

Sonographic measurement of splenic size and its correlation with body parameters

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Abstract. There are controversies regarding the normal size of the adult spleen and its correlation with age, sex and body parameters. The present study aimed to establish a reference value of splenic dimensions, volume and their correlations with different body parameters. The present cross-sectional study was conducted on 300 healthy adult volunteers of both sexes. Age, sex, height, weight and body mass index (BMI) were recorded. The ultrasound measurements of spleen parameters included length, thickness and width. The spleen volume was calculated using the standard prolate ellipsoid formula (length x thickness x width x 0.523). The mean \pm SD age was 38.7 \pm 14 years, the mean height was 166 \pm 9.9 cm, the mean weight was 74.7 \pm 15.8 kg and the mean BMI was 27 \pm 5 kg/m². The mean spleen length, thickness, width and volume were 10.68 \pm 1.28 cm, 4.1 \pm 0.58 cm, 7.3 \pm 0.9 cm and 174.4 \pm 52.4 ml, respectively. Males had larger spleen parameters than females. Spleen volume significantly correlated with the subjects' height ($r=0.655$, $P<0.001$) and weight ($r=0.643$, $P<0.001$). However, weaker correlations were detected between age ($r=-0.238$, $P<0.001$) and BMI ($r=0.299$, $P<0.001$) with spleen volume. A higher significant correlation was found between spleen volume and spleen length rather than with its thickness and width. In the present study, the normative data of splenic dimensions and volume have been provided and may be used in certain clinical situations.

Introduction

The spleen is regarded as mobile and the largest single lymphatic organ, which is intraperitoneally located in the

superolateral part of the left upper quadrant of the abdomen (1). The shape and position of the spleen are quite variable in normal healthy individuals; this may thus lead to difficulties and to the mismeasuring of real splenic size or the false interpretation of splenic disease on variant imaging modalities (2). Ultrasound (US) is a non-invasive and low-cost modality for spleen assessment without ionizing radiation, which can detect many abnormalities, such as the occurrence and composition of splenic masses, splenic texture disruption and any changes in spleen size (3,4). Although US is regarded as a useful imaging tool for the diagnosis and follow-up of splenic abnormalities, sometimes the location of the spleen prevents a proper examination from taking place due to shadowing from the ribs, bowel gas and overlying lungs (1).

As with other body organs, it is necessary to have a standard measurement to establish normality limitations in spleen size. Clinically, if the spleen extends below the left costal margin, it is termed splenomegaly. There is no precise reliability to clinical palpation and it has 56-82% sensitivity in identifying splenomegaly compared to imaging studies (5). Prior to sonography advancement, a plain X-ray was used to measure the spleen length and size. However, it was not always reliable due to composite shadows (6).

Establishing a standard and normal range of sonographic measurements for adult splenic size is difficult due to its complex three-dimensional shape. Previous studies have tried to correlate the ethnicity of the subjects with spleen size using different imaging methods. Asian cohort studies have revealed smaller spleen sizes in the US compared to the published literature (7,8). Spleen size has been found to be smaller in African American collegiate athletes compared to Caucasian Americans (9). Spleen volume in African adults is smaller than that in adults from western populations (10).

Since the US data from previous studies have demonstrated that racial differences can affect the volume of the spleen, conflicting data also exist regarding the association of splenic volume with sex, age and body parameters. The present study aimed to establish a reference value of splenic dimensions and volume in a healthy adult Kurdish population and their correlations with age, sex, height, weight and body mass index (BMI). The present study was written in line with PROCESS guidelines (11).

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Key words: ultrasonography, spleen volume, spleen length, normal range of spleen

Subjects and methods

Subject selection and registration. The present study was a single-center cross-sectional study performed over a 6-month period. The study registry has been provided in line with the Declaration of Helsinki: 'Every research study involving human subjects must be registered in a publicly accessible database before recruitment of the first subject'. The research was registered in the Research Registry with a registration number of research registry 7473 (<https://www.researchregistry.com/register-now#home/registrationdetails/61c1b60818f8b3001ec8448d/>).

Inclusion and exclusion criteria. Normal healthy Kurdish male and female adults who had a normal complete blood count (CBC) were included in the study. The exclusion criteria were as follows: i) Patients <20 years of age; ii) patients with clinical or laboratory evidence of infection or jaundice either at the time of the examination or within at least 6 weeks prior to the examination; iii) a history of rheumatoid diseases; iv) anemia or haemoglobinopathies (thalassemia and sickle cell anemia); v) a history of lymphoproliferative disorders or myeloproliferative neoplasm; vi) focal spleen lesions; vii) a history of splenic trauma or those with partial splenectomy; viii) liver diseases (cirrhosis or portal hypertension); ix) gravid females; x) non-Kurdish races; and xi) those whose entire length of the spleen could not be properly documented by the US.

Data collection and ultrasonographic examinations. The baseline data included age, sex, height and weight (the height and weight of the patients were measured using the standard anthropometric technique). Height was recorded in centimeters (cm) and weight was recorded in kilograms (kg). The BMI was calculated using the formula of weight (kg)/height (m²). Splenic length, thickness and width were recorded for each subject. Each dimension was measured three times and the mean value was obtained for the accuracy of the result. Spleen volume was calculated for each subject according to the standard prolate ellipsoid formula (length x thickness x width x 0.523); which is usually used for estimating the volume of irregularly shaped organs.

The subjects were scanned using different US machines with curvilinear probes of (2-6 MHz). After explaining the purpose of the examination and obtaining written consent, the subject was placed in the right lateral decubitus (RLD) position with the left arm stretched up over the head. The examination was performed on deep inspiration so that the spleen descended downward. Occasionally, when the lung base obscured the spleen on deep inspiration, scans were obtained on shallow inspiration or at rest.

A longitudinal section (coronal oblique view) was obtained with the transducer aligned parallel to the intercostal spaces in the left upper quadrant, with the maximum diameter between superomedial and inferolateral points (length). The perpendicular diameter from the hilum to the lateral surface of the spleen (thickness) was measured in this section (Fig. 1). The transducer was then rotated 90° counterclockwise to image the spleen in the transverse section, and the anteroposterior diameter (width) was measured in this section (Fig. 2).

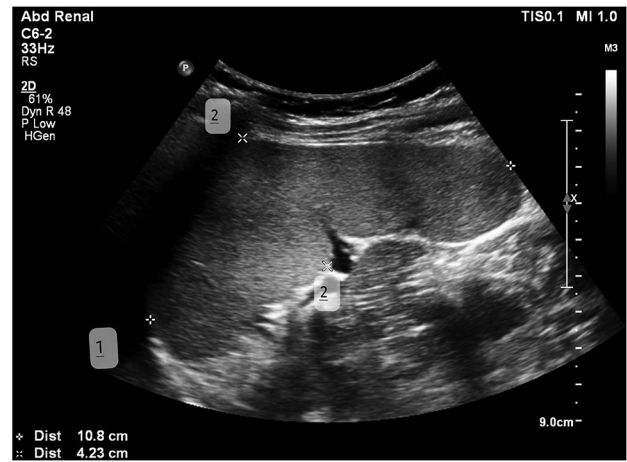


Figure 1. Spleen diameters at the level of the hilum in a longitudinal flank. In the scanned image, 1 refers to length and 2 to thickness.



Figure 2. Spleen diameter at the level of the hilum in transverse. In the scanned image, 3 refers to width.

All measurements were made on sections through the splenic hilum in order to create a constant reference point for repeating measurements according to the guidelines of the American Institute of Ultrasound in Medicine and as previously described by Lamb *et al* (12).

Ethical approval. The present study was approved by The Scientific Research and Ethics Committee of the College of Medicine, University of Sulaimani, Sulaimani, Iraq with a reference number of 1125/21. Institutional ethical approval was obtained from the authorities of the Sulaimani Teaching Hospital. Informed written consent was obtained from all subjects prior to the examination. The reason for the study, possible effects and stages of examination were explained to the subjects. All procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation.

Statistical analysis. The data were analyzed using the Statistical Package for Social Sciences (SPSS, version 19; IBM Corp.). The unpaired Student's t-test for two independent samples was used to compare the mean values of the anthropometric data. Categorical data were compared using Fisher's

Table I. Anthropometric data of the whole sample size and for males and females.

Subjects	No. of subjects	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m ²)
All subjects	300				
Mean		38.74	166.11	74.70	27.02
SD		14.166	9.9	15.806	5.07
Median		35.00	166.50	74.00	26.45
Minimum		20	146	40	16.44
Maximum		87	197	138	52.21
Males	145				
Mean		37.92	173.36	81.02	26.94
SD		13.104	6.831	14.136	4.30
Median		34.00	173	79.00	26.42
Minimum		20	155	51	16.98
Maximum		86	197	125	41.51
Females	155				
Mean		39.50	159.34	68.79	27.10
SD		15.094	7.143	15.013	5.71
Median		36.00	158	67.00	26.64
Minimum		20	146	40	16.44
Maximum		87	185	138	52.21
P-value		0.335	<0.001	<0.001	0.796

BMI, body mass index.

Table II. Correlation between age, weight, height and BMI with each of the studied spleen parameters.

Patients' age and anthropometry		Spleen parameters (n=300)			
		Length	Thickness	Width	Volume
Age	r	-0.187	-0.163	-0.253	-0.238
	P-value	<0.001	<0.005	<0.001	<0.001
Weight	r	0.558	0.408	0.478	0.643
	P-value	<0.001	<0.001	<0.001	<0.001
Height	r	0.597	0.425	0.578	0.655
	P-value	<0.001	<0.001	<0.001	<0.001
BMI	r	0.32	0.221	0.168	0.299
	P-value	<0.001	<0.001	<0.004	<0.001

exact test. One-way analysis of variance (ANOVA) was used to compare the mean of different age groups. A post hoc test (Hochberg GT2) was used to compare each two age groups (due to different sample sizes in each age group). Pearson's correlation coefficient (r/r^2) was used to measure the strength of the correlation between the two numerical variables. A P-value ≤ 0.05 was considered to indicate a statistically significant difference.

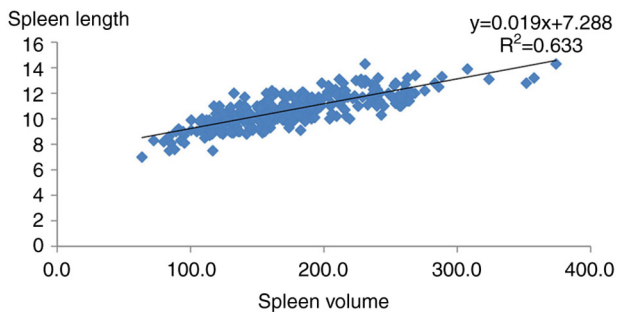
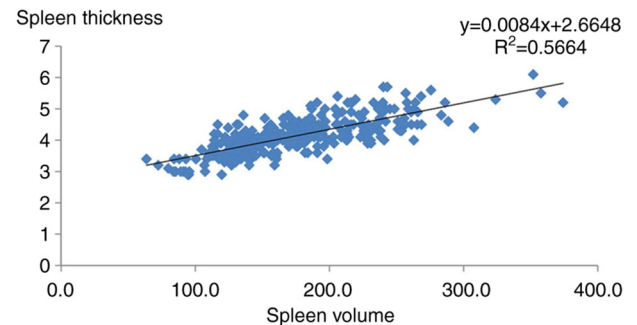
Results

The total number of participants was 300. The proportion of females (155, 51.7%) was almost equal to that of males (145,

48.3%). The male to female ratio was 0.93:1. The weight of 35.7% of the sample group was normal, 41.3% of the subjects were overweight (25-29 kg/m²) and 23% (≥ 30 kg/m²) were obese. The age of the subjects ranged from 20 to 87 years, with a median of 35 years. The mean values for the weight and height of the males were significantly higher than those of the females (P<0.001), while no significant differences were detected between the mean age and BMI of the males and females (Table I). The spleen volume significantly correlated with the subjects' height ($r=0.655$, P<0.001) and weight ($r=0.643$, P<0.001). However, weaker correlations were detected between age ($r=-0.238$, P 0.001) and BMI ($r=0.299$, P<0.001) with spleen volume (Table II). The mean spleen

Table III. Spleen parameters of the whole sample size and comparisons between males and females.

Subjects	No. of subjects	Spleen length (cm)	Spleen thickness (cm)	Spleen width (cm)	Spleen volume (ml)
All subjects	300				
Mean		10.685	4.134	7.388	174.414
SD		1.283	0.587	0.924	52.449
Median		10.700	4.100	7.400	169.487
Minimum		7.000	2.900	5.100	63.603
Maximum		14.100	6.100	9.600	374.061
5th percentile		8.705	3.200	6.000	95.750
95th percentile		12.990	5.200	8.900	262.838
Males	145				
Mean		11.266	4.335	7.779	200.611
SD		1.160	0.558	0.846	47.950
Median		11.200	4.300	7.800	192.350
Minimum		8.500	3.200	6.000	110.637
Maximum		14.100	6.100	9.600	374.061
5th percentile		9.390	3.500	6.500	135.401
95th percentile		13.200	5.370	9.300	282.970
Females	155				
Mean		10.141	3.946	7.023	149.907
SD		1.149	0.552	0.843	44.051
Median		10.100	3.900	7.000	141.648
Minimum		7.000	2.900	5.100	63.603
Maximum		12.800	5.700	9.300	283.312
5th percentile		8.180	3.000	5.700	87.471
95th percentile		12.000	4.920	8.640	243.423
P-value		<0.001	<0.001	<0.001	<0.001

Figure 3. Correlation between spleen length and spleen volume ($r^2=0.633$, $P<0.001$).Figure 4. Correlation between spleen thickness and spleen volume ($r^2=0.5664$, $P<0.001$).

parameters of the males were significantly greater than those of the females ($P<0.001$; Table III). Significant differences in splenic parameters among the age groups were detected. There was a steady increase in spleen dimensions from the age of 20 to 39 years; thereafter it began to gradually decrease as age increased (Table IV). The mean splenic volume, width and thickness for males were higher than those of females. All the parameters exhibited significant differences, apart from the age group of 50-59 years (Table V). The results revealed a more highly significant correlation between spleen volume

and spleen length ($r^2=0.633$, $P<0.001$) in comparison to spleen thickness ($r^2=0.5664$, $P<0.001$) and spleen width ($r^2=0.572$, $P<0.001$) (Figs. 3-5). The spleen length was categorized into three groups (≤ 12 , >12 and >13 cm). It was revealed that 16.5% of males had a spleen length >12 cm compared with 3.9% of females. Only 3% of the individuals had a spleen length >13 cm and all of these were males. However, the spleen length was ≤ 12 cm in 87% of the sample population. The spleen length in males was significantly higher than that in females ($P<0.001$; Table VI).

Table IV. Mean values of spleen parameters by age group.

Parameters	Age group (years)	No. of subjects	Mean	SD	P-value (ANOVA)
Spleen length (cm)	20-29	88	10.633	1.182	<0.001
	30-39	99	11.017	1.267	
	40-49	59	10.680	1.158	
	50-59	19	10.600	1.113	
	≥60	35	9.929	1.552	
	Total	300	10.685	1.283	
Spleen thickness (cm)	20-29	88	4.194	0.639	0.055
	30-39	99	4.215	0.546	
	40-49	59	4.090	0.519	
	50-59	19	3.947	0.433	
	≥60	35	3.931	0.690	
	Total	300	4.134	0.587	
Spleen width (cm)	20-29	88	7.326	0.803	<0.001
	30-39	99	7.757	0.937	
	40-49	59	7.229	0.779	
	50-59	19	7.558	0.970	
	≥60	35	6.680	0.903	
	Total	300	7.388	0.924	
Spleen volume (ml)	20-29	88	174.161	52.003	<0.001
	30-39	99	191.963	53.511	
	40-49	59	167.491	43.564	
	50-59	19	169.216	48.285	
	≥60	35	139.903	48.230	
	Total	300	174.414	52.449	

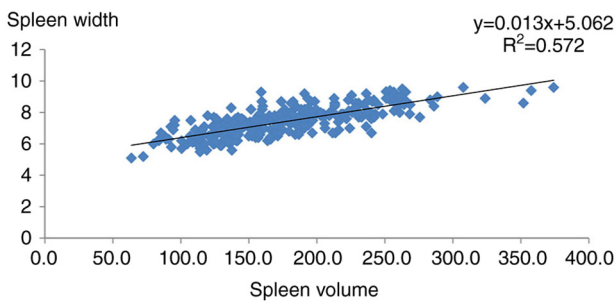


Figure 5. Correlation between spleen width and spleen volume ($r^2=0.572$, $P<0.001$).

Discussion

Due to the wide range of splenic size that has been reported in the literature, the establishment of a normal range is difficult. The US data from previous studies have demonstrated that racial differences can affect splenic volume. This necessitates the establishment of normative data on splenic dimensions for different regions (10,13).

The underlying concept of determining splenic volume by ultrasound has been presented in a number of previous studies. There are also variable data for the mean and upper limits of normal spleen volume in adults (10,14). Badran *et al* (15)

used the conventional US in the Jordanian population to assess spleen volume and found a mean spleen volume of 184 ± 80 ml (206.4 ± 83 ml for males and 155.7 ± 65 ml for females). Ehimwenma and Tagbo (16) determined spleen dimension in an endemic tropical environment (Nigeria) and reported an average spleen volume of 202 ± 49 ml in males and 153 ± 33 ml in females, with an overall of 177.5 ml. The mean and maximum spleen volume in the present study were 174.4 ± 52 and 374.1 ml, respectively (200.6 ± 47.9 ml in males and 149.9 ± 44 ml in females).

Kaneko *et al* (8) reported a mean spleen volume of 123 ± 45 ml in 238 Japanese subjects. In another study on the same population, Harris *et al* found the mean spleen volume to be 127 ± 63 ml in 230 individuals (17). The smaller spleen volume in Japanese individuals is probably due to the smaller body size compared to the Kurdish population. Mustapha *et al* (10) also recorded smaller mean spleen volume (120 ± 56 ml) in the normal adult African population and this can only be explained by regional and racial difference which has affected the spleen volume; this finding has also been reported by Hosey *et al* (9), who found that African American athletes had smaller spleens despite being taller and heavier than Caucasian American athletes.

In another study on 52 American volunteers, a mean and maximum spleen volume of 192 ± 72 and 411.8 ml was recorded, respectively (18). Another study based on CT

Table V. Mean values of spleen parameters by age and sex.

Spleen parameters	Males		Females		P-value
	Mean	SD	Mean	SD	
Volume (ml)					
20-29	204.81	52.28	148.62	35.67	<0.001
30-39	209.23	47.60	166.49	52.04	<0.001
40-49	196.33	40.20	146.29	32.67	<0.001
50-59	181.27	30.41	166.00	52.41	0.589
≥60	171.68	43.46	109.89	30.19	<0.001
Length (cm)					
20-29	11.33	1.04	10.05	0.97	<0.001
30-39	11.41	1.17	10.43	1.19	<0.001
40-49	11.37	1.15	10.17	0.88	<0.001
50-59	10.43	0.98	10.65	1.17	0.734
≥60	10.65	1.30	9.25	1.49	0.006
Thickness (cm)					
20-29	4.46	0.62	3.98	0.58	<0.001
30-39	4.31	0.51	4.08	0.57	0.043
40-49	4.26	0.50	3.96	0.50	0.029
50-59	4.23	0.26	3.87	0.44	0.154
≥60	4.29	0.70	3.59	0.49	0.002
Width (cm)					
20-29	7.67	0.79	7.04	0.70	<0.001
30-39	8.06	0.84	7.31	0.89	<0.001
40-49	7.71	0.65	6.87	0.67	<0.001
50-59	7.85	0.85	7.48	1.01	0.514
≥60	7.14	0.89	6.24	0.69	0.002

Table VI. Spleen length categories among males and females.

Spleen length (cm)	Male		Female		Total		P-value
	No. of subjects	%	No. of subjects	%	No. of subjects	%	
≤12	112	77.2	149	96.1	261	87	<0.001
>12-13	24	16.5	6	3.9	30	10	
>13	9	6.2	-	-	9	3	
Total	145	100	155	100	300	100	

in Saudi Arabia reported an adult mean spleen volume of 255 ± 72 ml (males, 285 ± 64 ml; and females, 220 ± 65 ml) (19). Geraghty *et al* (20) found a mean spleen volume of 209 ml in 149 individuals (maximum of 399.5 ml in males and 332.1 ml in females). Furthermore, Prassopoulos *et al* (21) reported a mean spleen volume of 214.6 ml in 140 patients. The mean and maximum spleen volume of the Kurdish population were smaller than in the aforementioned literature and these differences in spleen volume may be due to differences in mean age, sex, height, weight, technique and modality

enrolled in the study and regional variations between the studied populations.

On the basis of sex, the present study found that the mean spleen parameters in male subjects were significantly higher than those of female subjects ($P < 0.001$). As there are moderate positive correlations between spleen parameters and both body height and weight, a greater average of spleen parameters was expected in males, on the basis of their larger body parameters recorded in the present study for the same age groups, apart from the age group of 50-59 years (in which spleen length was

higher in females). This is concordant with the majority of previously conducted studies (4,7,9,17,19,20). However, there are also studies that have found no differences in spleen size between the sexes (17,21-23).

There was a steady increase in spleen dimensions from the age of 20-39 years in the Kurdish population; thereafter, it began to gradually decrease as the age increased. In general, a significant difference was observed between the mean of the spleen parameters of those aged ≥ 60 years with the mean of the younger age groups ($P < 0.001$). This finding may be due to the aging process in which older individuals have a smaller mass of organs compared to younger individuals (23).

Spleen length measurement on a longitudinal coronal oblique scan with the subject in supine and/or RLD position is reliable and widely used in clinical practice and highly correlates with spleen volume (9,10,12,14,23-26). The study by Loftus *et al* (26) on 30 cadavers found a significant correlation between a sonographic measurement of splenic length and the actual length and volume as measured at autopsy. The present study revealed a strong significant correlation between spleen length and spleen volume ($r = 0.796$, $P < 0.001$). A correlation was also found between spleen width and thickness with spleen volume ($r = 0.757$, $P < 0.001$ and $r = 0.753$, $P < 0.001$, respectively). Mustapha *et al* (10) also reported a strong correlation between spleen width and depth with spleen volume. The mean of recorded spleen length in the present study was 10.68 ± 1.28 cm; the length of the spleen was ≤ 13 cm in 97% of the individuals and the maximum spleen length was 14.1 cm. There are variable data for the upper limits of normal spleen length with values ranging from 12 to 14 cm in adults (4,7,9,12,27). In a German study on 703 normal adults, the length of the spleen was < 11 cm in 95% of the subjects (28). Rosenberg *et al* (23) established an upper limit of normal splenic length of 12 cm for girls and 13 cm for boys (≥ 15 years). Hosey *et al* (9) demonstrated a mean splenic length of 10.65 cm and they also noted that 7% of athletes had a spleen length > 13 cm. Capaccioli *et al* (29) found a mean spleen length of 10.5 cm in a population of 180 Italian adults, without stratifying for age. A similar result for mean spleen length was also recorded by other studies (12,14,23). Moreover, Badran *et al* (15) and Serter *et al* (13) reported a maximum spleen length of 15.6 and 17 cm, respectively. Spielmann *et al* (4) suggested that the maximum spleen length for an individual who had a height > 183 cm was > 13 cm. In the present study, the average spleen length was consistent with previously reported normal values for the general adult population. These observations suggest that there is no significant racial bias in spleen length.

In conclusion, the present study provides normative data on splenic dimensions and volume in normal Kurdish adults which may be used in certain clinical situations. Further studies are required to determine the normal value of spleen size by US for infants and children in the Kurdish population.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

SMF was a major contributor to the conception of the study, as well as in the literature search for related studies. HOA, SHT and FHK were involved in the literature review, the writing of the manuscript, and data analysis and interpretation. AMS, BAA, SHM, HAH and DAH were involved in the literature review, the design of the study, revision of the manuscript and in the processing of the figures. SMF, NAM, KAM and AHH were the radiologists who performed the assessment of the subjects' spleen size. SMF and HAH confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

The present study was approved by the Scientific Research and Ethics Committee of the College of Medicine, University of Sulaimani, Sulaimani, Iraq with a reference number of 1125/21. Institutional ethical approval was obtained from the authorities of Sulaimani Teaching Hospital. Informed written consent was obtained from all subjects before being examined. The reason for the study, possible effects and stages of examination were explained to the subjects. All procedures were followed in accordance with ethical standards of the responsible committee on human experimentation.

Patient consent for publication

Written informed consent was obtained from the patient for the publication of any related images.

Competing interests

The authors declare that they have no competing interests.

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