# Evaluation of Spleen with Ultrasonography: Single Measurement or Volume Detection?

## Ultrasonografi ile Splenomegali Tespiti: Tek Ölçüm mü Yoksa Hacim Hesabı Mı?

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## Abstract

**Objective:** Splenomegaly is an important finding for many diseases. Splenic long axis greater than thirteen cm are investigated and sometimes invasive examinations are performed. Splenic size may differ depending on age, gender, body mass index, and racial differences. The aim of this study is to investigate the relationship between splenic dimensions and volume in the patients attended gastroenterology outpatient clinics.

**Material and Method:** Patients without a known disease and applied to gastroenterology outpatient clinic who needed basic evaluation with ultrasonography are included in the study. A single skilled radiologist performed ultrasonographic measurements. Splenic volume is calculated by prolate ellipsoid formula (length × width × depth × 0.523).

**Results:** A total of 245 patients (146 female, 99 male) were enrolled in the study. In correlation analysis spleen volume was positively correlated with height *(r=0.505; p<0.05)*, weight (*r=0.367; p<0.00*), waist circumference (*r=0.208; p<0.05*), and body surface area (*r=0.269; p<0.05*) and negatively correlated with age (*r=-0.269; p<0.05*). In logistic regression analysis, the main determinants of maximal length were found to be body surface area (BSA), age, and weight.

**Conclusion:** Splenic volume measurements are the most correlated with width of spleen. Splenic volume decreases with age and is correlated with BSA and weight. Measuring splenic volume may be helpful in detecting splenomegaly.

**Keywords:** Splenic volume; Splenomegaly; Ultrasonography

## Özet

**Amaç:** Splenomegali birçok hastalık için önemli bir bulgudur. Dalak uzun ekseni on üç cm'den büyük ise araştırılır ve bazen invaziv incelemeler yapılır. Dalak büyüklüğü yaşa, cinsiyete, vücut kitle indeksine ve ırksal farklılıklara bağlı olarak değişebilir. Bu çalışmanın amacı, sağlıklı bireylerde dalak boyutları ve hacmi arasındaki ilişkiyi araştırmaktır.

**Gereç ve Yöntem:** Bilinen bir hastalığı olmayan ve gastroenteroloji polikliniğine başvuran, ultrasonografi ile temel değerlendirme yapılan hastalar çalışmaya dâhil edildi. Ultrasonografik ölçümler tek bir uzman radyolog tarafından yapıldı. Dalak hacmi, prolate elipsoid formülüyle hesaplandı (uzunluk × genişlik × derinlik × 0,523).

**Bulgular:** Çalışmaya toplam 245 hasta (146 kadın, 99 erkek) dâhil edildi. Dalak hacmi korelasyon analizinde boy (*r=0,505; p<0,05*), ağırlık (*r=0,367; p<0,00*), bel çevresi (*r=0,208; p<0,05*) ve vücut yüzey alanı ile pozitif korelasyon (*r =0,269; p<0,05*) ve yaş ile negatif korelasyon (*r=-0,269; p<0,05*) gösterdi. Lojistik regresyon analizinde maksimal uzunluğun ana belirleyicilerinin vücut yüzey alanı, yaş ve ağırlık olduğu bulundu.

**Sonuç:** Dalak hacmi ölçümleri çoğunlukla dalak genişliği ile ilişkilidir. Dalak hacmi yaşla birlikte azalır ve vücut ağırlığı ve vücut yüzey alanı ile ilişkilidir. Dalak hacminin ölçülmesi, splenomegalinin saptanmasında yardımcı olabilir.

**Anahtar Kelimeler:** Dalak hacmi; Splenomegali; Ultrasonografi

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## Introduction

The spleen, the largest organ of the reticuloendothelial system, expands clinically, especially in chronic liver disease, immunological disorders, hematological illnesses, portal hypertension, and splenic vein thrombosis (1). Patients with splenomegaly diagnosed using ultrasonography and computed tomography were seen in the outpatient clinic. A variety of tests, some of which are invasive, are performed on persons with a spleen long axis of more than 13 cm to determine the reason (1, 2).

Spleen size changes with age, sex, body mass index (BMI), and race. Since the physical examination used to determine splenomegaly is subjective, radiographic diagnostic methods are often employed to measure the spleen size. Ultrasonography is the most commonly used technology because it is inexpensive, widely accessible, non-invasive, and does not release radiation.

If a relationship between normal spleen size, sex, and physical characteristics can be discovered, unnecessary research may be avoided. This study aimed to examine the relationship between spleen measurements and ultrasonography-calculated spleen volume, age, sex, height, weight, and body mass index in healthy individuals.

## Material and Method

Included in the research were patients who presented to a gastrointestinal outpatient clinic with dyspepsia symptoms and required basic screening with ultrasonography, but did not have a known cause of splenomegaly. After obtaining informed permission from individuals who wanted to participate in the research, their extensive medical histories were obtained. Weight, height of the patients is detected and body mass index (BMI) is calculated using the formula BMI = kg/$m^2$ where kg is a person's weight in kilograms and $m^2$ is their height in meters squared. Body surface area was calculated using the Mosteller formula:

$$\sqrt{(Ht(cm)\times Wt(kg))/3600}$$

The approval number for ethics committee permission was acquired on 11/09/2018 from the local ethics committee and was 982. All the procedures were conducted in compliance with the ethical guidelines and principles of the Declaration of Helsinki.

*Inclusion criteria*

The participants were those who applied to the gastrointestinal outpatient clinic with abdominal distension, bowel irregularity, dyspepsia, and nonspecific abdominal discomfort; did not have a known condition that may induce splenomegaly; and agreed to participate in the study.

*Exclusion criteria*

Individuals with hepatitis, liver cirrhosis, portal hypertension, anemia, infection, lymphoma, hematological disorders, storage diseases, recent infection history, known autoimmune diseases, and those who declined to participate were excluded from the trial. This therapy is ineligible for individuals with a history of splenic trauma, non-traumatic benign splenic lesions (such as infarctions, lobulations, cysts, accessory spleens, and hemangiomas), malignant splenic lesions, or pregnancy.

*Radiologic evaluation*

A single skilled sonographer performed ultrasonographic measurements of the spleen, with the subject lying in the right lateral decubitus position. A 3.5-MHz (RS85 Prestige (Samsung, 2021) convex transducer was used. Maximum length: maximum distance between the most superomedial and inferolateral points on a longitudinal plane, and the splenic width is the maximum anteroposterior dimension measured on a transverse plane. Splenic thickness is the mediolateral distance from the hilum to the capsule measured on the same transverse plane. The splenic volume was measured using the prolate ellipsoid formula (length × width × depth × 0.523).

## Statistical analysis

Statistical analysis was performed using the statistical software SPSS (version 20.0; SPSS Inc., Chicago, IL, USA). Normal distribution of the quantitative data was confirmed using the Kolmogorov-Smirnov test. An independent samples t-test was used for comparisons. Correlations between variables were assessed using Pearson's correlation coefficient (r). Logistic regression analysis (curve fit) was used to determine the exact pattern of the relationship, and equations were constructed accordingly. Statistical significance was set at $p<0.05$.

## Results

A total of 245 patients (146 female and 99 male) were enrolled in this study. The mean age of the patients was 45±13. The mean height of the patients was 166±10 cm. The mean weight was 75±15 kg, and waist circumference was 95±14 cm. Mean body mass index was calculated as 27.22±5.05 kg/"m2 and body surface area (BSA) was calculated as 1.7±0.54. Maximal length was 107.37±13.49 mm, mean width was 43.99±6.97 mm, and thickness was 39.16±7.23 (Table 1).

**Table I.** Findings of the study population

| | Mean ± Standard Deviation |
|---|---|
| Age (years) | 45±13 |
| Height (cm) | 166±10 |
| Weight (kg) | 75±15 |
| Waist (cm) | 95±14 |
| ML (mm) | 107.37±13.49 |
| W (mm) | 43.99±6.97 |
| T (mm) | 39.16±7.23 |
| Volume ($cm^3$) | 101.69±41.1 |
| BSA ($m^2$) | 1.70±.54 |
| BMI (kg/$m^2$) | 27.22±5.05 |

Abbreviations: ML: maximal length, W: width, T: thickness, BSA: body surface area, BMI: body mass index

When the patient population was analyzed according to sex, age and waist circumference were not different between female and male patients (46±13 cm vs. 43±13 cm; p=0.209 and 94±15 cm vs. 96±12 cm; $p=0.273$, respectively). On average, male patients weighed more (81.15±15 kg vs. 71±14 kg; $p<0.05$) and were taller (174±7 cm vs. 160±7 cm; $p<0.05$). Maximal length was higher in male patients (113.93±11.28 mm vs 102.86±13.11 mm; $p<0.05$). When the volume of the

spleen is calculated, it was found that the spleen volume was higher in male patients (123.75±37.95 cm 3vs 86.73±36.19 $cm^3$ *p<0.05*) (Table 2).

Correlation analysis revealed that the maximal length was positively correlated with height (*r=0.501; p< 0.05*), weight (*r=0.809; p<0.05*), waist circumference *(r=0.240; p<0.05)*, and BSA (*r=0.269; p<0.05*). Maximal length was negatively correlated with age (*r=-0.269; p<0.05*) (Table 3).

Positive correlations were detected between spleen volume and height (*r=0.505; p<0.05*), weight *(r=0.367; p<0.00*), waist circumference (*r=0.208; p<0.05*), and BSA (*r=0.269; p<0.05*). Spleen volume was negatively correlated with age (*r=-0.269; p<0.05*). Splenic volume was highly correlated with the maximal length ((*r=0.846; p<0.05*), width (*r=0.846; p<0.05; r=908*), and thickness (*r=904, p<0.05*) (Table 4)).

Logistic regression analysis revealed that the main determinants of maximal length were BSA, age, and weight (Table 5).

**Table II.** Findings of the study population

| | Female (n=146) | Male (n=99) | *p* |
|---|---|---|---|
| Age (years) | 46±13 | 43±13 | *0.209* |
| Height (cm) | 160±7 | 174±7 | *0.00* |
| Weight (kg) | 71±14 | 81±15 | |
| Width (mm) | 94±15 | 96±12 | *0.273* |
| ML (mm) | 102.86±13.11 | 113.93±11.28 | *0.00* |
| Volume ($cm^3$ ) | 86729±36087 | 123749±37947 | *0.00* |
| BSA ($m^2$) | 1.62±.52 | 1.83±0.54 | *0.00* |
| BMI ($kg/m^2$) | 27.69±5.32 | 26.53±4.48 | *0.33* |

Abbreviations: ML: maximal length, BSA: body surface area, BMI: body mass index

**Table III.** Correlation of maximal length

| | *r* | *p* |
|---|---|---|
| Volume | *0.846* | *0.00* |
| Age | *-0.211* | *0.001* |
| Height | *0.501* | *0.000* |
| Weight | *0.389* | *0.00* |
| Width | *0.240* | *0.001* |
| BSA | *0.269* | *0.00* |

Abbreviations: BSA: body surface area

**Table IV.** Correlation of splenic volume

| | *r* | *p* |
|---|---|---|
| Length | *0.846* | *0.00* |
| Age | *-0.196* | *0.002* |
| Height | *0.505* | *0.000* |
| Weight | *0.367* | *0.00* |
| Width | *0.208* | *0.004* |
| BSA | *0.269* | *0.00* |

Abbreviations: BSA: body surface area

**Table V.** Regression analysis of maximal length

| Model | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | .595 | .553 |
| (Constant) | 13.353 | 22.435 | 2.932 | .595 | .553 |
| BSA | 184.348 | 81.114 | 2.932 | 2.273 | .024 |
| AGE | -.203 | .077 | -.193 | -2.643 | .009 |
| HEIGHT | -.572 | .487 | -.413 | -1.175 | .242 |
| WEIGHT | -2.143 | 1.003 | -2.355 | -2.137 | .034 |
| | 0.183 | 0.136 | 0.192 | 1.322 | 0.181 |

a. Model Abbreviations: BSA: body surface area

## Discussion

Splenomegaly is a frequent finding in radiologic assessments. Splenomegaly may develop as a result of an unexpected imaging discovery, the expected outcome of a recognized clinical entity, or the patient's underlying symptoms or clinical presentation. Each of these scenarios was feasible. Splenomegaly may be caused by any one of these disorders (1).

The average size of the spleen may be interpreted differently depending on where the interpretation is required on the receiver operating characteristic curve. Splenic volumes have a normal distribution and a wide range of variations. Imaging findings with a maximal diameter of > 13 cm should be considered abnormal (1, 2), despite the fact that typical spleen sizes and volumes vary by sex, age, and ethnicity.

Many studies with individuals from diverse demographic backgrounds have examined the range of spleen size and volume in healthy individuals. Imaging methods are often employed in this research to determine SM by either measuring its dimensions or calculating its SVol. Throughout our investigation, we used the ellipsoid formula to calculate spleen volume.

Splenic volume (SVol) was highly associated with all other variables, with width (W) having the highest correlation indices. These results are in line with those of previous research (2-7). Many studies have demonstrated that the maximum length (ML) of the spleen is strongly associated with its volume (SVol). Bezerra et al. (3) discovered the strongest associations between ML, W, and SVol. Prassopoulos and Cavouras (4) showed in a similar investigation that thickness (T) may be used to identify splenomegaly (SM). SVol was linked to L, W, and T by Mustapha et al. (5) and Srisajjakul et al. (6).

In clinical practice, length is often employed to assess SM; however, the ML cutoff values utilized in different studies may vary. According to the data acquired, the ML measured 146 mm and the spleen averaged 107.37 millimeters. Loftus et al. reported that the maximum spleen length varied from 10.53 cm to 15.3 cm (8). This was consistent with the data gathered.

Since the upper limits of normal splenic size are described in several ways in the medical literature, a single measurement and size cutoff for SM is likely to be inadequate for certain people. This difference might be attributed to a variety of factors, such as participant ethnicity and the use of non-standardized assessment processes. Previous studies have indicated that the volumetric reference standard consists of counting CT voxels to estimate SVol (3, 9).

The average SVol was 101.6941.0 $cm^3$. The SVol varies by group: it was 120 $cm^3$ in a Japanese study (10), 215 $cm^3$ in

a European study (11), and 120 $cm^3$ in an African study (5). Prior research has demonstrated that racial or ethnic characteristics may affect SVol (5, 12), although the main difference may be the different measurement techniques used. SVol was substantially lower in our analysis than in previous investigations. These inequalities might be attributed to a number of reasons, including changes in the number of patients who participated in the research, the average age of those patients, the sex of the patients, the study's methodology, and geographical differences across populations.

SVol had a statistically significant positive correlation with height, weight, waist circumference, and body surface area ($p< 0.001$). We found a negative relationship between SVol and age. Some studies found no relationship between age and SVol, whereas others found an inverse relationship (3). Despite a lack of agreement in the scientific literature regarding the link between age and SVol, age has a major influence on the involvement of various organs, including the pancreas and kidneys (13). Postmortem investigations have shown that the size of the spleen decreases steadily beyond 20 years of age. (14-16). As previously established in the scientific literature, the aging process is related to a decrease in spleen size in our research group (13, 17).

According to the findings of our study, males had a higher mean SVol than women. A few studies (17, 18) support this; however, another study found no statistically significant changes in SVol between sexes (10, 19). Even after accounting for body height, women have a much smaller spleen than men, and this disparity grows as body height increases (20). This gender disparity may be one of the factors leading to this result. However, there are various possible explanations for this disparity, including genetic and physical factors.

According to the findings of our research, a correlation may be shown between ML and SVol and patients' height, weight, waist circumference, and body mass index. The results of a regression study showed that body mass index (BMI) and weight were positively associated with splenic size, but age had an inverse relationship with splenic size. There was no longer a statistically significant association between a person's height and waist circumference.

Many studies (17, 18) have reported a link between SVol and height and/or weight; however, other studies did not find a correlation (5, 10). Variations in spleen size and volume may arise from genetic, environmental, or socioeconomic differences between different populations. These factors may also contribute to observable differences in gender characteristics.

Our study had some limitations.

(a) To calculate SVol, we used the methodology described in published research. SVol, which is estimated using techniques that include direct volume morphometry, could be more accurate.

(b) CT and MRI are less reliant on the operator than USG and may offer accurate and consistent measurements of organ size. Due to the fact that ultrasonography is an operator-dependent examination, examining the compatibility of measurements amongst various practitioners might be beneficial in terms of data objectivity and reproducibility.

(c) Relatively small number of the patients

As a result, the width of the spleen is highly correlated with its volume, and men have a greater spleen volume. The Turkish population shows a natural decline in splenic volume with increasing age, which is mostly associated with body mass index and weight. Splenomegaly may be diagnosed by splenic volume evaluation using relevant equations.

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