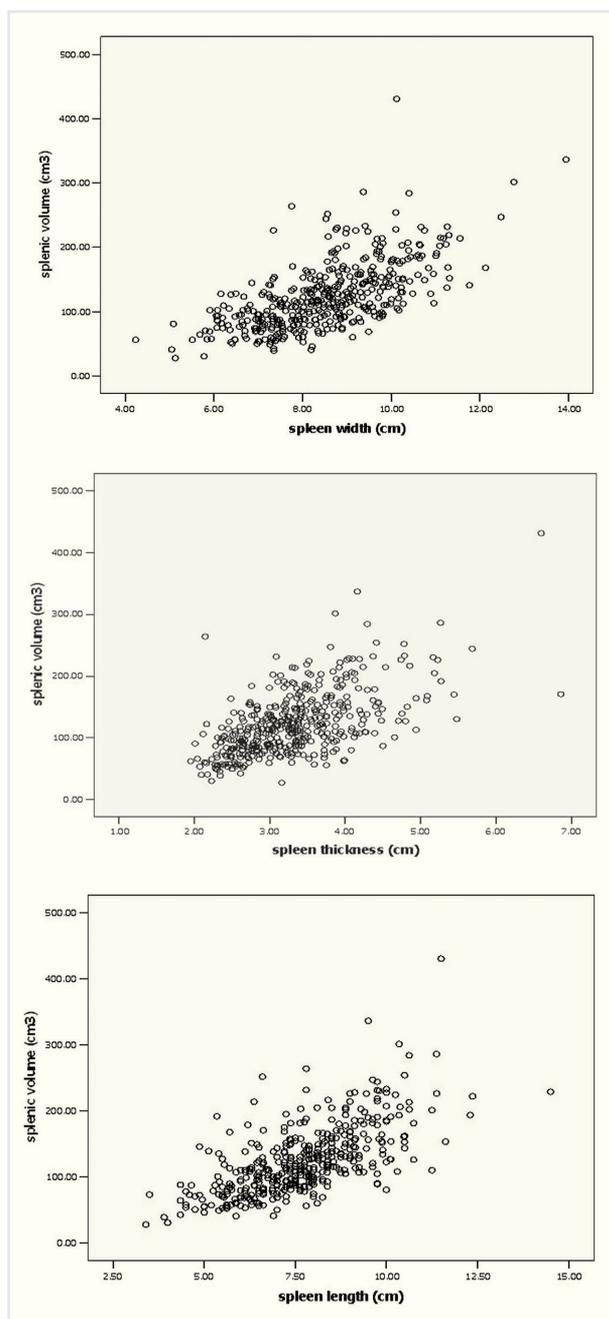


Fig 3. Scatterplot of data shows good correlation between splenic volume and width, thickness and length.

volume of 219 cm³ in a normal population, as calculated from CT, but the number of subjects was small ($n = 11$). Prassopoulos et al.,⁸ calculated a mean splenic volume from CT and reported that the mean value was 215 cm³ in a normal population ($n = 140$) while Geraghty et al.,⁹ reported an overall mean splenic volume of 209 cm³ in 149 adult patients. The difference between the average splenic volumes could be due to the differences in the body habitus of the patients studied from different ethnic groups.

We found that the splenic volume decreases with an increase in age and increases with an increase in body weight, height and BMI. This finding is supported by previous studies.^{2,6,10,11} However, in our study, the splenic volume estimated by CT has a weak linear correlation with and significantly correlated with age, and body habitus.

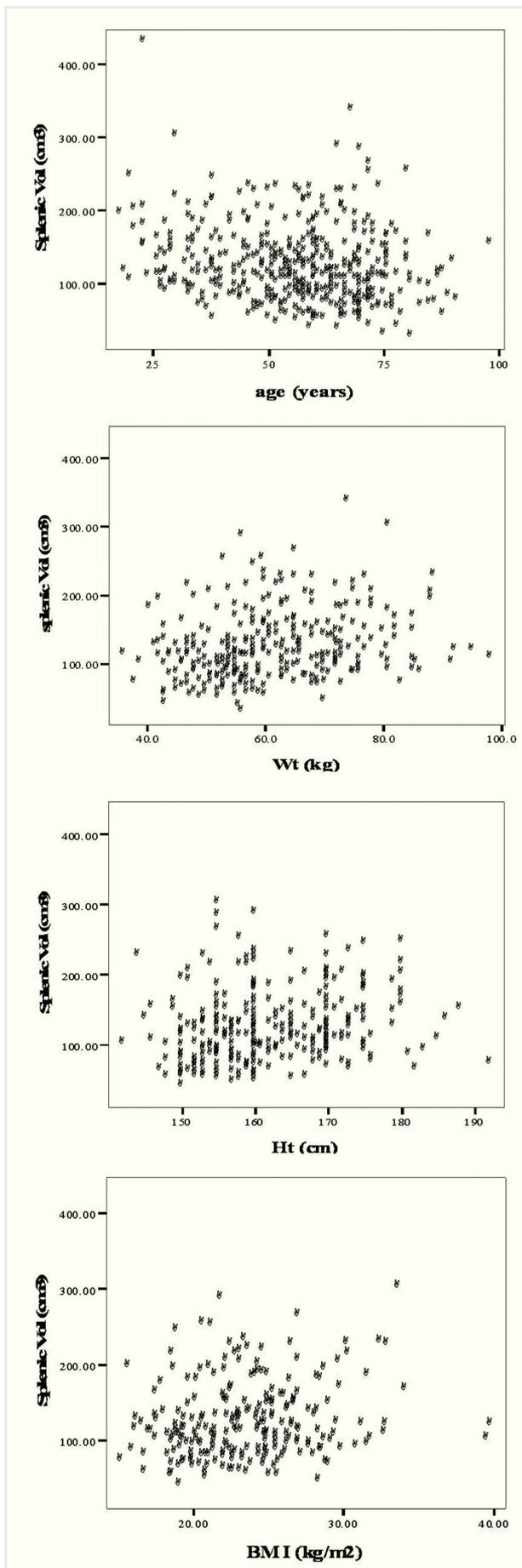


Fig 4. Scatterplot of splenic volume with (a) age, (b) weight (n=289), (c) height (n=292), and (d) BMI (n=234).

The splenic volume was larger in males than in females with statistical significance. The results were consistent with previous data.²

The limitation in this study, is the splenic volume calculated by this proposed formula cannot be applied in the case of abnormal splenic contour or some conditions such as polysplenia, asplenia or splenosis.

CONCLUSION

The average splenic volume was $124.1 \pm 51.8 \text{ cm}^3$. Splenic length and multidimensional indexes correlate well with splenic CT volume.

The normal range for splenic volume and two formulas of splenic measurement index addressed in this study can be effective to estimate splenic volume as well as determine whether or not there is the presence of splenomegaly.

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