Sudan University of Science and Technology

College of Graduate Studies

Estimation of Splenic Volume in Sudanese adults using ultrasonography

تقدير حجم الطحال لدى السودانيين البالغين باستخدام التصوير بالموجات فوق الصوتية

A thesis submitted for partial fulfillment for the requirement of M.Sc. degree in Diagnostic Medical Ultrasound

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الآيــة

(وَاللَّهُ أَخْرَجَكُم مِّن بُطُونِ أُمَّهَاتِكُمْ لَا تَعْلَمُونَ شَيْئًا وَجَعَلَ لَكُمُ السَّمْعَ وَالْأَبْصَارَ وَالْأَفْئِدَةَ لَعَلَّكُمْ تَشْكُرُونَ)

صدق الله العظيم

سورة النحل – الآية (78)

Dedication

To my colleagues

To the people who volunteering to give their information to be part of this research

Acknowledgement

My thanks and gratitude to my supervisor Dr. Ahmed Mostafa Abukonnafor being so helpful and supportive, and I also acknowledged all the staff of the university who tough us not only ultrasound but also a way of living.

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Abstract

The spleen is the largest haemolymph nodes in the body and large part of the reticuloendothelial tissue of the body is concentrated in it.

This is an experimental study designed to determine the application of ultrasound for estimation of splenic weight, length and height of Sudanese adult patients. Fifty adult patients were enrolled in the study; healthy volunteer persons who referred to ultrasound department for abdomen ultrasound were included. Any person with abnormal splenic measurement was excluded.

The result of the study revealed that the splenic length, width, and thickness were measured the mean of each was 9.5±1.1 cm, 6.6±0.8 cm and 3.4±0.5 cm respectively.Splenic volume was calculated, the mean of it was 161.4± 41.7.The weight and length of the spleen compared with body height and weight, it showed a significant correlation.Furthermore, there is a linear relationship between BMI and splenic volume.

The results of this study could be used as a practical and comprehensive guide to indicate the normal spleen length; according to the age and body habitus. With this in mind, so as to distinguish and thus better assess individuals with markedly long spleens outside the normal range but whose body parameters are within the normal range.

الخلاصة

الطحال من أكبر العقد الليمفية الدموية في الجسم، وجزء كبير من أنسجة الشبكة البطانية من الجسم تتركز فيه. أجريت هذه الدراسة التجريبية وقد هدفت إلى تحديد وتطبيق التصوير بالموجات فوق الصوتية لتقدير وزن الطحال وطوله وارتفاعه لدي البالغين السودانيين. تم تسجيل خمسين بالغا متطوعين أصحاء أحضروا إلى قسم الموجات فوق الصوتية لفحوصات البطن. تم استبعاد أي شخص لديه اي مرض يؤدي لقياس طحال غير طبيعي.

أظهرت نتائج الدراسة أن طول كل من الطحال والعرض والسماكة كان متوسط كل منها 9.5 ± 1.1 سم ، 6.6 ± 0.8 سم ، 3.4 ± 0.5 سم على التوالي .تم حساب حجم الطحال ، وكان متوسطه 161.4 ± 41.7 . وزن وطول الطحال مقارنة مع ارتفاع الجسم والوزن ، وأظهرت علاقة ذات دلالة إحصائية.علاوة على ذلك ، هناك علاقة خطية بين مؤشر كتلة الجسم وحجم الطحال.

نتائج هذه الدراسة يمكن أن تستخدم كدليل عملي وشامل للدلالة على طول الطحال العادي؛ وفقا للعمر وشكل الجسم. مع وضع عمر الشخص و الهيكل العام في الاعتبار، يمكن الحصول علي أفضل تقييم للطحال.

Chapter one

Introduction

1.1Introduction:

The spleen is the largest organ in the reticuloendothelial system. It has been standard practice, for many years, to use splenic size as an indicator of disease activity in a variety of disorders of the reticuloendothelial system. However, it is not known how well the measurement of splenic length that is routinely obtained at ultrasound examination represents true splenic size(Chaudhry and Bhimji, 2018).

The spleen is an organ shaped like a shoe that lies relative to the 9th and 11th ribs and is located in the left hypochondrium and partly in the epigastrium. Thus, the spleen is situated between the fundus of the stomach and the diaphragm. The spleen is very vascular and reddish purple in color; its size and weight vary. A healthy spleen is not palpable(Chadburn, 2000).

The spleen response to antigenic challenge, distract abnormal red cells and phagocytosis of foreign substances platelets and erythrocyteproduction. The spleen has variable size and shape but generally isconsidered to be ovoid with smooth borders and convex superior andinferior surface(Nemati et al., 2016).

In ultrasound the spleen has a homogeneous, "inverted comma" appearance when it becomes enlarged it loses this shape and, as it expands, it becomes very rounded and sometimes appears as an egg shape extending beyond the Left kidney. Measurement:Normal Spleen Size<13 cm superior to inferior axis, 6-7cm in the medial to lateral axis, 5 to 6cm in the anterior to posterior plane. Average volume is approximately 350ml(Xu et al., 2009).

Several studies have proved that the normal dimensions of the spleen vary according to age, weight, body surface area, height and sex. The size of the spleen undergoes changes in accordance with the nutritional status of the patient, as it exhibits a slight growth after meals(Yeung et al., 2017). As splenomegaly is common to many conditions, it is important to know in clinical practice when to consider that a spleen is enlarged. In a study of human cadaveric spleens have been analyzed, the average length of the spleens examined was 9.66 cm (ranging from 5 cm to 13 cm), the average width of 6.22 cm (values ranged between 3.5 cm and 9.5 cm) and the thickness varied between 1.5 cm and 5.5 cm, with an average of 3.06 cm. The weight also showed great variations, ranging between 80 and 300g, 145.76g being the average weight (Al-Salem et al., 1998). The current clinical practice guidelines accept 11-12 cm (less than 13 cm) as the normal length of the spleen in a healthy adult, 3-4 cm in breadth and a weight of about 150g. The spleen shrinks proportional to the aging process (Ignjatovic et al., 2002).

In order to establish our own standards and suggest upper limits and to provide additional data to the literature on this subject, the purpose of our study was to investigate normal spleen length in healthy adult Sudanese using Ultrasound.

1.2 Problem of the study:

There is no reference value for splenicvolume in Sudanese population.Sonographic measurements allow accurate determination of splenic volume.

1.3 Objectives of the study:

1.3.1 General objective:

The general objective of this study is to identify the volume of thespleen in Sudanese population.

1.3.2 Specific objectives:

- To measure the splenic length, thickness,width and calculate splenic volume.
- To find the correlation between splenic dimensions and BMI.
- To find the correlation between splenic volume and BMI
- To correlate between splenic volumeand body characteristics.

1.4 Overview of the study:

The study consist of Chapter one include the introduction,chapter twoinclude the previous study and literature review ,chapter three include thematerial and method chapter four contains the results ,chapter five consist of discussion,conclusion and recommendation.

Chapter two

Theoretical Background and related literature

2.1 Anatomy of the spleen

2.1.1 Development

The spleen develops in the cephalic part of dorsal mesogastrium (from its left layer; during the sixth week of intrauterine life) into a number of nodules that fuse and form a lobulated spleen. Notching of the superior border of the adult spleen is evidence of its multiple origins(Zheng et al., 2015).

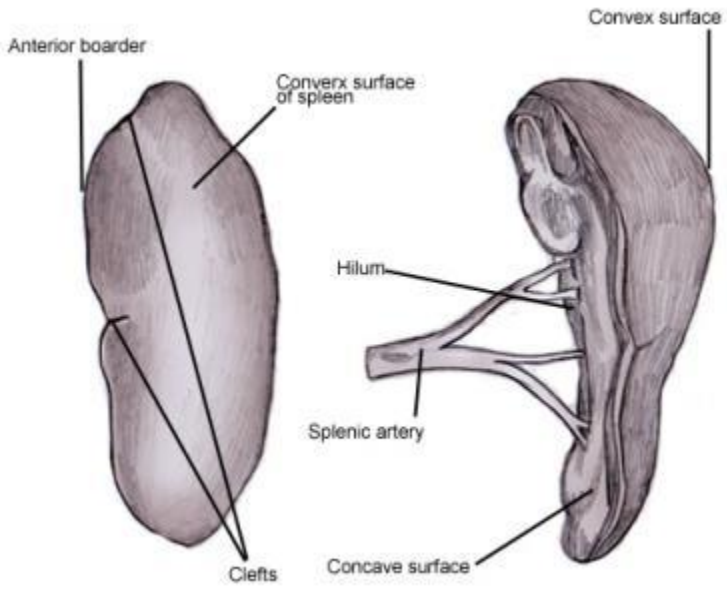

Figure 2.1 Surface anatomy of the spleen

2.1.2 Gross Anatomy:

The spleen's 2 ends are the anterior and posterior end. The anterior end of the spleen is expanded and is more like a border; it is directed forward and downward to reach the midaxillary line. The posterior end is rounded and is directed upward and backward; it rests on the upper pole of the left kidney(Zheng et al., 2015).

The spleen's 3 borders are the superior, inferior, and intermediate. The superior border of the spleen is notched by the anterior end. The inferior border is rounded. The intermediate border directs toward the right. The 2 surfaces of the spleen are the diaphragmatic and visceral. The diaphragmatic surface is smooth and convex, and the visceral surface is irregular and concave and has impressions. The gastric impression is for the fundus of the stomach, which is the largest and most concave impression on the spleen. The renal impression is for the left kidney and lies between the inferior and intermediate borders. The colic impression is for the splenic flexure of the colon; its lower part is related to the phrenicocolic ligament. The pancreatic impression for the tail of the pancreas lies between the hilum and colic impression (Ignjatovic et al., 2002).

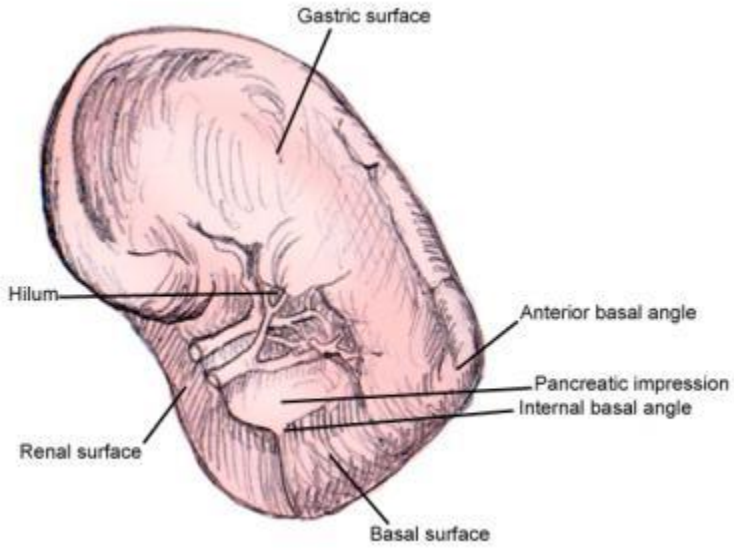

Figure 2.1 shows different surfaces and impressions caused by different organs in relation to the spleen's hilum.

The hilum can be found on the inferomedial part of the gastric impression (see the image above). The hilum transmits the splenic vessels and nerves and provides attachment to the gastrosplenic and splenorenal (lienorenal) ligaments. The spleen is surrounded by peritoneum and is suspended by multiple ligaments, as follows:

- The gastrosplenic ligament extends from the hilum of the spleen to the greater curvature of the stomach; it contains short gastric vessels and associated lymphatics and sympathetic nerves.
- The splenorenal ligament extends from the hilum of the spleen to the anterior surface of the left kidney; it contains the tail of the pancreas and splenic vessels.
- The phrenicocolic ligament is a horizontal fold of peritoneum that extends from the splenic flexure of the colon to the diaphragm along the midaxillary line; it forms the upper end of the left paracolic gutter.

The visceral surface of the spleen contacts the following organs:

- Anterior surface of the left kidney
- Splenic flexure of the colon
- The fundus of the stomach
- Tail of the pancreas

The diaphragmatic surface is related to the diaphragm; the diaphragm separates the spleen from the pleura and the lung(Dong et al., 2015).

2.1.3 Microscopic Anatomy

The spleen is made up of the following 4 components:

- Supporting tissue
- White pulp
- Red pulp
- Vascular system

Supporting tissue is fibroelastic and forms the capsule, coarse trabeculae, and a fine reticulum.

The white pulp consists of lymphatic nodules, which are arranged around an eccentric arteriole called the Malpighian corpuscle.

The red pulp is formed by a collection of cells in the interstices of the reticulum, in between the sinusoids. The cell population includes all types of lymphocytes, blood cells, and fixed and free macrophages. The lymphocytes are freely transformed into plasma cells, which can produce large amounts of antibodies and immunoglobulins(Dong et al., 2015).

2.1.4 Vasculature:

The splenic artery, a branch of the celiac artery, supplies the spleen. The artery branches into arterioles and capillaries, which may either:

- Connect with the venous sinuses, or
- Terminate with open ends in the splenic cords

Blood released into the splenic cords, either from the sinuses or capillaries, eventually filters back into the sinus network. The sinuses converge and empty into trabecular veins, which then merge into a single splenic vein which then empties into the portal vein.

Lymphocytes in the arterial blood migrate from the red pulp sinuses, through the splenic cords and through the white pulp. T cells specifically migrate through the PALS and B cells specifically migrate through the follicles. Antigen in the blood is filtered by the large numbers of macrophages in the splenic cords and white pulp(Paraskevas et al., 2016).

2.1.5 Innervation:

Innervation is purely sympatheticand nerve fibers travel with the artery into the spleen.

2.3 Natural and Pathophysiologic Variants:

- Accessory spleens or splenunculi are natural anatomic variants formed from nodules that fail to fuse during development. These are found in various locations such as the gastrosplenic ligament, splenorenal ligament, gastrophrenic ligament, and gastrocolic ligament. They have also been reported to have been found in the broad ligament of the uterus and in the spermatic cord.
- Pathophysiologic anatomic variants include splenomegaly, asplenia, and autosplenectomy. Splenomegaly is the enlargement of the spleen. It occurs due to various conditions, such as infections (eg, malaria, kalaazar), malignancies (eg, lymphomas, leukemias), and other conditions (eg, portal hypertension). The spleen then projects toward the right iliac fossa in the direction of axis of the 10th rib.
- Asplenia is a rare condition in which a congenital absence of the spleen occurs.
- Autosplenectomy is a condition in which splenic infarction occurs due to sickle cell anemia(Paraskevas et al., 2016).

2.2 Functions of the Spleen:

2.2.1 Immune responses:

After antigenic stimulation, increased formation of plasma cells for humoral responses and increased lymphopoiesis for cellular responses occurs.

2.2.2 Phagocytosis:

One of the spleen's most important functions is phagocytosis. The spleen is a component of the reticuloendothelial system. The splenic phagocytes include reticular cells, free macrophages of the red pulp, and modified reticular cells of the ellipsoids. Phagocytes in the spleen remove debris, old and effete red blood cells (RBCs), other blood cells, and microorganisms, thereby filtering the blood. Phagocytosis of circulating antigens initiates the humoral and cellular immune responses(Zheng et al., 2015).

2.2.3 Hematopoiesis:

The spleen is an important hematopoietic organ during fetal life; lymphopoiesis continues throughout life. The manufactured lymphocytes take part in immune responses of the body. In the adult spleen, hematopoiesis can restart in certain diseases such as chronic myeloid leukemia and myelosclerosis(Ou et al., 2015).

2.2.4 Storage of red blood cells:

The RBCs are stored in the spleen. Approximately 8% of the circulating RBCs are present within the spleen; however, this function is seen well in animals than humans.

2.2.5 Erythrocytes & Platelets:

In the fetus the spleen also has a role in haematopoiesis when it becomes the main erythrocyte producing organ during the haematopoietic transitional phase. In the developed animal the red pulp is involved in the removal of aged, damaged or abnormal erythrocytes (along with the liver and bone marrow). As erythrocytes age they become less supple and this causes them to become damaged when they pass through the very narrow capillaries of the spleen, after which they are phagocytised by splenicmacrophages.

If a splenectomy is performed the number of aged erythrocytes in circulation increases.The red pulp also acts as a storage site for erythrocytes. The degree of storage is variable between species but is particularly notable in horses which, during exercise under sympathetic activity, can contract their spleen to increase the concentration of circulating erythrocytes. In some species such as cats and rodents the red pulp acts as a storage site for platelets and contains megakaryocytes(Ou et al., 2015).

2.2.6 Lymphoid:

Blood flows through the marginal sinus. This means that most antigens present in the blood come into contact with the B lymphocytes and dendritic cells in the spleen. Dendritic cells in the marginal sinus and red pulp take up antigens from the blood and transport them to the primary follicles in the white pulp. If the antigen activates the B lymphocytes then a germinal centre will form in the primary follicle and this is called a splenic nodule. Antibody producing cells then migrate to the red pulp and marginal zone. Following splenectomy this doesn't occur and animals are predisposed to septicaemia and infection with blood protozoa(Ou et al., 2015).

2.3 Normal Sonographic Anatomy

The spleen is located in the left hypogastric quadrant of the abdomen and is fixed in its intraperitoneal position beneath the 9th to 11th intercostal spaces by the splenorenal, splenocolic, splenogastric, and phrenicosplenic ligaments. The organ's convex face lies adjacent to the diaphragm and is located in close proximity to the left pleural cavity. The concave side of the spleen has contact with the stomach, left kidney, and colon flexure. Then splenic hilum is found within this concavity and acts as an entry and exit route for the arterial, venous, and lymphatic vessels and nerves. Here, the tail of the pancreas protrudes toward the spleen. On

sonography, the spleen is crescent shaped. Its outer convexity is smooth, whereas the inner margin may be indented or nodulous. Its echo structure is homogeneous and only slightly more echogenic than healthy liver tissue and markedly hyperechoic compared to kidney tissue(Nemati et al., 2016).

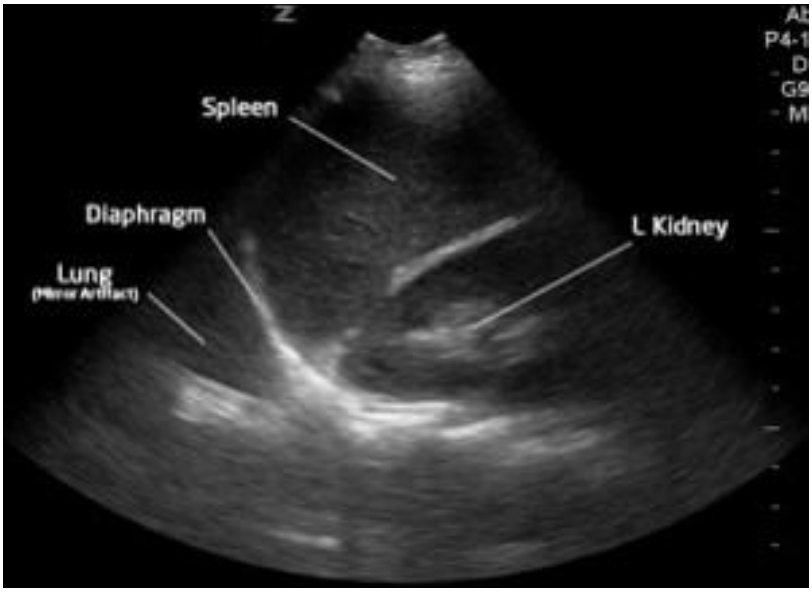

Figure 2.2 Sonograph of normal spleen

2.4 Examination Technique and Technical Requirements:

The spleen should be examined with the patient in a supine or lateral recumbent position. Imaging is performed while the patient exhales because the upper pole of the spleen is otherwise covered by lung tissue. The 10th and 11th intercostal spaces constitute the ideal acoustic window for ultrasound transmission. The spleen is sonographically examined from the diaphragmatic end to the lower pole from this window. A curved array transducer with a median frequency of 3 to 5 MHz is best suited for sonographic examination of the spleen. The normal spleen size on sonography in adults is about 10 to 12 cm in length. However, a spleen size of about 12 cm is considered the edge of normal; thus, it is almost impossible to

image the entire organ with a sector or linear array transducer. The curved array transducer renders a trapezoid-shaped image and allows for the largest possible image. Fusion of multiple images or the use of panoramic images (computer-assisted addition of sonographic images with movement of the transducer) becomes necessary when an enlarged spleen (length >12 cm) is to be assessed and measured in its full length(Benter et al., 2011).

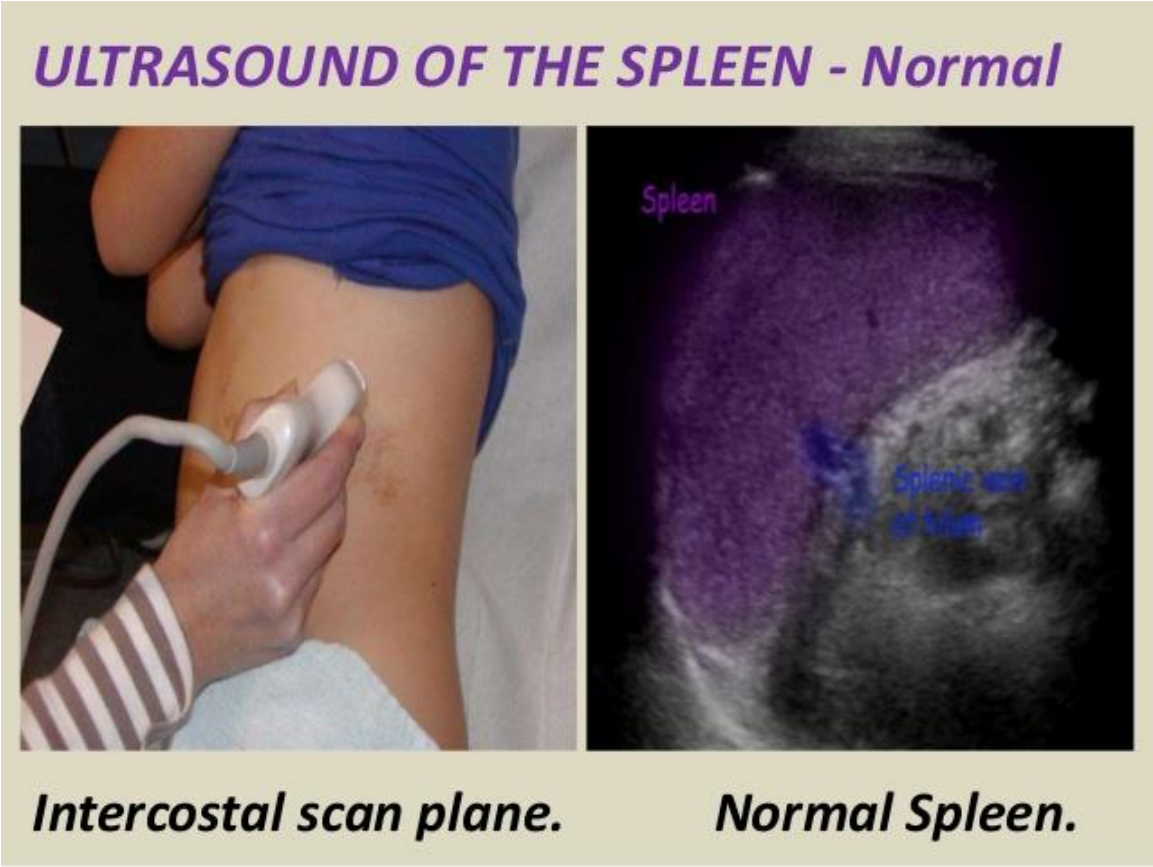

Figure 2.3 Sonographic examination of the spleen

2.5 Contrast-Enhanced Sonography

Splenic perfusion can be examined in detail with contrastenhanced sonography. Especially with the use of second generation contrast enhancers (eg, SonoVue; BraccoSpA, Milan, Italy), the specific hepatosplenic absorption is visible after the

first blood pool phase, and the contrast agent accumulates in the spleen's parenchyma. During the arterialphase (8 to 25 seconds; Figure 5), the physiologically inhomogeneous splenic parenchyma becomes visible. The inhomogeneous aspect is caused by the above-mentioned vascularization of the spleen. In the late parenchymatous phase (25 to 50 seconds), the splenic tissue shows homogeneous contrast (Figure 6). Hence, this phase is particularly useful for the detection of focal lesions. Contrast-enhanced sonography of focal lesions of the spleen has a diagnostic benefit for 48% of all patients with perisplenicl esions.The diagnostic value of splenic contrast-enhanced sonography seems to be greatest in the detection of infarctions, ruptures, and hemangiomas as well as accessory spleens(Catalano et al., 2006).

2.6 Pathologic Conditions of the Spleen

2.6.1 Splenomegaly

Splenomegaly is the acute or chronic enlargement of the spleen, defined as a weight of greater than 250 g and a sonographic width of greater than 4 cm, diameter of greater than 7 cm, and length of greater than 11 cm in adults. The size of the spleen correlates with height and can exceed the normal size in tall healthy athletes. Splenomegaly causes bulging of the organ's shape and rounding of its poles. In extreme cases, the upper pole may even touch the left lobe of the liver.Splenomegaly is divided into 3 categories: mild, moderate, and severe(Rufer and Wuillemin, 2013).

2.6.2 Hyposplenism

There are many causes of hyposplenism, and congenital, hematologic, and autoimmune diseases should be considered in the differential diagnosis.10Sickle

cell anemia with autoinfarction is another important cause of hyposplenism. Hyposplenism often results in decreased splenic function. The diagnosis of hyposplenism does not necessarily coincide with a sonographically decreased splenic volume. However, a continuous loss of the organ's volume may indicate impaired splenic function(Cheng et al., 2016).

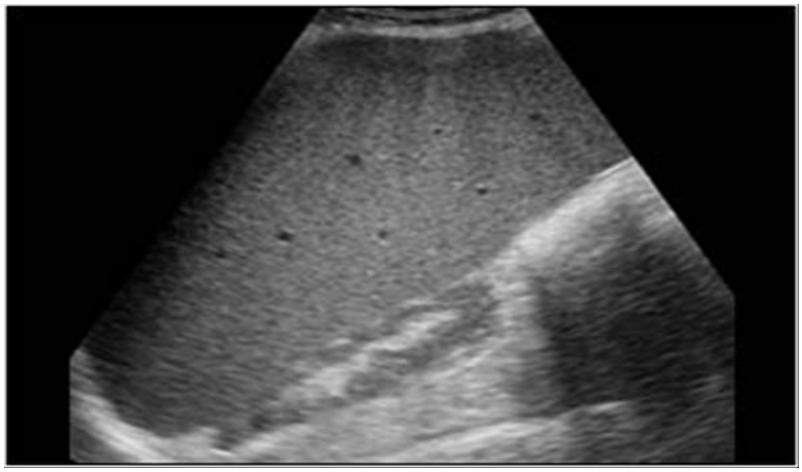

Figure 2.4 sonographic image of Hyposplenism

This condition is the case in patients with graft-versus-host disease after bone marrow transplantation.11Moreover, decreased splenic vascularization was shown to be associated with hyposplenism in a retrospective study with color Doppler imaging.12The diagnosis is primarily defined by a decrease in filter function and a reduced immune status. The filter function is assessed by quantification of Howell-Jolly bodies in erythrocytes as well as their capacity to absorb technetium colloid(Di Sabatino et al., 2018).

2.6.3 Focal and Diffuse Lesions of the Splenic Parenchyma

Focal lesions of the spleen are rare and typically detected coincidentally during sonographic examinations of the abdomen (<1%). Focal lesions of the spleen may

take various appearances in sonography. In the following sections, we provide an exemplary selection of various focal splenic lesions.

2.6.4 Benign Lesions of the Spleen:

A rupture of the spleen is typically caused by blunt force trauma to the abdomen. An acute rupture of the spleen is often difficult to detect with sonography. Fissures may be hyperechoic or hypoechoic compared to splenic parenchyma.13 More severe lesions can also cause a subcapsular hematoma (Figure 10). Free fluid in the perisplenic region of the abdominal cavity is an indirect sign of a ruptured spleen. A so-called 2-timed splenic rupture describes the delayed development of hypovolemia, hours to days after the initial trauma, which is consecutively caused by a secondary rupture of the splenic capsule or the development of a subcapsular hematoma. A 2-timed delayed rupture of the spleen cannot be detected by sonography and remains a predicament in acute diagnosis of blunt trauma to the abdomen with CT(Rufer and Wuillemin, 2013).

The diagnosis of an active hemorrhage is extremely rare and is occasionally found in spontaneous ruptures of the spleen. High mortality rates within the first 30 days. Spontaneous rupture caused by malignant tumor infiltration has been described.Hyperechoic or complex changes of the parenchyma as indicators of hemorrhage are much more common. Color Doppler and contrast- enhanced sonography are helpful in detecting hemorrhage and posttraumatic splenic pseudoaneurysms. Both modalities bridge the gap to CT imaging, which to date is considered the reference standard in the monitoring and assessment of splenic trauma. With contrast-enhanced Sonography, acute hemorrhages and pseudoaneurysms are indicated by increased pooling of the contrast agent. Consecutive hematomas of the spleen are characterized by decreased or a lack

ofcontrast agent uptake. Splenic ruptures are graded in 5 categories. These are easily differentiated with color Doppler Sonography (Back et al., 2017):

- Grade1capsular fissures and nonexpansivesubcapsular hematoma.
- Grade 2 lesions of the capsula and parenchyma without lesions of the segmental arteries.
- Grade 3 lesionsof the capsula, parenchyma, and segmental arteries.
- Grade 4 lesions of the capsula, parenchyma, and segmental and hilar arteries and rupture of the vessel hilus of the spleen.
- grade 5rupture of the organ from the splenic hilus and devascularization.

Hematoma: A fresh hematoma of the spleen imposes a hyperechoic structural change within the splenic parenchyma. It may be subcapsular or located within the parenchyma. An organized hematoma of the spleen shows a varied echogenic structure on sonography(Di Sabatino et al., 2018).

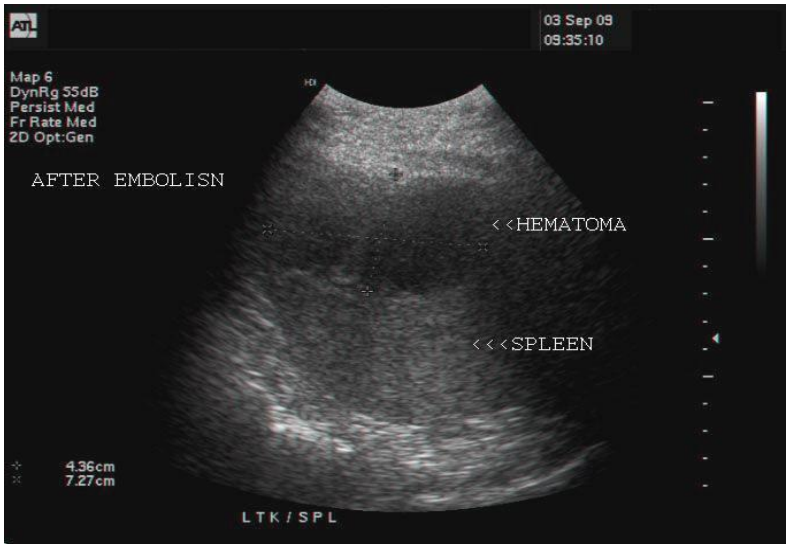

Figure 2.5 Nontraumatic Lesions of the Spleen

Infarctions of the Spleen: Infarctions of the spleen are imaged as subcapsularhypo - echoic segmental lesions. Contrast-enhanced sonography provides improved imaging of splenic infarctions.17 Most infarctions of the spleen are infiltrative or hematologic lesions.18Anemic infarctions, caused by emboli blocking the splenic arteries (eg, rheumatic endocarditis), are also quite common. Infarctions secondary to portal hypertension, tumor infiltration of the hilus, or splenomegaly are much less common. Complications afte a splenic infarction occur in 12% of all cases, eg, increasing colliquation of the afflicted segment, ensuing subcapsular hemorrhage, and later, pseudoarteriovenous fistulas(Gorg et al., 2006).

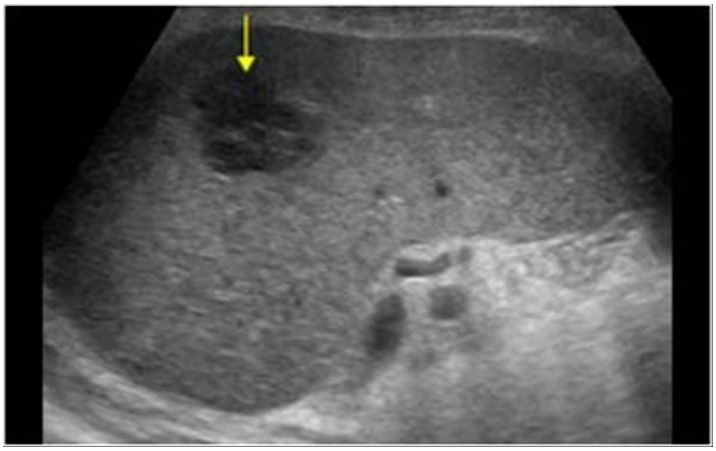

Figure 2.6shows infarcted area in the spleen

Splenic Hemangioma: A hemangioma is the most common benign tumor of the spleen and typically does not exceed 2 cm in size. Willcoxet al19 found hemangiomas of the spleen in up to 10% of their patients. However, the less common subcapsularhemangiomas may cause spontaneous ruptures of the capsula.20Histologically, 2 types of splenic hemangiomas are differentiated. Each type is distinguished by its specific sonographic characteristics. A histologically cavernous hemangioma is typically imaged as a mixed echogenic or

hypoechoicstructure and may show partial calcifications or cystic structures on sonography(Gorg et al., 2006).

In comparison, a capillary hemangioma is imaged as a hyperechoic lesion with defined margins (Figure 13). Coincidentally diagnosed lesions, which are not positively definedashemangiomas, constitute a difficult diagnostic issue. In particular, hamartomas, metastases, extramedullary hematopoiesis, and acute hemorrhage or lymphoma of the spleen may appear as round hyperechoic tumors. In these cases, contrast- enhanced sonography may be helpful in aiding the differential diagnosis(Bhasin et al., 2001).

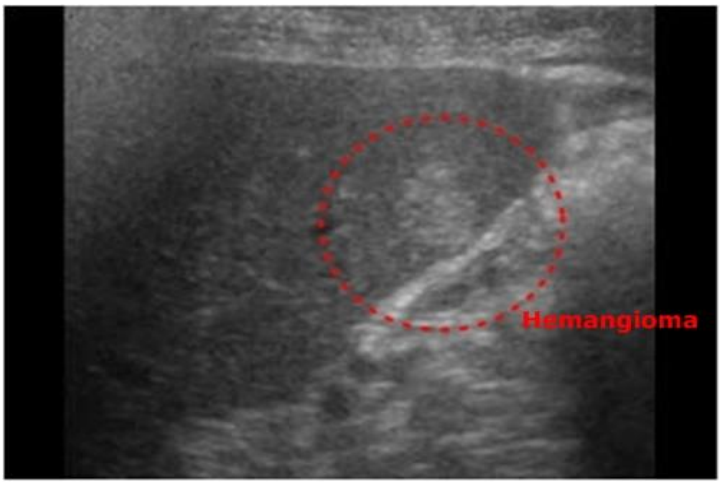

Figure 2.7 hemangioma in the spleen

A hamartoma is a very rare benign tumor of the spleen. Histologically, it originates from the red pulp but may also show cystic or necrotic portions as well as small calcifications. Most hamartomas are smaller than 3 cm in diameter. On sonography, hamartomas are typically solid, sharply defined processes of mixed to high echogenicity. Incidentally diagnosed hypoechoichypervascularized tumors of the spleen are most likely to be benign, eg, hamartomas or capillary hemangiomas. An increase in size is rare. Contrast-enhanced sonography contributes to the

differential diagnosis of hypervascularized lesions. Follow-up with sonography and contrast-enhanced CT is recommended(Kim et al., 2007).

In 1991, littoral cell angioma of the spleen was first described as a vascular tumor.22Littoral cells are physiologically present in the vascular ducts of the red pulp. They express surface markers of endothelial cells (eg, CD31) and histiocytes (eg, CD 68).23 At first, the tumor was thought to be benign, until various publications suggested malignant characteristics and an association with malignancy.24On occasion, littoral cell angiomas are diagnosed in patients who undergo a sonographic examination for anemia, thrombocythemia, or splenomegaly. In these patients, the tumor is characterized and diagnosed by its hypoechoic characteristics on sonography Follow-up protocols are identical for all vascular tumors of the spleen(Gorg, 2007).

Late residual lesions and associated tissue changes are sometimes found in the spleen after a tuberculosis infection. They are defined sonographically by multiple characteristic miliaryhyperechoic lesions (Figure 16). Histoplasmosis, Pneumocystis carinii infection in human immunodeficiency virus/acquired immunodeficiency syndrome, and Mycobacterium aviumintracellulare represent other common causes of splenic calcifications(Benter et al., 2011).

A typical cyst is imaged as a round homogeneous non - echogenic lesion with marked acoustic enhancement and a delicate wall. Occasionally, thin septations, irregular cystic walls, and structures of mixed echogenity are found. These are morphologic correlates of debris, hemorrhagic residue, and parasitic retention. Marginal echogenic areas with distal acoustic shadowing may also become visible and may indicate calcifications of the cystic wall. A first hint of a cyst’s origin is given by its unifocal or multifocal presence, whereas multiple cysts are typically of

parasitic origin. Contrast-enhanced CT plays an important role in precluding gastrointestinal fistulas in the differential diagnosis of cystic lesions of the spleen. Preoperative sonography, CT, and magnetic resonance imaging offer vital information on a cyst's location in relation to other organs(Kim et al., 2007).

Depending on the presence of an epithelial wall surrounding the cyst, primary and secondary cysts are differentiated. The latter usually occurs after trauma to the spleen or after infarction or infection, eg, malaria, infectious mononucleosis, or tuberculosis. These pseudocysts are typically filled with liquid and necrotic debris. Primary cysts are divided into parasitic (eg, caused by EchinococcusgranulosusandTaeniasolium; Figure 18) and nonparasitic cysts. Nonparasitic cysts are further differentiated in congenital (eg, dermoid and epidermoid cysts) and neoplastic cysts. Overall, splenic cysts are quite rare(Kim et al., 2007).

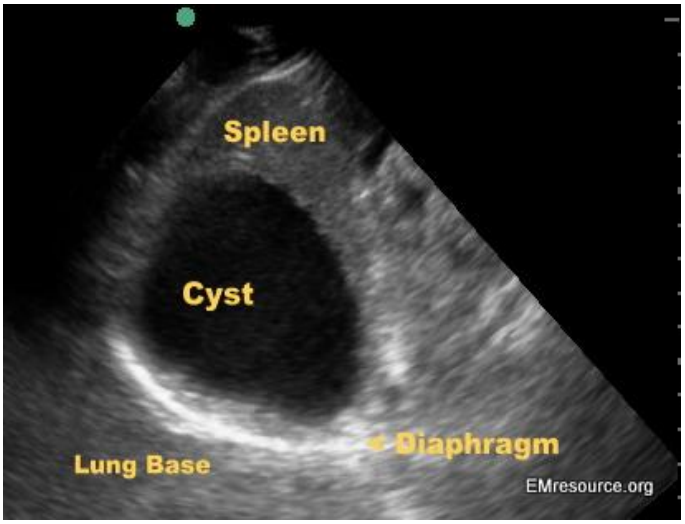

Figure 2.8 splenic cyst

2.6.5 Malignant Lesions of the Spleen:

Lymphomas of the spleen are more common than metastases.27In a retrospective pathologic study of 1280 extirpated spleens, metastases were found in 1.3% of all cases, whereas lymphomas of the spleen were identified in 15.6%. Primary lymphomas of the spleen constitute 1% of all lymphomas. Histologically, the tumor typically infiltrates the white pulp but may also spread to the red pulp.30Lesions of the spleen secondary to other lymphoma entities are much more common. On histopathologic examination, these lymphomas can be further differentiated. Malignant cells of hair cell leukemia typically infiltrate the red pulp, coinciding with atrophy of the white pulp. Follicular lymphomas and chronic lymphatic leukemia commonly afflict the white pulp. Four infiltration patterns can be sonographically differentiated: diffuse infiltration, a small nodular pattern, a large nodular pattern, and bulky lesions(Di Sabatino et al., 2018).

In most cases, the pattern of infiltration allows a specific diagnosis of the type of lymphoma. Diffuse and small nodular patterns are indicative of indolent lymphomas, whereas large nodular patterns and bulky lesions point to aggressive lymphomas. Splenic lymphomas with villous lymphocytes contribute to only 2% of all indolent lymphomas. However, sonography plays an important role in the diagnosis of this lymphoma entity. When a positive diagnosis is not possible with immunologic phenotype determination, a splenic biopsy may help achieve this goal. Generally, lymphomas appear as hypoechoic lesions on sonography. However, at times hyperechoic lesions are diagnosed as lymphomas on histopathologic examination. Sonographic diagnosis of splenic infiltration is of great importance in the staging of Hodgkin lymphoma. Catalano et al31 described increased perfusion of focal Hodgkin lymphoma on contrast-enhanced sonography during the arterial phase. The increased perfusion remained visible throughout the

later phases. The role of contrast-enhanced sonography in the differential diagnosis of Hodgkin lymphoma has been discussed controversially and has very limited clinical relevance for the diagnosis of splenic lymphomas(Guibaud, 2001).

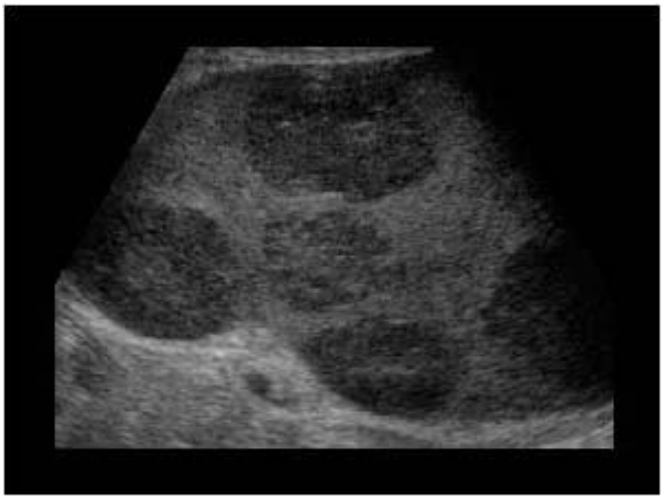

Figure 2.9 spleen metastases

Most metastases appear as hypoechoic tumors on sonography. On occasion, hyperechoic (eg, carcinoma of the colon) or inhomogeneous lesions with a necrotic (nonechogenic) center or “target sign” can be found. With the exception of metastases of mucinous primary tumors, calcifications are rarely seen. Metastatic tumors of the spleen are uncommon and rarely isolated but are usually seen in the setting of widespread metastatic disease. In an analysis of our oncologic patients (n = 218), primary tumors were mainly bronchogenic carcinomas, osteosarcomas, soft tissue sarcomas, and renal cell carcinomas.33–35Other important primary tumors with splenic metastases represent breast and ovary cancer. Moreover, the incidence of metastatic melanoma is noteworthy. Overall, patients with splenic metastases have a poor prognosis. The morphologic transition from solid to cystic metastases is explained by central necrosis due to rapid tumor growth or a mucinous origin of the primary tumor (eg, ovarian carcinoma). The lesions either remain

asymptomatic or become symptomatic with pain caused by increasing tumor size(Oliveira et al., 2018).

2.7 Previous studies:

Shah et al., 1996 noted that splenomegaly is common in portal hypertension due to hepatic cirrhosis, but there are little data comparing different methods of spleen measurement. We have compared ultrasound with radionuclide imaging in measuring splenomegaly. The relation of splenomegaly to hypersplenism and portal hemodynamic factors was also studied. Results: Ultrasound and radionuclide measures of spleen volume gave comparable results (r = 0.95, p <0.0001). Phagocytic activity of the spleen measured by radionuclide uptake increased as the volume of the spleen increased (r = 0.46, p <0.03) but was not related to diminishing liver phagocytic activity. Spleen volume was correlated negatively with leukocyte counts (r = 0.43, p <0.05) but not with hemoglohin or platelet counts. Spleen radionuclide uptake was negatively correlated with hemoglobin (r = 0.48, *p*<0.04) and leukocyte counts (r = 0.46, p < 0.04) but not with platelet counts. Spleen volume was related to portal vein cross-sectional area (r = 0.91, p <0.0001) and portal vein blood flow volume (r = 0.57, p< 0.008) but not to portal vein blood flow velocity, portal pressure gradient, or azygos blood flow. Conclusions: Spleen size measured by ultrasonography and radionuclide studies gives comparable results(Shah et al., 1996).

(Spielmann et al., 2005)study was to establish the range of spleen sizes in tall healthy athletes. Sonographic measurements of spleen size and left renal length were performed on 129 college athletes (82 men, 47 women). Length, width, and thickness of the spleen and left renal length were obtained. In addition, the height, weight, and age of each athlete were recorded. Pearson's product moment

correlation coefficients were calculated, and linear regression analysis was used to create a model for calculating normative values The mean body height for men was 74.3 (189 cm) ± (SD) 3.7 inches (9 cm) and for women was 69.3 (176 cm) ± 3.7 inches (9 cm). Spleen length was greater than 12 cm in 31.7% of the men (mean spleen length, 11.4 ± 1.7 cm) and in 12.8% of the women (means spleen length, 10.3 ± 1.3 cm). In women, height correlated with spleen length ($r = 0.3$, $p = 0.05$), width ($r = 0.4$, $p = 0.01$), and volume ($r = 0.3$, $p = 0.02$) but not with thickness ($r = 0.08$, $p = 0.6$). Spleen length did correlate with left renal length ($r = 0.5$, $p = 0.0005$). In men, height correlated with spleen length ($r = 0.4$, $p = 0.0003$), width ($r = 0.5$, $p = 0.0001$), and volume ($r = 0.4$, $p = 0.0002$) and less with thickness ($r = 0.3$, $p = 0.01$). Spleen length and left renal length were poorly correlated ($r = 0.2$, $p = 0.04$). Regression analysis showed that in women taller than 5 ft 6 inches (168 cm), the mean splenic length of 10 cm increased by 0.1 cm for each 1-inch incremental increase in height. In men taller than 6 ft (180 cm), the mean splenic length of 11 cm increased by 0.2 cm for each 1-inch incremental increase in height. Spleen size correlates with height in tall healthy athletes. Nomograms from this data can be used to gauge the risk of returning to play after episodes of acute splenomegaly, as with infectious mononucleosis(Spielmann et al., 2005).

Okoye, (2005) study aimed to establish ultrasonic splenic dimensions which can be used as normogram for adult Nigerians. Their study include 250 adult subjects were scanned prospectively using a 3.5MHZ ultrasound sector probe. The splenic length, width and thickness were obtained in the supine position and the weight calculated using Downey's formula. Differences in splenic dimensions were determined using Z test, while the relationship between the splenic dimension and the subjects' age, BMI, and height were analyzed using Pearson Moment Correlation. The normal splenic sizes obtained ranged from 9.9 -11.5cm (length —

L), 6.0-7.5cm (Width W) and 4.0- 4.5cm (thickness -T). The splenic dimensions for males were 11.1 + 0.7cm (L), 7.3 + 0.2cm (w) and 4.2+ 0.2cm (T). The corresponding values for females were 10.6 + 0.7cm, 6.8 + 0.5cm and 4.2 + 0.2cm respectively; thus showing a statistically significant difference between the males and females ($P < 0.05$). A poor correlation was shown to exist between splenic dimensions and age but splenic weight increased with body weight ($r=0.75$). Even though value of the splenic sizes were similar to those of a Caucasian population compared with them (P0.05), the maximum splenic weights occurred in the 4 decade in Nigerians and in the 2 decade in Caucasians.this finding appear to bear credence to existing opinion by Chauhan et al that splenic recession rather than Splenomegally is prevalent in adults living in endemic falciparum zones.

Statistically significant differences between splenic length and weights of the sexes have been established by the study. The good correlation between subject height and splenic length portends profound options of predicating subjects splenic size and matching his ultrasound values with this predicted splenic length (SPL = I .2 ÷ 0.063). They found that there were 164 females and 86 males in the study group and the modal age was 30-8Oyear age group. The splenic length for both sexes ranged from 9.9 11 .5c in with a mean of 1 0.9+ 0.7. The mean splenic length for the males is 11. I + 0.7cm while that of the female is 10.6+ 0.07cm and the difference was statistically significant ($P< 0.05$). The splenic length increased with age till 39years and thereafter showed a decrease with age. There was also a positive correlation between splenic length and subject height. The splenic width for the study population ranged from 6.0-7.5cm for both sexes. The mean splenic width for males is 7.2±0.2cm and that for the female is 6.8±0.5cm. The splenic width reached maximum size at 39years in males while the maximum width occurred at 49years in females, thereafter; there was a decrease in the width for

both sexes. The splenic thickness for the males is 4.2±0.2cm and that of the female is 4.2±0.2cm. The range of the computed splenic weight is 105-158gm for both sexes. I however while the mean splenic weight for the males is 145.0±11gm, that for the female is I 30±1 I gm indicating that statistical significant differences between the sexes of $P<0.05$. There was a positive correlation between splenic weight and body weight ($r=0.75$) for those who weighed 60kg and above only(Okoye et al., 2005).

Chapter Three

Materials and Method

3.1 Material:

3.1.1 Machine used

Toshiba diagnostic ultrasound equipment model SSA-320A and Medison diagnostic ultra sound machine model sonoace x6, standardized transabdominal scan using curvilinear transducer 3.5MHZ was carried on.

3.1.2 Subjects:

Fifty adult patients were enrolled in the study; healthy volunteer persons who referred to ultrasound department for abdomen ultrasound were included. Any person suspected with abnormal splenic measurement by ultrasound examination was excluded .The population of this study includesmales and females aged (19-80) with normal status, the data of this study collected from Alsalam hospital in three months.

The researcher got an ethical approval from the hospital and the department to collect the data from the patient and verbal agreement from the patient.

3.2 Method:

3.2.1 Technique Used:

Trans-abdominal ultrasound technique was performed with patient laying in supine position angle the probe between the ribs intercostally from postero lateral approach.

Each subject from sample was fasting for 8hours and having abdominal preparation then ultrasound scan for splenic measurement (length, width, thickness, splenic weight, also body weight and height must be measured.

3.2.2 Method of data analysis:

Data were collected with special data collection sheet encompass patient demographic data and ultrasound findings. Then the Data were analyzed using SPSS and excel software. Descriptive statistics as well as correlations were performed.

Chapter Four

Results

4.1 Results:

Table 4.1 descriptive statistics of study variables

	N	Mean	Std. Deviation	Minimum	Maximum
Age	50	26.98	7.463	18	52
Weight	50	63.94	10.34	50	89
Height	50	1.63	0.07	1.50	1.86
BMI	50	24.24	3.9701	19.5	35.4
Spleen length	50	9.51	1.12	7.8	12.8
spleen thickness	50	3.49	0.56	2.7	5.0
Spleen width	50	6.696	0.89	4.0	9.0
Spleen Volume	50	161.43	41.7	89.9	309.3

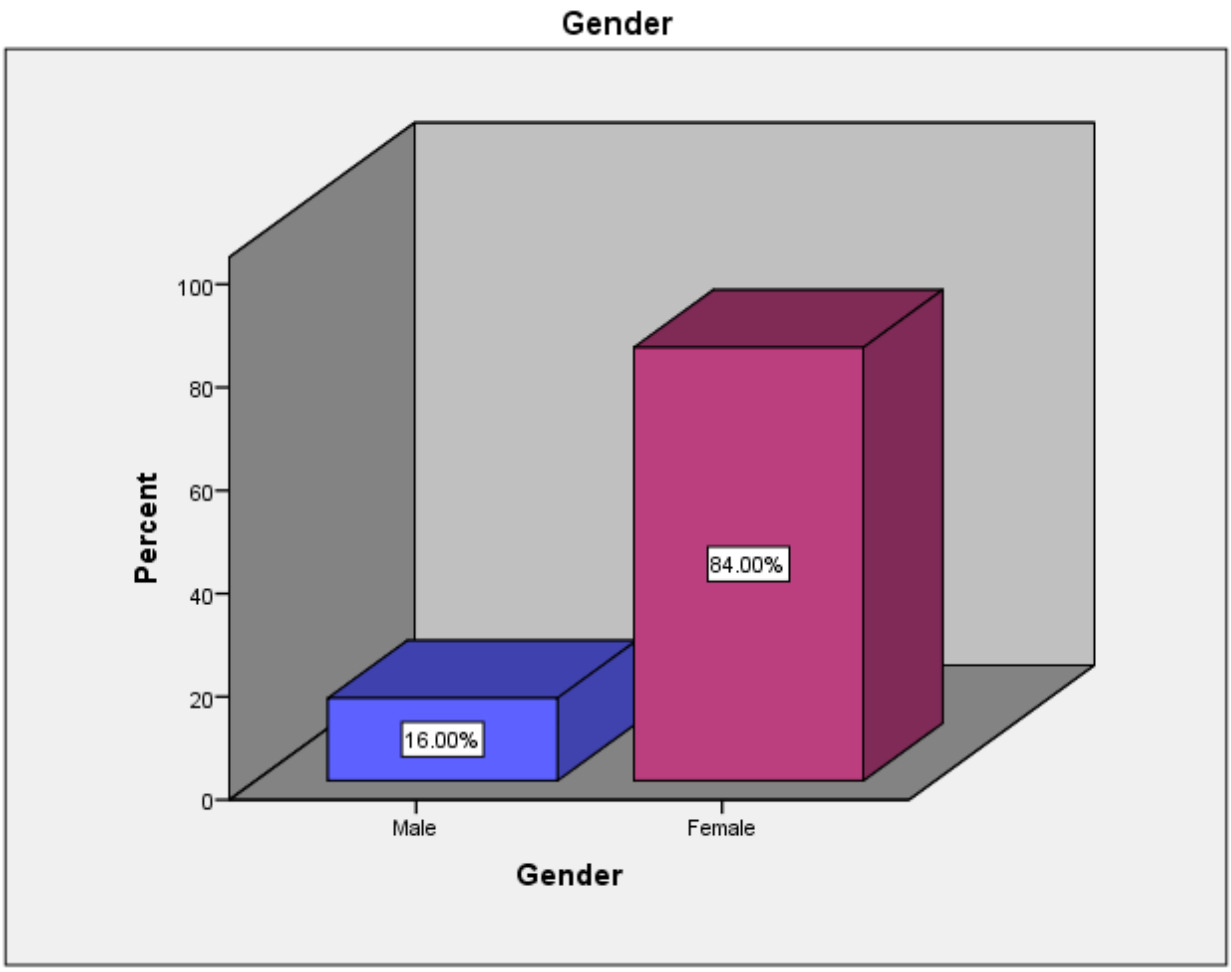

Figure (4.1): Frequency distribution of gender in percentage.

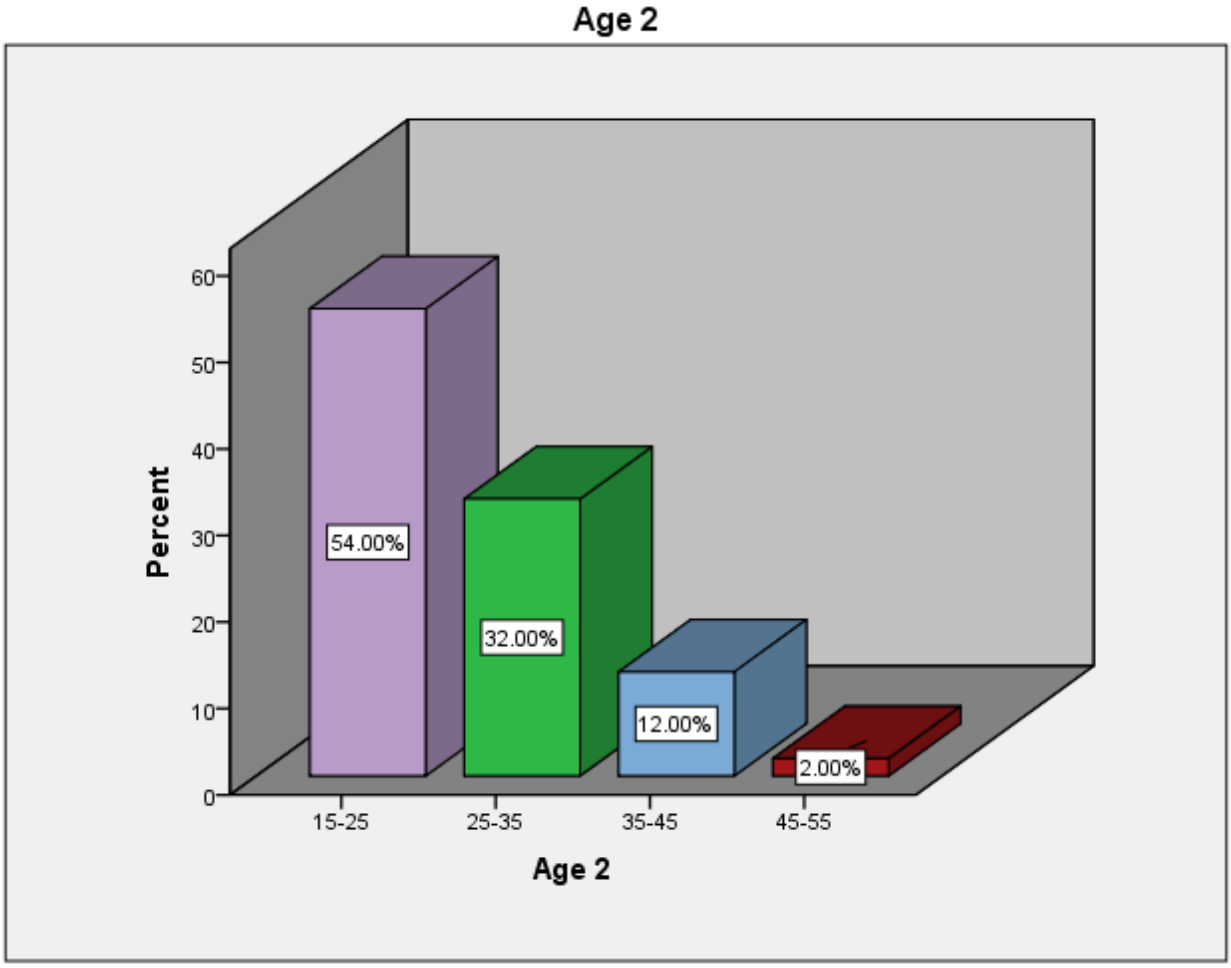

Figure (4.2): Frequency distribution of age groups in percentage.

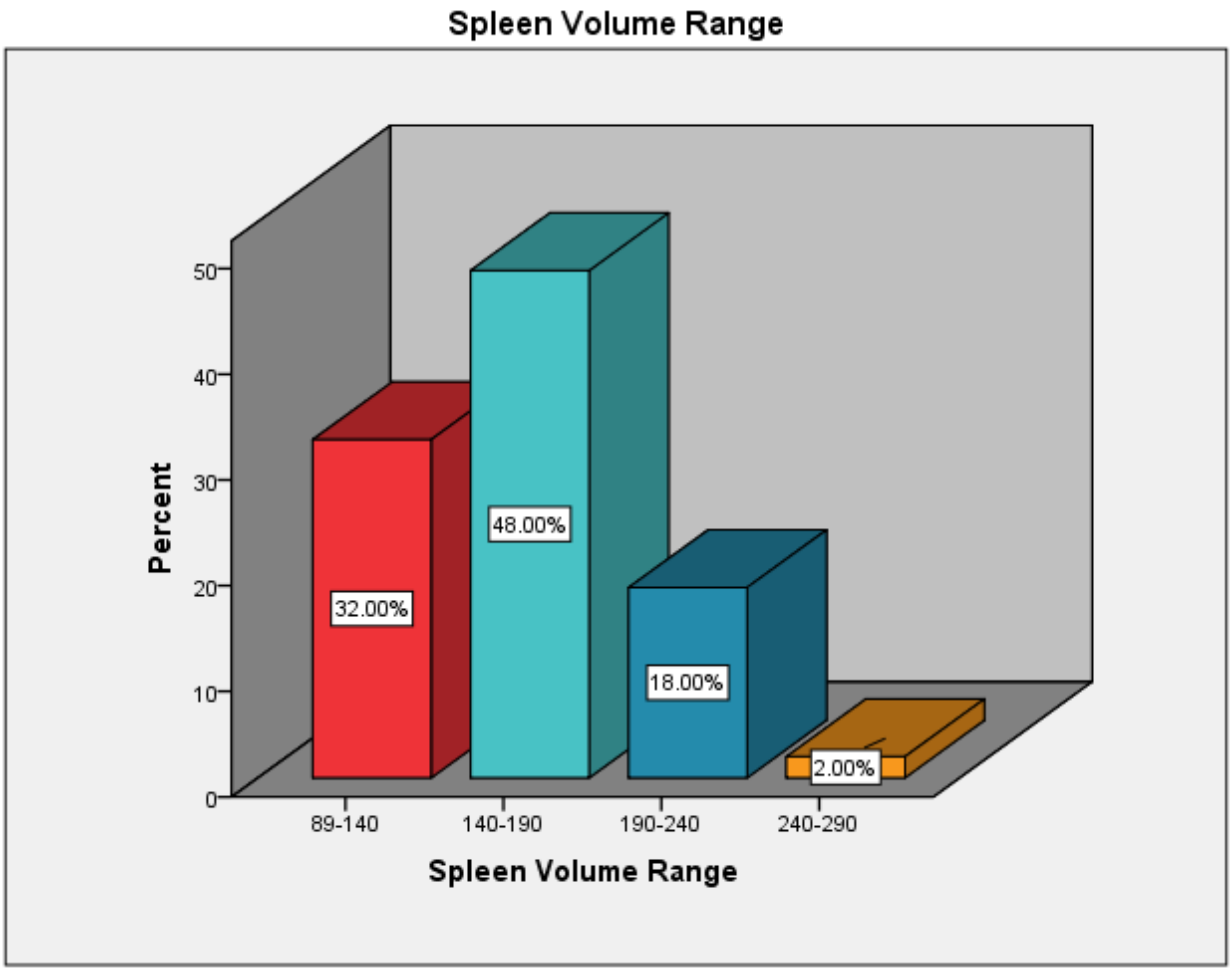

Figure (4.3): Frequency distribution of splenic volume in percentage.

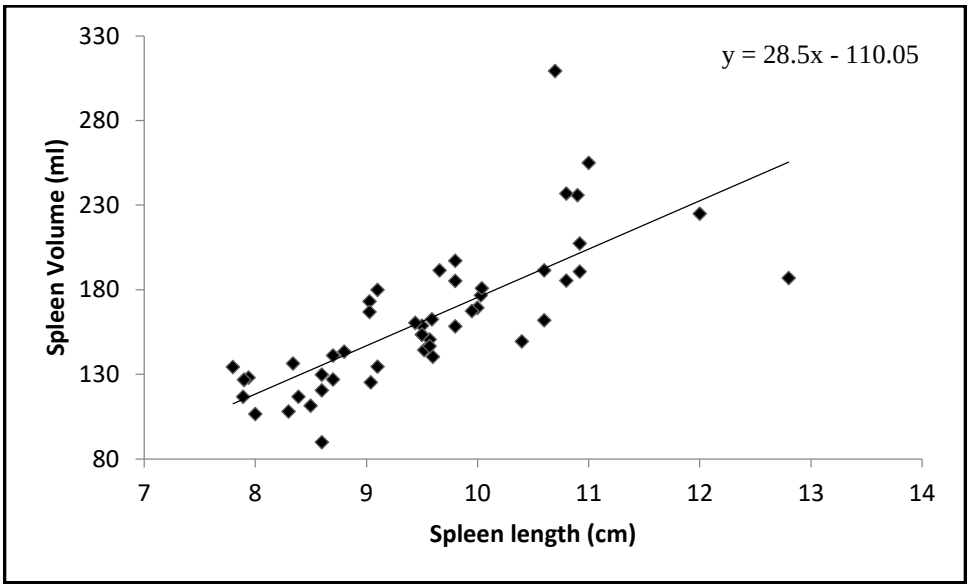

Figure (4.4): linear relationship between splenic length and splenic volume.

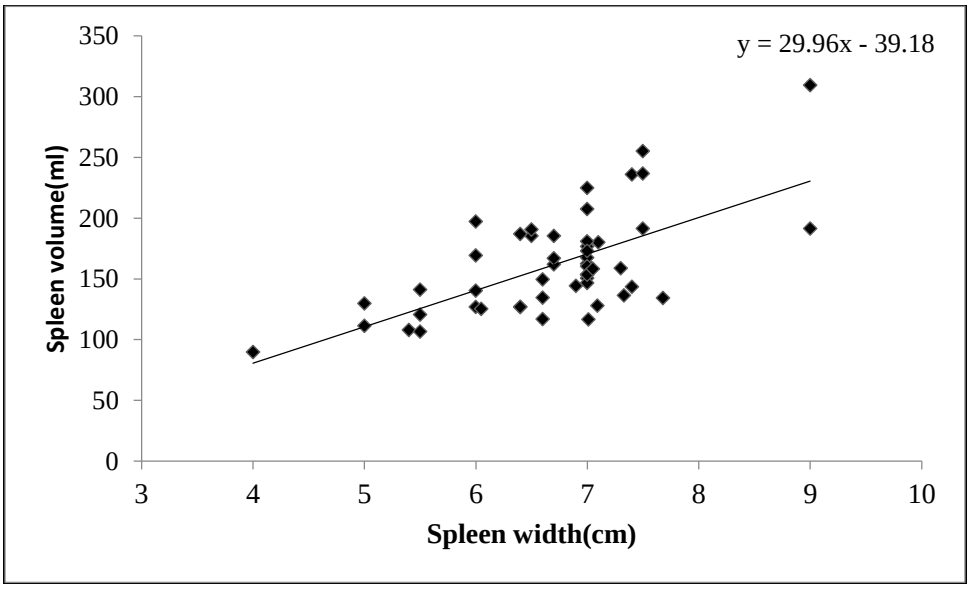

Figure (4.5): linear relationship between splenic width and splenic volume.

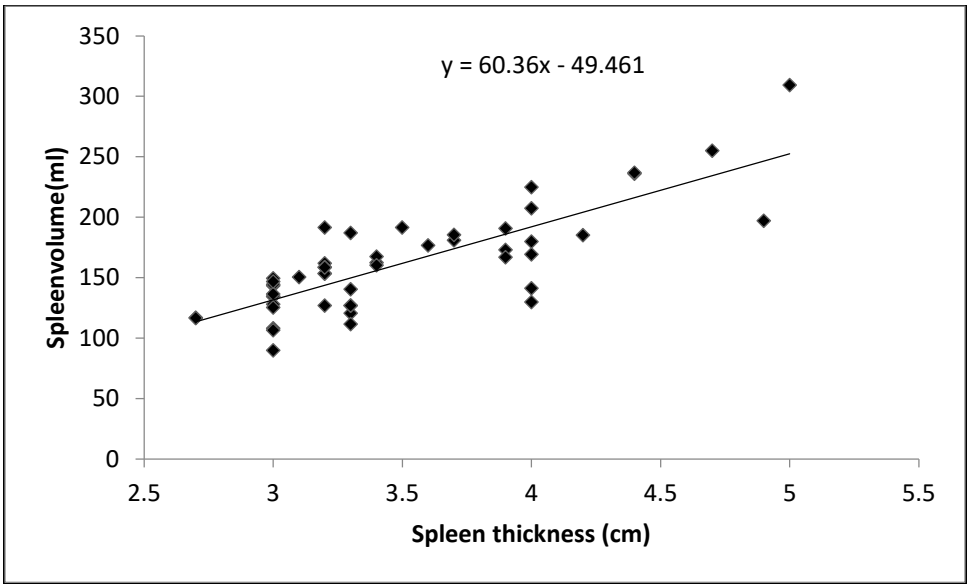

Figure (4.6): relationship between splenic thickness and splenic volume.

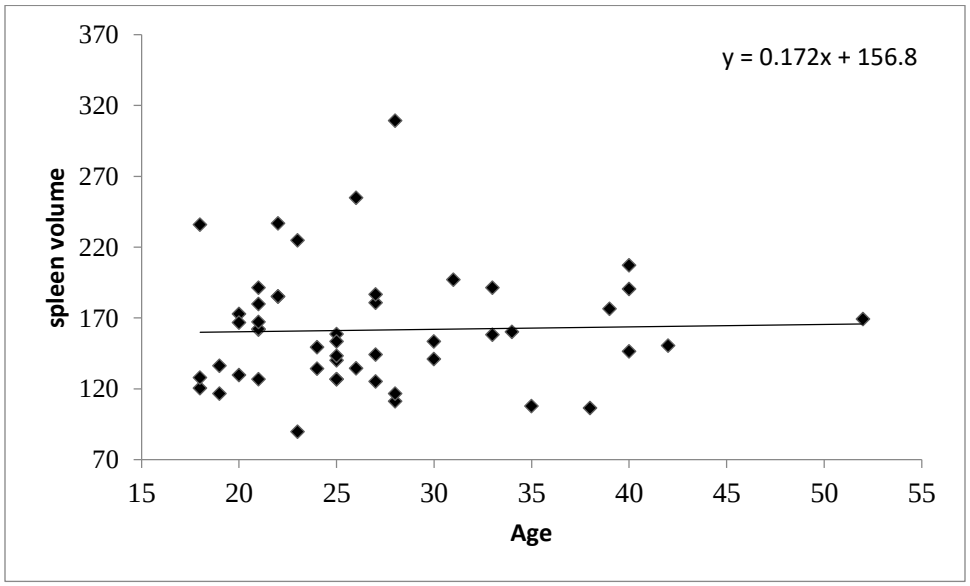

Figure (4.7): linear relationship between age and splenic volume.

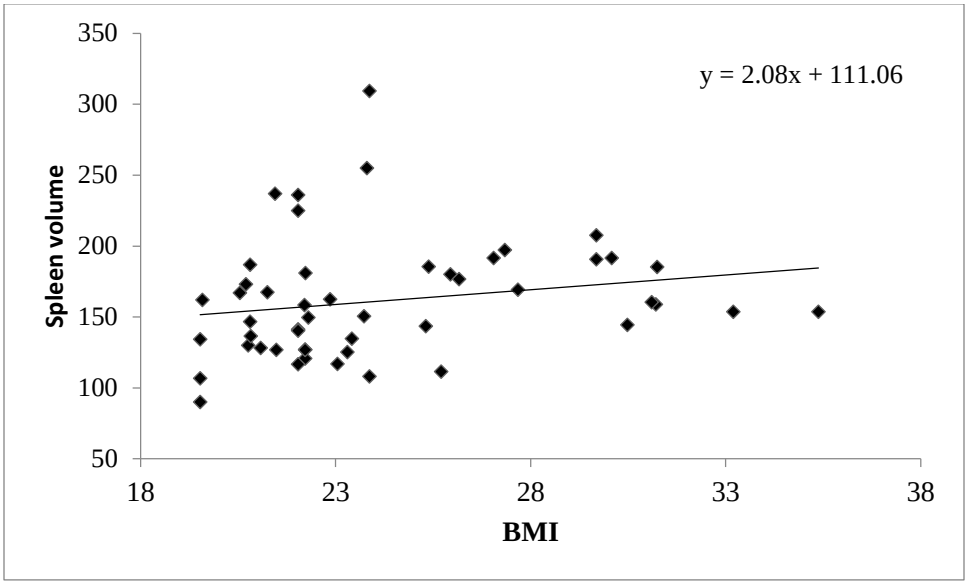

Figure (4.8): linear relationship between BMIand splenic volume.

Chapter Five

Discussion, Conclusion and Recommendations

The study was done to evaluate the splenic volume in normal adult Sudanese population. They were fifty patients aged between 18-52 years old with mean age 26±7.4 years old. Their weight was between 50-89 Kg, with mean weight 63±10.3 Kg. The height of the patients was between 1.5-1.8 meters, with mean height 1.6±0.07 meter. BMI was calculated, the mean of it was 24±3.9 Kg/m2.The study divided the age into four groups,from (15-25), (25-35), (35-45) and (45-55) Years, the percentage of each was 54%, 32%, 12% and 2% respectively.

The result of the study revealed that the splenic length, width, and thickness were measured the mean of each was 9.5±1.1 cm, 6.6±0.8 cm and 3.4±0.5 cm respectively.Splenic volume was calculated, the mean of it was 161.4± 41.7.These measurements are consistent with previous normal values reported for the general adult population(Capaccioli et al., 2000).

The morphology of visceral organs varies from person to person. During the maturation process from infancy through adolescence, growth of visceral organs, including the spleen, shows a high correlation with gains in height, weight, and body surface area(Konuş et al., 1998). In this study the weight and length of the spleen compared with body height and weight, it showed a significant correlation. This observation probably results from the cessation of rapid body growth that occurs with attainment of mature body morphology. Thus it is difficult to predict spleen size reliably on the basis of these variables alone.

Regarding the correlate between splenic length and splenic volume, it was found thatthere is a linearrelationship between splenic length and splenic volume, the splenicvolume increase by 28.5 ml per each cm of splenic length.The correlation

between splenic width and splenic volume also was studied it was found that the splenic volume increases by 29.9 ml per each cm of splenic width.

The result of the study also Found that there is alinear relationship, and the splenic volume increases by 60.3 ml per each cm ofsplenic thickness. Furthermore, there is a linear relationship between BMI and splenic volume, and the splenic volume increases by 2.07 ml per each kg/cm2.

The results of this study could be used as a practical and comprehensive guide to indicate the normal spleen length; according to the age and body habitus. With this in mind, so as to distinguish and thus better assess individuals with markedly long spleens outside the normal range but whose body parameters are within the normal range.

Conclusion:

Ultrasound is a noninvasive modality forthe imaging theskull base. Since this procedure is widely done, thismodality was preferred.Toconclude,The dimensions of spleen have clinical importance and the present study regarding morphometry ofspleen shows dimensions of spleen The radiological and anatomical measurements indicatedthat the radiological assessment greatly helps to organize the preoperative preparation.

Current study findings may consider as reference forSudanese, and the measurements may describe thenormal morphological variants of spleen for Sudanese. Sincethe anatomy of the spleen is of interest to many radiologicalfields.

Recommendations:

- We have to increse the number of patients to give more acurate study.
- Study can also be done in depth for other types of medical images like CT and MRI .
- Initiation of Ultrasound units with Doppler faciilties can help a lot in detectingspleenic problems.

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