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ASSESSMENT OF NORMAL SPLEEN SIZE

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ABSTRACT

Determination of abnormal changes in size of organs during diseases entails knowing the normal range of their dimensions in healthy individuals. This review discusses the use of different methods over time to assess normal splenic volume in different populations of different parts of the world. It also oversees the normal size of spleen proposed by various researchers. This consideration has become more relevant in recent years, as doctors are keen to know the level of the involvement and or secondary effects of a disease process on spleen. Besides they want to know the progress of a disease process and/ or effect of a treatment plan by evaluating the splenic volume. A structured literature search was conducted on PubMed (Medline), Google Scholar, Embase and other databases till December, 2014to look for studies reporting normal spleen size using various techniques. There is a large range of normal splenic dimensions among individuals. Among the different techniques employed for assessment of normal or otherwise spleen size, ultrasonographic measurements have been considered to be the most feasible and accurate. Ultrasonography can be a useful technique as it is noninvasive and does not involve any risk of radiation. Ultrasound, therefore, has become the most common practice to differentiate pathologically enlarged or reduced spleen in patients.

KEYWORDS: **Spleen size – Splenomegaly –Assessment techniques**

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Spleen anatomy

Spleen is a firm soft organ about the size of a clinched fist and is the largest member of lymphoid organs. It lies in the left hypochondrium part of abdominal cavity, wedged between fundus of stomach and the diaphragm. It lies obliquely, applied to 9th, 10th and 11th ribs behind mid axillary line. Its long axis is along the 10th rib[1]. Its usual dimensions are one inch thick, three inches broad and five inches long (2.5 × 7.5 ×12.5 cm) but its size varies considerably.[1] It has superior and inferior ends, anterior and posterior borders and diaphragmatic and visceral surfaces. The upper end lies in line with spine of 10th thoracic vertebra about 4 cm from mid line. The lower end does not project beyond mid axillary line. The posterior border is rounded, but the anterior border is notched. The diaphragmatic surface is convexly curved to fit the concavity of the diaphragm while the visceral surface is related to stomach, left kidney, left suprarenal gland and left colic flexure[2]. Tail of pancreas is applied to the hilum that lies in the angle between stomach and left kidney[3]. The spleen is entirely surrounded by peritoneum except at the hilum, where the splenic branches of the splenic artery and vein enter and leave[2]. The spleen is anchored to stomach by means of gastro-splenic ligament and to posterior abdominal wall by leino-renal ligament. It rests on the left colic flexure and the fold of peritoneum that extends from left colic flexure to diaphragm, the phrenicocolic ligament. It is due to this ligament that the spleen when enlarges doesn't extend vertically downward. It rather moves downwards and medially towards umbilicus. The spleen normally does not descend inferior to the costal margin. It does so when it enlarges and is then identified by the presence of notch in the anterior border upon palpation. Although it is not a part of digestive system, its venous blood is drained into portal vein and to the liver.

Splenomegaly

Splenomegaly is a clinically important finding[4].Splenic enlargement is associated with a number of diseases. It may be the only indication of a serious underlying disease process such as lymphoma. Therefore, it is important to assess spleen size when physicians evaluate patients[5].Assessment of organ size helps in the diagnosis of a disease process or determining its prognosis[6]. A change in splenic size may be due to its own involvement in a disease process or it can be a manifestation of a disease process elsewhere in the body. Spleen is involved and therefore enlarged in a variety of clinical conditions. These can be infections, hematological disorders, infiltrative states and immunological and malignant diseases. Infections are the most common causes of splenomegaly. Among them are infectious mononucleosis, malaria, kala azar (lieshmaniasis), bacterial endocarditis, tuberculosis, brucellosis and salmonellosis[7]. Hematological disorders include lymphomas and lymphatic leukemias, hemolytic anemia, chronic anemia, congenital spherocytosis and myeloproliferative diseases such as polycythemia verra and myelofibrosis. Conditions causing portal hypertension such as cirrhosis or malignancy of liver invariably involve and cause enlargement of spleen. Congestive heart failure with ascites and hepatosplenomegaly, lymphoid tissue and hematological malignancies, glycogen storage disorders, sarcoidosis and amyloidosis are other important causes of splenic involvement. A spleen must double its size before its anterior borders descends beyond left costal margin and is clinically palpable[1]. Early diagnosis of splenic enlargement before it becomes clinically palpable is important to a clinician for making diagnosis. Establishment of splenic enlargement by clinical examination is difficult and often inaccurate, particularly a mild enlargement[5]. Therefore, objective diagnostic means have been sought and the imaging techniques have become necessary for the accurate determination of spleen size and its serial observation over the course of patient's illness[3]. About 50 research articles on the subject were retrieved from online data bases such as PubMed, Saudi digital library, BMJ, Pro Quest, Wiley online library, Science direct and Scopus. We have tried to evaluate the most suitable method for assessment of spleen size

and the normal size of spleen in different sets of populations.

Techniques used for assessment of spleen size

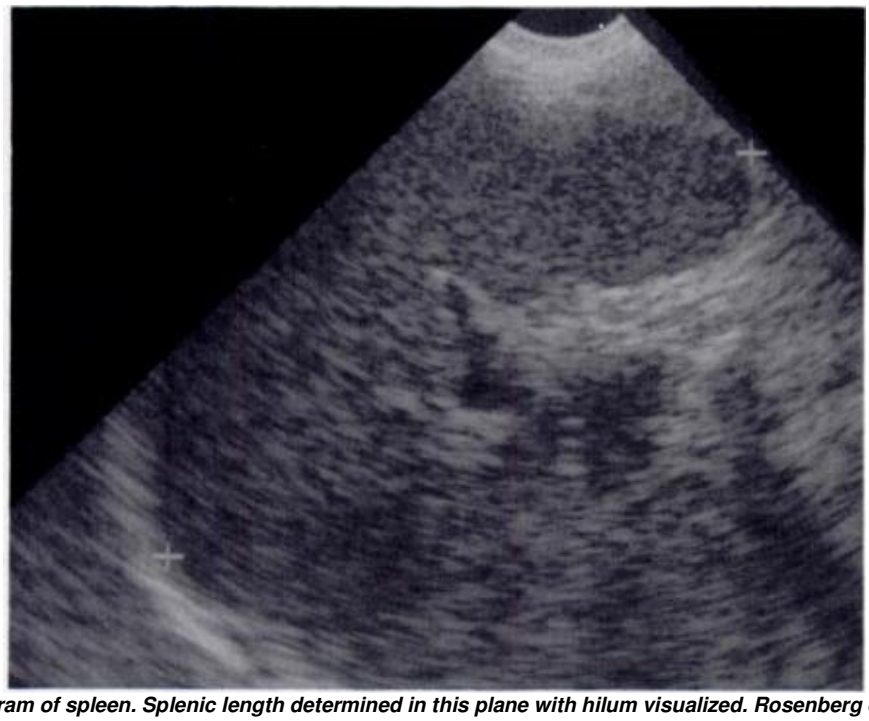
The assessment of spleen size in situ is important in making a diagnosis and evaluating the prognosis of different diseases. The diagnosis of a gross splenomegaly should not pose any problem. However mild splenomegaly may not be palpable clinically and some diagnostic technique has to be employed.

Several studies have been carried out using different techniques for determining the in vivo volume of the spleen and hence to develop standard splenic size. These techniques include conventional radiology[9-11],scintigraphy/ radionuclide scanning[12-20], water volume displacement[5,6], ultrasonography[4,5,8,21-38] computed tomography[6,34,38-49], magnetic resonance imaging[50] and by utilizing automatically contouring software[46-49].

Conventional radiology was first used for determining in vivo organ size in 60s. The method however was associated with its inability to clearly define the contours of the organ and therefore reduced level of accuracy [6]. It was also associated with a risk of radiation exposure.

Scintigraphic methods were then employed for obtaining the images of spleen and measurement of its dimensions during early 60s[12]. Zhang&Lewis (1987) obtained the image of spleen on the scan, using artificially damaged red blood cells and used it for determination of splenic volume[17]. Marksiz(1987)used sulfur colloid to obtain the image of spleen and measure its volume[18]. Revesz (1993) used gamma camera imaging for determination of spleen size in some patients with essential thrombocythaemia (ET) and others with reactive thrombocytosis (RT)[19]. Scintigraphy also required exposure to radiation. These imaging techniques i.e. conventional radiology or nuclear medicine were therefore considered unsuitable as routine diagnostic procedures because of their radiation exposure.

Ultrasonography was then employed to obtain the measurements of splenic dimensions and determination of splenic size and volume by mathematical calculations. It has since been the most common practice as it is noninvasive and does not involve any risk of radiation. Usually a coronal view of the spleen is taken that includes its hilum for the measurement of its dimensions. The maximum longitudinal distance between the dome and the tip of spleen measured at the hilum is taken as its length. Measurement for the width of the spleen is made at hilum whereas the depth measurement is taken at a point bisecting the line of measurement of width. Ultrasound is a safe, non-invasive and relatively inexpensive technique that can be used for serial measurements. Dittrich(1983) established a nomogram for determining spleen size sonographically and argued that there are no contraindications for this investigation technique and the indication for study can be established on a routine basis[21]. Rosenberg(1991), Konus(1998), Yetter(2003) and Spielmann(2005)considered sonography as a simple, quick, inexpensive, reliable and therefore widely used means of visualizing and measuring spleen without the risk of ionizing radiation[8,24,28,34]. Yetter(2003)found its portability to be an additional advantage as it can be used for imaging patients in places other than the imaging room[34].



Coronal sonogram of spleen. Splenic length determined in this plane with hilum visualized. Rosenberg et al.(1991).[24]

Ishibashi et al. (1991) and Al-Imam et al. (2000) found ultrasound to be the most useful technique for assessing non-palpable spleens[25,31]. Capaccioli et al.(2000) and Rohani(2000)found ultrasound to be a useful technique to differentiate pathologically enlarged or reduced organs in patients of all ages[32.33]. Pietri and Boscaini(1984) devised a splenic volumetric index (SVI) from spleen dimensions obtained by ultrasound in 45 normal adult subjects. The product of multiplication of length, breadth and thickness was divided by 27, the cube of three values. In 95% of the subjects the SVI was found to be between 8 and 34[22]. Ishibashi et al.(1991)and Rohani(2000) also devised a splenic index by multiplying the transverse and vertical diameters of the maximum cross-sectional sonographic image of the spleen[25,33]. Ishibashi et al.1991 reported a normal SI of 19.8±12.3 cm2 in 204 healthy adults[25]. Frank et al.(1986) obtained sonographic dimensions of spleen in 793 male and female adult patients with healthy spleen. They reported splenic length to be less than 11cm, the breadth below 7cm and thickness below 5cm in 95% of the patients. They also determined the weight of spleen by rotation ellipsoid formula[23]. Rosenberg et al. (1991) studied 230 patients by sonography. They reported a splenic length of 12 cm at age of 15-20 years in girls and 13 cm at same age in boys[24]. Rodrigues junior et al.(1995) removed 32 normal spleens from the corpses and measured their maximal height, breadth and thickness by a pachymeter. After that the same measurements were determined by ultrasound. They found no significant difference between the two measurements. The mean height, breadth and thickness obtained by pachymeter were 11.1cm±2.0, 7.8cm±1.7 & 2.8cm±0.7 and by ultrasound 11.1cm±2.0, 7.9cm±2.0, & 2.9cm±2.0.The mean calculated volume from ultrasound dimensions was 283.8cm^3±168.27. They also determined the actual volume of the spleen by immersing them in a labelled water tank and noting the volume of displaced water. It was 147.5cm^3±81.46[5]. Friis H et al.(1996) conducted ultrasonographic examination of 144 children (8-16years of age) in Zimbabwe and measured the length, depth and width of spleen. The children were kept in right recumbent position for examination of spleen. They reported mean splenic length to be 6.3 cm, width 4.2cm and thickness 3.1cm[26]. Loftus and Metreweli (1997) used ultrasonography to examine 783 Chinese patients (with conditions not involving spleen) for establishment of normal range of spleen

dimensions. They found the upper limit of normal spleen length in age group15-40 years to be 12 cm ±2.0.Spleens of men being 0.5cm longer than those of women[27].

Diagram showing the method for measuring splenic length Loftus (1999).[29]

Loftus et al.(1999) then attempted to find a correlation between the sonographic measurements of spleen with its actual measurements obtained at autopsy. They found a very good linear correlation between ultrasonic and actual splenic dimensions. The mean sonographic maximum length was 9.3 cm ±2.10 and the mean actual splenic length was10.5 cm±3.0[29]. Konus et al.(1998) examined 307 pediatric subjects with ultrasonography to evaluate normal dimensions of liver, spleen and kidney. They reported splenic length to be 5.3cm at 3months, 5.9cm at 6 months, 7cm at 12 months, 7.5 cm at 2-5 years, 8.4 cm at 7 years, 8.6cm at 9 years, 9.7 cm at 11 years 10.1 cm at 12-16 years[28]. Haddad-zebouni et al.(1999) evaluated ultrasonographic size of spleen, liver and kidney in 150 children. They found splenic length of 9.03 cm in 5-10 years old and 10.8cm in 11-15 years old children[30] Al-Imam et al.(2000) measured the lengths of spleen by ultrasound in 184 normal Jordanian children. They found splenic length of 10.4 cm in10-15 year children and 10.5cm in16-20 year subjects[31]. Capaccioli et al(2000)found a mean splenic length of 10.5 cm by ultrasound examination of 180Italian adults.[32]. Spielmann et al. (2005) carried out sonographic measurements of splenic dimensions as well as left renal length in 129 college athletes. They found out the mean splenic length to be11.4cm ±1.7 in males and 10.3cm ±1.3 in females. They also noted a splenic length of more than 12cmin 31.7% of men and 12.8% of the women[8]. Hosey et al.(2006)determined splenic dimensions in 631 adult athletes by ultrasound examination. They reported mean splenic length in male subjects to be 11.29cm (SD 1.49) and in females 9.91cm±1.27. The breadth was 5.54cm ±1.28 in males and 4.74cm ±0.91 in females[4]. Mustapha Z et al.(2010)evaluated splenic dimensions by ultrasonography in 374 African adult patients who were examined for conditions not involving spleen. The volume was calculated from the measurements of splenic length, breadth and thickness. They reported the mean splenic volume to be 120cm^3[36]. Ehimwenma and Tagbo(2011) determined normal dimensions of spleen in 200 Nigerian adults by ultrasonography. They found the mean length, breadth and thickness of the

spleen to be 11.1cm±0.9, 7.8cm ±0.6 and 4.4cm ±0.5 in male subjects. In females the same measurements were 10.1cm±0.7, 7.1cm±0.5 and4.0cm±0.4[37].

Many researchers concluded that calculation of splenic volume, area or index from its dimensions is a difficult and time consuming task so it cannot be employed for routine clinical use. They further maintained that sonographic measurements of splenic dimensions can give a true indication of its size. Therefore measurement of the length of spleen is generally the standard practice for clinical use.

Rosenberg et al. (1991) found that a simple measurement of splenic length was accurate as a guide to spleen size[24]. Loftus (1999) also found that splenic length measured by ultrasonography provides an objective and reliable way to assess spleen size. Therefore a sonographic diagnosis of mild splenomegaly can be made with confidence[29]. Capaccioli(2000) suggested that splenic dimensions measured by ultrasound are sufficient for assessment of spleen size as he found a high correlation between linear measurements taken by ultrasound and the volume assessed with CT[32].Lamb (2002) also found the splenic length measured by ultrasound to be a good indicator of actual splenic size[38].He therefore suggested it to be used in routine clinical practice. Spielmann 2005 declared that splenic dimensions measured by ultrasound gives a pretty good estimate of actual spleen size[8].

Li et al.(2004)evaluated the inter-observer and intra-observer variability (reproducibility and repeatability) in sonographic measurement of the maximum and mean splenic length. They found reproducibility to be 89% for estimating mean splenic length and the short term repeatability to be 94%.These results suggested that the mean splenic length has a higher reliability in sonographic measurement and should be used in routine clinical practice[35].

Hoefs et al. (1999) maintained that although spleen length is an easy measurement and correlates well with volume but variations in spleen shape prevent the reliance on this parameter. They proposed measurement of functional splenic volume from LSS (liver spleen volume). This technique required determinations of total counts in the organ and then division of the total organ counts by a representative voxel count concentration. The technique also involved intravenous administration of colloidal sulphur[20].

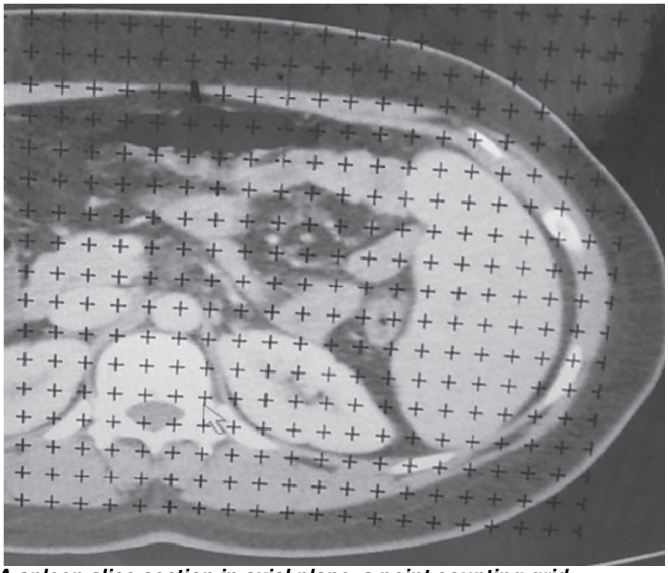
Asghar etal. 2011 argued that volume determination by 2D ultrasonography can be inaccurate because of the variable, irregular contour of spleen and overlapping of its outline by bone, bowel gas or left kidney. They also identified some other sources of potential error in sonographic measurement, such as physical limitations in resolution, technical limitations, errors in scanning technique, and errors in interpretation. According to them volumetric measurements are most accurately obtained on computed tomography or magnetic resonance imaging[48]. Breiman et al. (1982)also mentioned computed tomography (CT) to be the most accurate noninvasive means of in vivo organ/tumor volume estimations[6]. Bazzera et al.(2005)suggested that CT can identify changing splenic volume with the highest sensitivity and specificity[41].CaglarV (2014) also suggests CT to be a reliable and accurate method for assessing volumes and sizes of the spleen and other intra-abdominal organs[42].

Breiman et al. (1982) obtained contiguous 1cm thick scans through human spleens and calculated cross sectional areas of each section. The volume of the spleen was then determined with mathematical integration. The obtained volume of the spleen was then compared with its actual volume determined by water displacement. The determined splenic volume correlated well with the actual volume[6].

Henderson et al.(1981) and Schlesinger, Edgar& Boxer(1993) measured liver and spleen dimensions from axial computed tomographic (CT) scans. They then calculated volume by adding together the area measurements obtained from successive transverse abdominal scans[43,44]. Henderson et al.(1981) found splenic volume to be 219 ±76 cm3 in 11 subjects[43].

Bezzera et al. (2005) in 249,Caglar V etal. (2014) in 212 and Prassopoulos et al. (1994)in 153 subjects also determined the splenic

dimensions from CT scans and calculated the volume by summing the volumes of multiple contagious scans[41,42,45]. Prassopoulos et al.(1994) found an upper limit volume of 314.5 cm^3 for the normal spleen[45].Caglar et al.(2014)calculated the area of each transverse CT section of the spleen by placing a square grid system(with a distance of 0.5 cm) upon the image of spleen (figure) and counting the points hitting the image. They found the mean SV values were 198 ± 88 (range 61–562) cm3 for the total study population, 184 ± 84 (range 70–462) cm3 for females and 210 ± 90 (range 61–562) cm3 for males[42]. Bezerra et al.(2005)then correlated the splenic dimensions to its volume and found splenic length to correlate well with the CT volume. They suggested that a splenic length of 9.76cm can be taken as the normal and can replace multiple time consuming volume assessment measures in routine clinical practice[41].

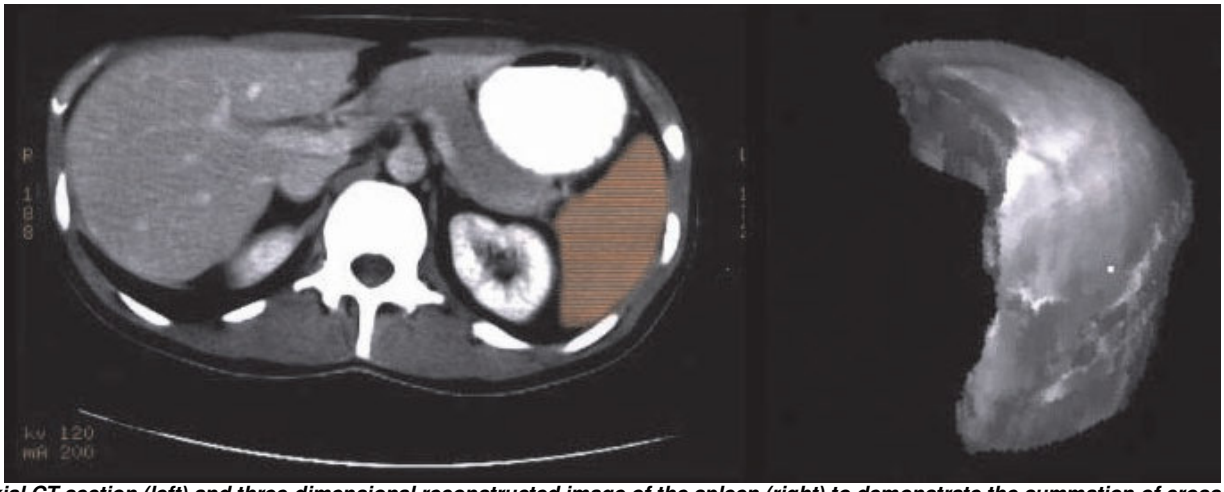


A spleen slice section in axial plane, a point counting grid superimposed on the computed tomography scan. CaglarV (2014).[42]

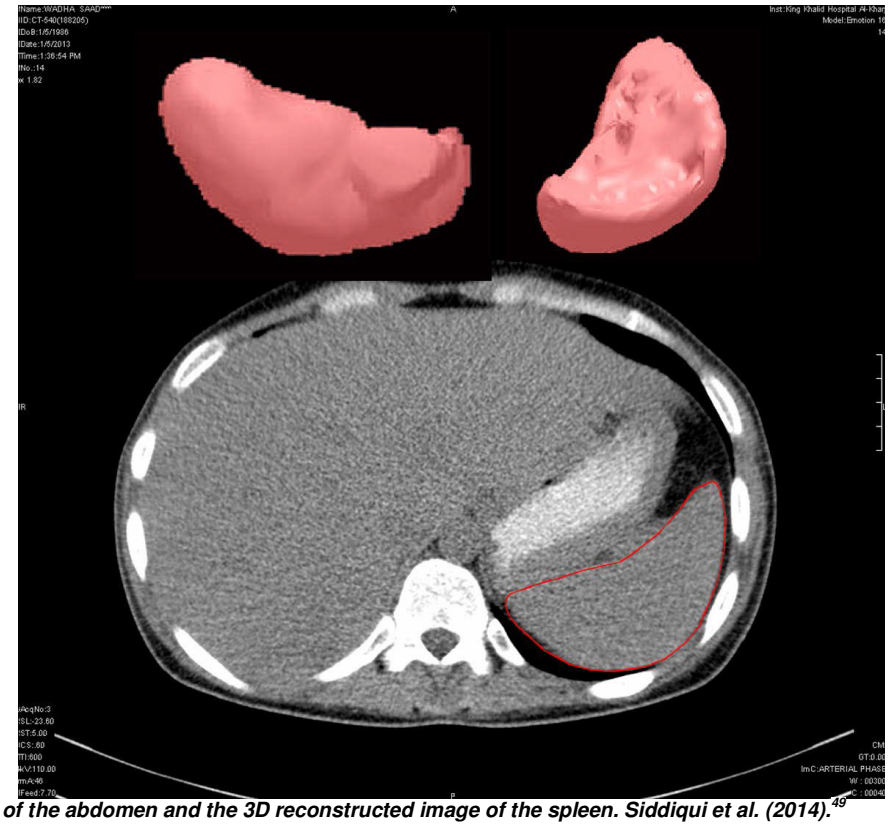
Lamb et al.(2002) and Yetter et al. (2003)measured splenic dimensions by ultrasonic examination of adult patients and correlated them with three dimensional CT volume assessments[38,34]. Lamb et al.(2002) reported that the linear measurements of width and length by sonography taken in right lateral decubitus (RLD) position correlated well with the CT assessed volume[38]. Yetter et al.(2003) also devised standard ellipsoid and linear regression formulas. The volume of spleen calculated with standard ellipsoid formula correlated well with CT determined volume. The authors therefore believe that estimating splenic volume with formula $0.524 \times W \times T \times (ML + CCL) / 2$ will give accurate determination of splenic volume[34].

Schlesinger, Hildebolt, Siegel & Pilgrim (1994)measured splenic dimensions from axial computed tomographic (CT) scans and obtained the splenic volume with the use of the software program in the CT computer[46]. Harris et al. (2010), Asghar A et al. (2011) and Siddiqui et al.(2014) used a new technique for estimating spleen volume[47,48,49]. They employed 3D contouring software which contoured the spleen using CT scan images and quickly calculated its volume. They calculated splenic volume of 230, 21 and 34 patients respectively whose CT Abdomen scans were performed for conditions not involving spleen. The measured volume was then correlated with height, weight, BMI and surface area of patients. Harris et al.[47] found out that the volume of spleen was most closely related with weight while Asghar et al.[48] reported a linear correlation with height. Mazonakis M et al. (2000) estimated splenic volume from MR images and concluded that this technique can be used for quick spleen

volume estimates being quiet accurate and also reproducible[50].



Axial CT section (left) and three-dimensional reconstructed image of the spleen (right) to demonstrate the summation of cross-sectional areas technique to calculate spleen volume. Lamb (2002).[34]



A CT scan of the abdomen and the 3D reconstructed image of the spleen. Siddiqui et al. (2014).[49]

Spleen dimensions and size

Normal splenic dimensions and size vary widely in different individuals. Some studies consider a length of 10-12 cm to be normal and acceptable in clinical practice[27, 41]. Other studies found a good proportion of their participants having splenic length greater than 13 cm[4, 8]. Some studies found spleen size to be larger in men than in women.[4,8,27,40] but other studies have found no difference in spleen size between the genders[39.45].This indicates that there is no consensus as to what constitutes a normal splenic volume[38].

Spleen Size

S. No	Author	Mean volume of spleen(cm^3)	Technique	Range
1	Schulz et al. cited by CaglarV (2014) [42]	169	CT	
2	Geraghty et al.(2004) [40]	209		
3	Ehimwenma and Tagbo(2011)[37]	202±49 M 153±33 FM	USG	
4	Hoefs et al.(1999) [20]	201±77	Liver-spleen scan	
5	CaglarV (2014)[42]	241	CT	
6	Prassopoulos et al.91994) [45]	214.6	CT Summation-area technique	107.2–314
7	Henderson et al.(1981) [43]	209±76	CT Summation-area technique	
8	Kaneko et al. cited by Asghar et al.(2011) [48]	123 ± 45		
9	Harris et al.(2010) [47]	127.4 ± 62.9		
10	Loftus et al.(1997) [27]	110±70	Water displacement	26–250
11	Rodrigues junior et al.(1991)[5]	283.8±168.27 147.5±81.46	USG Water displacement	
12	Mustapha Z et al.(2010) [36]	120	USG	
13	Liu et al. cited by Asghar et al.(2011) [48]	190.94 ± 70.37	CT	
14	Mazonakis et al. cited by Asghar et al.(2011) [48]	208 204.8	Random marking on MR scan Manual planimetry on MR scan	115–293.6 117.9–289.8
15	Hidaka et al. cited by Asghar et al.(2011) [48]	104	3D USG	
16	Zhang et al.(1987) [17]	185	Radionuclide scan	
17	Picardi et al. cited by Asghar et al.(2011) [48]	140	USG	60–200 mL
18	Lamb et al.(2002)[38]		USG & CT –prolate ellipsoid	107–314
19	Spielmann et al.(2005) [8]	333.6±116.1	USG-prolate ellipsoid	
20	Harris et al.(2010) [47]	127.4+/-62.9	Contouring of spleen by software from CT slices	22 to 417
21	Asghar et al.(2011) [48]	192.29 ± 99.3 M 118.39 ± 47.7 FM	3D reconstruction of CT images	
22	Siddiqui et al.(2014) [49]	196.95 ± 46.81 M 121.45 ± 26.97 FM	3D reconstruction of CT images	
22	Kaneko et al. 2002[39]	112	CT	32-209
23	Geraghty et al.(2004) [40]	238.4 M 179.8 FM	CT	

Spleen Dimensions

No:	Author	Length cm	Breadth cm	Width cm	Technique
1	Frank (1986) [23]	11			US
2	Rosenberg (1991) [24]	13			US
3	Rodrigues (1995) [5]	11.1	7.9	2.9	US
4	Friis et al.(1996) [26]	6.3	4.2	3.1	US
5	Loftus and Matreweli(1997) [27]	12			US
6	Loftus et al.(1999) [29]	9.3 10.5			US Actual
7	Konus et al.(1998) [28]	10.1			US
8	Haddad-Zebouni et al.(1999) [30]	10.8			US
9	AL-Imam et al. (2000) [31]	10.5			US

10	Capaccioli et al. (2000)[32]	10.5			US
11	Spielmann et al. (2005) [8]	11.4M 10.3FM			US
12	Hosey et al. (2006) [4]	11.29M 9.91FM			US
13	Ehimwenma&Tagbo(2011) [37]	11.1 10.1	7.7 7.1	4.4 4.0	US
14	Bazerra et al.(2005) [41]	9.76			CT

The arithmetical mean of above mentioned splenic lengths is 11.33cm.

CONCLUSION

Ultrasonography is a useful technique as it is noninvasive and does not involve any risk of radiation. It is inexpensive and can be used for serial measurements. An additional advantage of its use is its portability. Ultrasound, therefore, can be used on a routine basis for establishing pathologically enlarged or reduced spleen in patients.

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CONFLICT OF INTEREST

No actual or potential conflict of interest exists.

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