الاية

(والله أخرجكم من بطون امهاتكم لا تعلمون شيئا"

وجعل

لكم السمع والأبصار والأفئدة لعلكم تشكرون)

صدق الله العظيم
سورة النحل الآية

Dedication

To my Family

Brothers

Friends and colleagues

Acknowledgement

My acknowledgements and gratefulness at the beginning and at last is to God who gave us the gift of the mind.

My gratitude is extended to my supervisor **Dr. Ahmed Mostafa Abukonna** for his support and guidance, without his help this work could not have been accomplished.

My gratitude is also extended to my colleagues in Radiology Department at Fedail hospital for their continuous help and support.

Finally, my profound thanks and gratitude to everyone who encouraged me to complete this thesis.

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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 mean of splenic width, length and weight were (7.9 ±1) cm, 9.3 ±.86) cm and (151.9 ± 36.1) gm respectively. These measurements are consistent with previous normal values reported for the general adult population.

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.

كشفت نتائج الدراسة أن متوسط عرض الطحال والطول والوزن كانت (7.9 ± 1) **سم،** (9.3 ± 0.86) **سم و**(151.9 ± 36.1) **جرام على التوالي. هذه القياسات تتفق مع القيم العادية المذكورة سابقا للسكان البالغين العام.**

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

1.1 Introduction:

The spleen is the largest haemolymph nodes in the body and large part of the reticuloendothelial tissue of the body is concentrated in it. It is general structure is like that of the haemolymph nodes, the argon being closely connected with the blood and with the lymphoid tissue. The spleen lies in the left hypochondrium with its axis along the shaft of the tenth ribs, it's lower pole extends forward as far as mid axillary line, the spleen is an intra peritoned organ covered with peritoneum over it entire extent except for small area at it's hilum where the vascular structures and lymph nodes are located. The peritoneum ligament attaches the spleen with peritoneum.

The spleen response to antigenic challenge, distract abnormal red cells. Phagocytosis of foreign substances platelets and erythrocyte production. The spleen has variable size and shape but generally is considered to be ovoid with smooth borders and convex superior and inferior surface.

The spleen is normally measured along its long axis, the normal spleen measures 8 to 12 cm in length 7 to 8 cm in anteroposterior diameter, and less than 6cm in thickness.

Sonographically the spleen must be smooth in its outer contour, mid gray to low level echoes splenic parenchyma, and homogeneous texture with less or same liver texture echogenicity.

Since the organ develops in the dorsal mesentery of the gut. The spleen is not essential to the life and it may be removed in both man and animals without ill effect. In same way as the red bone marrow and also the spleen is the fetal life the spleen is the site of formation of red and white cells in much the site for the destruction of old blood cells and the removal of their break down products.

The spleen plays important roles in regard to red blood cells (also referred to as erythrocytes) and the immune system. It removes old red blood cells and holds a reserve of blood, which can be valuable in case of hemorrhagic shock, and also recycles iron. As a part of the mononuclear phagocyte system, it metabolizes hemoglobin removed from senescent erythrocytes. The globin portion of hemoglobin is degraded to its constitutive amino acids, and the heme portion is metabolized to bilirubin, which is removed in the liver (Curry and Tempkin, 1995).

The spleen synthesizes antibodies in its white pulp and removes antibody-coated bacteria and antibody-coated blood cells by way of blood and lymph node circulation. A study published in 2009 using mice found that the spleen contains, in its reserve, half of the body's monocytes within the red pulp. These monocytes, upon moving to injured tissue (such as the heart), turn into dendritic cells and macrophages while promoting tissue healing. The spleen is a center of activity of the mononuclear phagocyte system and can be considered analogous to a large lymph node, as its absence causes a predisposition to certain infections (Krebs C.1993).

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. 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 published in 2012 in which 111 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 (Muataz. 2006). Another study indicates that normal average dimensions of the spleen in athletes taller than 2 m the average dimensions of the spleen were found to be approximately 11.2 cm, with the maximum value recorded of 14 cm. 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 (John and Tempkin 1995).

1.2 Problem of the study:

To the knowledge of the researcher there is no reference value for spleen measurements in Sudanese population.

1.3 Objectives

1.3.1 General objectives:

The general objective of this study is to identify the measurements of the spleen in Sudanese population

1.3.2 Specific objectives

- To establish the standard splenic measurements in normal Sudanese adults by using ultrasound
- To measure splenic diameters
- To correlate these measurements to the height and weight of the body
- To identify the relation between spleen and age

1.4 Thesis outlines

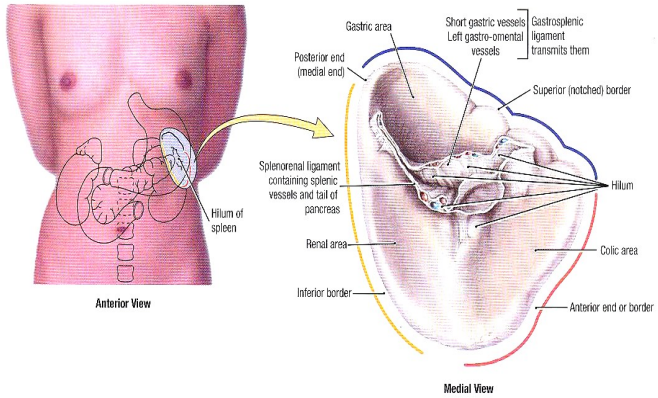
This thesis is concerned with the measurement of spleen in adults Sudanese individuals. It divided into the five chapters. Chapter one, which is an introduction, deals with theoretical frame work of the study. It presents the statement of the of the study problems, objectives of the study, it also provides an outlines of the thesis. Chapter two includes theoretical background material for thesis, and literature review (previous studies). Chapter three deals with material and method used to measure the spleen. Chapter fours deal with (results) data presentation. Chapter five discusses the data (discussion), analysis, and conclusion, recommendations for this thesis and suggestions for future work.

Chapter two

Literature review

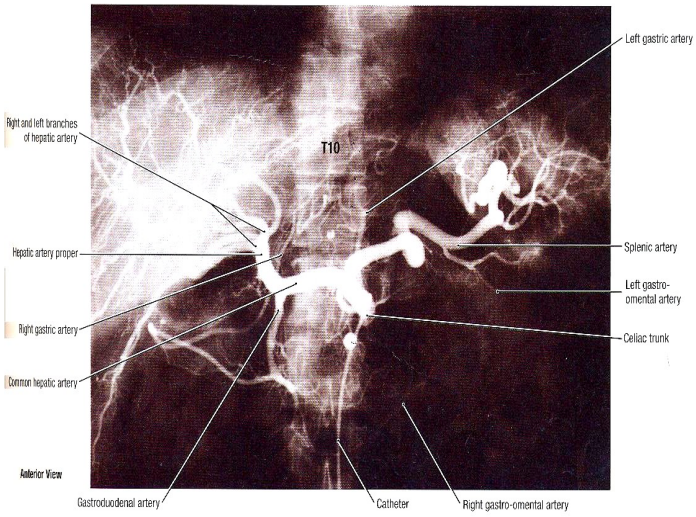
2.1 Anatomy of the spleen:

The spleen is an intra peritoneal organ located in the posterior portion of the upper quadrant of the abdomen. It lies parallel to the shaft of the tenth ribs. It is related to the diaphragm superiorly, laterally and posteriorly, to the stomach medially and anteriorly to the kidney inferiorly and medially to the tail of pancreas and splenic flexure medially. (Putz and Pabst, 1993)It's convex along its superior lateral border. And concave medially, the contour is generally smooth but contour lobulation can be seen as normal variant, the splenic artery enters and splenic vein leaves medially. At the hilum with the artery being the most posterior vessel. The normal adult spleen measuring 12-13 cm in length, 6-8 cm in anteroposterior dimension and 4-6 cm in transverse dimension. Figure 2.1. (Putz and Pabst, 1993)



Visceral surface of the spleen

Left: The surface anatomy of the spleen. *Right:* Note the impressions of structures in contact with the spleen.



Celiac arteriogram

Figure 2.1 shows the spleen surfaces.

Accessory spleen represented nodules of normal splenic tissue; the spleen develops from the fusion of separate masses arising from the left side of the dorsal mesogastrum. Failure of these masses to fuse may lead to the formation of on or more accessory spleen which are composed of reticuloendothelial tissue, receive there blood supply from the splenic artery and drain into the splenic vein. It's also referred to splenonucli occurring in about 10 to 30% of the population. Measuring approximately 1cm. it's generally solitary (88 percent). Most commonly are located in the splenic hilum, along splenic vessels, and in the vicinity of the tail of the pancreas.

Diagnosis of accessory spleen is essential because it can mimic a primary or secondary retroperitoneal neoplasm, or recurrent renal tumor. Following nephroectomy, following splenectomy hypertrophy of accessory spleen can produce recurrent symptoms in patient with haematologic disorders. (Warwick and Congman, 1973)

Splenic cleft Insignificant, causes contour lobulation. An irregular contour might cause the sonologist to suspect lesions within the spleen. However, homogeneous echo pattern and lack of enlargement should put that suspicion to rest. (Ardawi, Sukkar and El-Munshid, 2000)

The ectopic spleen has been given variety of names over the years including the aberrant spleen, floating spleen, splenic ptosis, and the wandering spleen. These all refer to the migration of the spleen from its normal left upper quadrant position the ectopic spleen may be congenital or related to trauma. Clinically, patient may have an asymptomatic abdominal or pelvic masses, splenic congestion may result from ligamentous or visceral pressure and cause mild abdominal discomfort. Severe abdominal pain and splenic rupture can occur with torsion and has result of splenic vein occlusion. A nuclear medicine study using technetium sulfide colloids "TCSC' can help confirm or abnormal splenic location in uncomplicated cases. Also color Doppler can help diagnosis by demonstrating the feeding vessels. The splenic artery is a largest branch of the celiac trunk. It's tortuous vessels that passes horizontally to the left behind the stomach and lesser sac, along the superior border of the pancreas and cross anteriorly to left supra renal gland and upper pole of the left kidney. The splenic artery divided into five or more branches when inter the hilum. The splenic vein is less tortuous than the splenic artery which begins as served tributaries from the hilum of the spleen. The splenic vein passes transversely to the right across the posterior abdominal wall and anterior to the splenic artery and posterior to the body and tail of the pancreas about 90% of blood passing through the spleen by

open circulation in which blood flows from arteries cord then to sinuses. The splenic pulp pressure reflected through the portal venous system. And the remaining 10% passes by the cord and sinuses through arteriovenous connection. The over all blood flows rate through the spleen is about 30ml/min. Figure (2-2, 2-3) (Ardawi, Sukkar and El-Munshid, 2000)

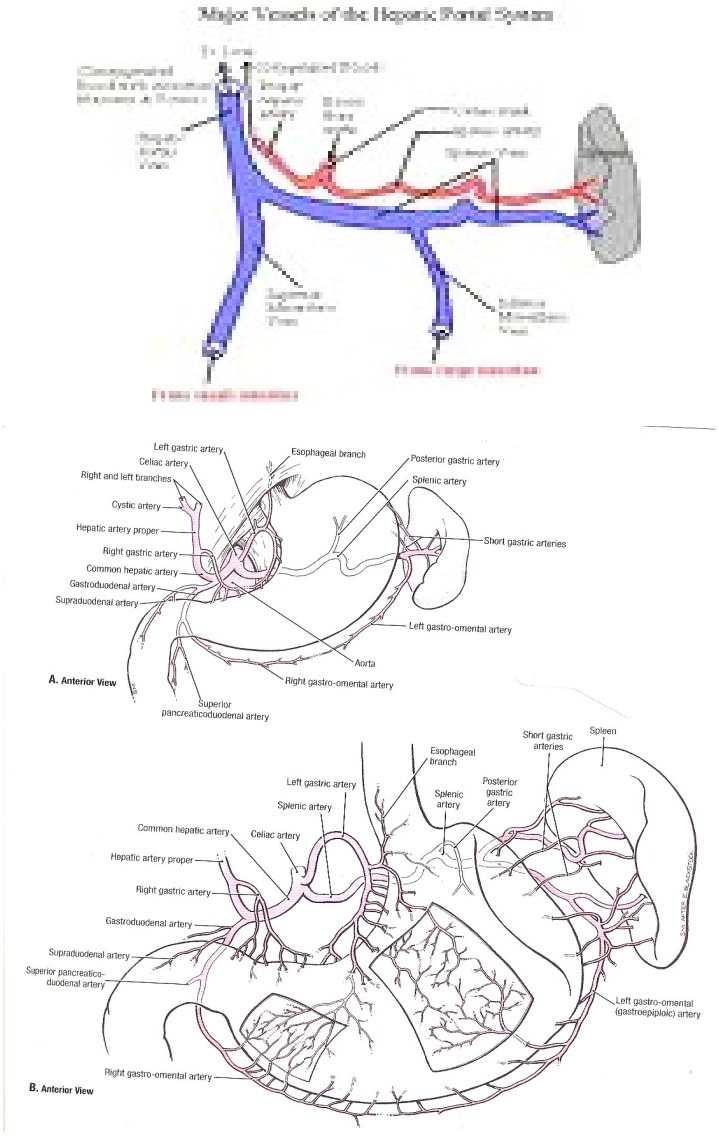


Figure 2.2 shows the blood supply of the spleen.

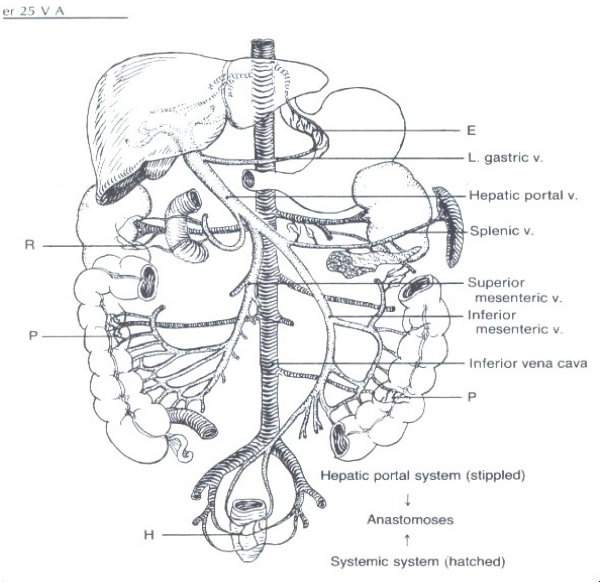


Figure 2.3 shows portal circulatory system

2.2 Relationship and Connection:

Stomach the spleen is an inner peritoneal organ located in the posterior portion of the left upper quadrant of the abdomen. It's related to:-

Laterally: the diaphragm, Posteriorly: the diaphragm, Superiorly: the diaphragm, Medially and anteriorly: the stomach, Inferiorly and medially: the left kidney and Medially: the tail of pancreas and splenic flexure. (Ernest et al 1996)

The spleen is connected to the greater curvature of the stomach by the gastrosplenic ligament, which contains the shunt gastric and gastromentas vessels and also it's connect to the left kidney by the splenorenal ligament which contains the splenic vessels both these ligaments are part of the greater omentum. **(Ardawi, Sukkar and El-Munshid, 2000) figure (2-4)**

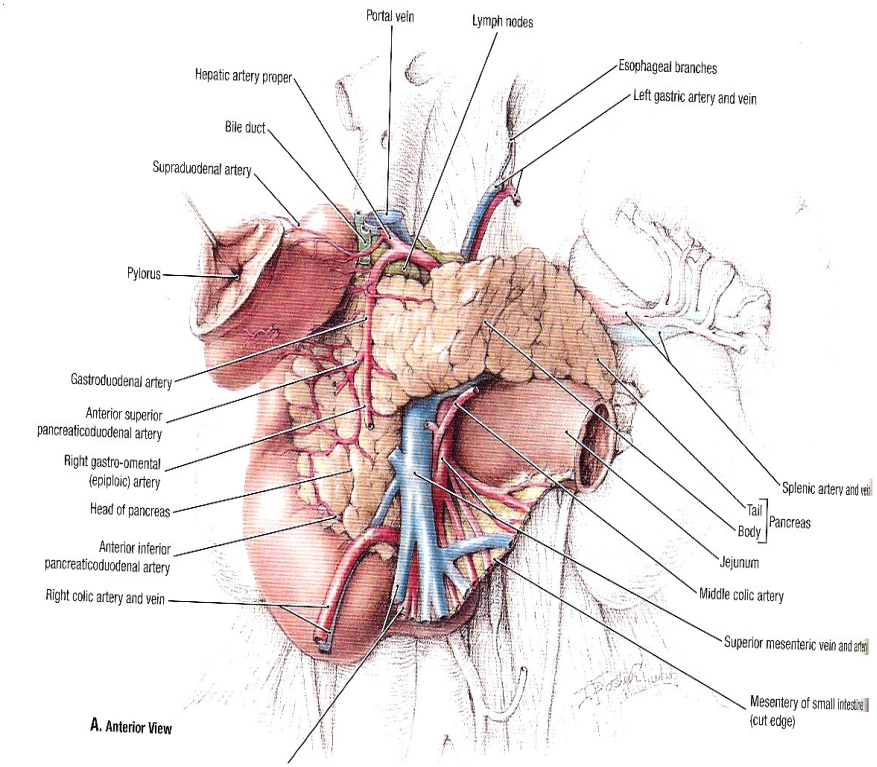


Figure 2.4 shows the relationship and connection of the spleen.

The spleen is the largest haemolymph organ in the body and the large part of the reticulo-endothelial tissue of the body is concentrated in it. Its general structure is like that of the haemolymph nodes, the organ being closely connected with the blood and with the lymphoid tissue: its peculiarities depend on its specialized vascular arrangements and on very large numbers of macrophages that it contains. The spleen is covered, except where it is attached, by the peritoneum: immediately beneath this is the capsule from whose inner surface project the trabeculae (or septa) that extend into the substance of the organ the trabculacaring the larger blood vessels branch and anastomose ,and are ultimately continuous with the branching reticular fibers and cells within the gland substance the space between the trabeculae is filled with lymphatic tissue the splenic pulp : the white pulp is distributed in roughly spherical or fusiform masses the red pulp occupies the remaining space . (Gartner and Haitt, 2001)

The capsule and trabeculae consist of dense connective tissue containing collagen and elastic fibers, fibrocytes and smooth muscle fibers: the thickest elastic fibers lie deeply in the capsule, and are most numerous in the trabeculae. The collagen fibers of the trabeculae continue directly into the reticular fibers are every where associated with typical reticular calls of the reticuloendothelial system. The white pulp consists of ordinary lymphoid tissue i.e. .a stroma of reticular fibers and reticular cells, with lymphocytes filling the interstices it is gathered into fusiform or cylindrical masses (formerly known as Malpighian corpuscles)that surround the smaller arteries or arterioles. Frequently a germinal centre can be seen, consisting of dividing, large type lymphocytes .In any section of the spleen, the center of many of the cylinders of white pulp may be seen to be occupied by the central arteriole; this is a valuable diagnostic feature to remember. The red pulp occupies the space between the large terminal venous sinuses that is not already occupied by the trabeculae and lymphoid cells of the white pulp : it was formerly called the splenic or [Billroth cords]. The red pulp is primarily a reticular mesh work honey-combed by venous sinuses. The non granular leucocytes are very numerous, including cells of all sizes. large, amoeboid phagocytic splenic cells (macrophages) are also present ,and frequently contain engulfed particles granular leucocytes and erythrocytes are also found in the meshes of the stroma . Giant cells are some times present. Of the cellular element in the red pulp there are there for two types belonging to the reticulo-endothelial series, namely, the reticular cells of the stoma and the macrophages. (Gartner and Haitt, 2001) Figure (2-5)

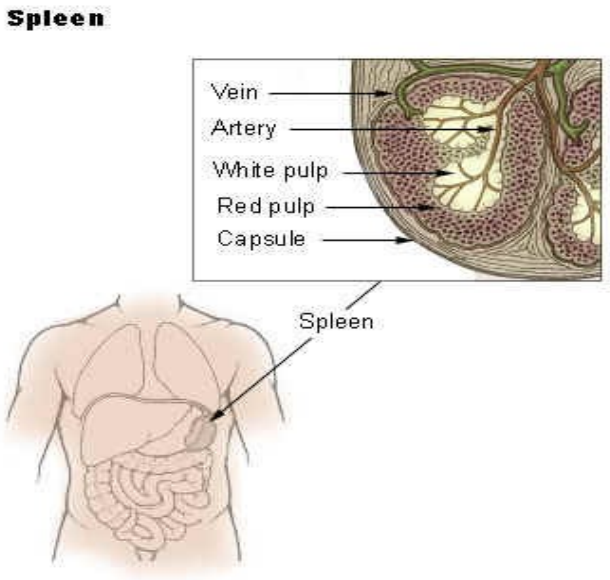


Figure 2.5 shows the red and white pulp and capsule of the spleen.

The structure of the spleen and the relation between the red and the white pulp depend on the arrangement of the blood vessels. The arteries enter at the hilum and are distributed at the first along the trabeculae, together with large viens: they are typical arteries of muscular type. The capsule has no separate blood supply. After much division the arteries leave the branches of trabeculae and the lymphoid tissues surrounds the arteries as a sheath almost up to the capillaries; in places the sheath is swollen into cylinders of white pulp. In a transverse section the artery is seen to be placed excentrically in capsule, the germinal center (if present) occupying the middle. As the swelling is often in the neighbourhood of branching of the artery, a section may show more than one blood vessels within a section of the white pulp. As a few capilarilies are given off to the white pulp and the artery then breaks up into a tuft of a straight arterioles, the penicillin. These arterioles pass into the red pulp dividing into capillaries that are invested in a special sheath of concentric lamellae or connective tissue infiltrated with lymphocytes and reticulo-endothelial cells: this is the ellipsoid. The arterial capillary leaves the ellipsoid, and is expanded into an ampula whose walls

blend with the pulp cells: the blood thus flows out into the splenic pulp. After wandering through the pulp, the blood from the venous sinuses, or too rapid a flow from the arterial side and also acts as a filtration bed for the blood.

The venous sinuses from an anatomizing network penetrating the whole of the red pulp, and draining away into the veins. The sinus has a wide lumen greatly with blood content of the spleen. It is lined actively phagocytic macrophages, supported externally by reticulum fibers. Reticulum fibers: there are small slit like openings through which blood cells pass freely. The lining cells are dilated in the regions occupied by their nuclei. The venous sinuses empty into the veins, which ultimately join to run in the trabeculae: the venous wall consists of endothelium directly touching the fibers of the trabeculae. The different views in relation to the circulation of the blood in the spleen result, in part, from the fact that there are considerable species differences. In the mouse, for example, which has been extensively used in investigations on the splenic circulation, there are no venous sinuses such as those described above. Much of the earlier work which claimed that the splenic circulation was "closed", that is that the arterial capillaries open directly into venous sinuses, was based on this animal. It must now be presumed that small veins rather than sinuses were observed. Although the subject is still controversial, there is increasing evidence, obtained from funnel-shaped openings. Figure 2-6. This "open" type of circulation provides, in the meshes of the red pulp, a mechanism for the separation of red cells from plasma. (Gartner and Haitt, 2001)

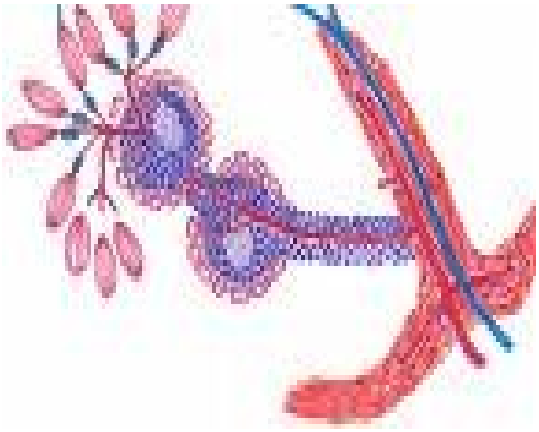


Figure 2.6 Union of arteries and veins

The actual pulp tissue of the spleen possesses no lymphatic, the tissue fluid passing directly into the venous sinuses. Lymphatic vessels are found in the largest trabeculae and in the capsule: near the hilum these anastomose and leave the organ in company with the blood vessels.). Most of the nerve fibers are non-myelinated. They are post-ganglionic sympathetic fibers derived from the celiac plexus, and enter at the hilum with the splenic artery and vein. The bundles accompany the arteries in all their ramifications, and ultimately form networks that provide bulbous endings in the smooth muscle of both arteries and trabeculae. The musculature of the splenic vein and its branches is similarly provided with non-myelinated vasomotor fibers. A few myelinated fibers, probably afferent in nature, are also present in the spleen. (Gartner and Haitt, 2001)

2.3 Physiology of the spleen:

The large amount of reticulo-endothelial tissue in the spleen is importance for the assimilation of the fragments of red blood corpuscles. These fragments are phagocytosed by the macrophages and the iron moiety of the haemoglobin is freed from the stroma of the destroyed red cell and stored as haemosiderin in the reticulo-endothelial cells until it is required by the body for the resynthesis of fresh haemoglobin. Many pyroninophil cells (probably plasma cells) are found in the red pulp of the spleen and hence this organ in

conjunction with the lymph nodes and thymus is an important site of anti-body manufacture. Because of its large content of lymphoid tissue, the spleen must be regarded as an important centre of lymphopoesis, the lymphocytes and monocytes being produced in the white pulp and then migrating to the blood stream via the red pulp. In some species other types of blood cell are produced in the spleen, e.g. granulocytes and the platelets. This is not so in man. Again, in other species it has been reported that the spleen may act as a reservoir for red blood corpuscles; this may be only of secondary importance in humans. (Blewett and Rackom, 1996)

The spleen is a part of reticuloendothelial system and it's not essential for life. The spleen is responsible for the Production of red blood cells. As well as digestion of the foreign substances by reticuloendothelial macrophagus inside the spleen. The spleen can also destruct the abnormal rigid red cell by pitting and culling the abnormal cell shape, and play great rate of life spar of red blood cells at 120 days (Blewett and Rackom, 1996)

2.4 Pathology of the spleen:

2.4.1 Splenomegaly

Splenomegaly is defined by increased splenic dimensions and volume. Spleen longitudinal and transverse diameters averaged over 13 cm, respectively over 5 cm are considered splenomegaly. Besides measuring the spleen diameters, there have been studies that used the calculus of the maximum area of the spleen in order to classify the splenomegaly using ultrasound. In a study describing portal hypertension in cirrhotic patients Gaiani defined a normal sized spleen by an area of <45 cm2, a moderately enlarged spleen by 45-65 cm2, and a marked splenomegaly by an area of >65 cm2. Splenomegaly usually occurs associated with other organs pathology and sometimes it can be the debut sign of a disease onset. Mild-to-moderate splenomegaly (weight < 1000g) are usually corelated with

portal hypertension or with infections, while severe splenomegaly (weight >1000 g) are common in hematological diseases, especially chronic leukemia and myelofibrosis.

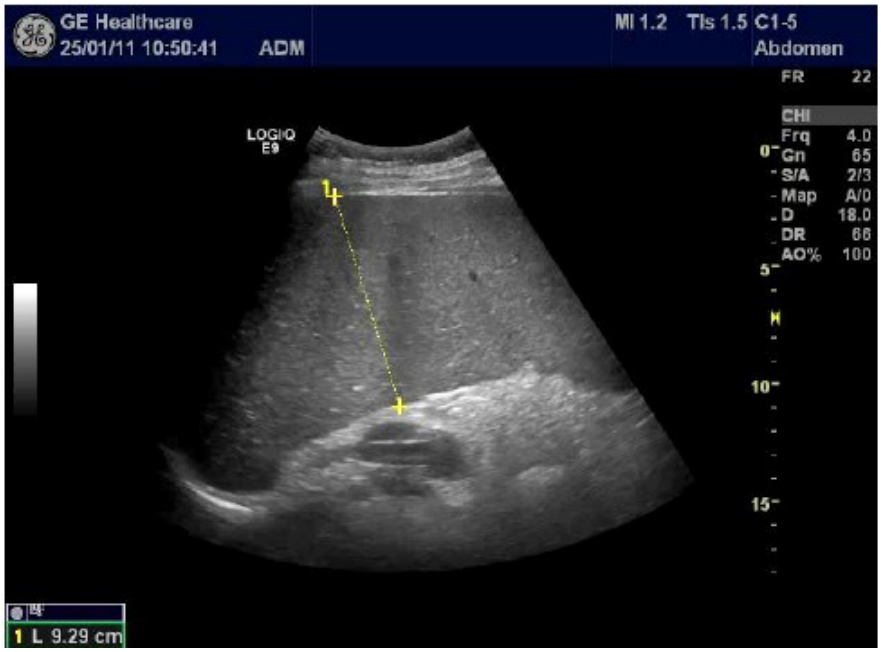


Figure 2.7 massive splenomegaly

2.4.2 Splenic abscesses :

It is important to know that in the course of infectious pathology of the spleen, we can meet both types of spleen injury, focal and diffuse. Usually a homogenous, mild to moderate splenomegaly is found. In case of severe infections of other organs that disseminate in the spleen (endocarditis, acute supra-infected pancreatitis, postoperative infection complications) occurring mainly in immunosuppressed patients, splenic abscesses can be found. The frequency of splenic abscesses is low, cited in literature as 0.14-0.17% cases discovered at autopsy. A splenic abscess has a variable ultrasound appearance, hypo or hyperechoic nodule. Large abscesses, usually unique, rarely multiple, are characteristic for microbial infection, and a wedge-shaped abscess may typically be seen in patients with infective endocarditis

and associated septic embolism. Usually they appear with well-defined contour but with an irregular wall, multilocular, with inhomogeneous, complex echostructure, most often hypoechoic. It may present debris, septa or gas (characteristic for anaerobic infections) and posterior enhancement, and usually are avascular on colour Doppler ultrasound. Splenic phlegmons differentiate by abscesses with a poorly defined border compared with the rest of the splenic parenchyma . Fungal abscesses, that are present in HIV and other immunosuppressive disorders are caused by Mycobacterium tuberculosis, atypical mycobacteria, Pneumocystis carinii and candidiasis and shows a characteristic appearance of multiple small lesions with hyperechoic center and hypoechoic rim, the typical “bull’s eye” appearance. The use of a high-frequency linear probe will enhance the detection of .micro-abscesses

Sometimes the ultrasound cannot distinguish between splenic abscesses and .tumours only using standard and Doppler examination

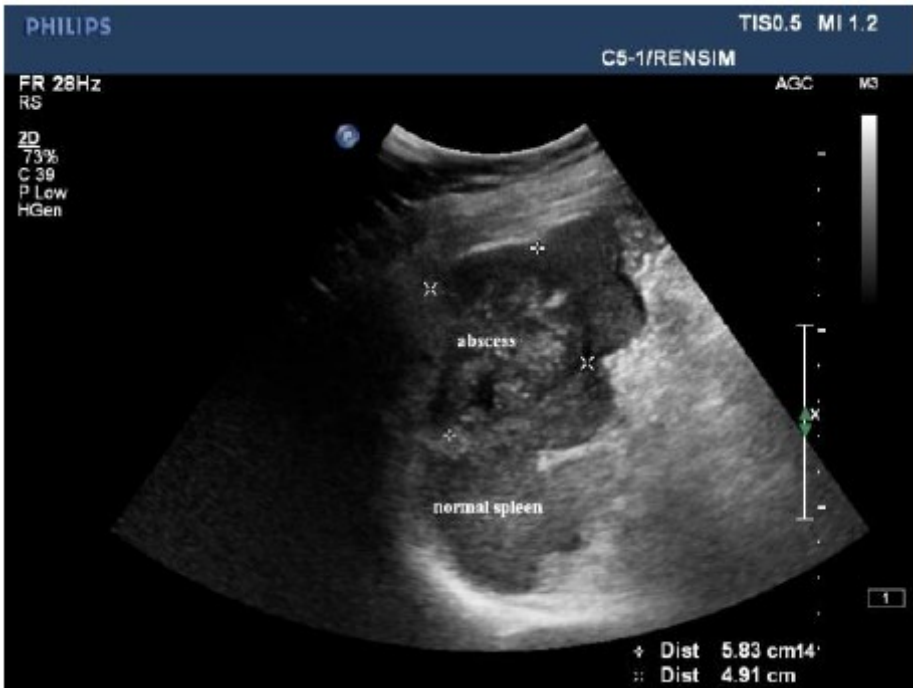


Figure 2.8 splenic abscess

Splenic hydatid cyst 2.4.3

The frequency of splenic hydatid cyst is very rare (less than 2% of all hidatydosis localizations) and generally appears by haematogenous dissemination of a hepatic hydatid cyst and not as a primary localization of the disease. Therefore, when a splenic hydatid cyst is suspected, also another .(possible localization should be sought (peritoneal, hepatic

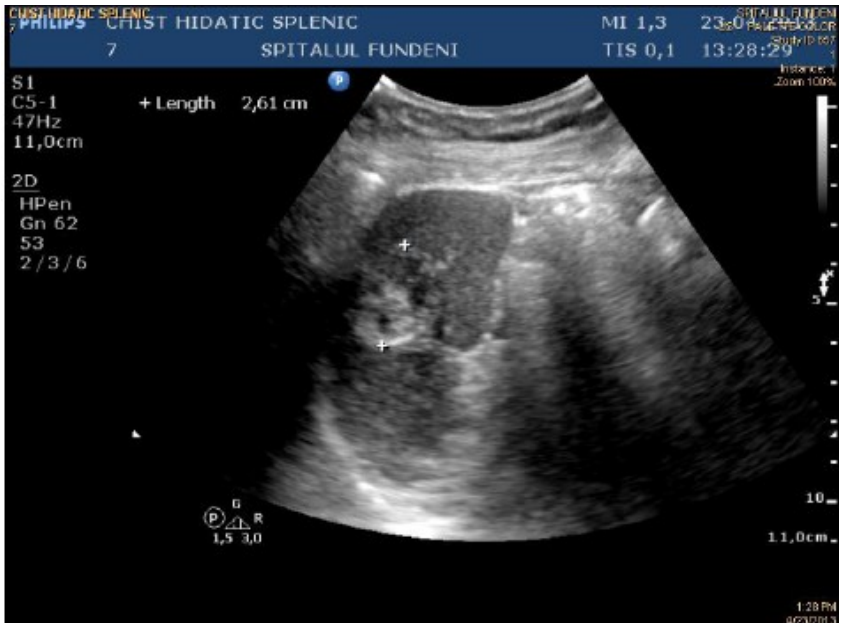


Figure 2.9 splenic hydatid cyst

Focal splenic lesions 2.4.4

It is a known fact that the focal splenic pathology is rare. The most recently published study, June 2010 by Neesse et al., extended over 6 years (between 2004 and 2009), with a total of 50,000 abdominal ultrasounds, only 279 (less than 0.6%) focal splenic lesions where reported. The 279 patients (≈ 0.6%) with focal splenic lesions were diagnosed on B-mode ultrasound as follows: 72 cases (25.8%) splenic infarction, 57 cases (20%) Non-Hodgkin's Lymphoma, 51 cases (18.4%) splenic incidentaloma (incidentaloma defined as incidentally detected focal splenic lesion, without patient's history of tumour, infection or trauma, lesion stable on follow-up examination), 35 cases (12.6%) splenic rupture, 7 cases (2.5%) splenic abscess, 25 cases (9,1%) miscellaneous splenic lesions (i.e., hemangioma, hamartoma), and 32

cases (11.5%) splenic metastases of solid tumours. Focal splenic lesions can be single or multiple, benign or malignant, and can occur on normal or enlarged spleen. Ultrasound is a proven procedure for detecting focal splenic lesions, but their characterization is difficult, the ultrasound pattern often being uncharacteristic for different pathologies. The low lesions number and the difficulty to obtaining a histological document, makes their analysis harder. Their diagnosis is often based only on CE-CT and/or CE-MRI and clinical follow-up, the spleen biopsy not being an option due to the increased .bleeding risk

2.4.5 Benign splenic lesions

2.4.5.1 Splenic cystic lesions

Splenic cystic lesions can be congenital (true epidermoid or false posttraumatic cysts) – characterized by the presence of an inner endothelial lining or posttraumatic cysts (pseudocysts) which do not have cellular lining. Congenital cysts include lymphangiomas and, very rarely, cystic hemangiomas. Ultrasound cannot make reliable differentiation between true cysts and pseudocysts. The cysts usually appear as transonic areas, well delineated, with sharp contour and posterior enhancement. They can have calcified walls and may contain cholesterol crystals or debris that appears as low-level echoes inside. When they bleed, the cysts appear partially or totally filled with fine, mobile echoes when the patient’s position is changed, or their content appears highly inhomogeneous, difficult to be differentiated from a tumour lesion. In addition to splenic cysts there is a spectrum of lesions that have a predominantly cystic appearance at imaging. Cystic splenic masses may be inflammatory (abscesses, hydatid cyst), vascular (infarction, peliosis), posttraumatic (hematoma, false cyst), or tumoral .((benign: hemangioma, lymphangioma, or malignant: lymphoma, metastasis

Parenchymal calcifications are quite common, non-specific, incidental findings, of different sizes. They could be secondary to splenic infarction, .granulomas, tuberculosis or metastases

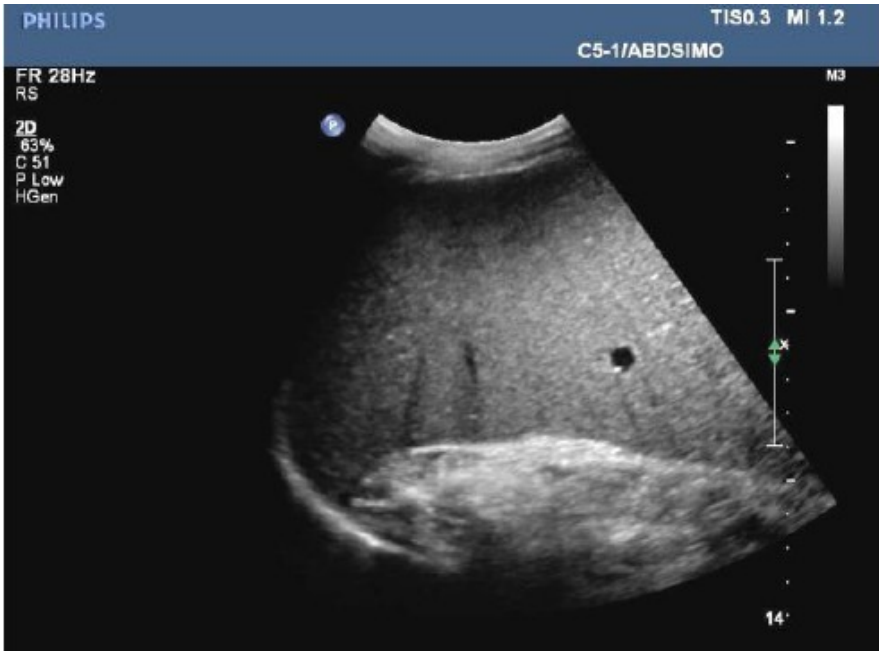


Figure 2.10 simple splenic cyst

2.4.5.2 Solid splenic lesions

The solid splenic lesions have a different pattern in B-mode ultrasound, hyper-, iso- or hypo-echoic than the surrounding normal tissue. Benign primary tumours of spleen are rare and include hamartoma, hemangioma and .cystic lymphangioma

Splenic hemangiomas have been reported in up to 14% of autopsy studies. They can be found isolated or may occur in the Klippel-Trenaunay-Weber syndrome. There is no ultrasound specific pattern for hemangiomas. The majority are hyperechoic homogeneous lesions, with precise contour, measuring less than 2 cm. Larger, cavernous hemangiomas (> 3 cm) may appear iso- to hypoechoic with cystic changes or calcifications. They show a greater enhancement degree, with rapid or slow opacification. Filling-in can

be centripetal or diffuse. Contrast enhancement is very pronounced and prolonged, with a possible shadowing in larger hemangiomas.

In a minority of cases hemangiomas are quickly enhanced with a centripetal direction of enhancement On ultrasound examination, hamartoma has both solid and cystic components, and generally appears hyperechoic. Ultrasonographic appearance of lymphangioma is as a multicystic mass replacing splenic parenchyma. Usually, benign splenic lesions are mostly hyperechoic. Lesions that do not wash out or only a little can be regarded as benign. The most common causes are previous granulomatous infections, as histoplasmosis, tuberculosis or sarcoidosis and we encountered similar aspects in LES cases, much less studied or quoted in the literature. Usually multiple hyperechoic small lesions can be seen diffusely throughout the spleen and can be associated with calcifications in the splenic artery. But in active, milliary tuberculosis multiple small hypoechoic splenic lesions or small cystic lesions can be seen, representing tuberculous abscesses. On CEUS examintation, the lesions appear hypoechoic, with progressive hypoenhacement in parenchymal phase.

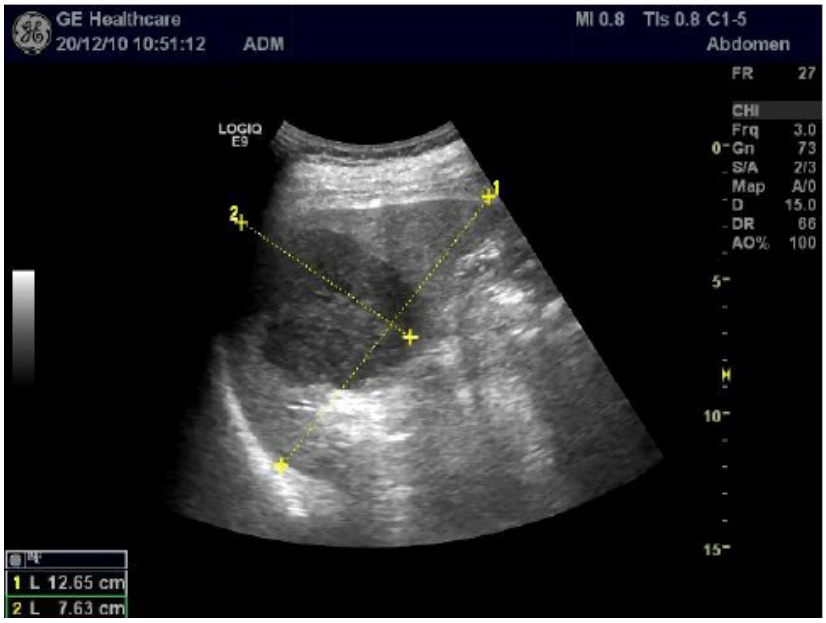


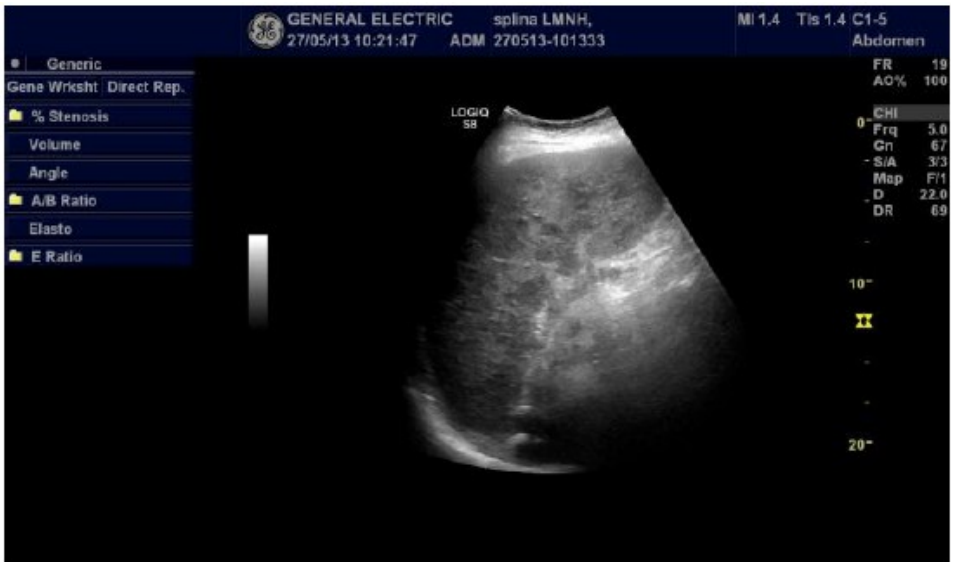
Figure 2.11 splenic granuloma

Malignant splenic lesions 2.4.6

Lymphomas 2.4.6.1

Splenic involvement in Hodgkin or Non-Hodgkin disease is the most common cause of focal splenic lesions. The detection of splenic involvement is very important for clinicians, as it might change the therapeutic approach. Different studies show that the spleen is involved in less than 25% of the cases. Therefore, Görg published a retrospective study in 2009 and found that in 41 out of 250 cases with a variety of lymphatic diseases had involvement of the spleen, and another study shows the spleen involvement in 101 cases out of 680. The data on CEUS contribution improving the splenic lesions detection in lymphomas is contradictory, Görg showing in a 250 patients study that CEUS examination is not superior to B-mode imaging in splenic focal lesions detection, while Picardi found in a study with 100 patients with Hodgkin disease that CEUS was the most sensitive imaging modality to detect splenic involvement and was superior to CT and FDG PET. On ultrasound, there are 4 types of splenic involvement in lymphomas: diffuse, with small focal lesions below 1cm in size, with large focal lesions and bulky disease. The diffuse involvement and the small focal lesions are frequently in LH and in low-differentiated lymphomas. This is why the tiny lesions can be best detected by using high frequency linear .probes

The focal splenic lesions are described as hypoechoic and mostly hypo-enhancing on CEUS, a small number being iso-enhancing during the arterial phase, but washing out in parenchymal phase. The small lesions in NHL might be overlooked even on CEUS as its microvasculature does not differ from the non-infiltrated tissue. In other cases the lesions are hypo-vascularized even during the wash in phase and may completely wash out .over time



.Figure 2.12 Infiltrated **spleen in Non-Hodgkin's Lymphoma**

Leukemias 2.4.6.2

.The splenic involvement in leukemias can be homogeneous diffuse or focal

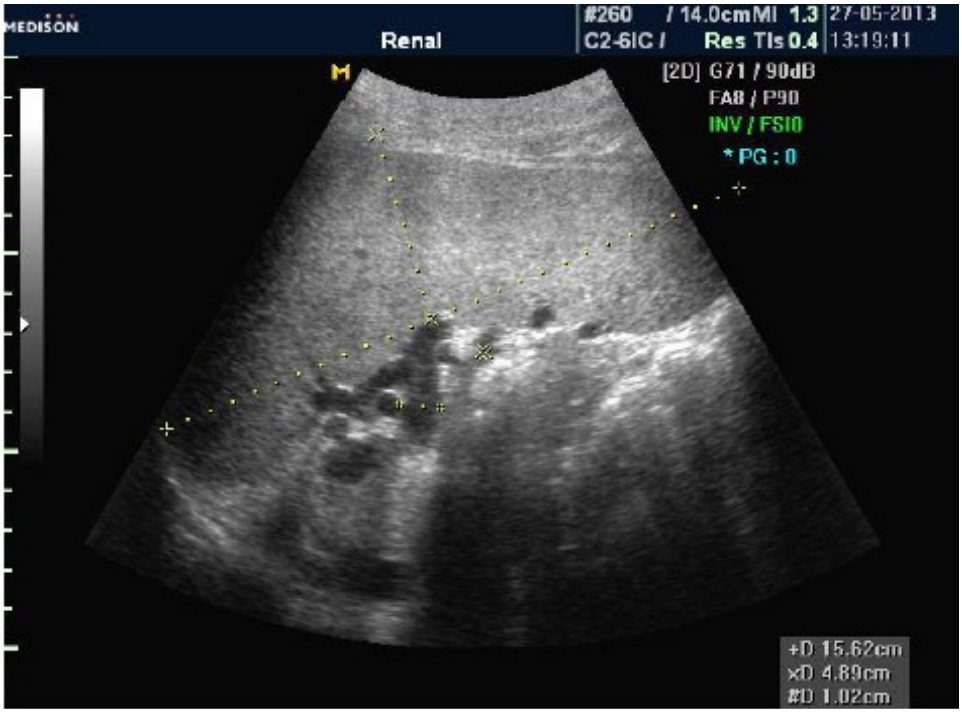


Figure 2.13 Diffuse homogeneous splenomegalia in patient with acute .leukemia

Metastases 2.4.6.3

Splenic metastases are mostly seen in far advanced malignant diseases, except in patients with testicular germ cell tumors, and small cell lung cancer in which the spleen might be the only abdominal organ showing a metastatic spread. Mostly splenic metastases have a hypoechoic appearance. But echogenicity alone is not a reliable sign for the lesion's character. Patients with testicular germ cell tumours (4 from 9 patients had splenic metastasis), malignant melanoma (9 from 27 had spleen metastasis), and small cell lung cancer (8 out of 106 had spleen metastasis) have the highest frequency of splenic involvement. In the majority of cases a biopsy is not needed, clincal context being clear, its proof or non-proof will not change the clinical management of these patients. Metastases are mostly hypoechoic .with no or only little tumour vasculature on colour Doppler imaging

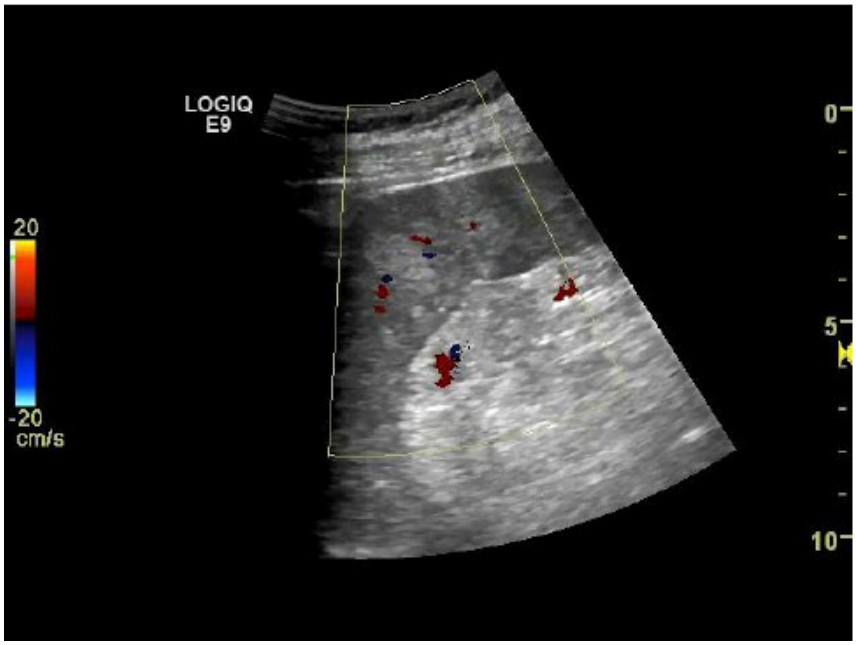


Figure 2.14 Splenic metastases in known hepatocellular carcinoma

2.4.7 Vascular disease

2.4.7.1 Infarction of the spleen

is considered the most common cause of focal splenic lesions. The study published by Neesse et al. reported a frequency of 25.8% splenic infarctions detected from all focal splenic lesions. They are caused by the embolic occlusion of the branches of the splenic artery or even of the splenic arterial trunk (thromboembolic diseases, septic distance embolism) or local thrombosis in cases of acute pancreatitis, hematological disorders (sickle cell anemia, leukemia, lymphomatous disorders) or other diseases (sarcoidosis, systemic lupus erythematosus, polyarteritis nodosa).

The ultrasound aspect differs according to the time elapsed from the initial moment (the occurrence of the infarction) and the sizes of the infarction area. Often, in the first 24 hours the splenic infarction, especially the small sized one, can escape the ultrasound examination, appearing only as an unhomogenous area, ill-defined in the splenic parenchima. After 24 hours the splenic infarction appears hypoechoic, with borders not always well delineated, and dimensions generally underestimated.

In time, due to fibrosis, splenic infarction appears hyperechoic, triangular shaped (wedge-shape) with the base always orientated to the splenic capsule and with capsular retraction. Sometimes the appearance can be nodular. Due to fibrosis, their dimensions decrease over time. They can keep the triangular aspect or they can produce linear scars, form calcifications or they can turn into pseudocysts. Sometimes they can mimic a tumoral mass. On colour Doppler examination infarction areas do not present vascular signals.

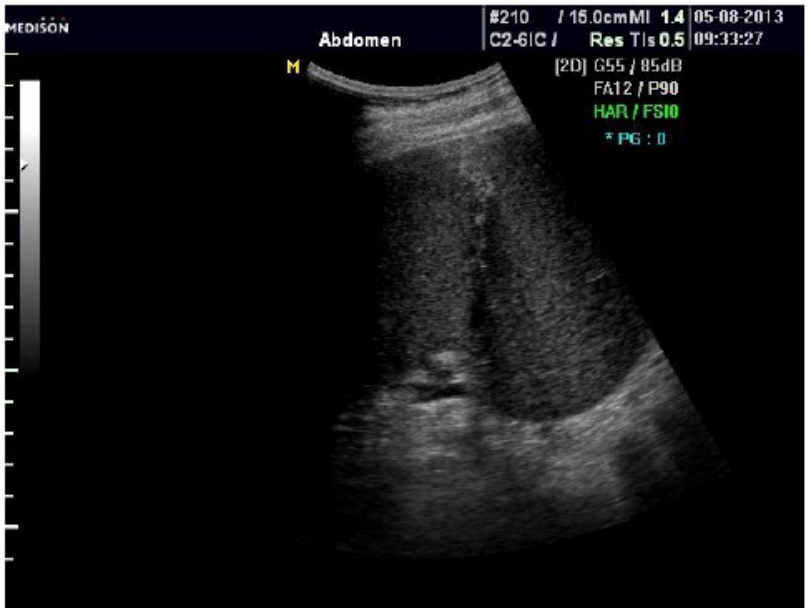


Figure 2.15 splenic infarction

Splenic vein thrombosis 2.4.7.2

is a common complication seen in patients with acute pancreatitis or sepsis. We also found splenic vein thrombosis in patients with hematologic malignancies. Recent partial or total thrombosis, in the first days appears hypoechoic and is quite difficult to diagnose it on 2D or colour Doppler .ultrasound examination

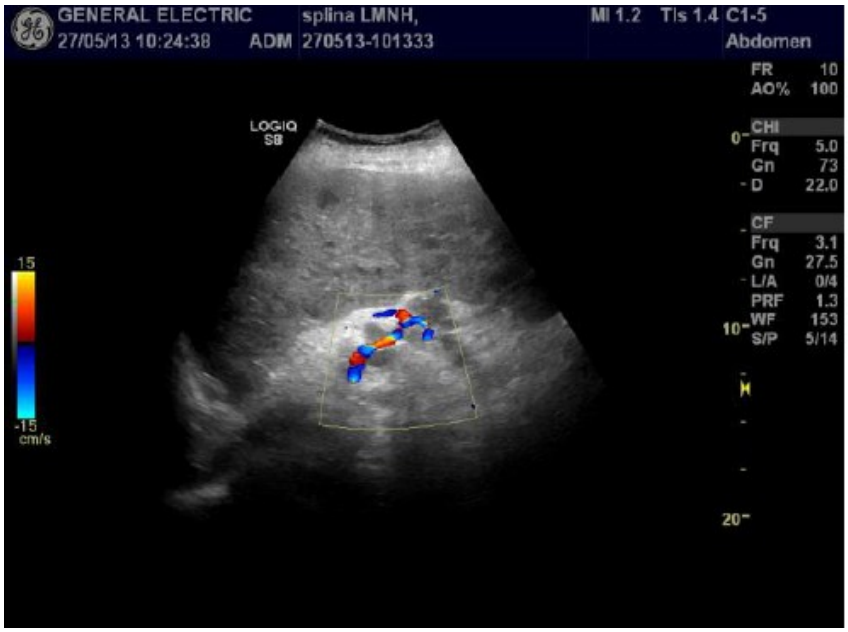


Figure 2.16 splenic vein thromboses

2.4.8 Traumatic spleen

The spleen is often affected in abdominal trauma, due to its fragility. In major trauma ultrasound has a major role in detecting life threatening complications due to the FAST protocol (Focused Assessment of Sonography in Trauma) commonly used today to detect or exclude the presence of free fluid in the pericardium or in the abdomen in cases of trauma.

Ultrasound is a fast technique, portable and proved that it can easily be integrated into the resuscitation of the patients with trauma without delay of the therapeutic measures. Routine abdominal ultrasound can be also performed at the bedside in trauma centers. Studies show that the use of screening ultrasound in the follow-up of traumatic patients can improve clinical decision making for the use of the emergency laparotomy. On the other side, in major trauma with clinically stable patients, contrast enhanced CT remains the method of choice, with the advantage of the entire examination of the abdominal cavity and the possibility of standardization. But its efficiency decreases in minor trauma, contusions, lacerations or oedemas, which can be ignored or overestimated on CT scan. But B-mode ultrasound has a poor detection rate in blunt splenic injury, especially in imaging minor tissue damage, therefore is not recommended in the assessment of stable trauma patients. In these situations CEUS examination allows a better evaluation of the blunt abdominal trauma, especially in children and has the advantage that it is not irradiant or toxic, and it may be used for cases treated conservatively to avoid unnecessary CE-CT examinations. The ultrasound exam can diagnose a series of traumatic lesions as hematomas, contusions, lacerations or capsular effraction. Frequently these lesions are combined, often associating traumatic lesions of other organs. We must note the traumatic context of these lesions, but the rare possibility of the spontaneous spleen rupture should not be neglected,

usually arising on a pathological spleen. The sonographic appearance of hematoma depends on the amount of splenic tissue damaged and the delay time between the trauma and the first US examination. Immediately post-traumatic, the hematoma has a hypoechoic appearance and can be easily differentiated from splenic parenchyma. But, within the first few hours, hematoma develops a nearly isoechoic appearance with inhomogenous areas inside and an intra-splenal hemorrhage might not be visible at all. Depending on the volume of hemorrhage the spleen may be enlarged causing local pain. Over the following days, hematoma becomes slightly hypo-echoic, due to re-liquefaction. Finally, a hematoma can be differentiated as clearly hypoechoic areas. Because the splenic capsule is very thin, we can receive important information about the integrity of the capsule analyzing the shape of the fluid collection. If the collection is crescent and conforms to the contour of the spleen, we can presume that hematoma is subcapsular. If the collection is irregularly shaped, perisplenic .hematoma is suggested

During the recovery process, hematoma sizes gradually decrease and its echostructure may become hyperechoic due to the fibrosis process. When the spleen recovers, it may contain small irregular foci or the parenchyma may have a homogeneous B-mode appearance again. Sometimes at a later scan, pseudocysts can be seen at the site of the hematoma. CEUS is the most sensitive US technique to prove minor defects during the follow up after splenic trauma (Figure 49, Figure 50). Blunt parenchymal trauma may cause other various injuries, such as lacerations, contusions, capsule rupture and vessel tears of different severities. B-mode ultrasound shows minimal or absent modifications of the splenic parenchyma. Most often an inhomogenous area in the parenchyma is seen or a hypoechoic area with ill-defined irregular borders; this, in time, can evolve to resolution or it can .(form a collection (hematoma

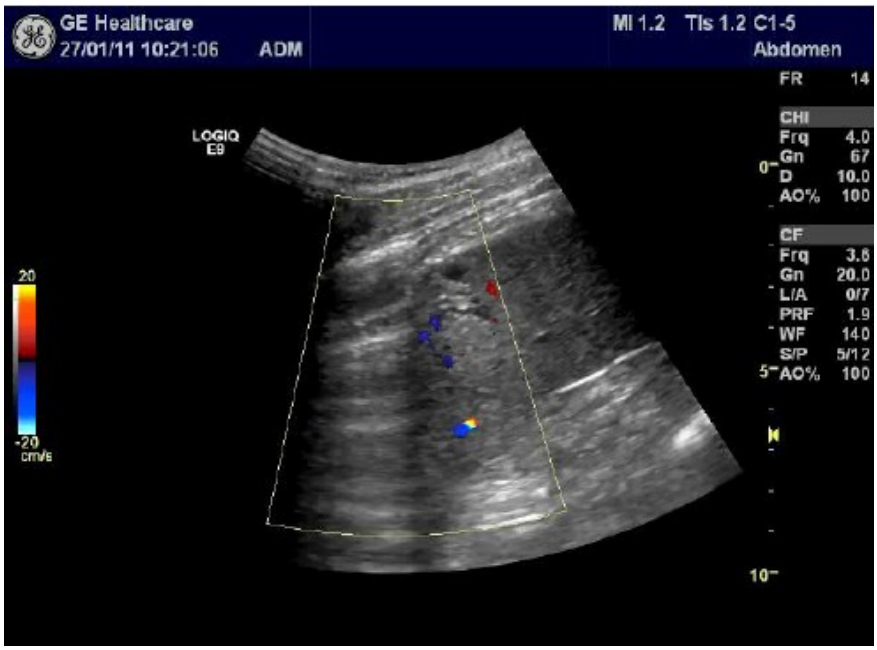


Figure 2.17 Posttraumatic follow-up. Inhomogeneous "wedge-shaped", .ill-defined subcapsular area with small cysts inside

2.5 Previous studies:

Audrey L 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.

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.

Rodrigues, A. J., et al Thirty-two morphologically normal spleens from adult corpses were excised and immersed into a graduated water tank and the water volume displaced was considered as the actual spleen volume. after that, the splenic maximal height, width, and breadth were determined by a pachimeter. all the reference points were marked with a metal clip. utilizing the metal clip references ultrasound maximal height, width, and breadth were determined. it was assumed that the ultrasound spleen volume was the result of the multiplication of the three ultrasonographic measurements previously obtained.

There was no significant difference between pachimeter and ultrasound determinations. The mean actual spleen volume was 147.5 cm3 (SD = 81.46). The mean ultrasound spleen volume was 283.8 cm3 (SD = 168.27). A roughly linear correlation between actual spleen volume (y) and ultrasound spleen volume (x) was found, y = 14.23 + 0.469 × (R2 = 0.94, $P < 0.01$).

Chapter three

Material and Method

3.1 Materials

3.1.1 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 were excluded

Machine used 3.1.2

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.

3.2 Method

3.2.1 Technique used:

Tran 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 will be 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 Data collection

Data were collected with special data collection sheet encompass patient demographic data and ultrasound findings.

Ethical issue

- Permission from ultrasound department was obtained.
- No patient identification data or detail published.
- Safe uses of ultrasound.

Chapter Four

Results

The following tables and figures show summary of the results including distribution of gender, age, body weight, body and height of the sample of study. They also include frequency of distribution of width, length, thickness and weight of the spleen and the association of these variations with male and female.

Table (4.1): study group Gender distribution

Gender	No of cases	Percentage
Male	29	58
Female	21	42
Total	50	100

Figure (4.1): study group gender

	N	Minimum	Maximum	Mean	Std. Deviation
AGE	50	16	73	36.12	13.297
Weight	50	46.0	98.0	67.630	11.8429
Height	50	1.5	1.9	1.669	.0859
BMI	50	16.9	32.0	24.243	3.5990

Table (4.2): Descriptive Statistics of patient body characteristics (age, height, BMI, and weight).

Table (4.3): Descriptive Statistics of splenic characteristics (length, Width, Thickness and weight).

	N	Minimum	Maximum	Mean	Std. Deviation
Spleen Weight	50	96.0	231.0	150.960	35.7520
Spleen Width	50	4.8	10.0	7.944	1.0393
Spleen Length	50	7.1	11.2	9.324	.8682
Spleen Thickness	50	3.3	6.4	4.600	.6581

Figure (4.2): Shows relationship between subject weight and splenic weight.

Table (4.4): Shows correlation between splenic measurements and body weight

		Weight	Spleen Width	Spleen Length	Spleen Thickness	Spleen Weight
Weight	Pearson Correlation	1	-.057	.216	.095	.371**
	Sig. (2-tailed)		.692	.131	.511	.008
	N	50	50	50	50	50
Spleen Width	Pearson Correlation	-.057	1	.364**	.296*	.212
	Sig. (2-tailed)	.692		.009	.037	.140
	N	50	50	50	50	50
Spleen Length	Pearson Correlation	.216	.364**	1	.325*	.520**
	Sig. (2-tailed)	.131	.009		.021	.000
	N	50	50	50	50	50
Spleen Thickness	Pearson Correlation	.095	.296*	.325*	1	.396**
	Sig. (2-tailed)	.511	.037	.021		.004
	N	50	50	50	50	50
Spleen Weight	Pearson Correlation	.371**	.212	.520**	.396**	1
	Sig. (2-tailed)	.008	.140	.000	.004	
	N	50	50	50	50	50

Table(4.5): Correlation between splenic length and body weight and height

		Weight	Height	Spleen Length
Weight	Pearson Correlation	1	.529**	.216
	Sig. (2-tailed)		.000	.131
	N	50	50	50
Height	Pearson Correlation	.529**	1	.376**
	Sig. (2-tailed)	.000		.007
	N	50	50	50
Spleen Length	Pearson Correlation	.216	.376**	1
	Sig. (2-tailed)	.131	.007	
	N	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

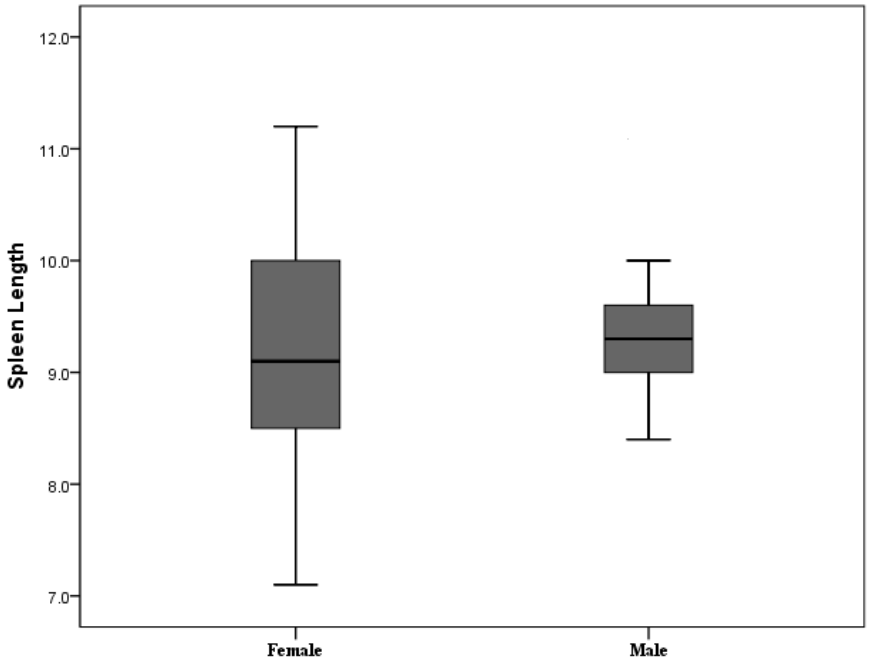


Figure (4.3): Shows splenic length in different gender.

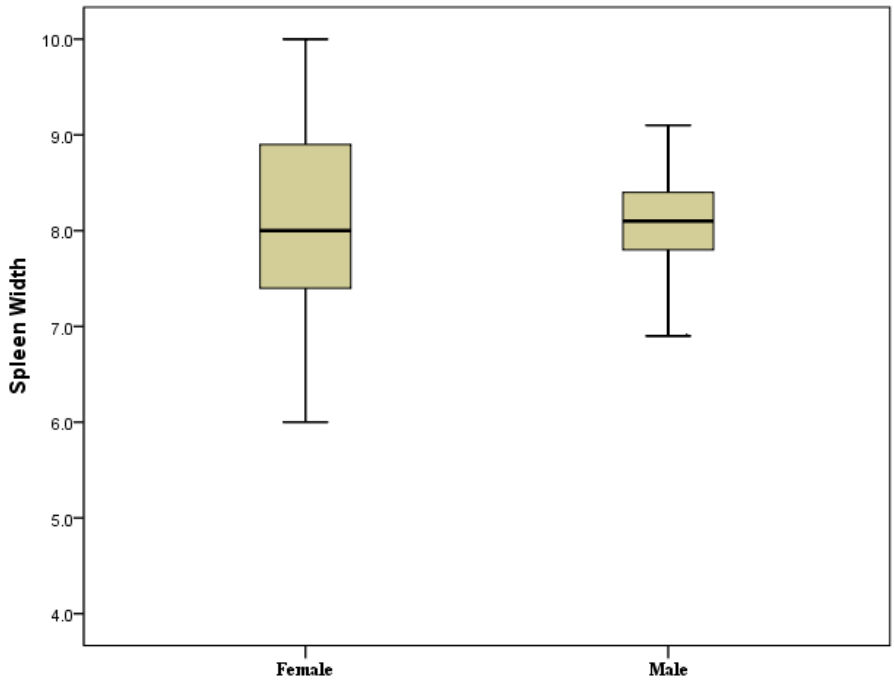


Figure (4.4): Shows splenic width in different gender.

Chapter Five

5.1. Discussion:

This is an experimental study designed to determine the application of ultrasound for estimation of splenic weight, length and height of Sudanese adult patients.

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 (Konus O, 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.

Splenic length measured by ultrasonography provides an objective and reliable way to assess spleen size. Measurement of splenic length by ultrasound is reliable within and between technicians. Measurement of splenic width, however, is less reliable, as evidenced by only moderate intra- and inter-rater reliability. This finding supports the historical assessment of splenomegaly based on spleen length.

The splenic weight was extracted from length, thickness and width of spleen which described the spatial relationship between spleen readings and body height. The mean of splenic width, length and weight were (7.9 ±1) cm, 9.3 ±.86) cm and (151.9 ± 36.1) gm respectively. These measurements are consistent with previous normal values reported for the general adult population (Capaccioli L et al, 2000).

Sex differences in normal splenic length and width were found to be significant. As there were moderate correlations between spleen size and both height and weight, we would expect a larger average spleen size in men on the basis of their larger body size. The fact that these significant differences persisted when controlling for height and weight independently may suggest that spleen size varies more as a product of these two variables, or that there are additional factors involved.

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.

5.2. Conclusion:

This study defines normative values for spleen size for Sudanese population. The variation in normal splenic dimensions in this study group underlies the diversity of body types observed. Setting an absolute cut off point for defining splenomegaly may be difficult because of the wide range of normal values encountered. This dataset may prove useful in future research to identify the natural course of splenic enlargement followed by normalization of influencing factors.

5.3. Recommendations:

- The operator should update their knowledge about technique used and any information regarding ultrasound measurements.
- Assessment of splenic size by physical examination is relatively insensitive, so when clinical decisions about return to play need to be made, ultrasonography is the most frequent diagnostic tool used.
- It is helpful to have such a large series of measurements in healthy individuals, taking into consideration sex and race

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