

Abdominal CT Scan Based Estimation of Splenic Index and Splenic Volume in North Indian Adults

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ABSTRACT

BACKGROUND

Exposure of various tropical infections and infestations like tuberculosis, filariasis, malaria, anemia, kala-azar and poor sanitation are major health concerns in Bihar and its neighboring state. Spleen size increases in several other diseases e.g., metabolism or storage disorder, malignancies and hematological disorders. Determining the normal parameters of spleen is essential for assessment of splenomegaly in routine ultrasonography (USG) or in the computed tomography (CT) scan. In this study, we wanted to estimate the CT based measurement of splenic dimensions in various planes, splenic index (linear dimension) and splenic volume and also to estimate the relationship of splenic index and splenic volume with age, gender and other splenic dimensions.

METHODS

It was a retrospective study and data was collected from January 2019 to December 2019. A total of 154 cases (including both genders) of age range 18 - 60 years were collected from the vitrea system (Vitrea software used for the 3-D assessment of splenic volume) and clinical data was collected from the medical record section. CT scan data of only those patients were included who had the clinical history of pain in abdomen, abdominal trauma or other diseases not affecting the spleen. Various measurements including splenic length and thickness at hilum and maximum thickness in axial view and height (maximum interpolar and true vertical height) in coronal views were recorded.

RESULTS

154 cases including both gender and age range of 18 - 60 years were included in our study. There were 60 males and 94 females. The average age of the male and female patients was 45.93 +/- 15.19 years and 45.87 +/- 15.12 years respectively. The mean splenic dimensions were 9.03 +/- 1.49 cm in length (axial view), 3.69 +/- 0.05 cm thickness at hilum (axial view) and 9.05 +/- 2.23 cm maximum craniocaudal length and 7.9 +/- 2.96 cm true vertical length (coronal view). Mean splenic index and mean splenic volume were 340.30 +/- 107.39 cm³ and 227.02 +/- 62.22 cm³ respectively. There was statistically significant correlation between splenic volume and maximum craniocaudal length ($r^2 = 0.4848$, $P = 0.001$), maximum axial length ($r^2 = 0.4765$, $P < 0.001$) and true vertical length ($r^2 = 0.3142$, $P = 0.001$) with 95 % confidence interval. For all splenic measurements, there was stronger correlation with maximum craniocaudal length followed by maximum axial length. However, there was no statistically significant correlation either of splenic volume with age in either gender ($r^2 = 0.019$, $P = 0.043$) or splenic index with age in either gender present ($r^2 = 0.016$, $P = 0.059$).

CONCLUSIONS

Maximum splenic length both in coronal (craniocaudal) and axial sections are positively and strongly correlated with splenic volume and splenic index but age of the individuals doesn't show any correlation either with the splenic volume or with splenic index. Hence, a regional reference of splenic parameters was established with a slightly different range of values reported previously.

KEY WORDS

Splenic Volume, Splenic Index, Computed Tomography

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BACKGROUND

Spleen is a lymphoid and largest reticulo-endothelial organ and site for destruction of red blood cells (RBC). Usually, normal spleen weighs 150 - 200 g and 10.9 +/- 1.4 cm long, 4.0 +/- 0.45 cm deep and 6.8 +/- 0.71 cm in diameter. Some say that, for daily routine practice a value of 10 cm should be used for the upper limit of normality for calculations of splenic length as it is easier to remember. Some radiologist also thought that if spleen touches the left lobe of liver, then it should be considered as splenomegaly; however, this proved to be statistically insignificant. It is a concavo-convex structure with convex outer margin having ribs impressions over it.¹ There is a wide range of normal spleen size values that is mentioned in different literature in different regions of the world. This makes the establishment of the normal values more difficult.

Spleen is not palpable till it increases two to three times normal. Reliability of clinical palpation is often imprecise as normal spleen is not palpable and a non-palpable spleen is not always normal.² Exposure of the various tropical infections and infestations like tuberculosis, filariasis, malaria, anaemia, kala-azar and poor sanitation are the major health concerns in Bihar and it's neighboring state. Spleen being the reticuloendothelial system and first defense organ, it's size increases in the exposed person in comparison to the non-exposed. Spleen size also increases in several other diseases e.g. metabolism or storage disorder, malignancies and hematological disorders.³

There are various radiological investigations to identify and to measure splenic volumes. They are abdominal radiography (prior to the development of sonography), ultrasonography, computed tomography, magnetic resonance imaging (MRI) and radionuclide scans.^{1,4} Out of these, ultrasonography and computed tomography are most commonly used and reliable radiological investigation tools for intra-abdominal organs.

Splenic index and splenic volumes were measured by several authors in different countries. Splenic index (SI) is a research tool and used as an indicator in malaria surveillance. It is measured by multiplying length, width and thickness.^{5,6} Lackner et al. describe a splenic index using a combination of the width, thickness and length of the spleen as a numeric measure of splenomegaly, with an upper limit of 480 cm³ for normal spleen.⁷ A high splenic index is usually of no concern. However, a low index indicates compromised immune system which makes individual susceptible to various infections like malaria, filaria etc.

Several studies have been done, based on sonography of the abdomen to measure linear dimension of splenic length, width and thickness with upper limit of splenic volume 314.5 cm³.⁸ Volume estimation by 2D USG is usually not accurate because of several limitations leading to difficulty in completing scanning the entire organ due to the presence of overlying structures such as bone, bowel gas or kidneys.

Abdominal CT examination is more accurate than ultrasonography in measuring abdominal organs because of lack of the above drawback. Volumetric measurements (multiplanar reconstruction techniques) are most accurately obtained on CT or MRI and is more accurate than the 2D USG.^{9,10}

METHODS

It is a retrospective study and has been done in the Department of Radiodiagnosis, Indhra Gandhi Institute of Medical Science, Patna, Bihar. The CT scan data was collected from January 2019 to December 2019 (12 months duration).

A total of 154 cases (including both genders) of age range 18 - 60 years were collected from the Vitrea System (Vitrea software and were used for the 3-D assessment of splenic volume) and clinical data was collected from the medical record section. CT scan data of only those patients was included who had the clinical history of pain in abdomen, abdominal trauma or other diseases not affecting the spleen. Patients whose spleen looked abnormal on CT e.g. focal or diffuse lesions were excluded from the study. Other diseases [e.g. hematological disorder, abdominal malignancies, infection, cirrhosis, portal hypertension, splenic space occupying lesion (SOL) and autoimmune disease] that affected the spleen were also excluded after clinical, laboratory and imaging evidence.

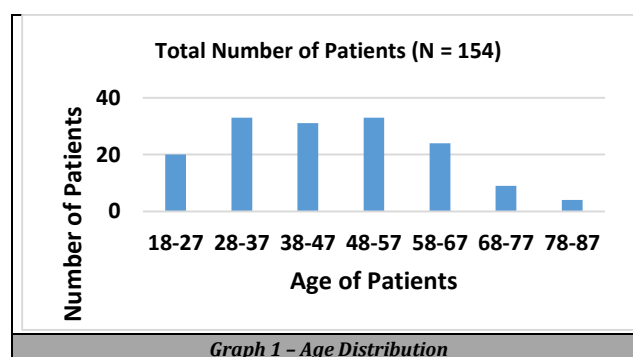
Technical parameters were 120 Kv potential, 120 mA tube current and 5 mm slice thickness with various reconstruction techniques. Pre-contrast and post-contrast images were obtained. Spleen were evaluated in the axial, sagittal and coronal plane. Various measurements including splenic length and thickness at hilum and maximum thickness in axial view and height (maximum interpolar/oblique length and true vertical height) in coronal views were recorded.

Statistical Analysis

All the data were recorded in the MS Excel sheet and were analyzed by using analysis tool pak software. Linear Pearson's correlation coefficient was used to assess the strength of correlation between various splenic dimensions (along with coefficient) and splenic volume/index. Regression analysis and student t-test was used to compare the means. Multiple regression analysis was applied.

RESULTS

One hundred and fifty four cases with age range of 18 - 60 years were included in our study. There were 60 males (38.96 %) and 94 females (61.04 %). More number of individuals present in the age group of 28 - 57 years constituted 62.99 % all together followed by 18 - 28 years of age.





Graph 2. Scatter Plot of Coefficient of Determination of SV and SI with Respect to the Maximum CC length, True Vertical Length, Maximum Axial Length and Age. (SV - Splenic Volume, SI - Splenic index, CC - Craniocaudal, Max. - Maximum)

Parameters	Total N = 154; Range (Mean +/- SD)	Female N = 94; Range (Mean +/- SD)	Male N = 60; Range (Mean +/- SD)
Age (in years)	45.79+ - 15.18 18 - 80	45.87+ - 15.12 19 - 80	45.93+ - 15.19 18 - 80
Max. axial length (in cm)	9.03+ - 1.36 4.8 - 12.3	8.77+ - 1.36 4.8 - 12.1	9.44+ - 1.36 6.2 - 12.3
Max. axial thickness (in cm)	3.93+ - 0.69 1.5 - 5.8	3.91+ - 0.69 1.5 - 5.7	3.97+ - 0.69 2.2 - 5.8
Max. axial thickness at hilum (in cm)	3.69+ - 0.66 2.3 - 5.7	3.63+ - 0.67 2.3 - 5.7	3.77+ - 0.66 2.4 - 5.1
Max. CC length (in cm)	9.05+ - 1.49 3.9 - 12.2	8.6+ - 1.49 3.9 - 11.9	9.35+ - 1.49 4.6 - 12.2
True vertical / CC length (in cm)	7.9+ - 1.72 3 - 11.9	7.78+ - 1.72 3 - 11.9	8.23+ - 1.72 4.7 - 11.3
Splenic index (SI) (in cm ³)	340.3+ - 107.39 95 - 525	322.28+ - 107.41 96 - 513	368.53+ - 107.63 95 - 525
Splenic volume (SV) (in cm ³)	227.02+ - 62.22 85 - 334	216.98+ - 62.23 86 - 328	242.75+ - 62.36 85 - 334
Splenic weight (SW) (in g)	238.34+ - 65.38 89 - 351	227.8+ - 65.39 90 - 344	254.87+ - 65.53 88 - 351

Table 1 - Various Linear Dimensions of Spleen as Well as SI, SV and SW among Female and Male

	Female (N = 94)	Male (N = 60)	P Value (> 0.001)
Mean splenic index (SI)	340.98 (+ - 107.42)	340.30 (+ - 107.26)	0.059
Mean splenic volume (SV)	227.41 (+ - 62.26)	227.02 (+ - 62.21)	0.043

Table 2 - Correlation of Splenic Index and Splenic Volume among Female and Male

The mean age was 45.79 +/- 15.18 years. The average age of the male and female patients was 45.93 +/- 15.19 years and 45.87 +/- 15.12 years respectively. The mean splenic dimensions were 9.03 +/- 1.49 cm in length (axial view), 3.93 +/- 1.72 cm in maximum thickness and 3.69 +/- 0.05 cm thickness at hilum (axial view). Maximum craniocaudal (CC) length was 9.05 +/- 2.23 cm and true vertical length was 7.9 +/- 2.96 cm in coronal view. Mean splenic index (SI) and mean splenic volume (SV) were 340.30 +/- 107.39 cm³ and 227.02 +/- 62.22 cm³ respectively (Table 1). Mean splenic weight was 238.34 +/- 65.38 g. There was no significant difference of SI and SV noted between male and female (Table 2).

Scatter plot in Graph 2 indicated that, coefficient of determination (r²) among splenic volume and splenic index with respect to maximum CC length, true vertical length and maximum axial length showed moderate positive linear relationship and this correlation was statistically significant (P < 0.001). However, splenic volume and splenic index showed a weak relationship with age (P > 0.043 and P > 0.059 respectively for SV and SI) and was not statistically significant.

DISCUSSION

In this study, we found that there were 60 males (38.96 %) and 94 females (61.04 %). Mean age was 45.79 +/- 15.18 years. The mean age of female and male was 45.87 +/- 15.12 years and 45.93 +/- 15.19 years respectively. Iwona Kucybala et al. showed that the mean age was 58.8 +/- 15.5 years. They also showed that 48.5 % and 51.5 % population were female and male respectively.¹¹ Ogbeide Ehimwenma et al. showed that the mean age of female and male was 29.7 +/- 9.0 years and 32.4 +/- 9.2 years respectively.¹²

For female, the mean splenic craniocaudal length, thickness and volume were 10.1 +/- 0.7 cm, 4.0 +/- 0.4 cm and 153 +/- 33.2 cm³ respectively. The corresponding values in male were 11.1 +/- 0.9 cm, 4.4 +/- 0.5 cm and 202 +/- 49.4 cm³ respectively showing increased parameters in male. Ogbeide Ehimwenma et al. did ultrasound based study to determine splenic dimensions in 200 Nigerian adults (20 - 60 years), for the female, the mean splenic craniocaudal length, thickness and volume were 10.1 +/- 0.7 cm, 4.0 +/- 0.4 cm and 153 +/- 33.2 cm³ respectively and the corresponding values in male were 11.1 +/- 0.9 cm, 4.4 +/- 0.5 cm and 202 +/- 49.4 cm³ respectively.¹² Kaneko J et al. found that the mean volume was 112 cm³, ranging from 32 to 209 cm³.¹³

Mean splenic index (SI) was 340.30 +/- 107.39 cm³ in our study. Adil Asgar et al. showed that the mean SI was 494.82 +/- 226.83.¹⁴ L. Grissom calculated and adjusted his upper normal value to 425 - 455 cm³.¹⁵ Prince Kapoor et al. calculated the mean splenic index as 342.62 cm³.¹⁶ Strijk et al. had measured the splenic index and gave a mean value of 449 cm³ on European population which is considerable higher than the value of our study.¹⁷ According to Grissom and Shintr, upper normal value was 425 - 450 cm³.¹⁵ Jong et al. defined the upper limit of normal as 725 cm³ and mean value of 395 +/- 163 cm³ in their study on 111 subjects which was again more than our findings.¹⁸

There was statistically significant correlation between splenic volume and maximum craniocaudal length (r² = 0.4848, P = 0.001), maximum axial length (r² = 0.4765, P < 0.001) and true vertical length (r² = 0.3142, P = 0.001) with 95 % confidence interval. For all splenic measurements, there was stronger correlation with maximum craniocaudal length followed by maximum axial length. Iwona Kucybala et al. showed that the strongest correlation of the splenic volume was detected for maximum height (r² = 0.804; P < 0.05), followed by true vertical height.¹¹

However, there was no statistically significant correlation either of splenic volume with age in either gender (r² = 0.019, P = 0.043) or splenic index with age in either gender present (r² = 0.016, P = 0.059) in our study. Ardene Harris et al. in their study in 2010 showed that the splenic volume has negative correlation with age of the individual.¹⁹ However, Kaneko J et al. showed in their study that there was significant correlation of splenic volume with age but not with gender.¹³

Mean splenic weight was 238.34 +/- 65.38 g in our study, which was at the upper limit of normal range. P. Prassopoulos et al. found that the average splenic weight was 150 g (range 100 - 250 g).

CONCLUSIONS

Determination of normal parameters of spleen is essential for it's assessment in routine ultrasonography or in the CT scan. The automatically contouring software as well as splenic volume calculator can be used to calculate the splenic volume, splenic index and splenic weight in certain cases where splenic involvement is suspected by various disease processes. Maximum splenic length both in coronal (craniocaudal) and axial sections are positively and strongly

correlated with splenic volume and splenic index, but age of the individuals doesn't show any correlation either with the splenic volume or with splenic index. Hence, a regional reference of splenic parameters was established. We also conclude that the mean splenic index and mean splenic volume in our study population lies below the European, American and Nigerian population and is less than the normal value 480 cm³. This probably makes our population more vulnerable to tropical infections.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.

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