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Original Article

Computed Tomography Assessment of Linear Splenic Dimensions and their Correlation with Anthropometric Measurements in Nepalese Population

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Abstract

Background
Geographical locations and ethnicity may influence variations in normal spleen dimensions, potentially leading to errors in assessment. This study aimed to correlate splenic dimensions with anthropometry and predict their variation with age and body surface area.

Materials and Methods
Subjects (n=384) undergoing abdominal computed tomography were selected by random sampling. Splenic volume was calculated using the standard prolate ellipsoid equation. Correlation of splenic volume with body surface area and body mass index was done with Pearson's correlation analysis. A multiple regression was run to predict splenic volume from age, height, and body surface area.

Results
The mean age was 45±18 (range, 18-90years). The mean splenic length, width, thickness, and volume were 7.6 ± 1.7 cm, 8.8 ±1.5cm, 3.8 ± 0.9 cm, and 139 ± 58.2 cm^3, respectively. The splenic width and splenic volume were significantly lower at extremes of age. A significant (P<0.05) correlation was seen between splenic volume, body surface area(r=0.393) and body mass index (r=0.126); a negative correlation was observed between splenic volume and age (r=-0.180). Splenic dimensions were significantly larger in males. Multiple regression revealed that an increase in body surface area (by 10 cm^2), predicted increased splenic volume was 4.3 cm^3. An increase in age (by 1-year), predicted decrease in splenic volume was 8.3 cm^3. For 10 cm increase in height, predicted increase in splenic volume was 1.7cm^3.

Conclusion
The study showed a positive correlation between splenic volume and body surface area, as well as body mass index and provides a crucial normative data for assessing splenic enlargement in Nepalese population.

Keywords: *Body mass index, Body surface area, Nepal, Spleen*

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Introduction

The spleen, a vital organ with significant anatomical variability among normal individuals, poses challenges in accurate size measurement, potentially leading to misinterpretations in imaging for those with splenic diseases [1]. Notably, variations in shape and position are common, introducing complexities in establishing a standard range for measurements. Illustrating the inherent diversity in normal anatomy the upper limit of normal splenic length in adults is conventionally around 12 cm, yet this can surpass 14 cm in taller males [2].

Clinical examinations exhibit limited sensitivity in detecting an enlarged spleen, as evidenced by studies reporting mere 40% sensitivity in physical examinations [3]. The advent of sonography revolutionized the measurement of splenic length, overcoming the limitations posed by plain radiographs. However, plane radiographs generated a composite shadow which could not discern spleen with certainty [4]. While ultrasonography remains a valuable tool, its efficacy can be hindered by factors such as bowel gas and rib shadows [5]. In contrast, computed tomography (CT) emerges as a precise and reproducible modality for accurate spleen assessment [6].

Ethnic disparities influence spleen dimensions, with variations reported in volume and length among different populations. Conflicting global data on the association between splenic dimensions and anthropometric measurements complicates understanding [7-9]. Despite numerous sonographic studies, a gap persists in normative CT-based data. This study aims to comprehensively evaluate linear splenic dimensions and volume in subjects without splenic disease, exploring correlations with anthropometric parameters and investigating age, body surface area, and height as predictors of splenic volume.

Materials and Methods

This cross-sectional study was conducted at the Department of Radiology of Bir Hospital, Nepal, over a one-year period. Approval from the institutional review board was secured, and all patients provided written informed consent based on the principles of the Declaration of Helsinki. The study included adults (>18 years) referred for abdominal CT at the radiology department unrelated to splenic disease. Exclusions criteria included patients with splenic or multi-organ injury, focal spleen lesions, prior splenectomy, and conditions affecting spleen position, hemoglobinopathies, myeloproliferative neoplasms, liver diseases, malaria, or a history of Kala-azar. Sample size calculation was done using the formulae: $N= [(Z\alpha/2 + Z\beta)\ 2\ X\ \{2(SD)2\}] / (\mu1-\mu2)\ 2$. In this formula, N=Sample size in each group, $\mu1$=mean change in group 1 or mean score at baseline, $\mu2$=mean change in group 2 or mean score after intervention, $\mu1-\mu2$=clinically significant difference, SD=standard deviation, $Z\alpha/2$=this depends on the level of significance (for 5%=1.96), $Z\beta$ =this depends on power (for 80%=0.84). An online calculator of the University of British Columbia was used for calculation. This calculator can be accessed using the link [https://www.stat.ubc.ca/~rollin/stats/ssize/n1.html.]. Sample size calculation was based on the principal of "Inference for a mean, comparing a mean to know a value.' To calculate the sample size, a pilot study was first done on 10 subjects. The mean splenic volume in subjects with BSA of 1.80 m^2 was 114m^3 and for subjects with BSA on 2.1 m^2 was 120m^3, respectively. The standard deviation was 42. Considering 80% power (alpha = 0.05), and a precision error of 5% to detect variation of 20% or more in splenic volume, the estimated sample size was calculated to be 384.

Axial and cross-sectional images of the spleen were obtained using a Philips Ingenuity CT scan machine, with parameters set at 120kV potential, 120mA current, 1.25 mm slice width, and a rotation time of 1.5 seconds. Spleen volume was manually calculated using the clinical prolate ellipsoid equation [0.524 × splenic index (max. length × max. width × max. thickness)]. The Splenic length (L) was obtained by multiplying the number of sections where the spleen was visualized by the thickness of the sections [10]. For splenic width (W), the maximum distance between the lateral and medial margins of the spleen in any axial plane was measured. The thickness of the spleen (T) was measured as the distance between the hilum and the outer convex surface of the spleen perpendicular to the plane of splenic width (Figure 1).

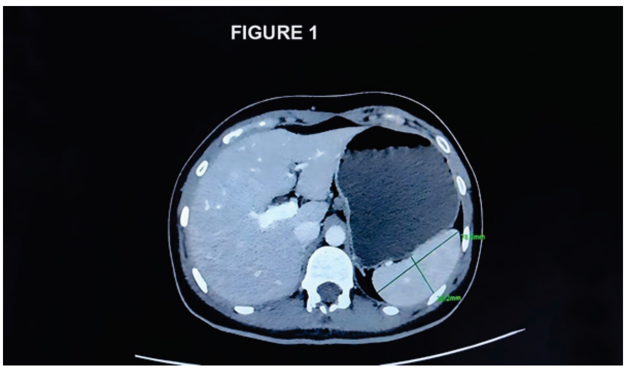

Figure 1: Image showing contrast enhanced CT abdomen in portal venous phase axial section at the level of spleen showing splenic measurements

Anthropometric parameters were recorded during CT scan examinations.
IBM statistical software, SPSS Statistics version 29, facilitated statistical analysis. The Shapiro-Wilk test assessed normality, and outliers were identified visually. Various statistical tests, including Chi-square, t-test, ANOVA, and Pearson correlation coefficient, were employed. Univariate analysis preceded a multiple regression considering age, height, and BSA to predict splenic volume, adjusting for potential confounders. Statistical analysis included tests for normality, expression of normally distributed data as mean±SD, Chi-square tests for categorical variables, t-tests for independent groups, ANOVA for multiple groups, and Pearson correlation coefficient for assessing linear relationships. Univariate analysis preceded multiple regression, and a significance level of P< 0.05 was applied.

Results

A total of 384 participants were included in this study with a 100% response rate. The mean splenic length, width, thickness, and volume were 7.6 ± 1.7 cm, 8.8 ± 1.5cm, 3.8 ± 0.9 cm, and 139 ± 58.2 cm^3, respectively. The mean age of participants was 45±18 (range, 18-91years). There were 207 (53.9%) males with male: female ratio of 1.16:1. The mean weight, height, body mass index (BMI), and body surface area (BSA) were 57.3 ± 12.2 kg, 5.6 ± 6.4 ft, 23.2 ± 5.5kg/m^2, and 1.6 ± 0.2m^2 respectively. More than half of participants (214, 55.7%) had a normal BMI (Table 1).

Table 1: Demographic characteristics

Variable	N (%)
Gender	
Male	207(53.9)
Female	117(46.1)
Age Groups	
<20	32(8.3)
20-40	142(37)
40-60	116(30.2)
60-80	87(22.7)
>80	7(1.8)
BMI	
Underweight	62(16.1)
Normal	214(55.7)
Overweight	66(17.2)
Obese	42(10.9)

Splenic dimensions were significantly larger (independent t-test, P<0.05) in Nepalese males as compared to females (Table 2).

Table 2: Splenic dimension variation with gender

Splenic dimension (Mean±SD)	Male	Female	P value
Length (cm)	7.7±1.7	7.3±1.7	0.024
Width(cm)	9.1±1.6	8.5±1.4	0.001
Thickness (cm)	3.9±0.9	3.7±0.8	0.020
Volume	149±61	126±52.7	0.001

The splenic width and splenic volume significantly differed (ANOVA, P<0.05) between age groups. These two parameters were significantly lower at extremes of age (Table 3).

Table 3: Splenic dimension variation with age

Age Group	<20	20-40	40-60	60-80	>80	P Value
S. Length (cm)	7.4±1.3	7.7±1.5	7.7±2	7.1±1.9	7.2±1.4	0.133
S. Width(cm)	8.7±1.4	9.2±1.5	8.9±1.5	8.3±1.4	7.6±2.5	0.001
S. Thickness (cm)	3.6±0.6	3.8±0.9	3.9±0.9	3.9±0.9	3.5±0.5	0.493
Volume	125±36	145±51	147±71	125±54	106±53	0.014

From the regression equation, the predicted splenic volume = -8.5 + (100.3 x BSA). For 10 cm^2 increase in BSA, splenic volume will increase by 4.3 cm^3 after adjusting for (gender, and BMI). For 1-year increase in age, splenic volume will decrease by 8.3 cm^3 (-8.5+ (-0.155 x Age). For 10 cm increase in height, splenic volume will increase by 1.7cm^3 (1.4+ (0.3 x Height). A significant and positive correlation was seen between splenic volume, BSA and BMI. An inverse but statistically insignificant correlation was observed between splenic volume and age.
On multiple regression (to predict splenic volume from gender, age, BSA and BMI), there was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 2.109. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, no leverage values greater than 0.2, and values for Cook's distance above 1. The assumption of normality was met, as assessed by a Q-Q Plot. The multiple regression model statistically significantly predicted splenic volume, $F(4, 379) = 17.90$, $p < .0001$, adjusted. $R^2 = 0.15$. Body surface area added statistically significantly to the prediction, $p < .05$. Regression coefficients and standard errors can be found in Table 4.

Table 4: Regression coefficients

Splenic volume	B	95% CI	SE	β
Constant	-8.5	-69-52	30.8	
Age	-0.155	-0.457-0.148	0.154	-0.48
Sex	-8.4	-21.8-4.9	6.8	-0.72
BMI	0.3	-0.87-1.5	0.6	0.03
BSA	100.3	66.6-134	17.1	0.349

B (Intercept), CI (confidence interval), SE (standard error), β(constant)

Discussion

The results of this study suggest that the splenic dimensions (length, width, thickness, and volume) were significantly larger (independent t-test, P<0.05) in males as compared to females. A significantly lower splenic volume and width was observed at extremes of age; there was an inverse (negative) correlation between age and splenic volume (Pearson's correlation coeffcient, r=-0.180). Our study found that a significant and positive correlation was seen between splenic volume, BSA (r=0.393) and BMI (r=0.126). On multiple regression analysis, BSA could significantly predict splenic volume (The predicted splenic volume from the regression equation = -8.5 + (100.3 x BSA).

Our study found a significant correlation between height of subjects and splenic width. An Indian study found that linear splenic dimensions best correlated with height of patients [11]. A study by Spielmann et al. found that linear splenic dimensions significantly (P<0.002) correlated with the height of participants [12]. Other studies in literature have also substantiated a correlation between linear splenic dimensions and height.

In our study, the mean splenic length was significantly lower in females compared to males. This observation was consistent with studies conducted in Turkey, Saudi Arabia, Nigeria, and Sudan but inconsistent with studies conducted in India and Egypt [13-16]. This difference could be attributed to a lower red cell mass in females and possibly genetic factors. Additionally, nutritional status and excess weight gain in women could account for this difference.

Increase in age was associated with a decrease in splenic dimensions in our study. This observation was consistent with other studies conducted in the subcontinent [17-18]. However, study conducted in Pakistan was not in agreement with this observation [19]. The difference is probably due to difference in nutritional status and consequently, larger anthropometric measurements and obesity observed in the study from Pakistan.

It has been suggested that with increasing age, the number and size of B cell follicles of white pulp of spleen decreases with a decrease of germinal centre of spleen [20]. Splenic volume significantly correlated with patient's height and with body surface area. The first observation was consistent with the studies conducted in Jordan, USA, India, and Sudan [13, 21-22]. In contrast, studies conducted in Turkey and Egypt did not find any correlation between height and splenic volume [23, 24]. In our study, the predicted increase in splenic volume was 42.9 cm^3.

Splenic volume was calculated using prolate ellipse formulae. This could lead to inaccurate measurements in subjects with irregularly shaped spleen. A single investigator performed all measurements. Having two observers would have been preferable to mitigate potential interobserver bias. Due to resource limitations absence of illness was not excluded using laboratory finding. Therefore, a multicentre, multiobserver study with larger sample size can be undertaken to overcome these limitations. Also, in order to avoid including patient with covert diseases that could affect spleen, blood tests can be conducted to confirm the absence of those diseases, prior to enrolling the subject to the study, rather than just depending upon the history of the patient.

Conclusion

The splenic dimensions, including length, width, thickness, and volume, were significantly larger in males compared to females. A significant correlation was observed between splenic volume and body surface area, as well as body mass index. Multiple regression analysis demonstrated that an increase in body surface area predicted an increase in splenic volume, while an increase in age predicted a decrease in splenic volume. This study provided normative data for Nepalese population for assessment of splenic volume.

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Conflict of interest: None

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