Sudan University of Science and Technology

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Determination of Normal Splenic Dimensions on Computed tomography Images in Sudanese Population

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A Research submitted for partial Fulfillment of the requirements of M.Sc. in Diagnostic Radiography

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الآيــة

قــال تــعــالى:

{ إِقْـرَأْ بِـاسْمِ رَبِّـكَ الَّـذِي خَـلَقَ (1) خَـلَقَ اَلْـإِنَـسَـانَ مِـنْ عَـلَقٍ (2)

إِقْـرَأْ وَرَبُّـكَ الْـأَكْـرَمُ (3) الَّـذِي عَـلَّمَ بِـالْـقَـلَمِ (4) عَـلَّمَ الْـإِنـسَـانَ مَـا لَـمْ

يَـعْـلَـمْ (5) }

سورة العلق الأيات (1-5)

صدق الله العظيم

Abstract:

Spleen is enlarged in a variety of clinical conditions including infectious, infiltrative, immunologic and malignant states. Evaluation of splenic size is important in every physical examination of the abdomen by a physician. Determination of its size by palpation can be extremely inaccurate because spleen is never palpable till it is enlarged 2 to 3 times its own size. The accurate diagnosis of splenic enlargement is a matter of considerable importance as it is a useful guide for arriving at a diagnosis of the disease. It is therefore of utmost importance to resort to a mechanism that will give us an accurate estimation of the size of spleen.

The aim of this work was to examine variations in normal splenic size in relation to age, gender and body habitus in Sudanese population and compare it with the published data.

A number of CT scans of 50 adult patients (male and female) aged between 18 – 70 years, having no splenic disorders, were collected from department of radiology at Almodaris Medical Center, Khartoum. Splenic volume was measured by the prolate ellipsoid formula [0.524 × splenic index (length × width × thickness)].

The results showed that the average splenic volume of all subjects was 211.9 ± 72.5 cm^3 with a range of 99.03 to 398.40 cm^3. The average splenic volume of males was 209.73 ± 62.74 and that of female was 214.06 ± 82.38 cm^3.

The study concluded that the obtained results provide normative data for evaluating patients with splenic enlargement.

المستخلص:

يتضخم الطحال لاسباب مرضية عدة منها حالات العدوى و الامراض التي تخترق الطحال و امراض جهاز المناعة و الامراض الخبيثة. يعتبر تقييم حجم الطحال مهما في كل فحص بدني للبطن. تحديد حجم الطحال بواسطة التحسس يمكن ان تكون عملية غير دقيقة للغاية لان الطحال لا يمكن جسه حتى يتضخم مرتين إلي ثلاثة مرات عن حجمه الطبيعي. التشخيص الدقيق لتضخم الطحال هو مسألة ذات أهمية كبيرة للتوصل لتشخيص المرض. لذا من المهم للغاية اللجوء إلى ألية من شأنها أن تعطينا تقديرا دقيقا لحجم الطحال.

الهدف من هذا البحث هو دراسة التغيرات في حجم الطحال الطبيعي تبعا للعمر والجنس و طبيعة الجسم عند السودانيين و مقارنتها مع البيانات التي تم نشرها.

تم جمع عدد 50 فحص أشعة مقطعية من قسم الاشعة في مركز المدرس الطبي, في الخرطوم, لمرضى بالغين (ذكور و إناث) اعمارهم تتراوح بين 18-70 سنه ولا يعانون من اي امراض في الطحال. تم حساب حجم الطحال بواسطة صيغة الاهليجي الممدود [0.524 × (طول الطحال × عرض الطحال × سماكة الطحال)].

أظهرت النتائج ان متوسط حجم الطحال لكل المرضى كان 211.9 ± 72.5 سم^3 و يتراوح مدى احجام الطحال لدى كل المرضى تحت الدراسة بين 99.03 ألى 398.40 سم^3. متوسط حجم الطحال للذكور كان 209.73 ± 62.74 سم^3 وللإناث كان 214.06 ± 82.38 سم^3.

و خلصت الدراسة إلى أن النتائج التي تم الحصول عليها توفر بيانات معيارية لتقييم المرضى الذين يعانون من تضخم الطحال.

Dedication

To my family

To my friends

To my teachers

...

Acknowledgment

First of all, I Thank Allah the almighty for helping me to complete this project. I Thank Dr. Salah my supervisor for his help and guidance .finally I would like to thank everybody who helped me in this project.

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List of abbreviations:

BMI: Body Mass Index

CT: Computed Tomography

GE: General Electric

SL: Splenic Length

SS: Splenic Size

SV: Splenic Volume

ST: Splenic Thickness

SW: Splenic Width

Chapter One

Introduction

1.1 Introduction:

Evaluation of splenic size is important in every physical examination of the abdomen by a physician. It is enlarged in a variety of clinical conditions including infectious, hematological, infiltrative, immunologic and malignant states. (M. A. Siddiqui et al 2014)

Among infections, viral illnesses such as infectious mononucleosis are by far the most common cause in the young population. Others include malaria, kala azar (lieshmeniasis), brucellosis, salmonellosis, tuberculosis and bacterial endocarditis. Hematological disorders include lymphomas and lymphatic leukemias, hemolytic anemia, chronic anemia, congenital spherocytosis and myeloproliferative diseases such as polycythemia verra and myelofibrosis. (M. A. Siddiqui et al 2014)

Among immunological states are rheumatoid arthritis and systemic lupus erythematosus. Other important causes include cirrhosis of liver, portal hypertension, congestive heart failure, glycogen storage disorders, lymphoid tissue and hematological malignancies, Sarcoidosis and Amyloidosis. (M. A. Siddiqui et al 2014)

Hypersplenism is a pancytopenia (low platelet count, white cell count and hemoglobin concentration) caused by splenic enlargement. Hematological disorders causing splenomegaly commonly, but not invariably, also cause enlargement of the liver. Hemolytic anemia causes mild splenomegaly without hepatomegaly. (M. A. Siddiqui et al 2014)

The spleen has to increase in size three fold before it becomes palpable, so a palpable spleen always indicates splenomegaly. (M. A. Siddiqui et al 2014)

1.2 Objectives:

1.2.1 General Objective:

To examine variations in normal splenic size in relation to age, gender and body habitus among Sudanese population.

1.2.2 Specific Objectives:

- To assess the normal Splenic Size measured on CT images with the normal splenic volume.
- To document normal splenic size and volume.
- To investigate the relationship between the changes in spleen volume and body mass index, gender, and abdominal diameters.
- To serve as a baseline for comparison in cases of splenomegaly.

Chapter Two

Literature Review

2.1 Theoretical Background

2.1.1 Anatomy of the Spleen:

The spleen is situated principally in the left hypochondriac region, but its superior extremity extends into the epigastric region; it lies between the fundus of the stomach and the diaphragm. It is the largest of the ductless glands, and is of an oblong, flattened form, soft, of very friable consistence, highly vascular, and of a dark purplish color. (Gray's Anatomy 2000)

2.1.1.1 Development:

The spleen appears about the fifth week as a localized thickening of the mesoderm in the dorsal mesogastrium above the tail of the pancreas. With the change in position of the stomach the spleen is carried to the left, and comes to lie behind the stomach and in contact with the left kidney. The part of the dorsal mesogastrium which intervened between the spleen and the greater curvature of the stomach forms the gastrosplenic ligament. . (Gray's Anatomy 2000)

2.1.1.2 Relations:

The diaphragmatic surface (facies diaphragmatica; external or phrenic surface) is convex, smooth, and is directed upward, backward, and to the left, except at its upper end, where it is directed slightly medialward. It is in relation with the under surface of the diaphragm,

which separates it from the ninth, tenth, and eleventh ribs of the left side (Fig 2.1), and the intervening lower border of the left lung and pleura.

The visceral surface (Fig. 2.2) is divided by a ridge into an anterior or gastric and a posterior or renal portion.

The gastric surface (facies gastrica), which is directed forward, upward, and medialward, is broad and concave, and is in contact with the posterior wall of the stomach; and below this with the tail of the pancreas. It presents near its medial border a long fissure, termed the hilum. This is pierced by several irregular apertures, for the entrance and exit of vessels and nerves. (Gray's Anatomy 2000)

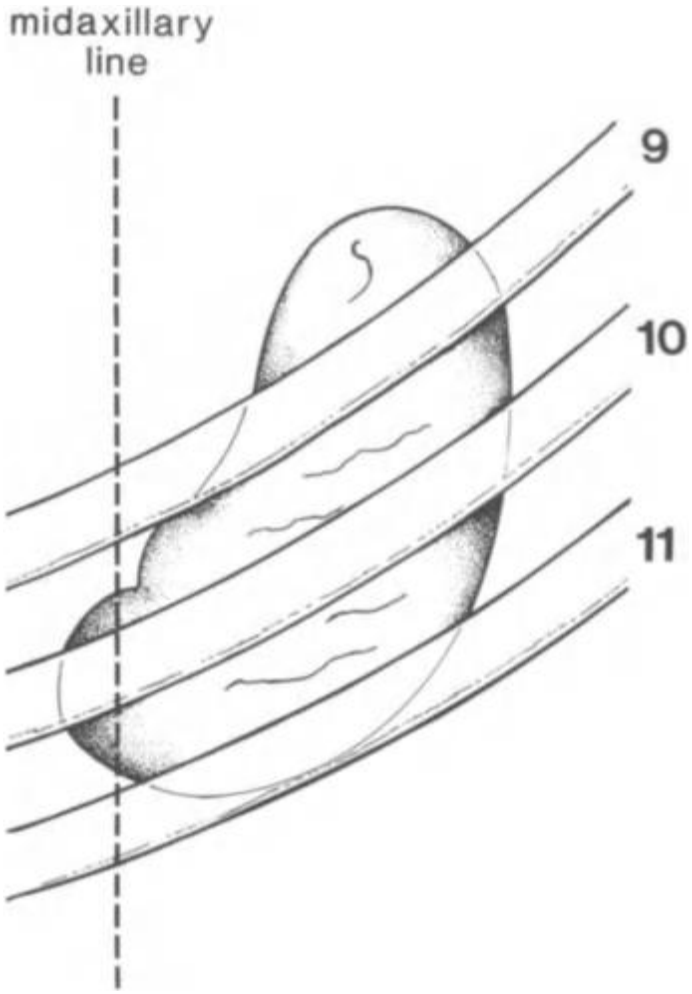

Fig 2.1. The diaphragmatic surface of the normal spleen, showing its relationship to the ninth, tenth, and eleventh ribs.

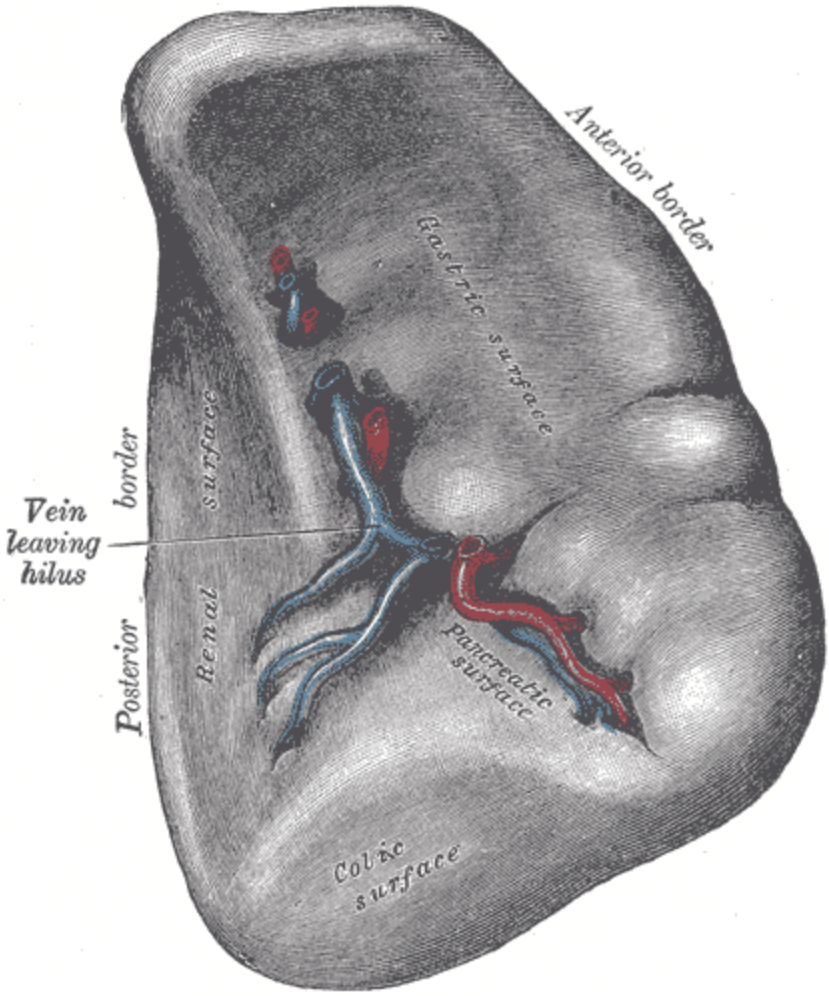

Fig 2.2. The visceral surface of the spleen.

The renal surface (facies renalis) (Fig. 2.2) is directed medialward and downward. It is somewhat flattened, is considerably narrower than the gastric surface, and is in relation with the upper part of the anterior surface of the left kidney and occasionally with the left suprarenal gland.

The superior extremity (extremitas superior) is directed toward the vertebral column, where it lies on a level with the eleventh thoracic vertebra. The lower extremity or colic surface (extremitas inferior) is flat, triangular in shape, and rests upon the left flexure of the colon and the phrenicocolic ligament, and is generally in contact with the tail of the pancreas. The anterior border (margo anterior) is free, sharp, and thin, and is often notched, especially below; it separates the diaphragmatic from the gastric surface. The posterior border (margo posterior), more rounded and blunter than the anterior, separates the renal from the diaphragmatic surface; it corresponds to the lower border of the eleventh rib and lies between the diaphragm and left kidney. The intermediate margin is the ridge which separates the renal and gastric surfaces. The inferior border (internal border) separates the diaphragmatic from the colic surface.

The spleen is almost entirely surrounded by peritoneum, which is firmly adherent to its capsule. It is held in position by two folds of this membrane. One, the phrenicolienal ligament, is derived from the peritoneum, where the wall of the general peritoneal cavity comes into contact with the omental bursa between the left kidney and the spleen; the lienal vessels pass between its two layers (Fig. 2.3). The other fold, the gastrolienal ligament, is also formed of two layers, derived from the general cavity and the omental respectively, where they meet between the spleen and stomach (Fig. 2.3); the short gastric and left gastroepiploic branches of the lienal artery run between its two layers. The lower end of the spleen is supported by the phrenicocolic ligament.

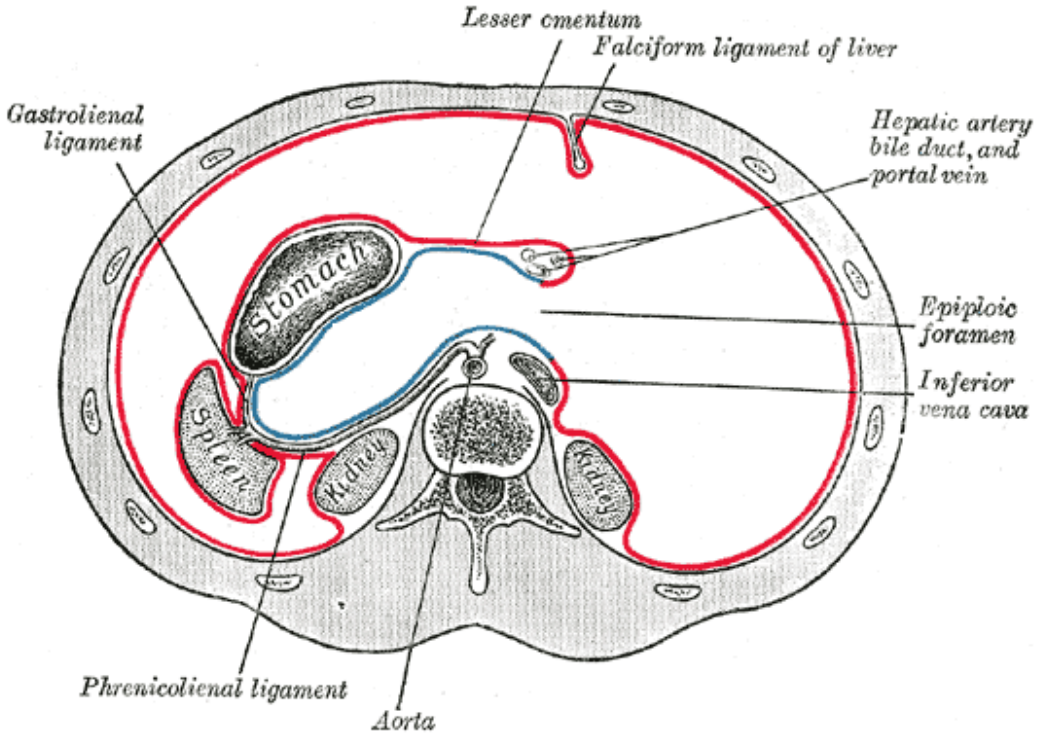

Fig 2.3. Horizontal disposition of the peritoneum in the upper part of the abdomen

The size and weight of the spleen are liable to very extreme variations at different periods of life, in different individuals, and in the same individual under different conditions. In the adult it is usually about 12 cm. in length, 7 cm. in breadth, and 3 or 4 cm. in thickness, and weighs about 200 grams. At birth its weight, in proportion to the entire body, is almost equal to what is observed in the adult, being as 1 to 350; while in the adult it varies from 1 to 320 and 400. In old age the organ not only diminishes in weight, but decreases considerably in proportion to the entire body, being as 1 to 700. The size of the spleen is increased during and after digestion, and varies according to the state of nutrition of the body, being large in

highly fed, and small in starved animals. In malarial fever it becomes much enlarged, weighing occasionally as much as 9 kilos.

Frequently in the neighborhood of the spleen, and especially in the gastrolienal ligament and greater omentum, small nodules of splenic tissue may be found, either isolated or connected to the spleen by thin bands of splenic tissue. They are known as **accessory spleens** (lien accessorius; supernumerary spleen). They vary in size from that of a pea to that of a plum. (Gray's Anatomy 2000)

2.1.1.3 Structure:

The spleen is invested by two **coats**:

a) An **external serous** and
b) An **internal fibroelastic** coat. 11

The **external** or **serous** coat (tunica serosa) is derived from the peritoneum; it is thin, smooth, and in the human subject intimately adherent to the fibroelastic coat. It invests the entire organ, except at the hilum and along the lines of reflection of the phrenicolienal and gastrolienal ligaments.

The **fibroelastic** coat (tunica albuginea) invests the organ, and at the hilum is reflected inward upon the vessels in the form of sheaths. From these sheaths, as well as from the inner surface of the fibroelastic coat, numerous small fibrous bands, trabeculæ (Fig. 2.2), are given off in all directions; these uniting, constitute the frame-work of the spleen. The spleen therefore consists of a number of small

spaces or areolae, formed by the trabeculae; in these areolae is contained the splenic pulp.

The **fibroelastic** coat, the sheaths of the vessels, and the trabeculae, are composed of white and yellow elastic fibrous tissues, the latter predominating. It is owing to the presence of the elastic tissue that the spleen possesses a considerable amount of elasticity, which allows of the very great variations in size that it presents under certain circumstances. In addition to these constituents of this tunic, there is found in man a small amount of non-striped muscular fiber; and in some Mammalia, e. g., dog, pig, and cat, a large amount, so that the trabeculae appear to consist chiefly of muscular tissue.

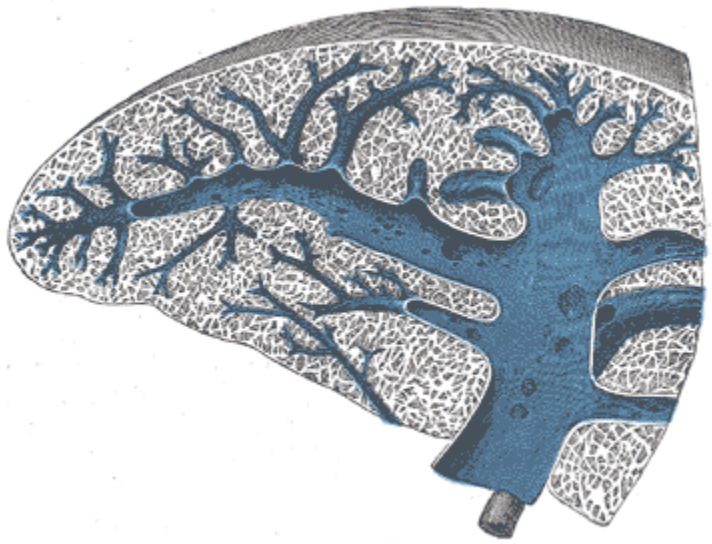

Fig 2.4 Transverse section of the spleen, showing the trabecular tissue and the splenic vein and its tributaries.

Fig 2.5 Transverse section of the human spleen, showing the distribution of the splenic artery and its branches.

The **splenic pulp** (pulpa lienis) is a soft mass of a dark reddish-brown color, resembling grumous blood; it consists of a fine reticulum of fibers, continuous with those of the trabeculae, to which are applied flat, branching cells. The meshes of the reticulum are filled with blood, in which, however, the white corpuscles are found to be in larger proportion than they are in ordinary blood. Large rounded cells, termed splenic cells, are also seen; these are capable of ameboid movement, and often contain pigment and red-blood corpuscles in their interior. The cells of the reticulum each possess a round or oval nucleus, and like the splenic cells, they may contain pigment granules in their cytoplasm. (Gray's Anatomy 2000)

2.1.1.4 Blood vessels of the Spleen:

The lienal artery is remarkable for its large size in proportion to the size of the organ, and also for its tortuous course. It divides into six or more branches, which enter the hilum of the spleen and ramify throughout its substance (Fig. 2.3), receiving sheaths from an involution of the external fibrous tissue. Similar sheaths also invest the nerves and veins.

Each branch runs in the transverse axis of the organ, from within outward, diminishing in size during its transit, and giving off in its passage smaller branches, some of which pass to the anterior, others to the posterior part. These ultimately leave the trabecular sheaths, and terminate in the proper substance of the spleen in small tufts or pencils of minute arterioles, which open into the interstices of the reticulum formed by the branched sustentacular cells. Each of the larger branches of the artery supplies chiefly that region of the organ in which the branch ramifies, having no anastomosis with the majority of the other branches.

The **arterioles**, supported by the minute trabeculae, traverse the pulp in all directions in bundles (pencilli) of straight vessels. Their trabecular sheaths gradually undergo a transformation, become much thickened, and converted into adenoid tissue; the bundles of connective tissue becoming looser and their fibrils more delicate, and containing in their interstices an abundance of lymph corpuscles (W. Müller).

The **nerves** are derived from the celiac plexus and are chiefly non-medullated. They are distributed to the blood vessels and to the smooth muscle of the capsule and trabeculæ. (Gray's Anatomy, 2000)

2.1.2 Functions of the Spleen:

As the largest secondary lymphoid organ, the spleen has a number of important roles in the immune response, including the clearance of effete or damaged cells from the bloodstream and host resistance to infection. Other organs serve some functions similar to those of the spleen. The widely dispersed system of lymph nodes situated throughout the host responds vigorously with antibodies and T -cells to foreign antigens that gain access to peripheral tissues. Again, like the spleen, the liver, with its large mass of phagocytic Kupffer cells lining vascular sinusoids, is an important site of clearance of particulate antigens from the bloodstream and a major contributor to resistance to infection. The spleen, however, has a unique place in host defense, because it combines all of these functions in one organ. Thus, because of its anatomic location directly connected to the circulation, it responds promptly to blood borne antigens with antigen-specific immune responses, much more effectively than can lymph nodes or other lymphoid tissues (Rowley, 1950 a,b).It also has a major role in mediating the effects of the innate immune system, and under some circumstances is more effective in its role in the reticuloendothelial system than the liver.

2.1.3 Pathology of The Spleen:

2.1.3.1 ANATOMIC VARIATIONS

2.1.3.1.1 ACCESSORY SPLEEN

Accessory spleen refers to one or more small foci of splenic tissue in the presence of an otherwise normal-sized spleen.

2.1.1.1.1 POLYSPLENIA

Poly splenia is a condition in which multiple spleens are present. As with the accessory spleen, these splenunculi are functional.

2.1.1.1.2 SPLENOSIS

A second form of ectopic splenic tissue results from the regeneration of splenic fragments implanted at suitably supportive sites for growth, usually following traumatic rupture of the organ, but also, less commonly, following splenic surgery.

2.1.3.2 Splenomegaly

2.1.3.2.1 INFECTION

- Acute. Infectious mononucleosis; viral hepatitis; cytomegalovirus infection; septicemia (including tuberculous); salmonelloses; relapsing fever; tularemia; splenic abscess; toxoplasmosis.
- Subacute and chronic Chronic septicemias; tuberculous splenomegaly, leprosy; Yersinia; subacute bacterial endocarditis; brucellosis; syphilis; malaria; leishmaniasis;

schistosomiasis; systemic fungal disease; inflammatory pseudotumor.

2.1.3.2.2 IMMUNE PROLIFERATIONS AND NONINFECTIOUS GRANULOMATOUS DISORDERS

Angioimmunoblastic lymphadenopathy; angiofollicular hyperplasia; systemic lupus erythematosus; rheumatoid arthritis; Still's disease; rheumatic fever; Behcet's syndrome; serum sickness; sarcoidosis; berylliosis; necrotizing splenic granulomas.

2.1.3.2.3 VASCULITIDES

Polyarteritis nodosa; leukocytoclastic angiitis; peliosis.

2.1.3.2.4 CONGESTIVE SPLENOMEGALY

- Intrahepatic. Portal cirrhosis; postnecrotic scarring; biliary cirrhosis; Wilson's disease; hemochromatosis; veno-occlusive disease; congenital fibrosis; bilharziasis.
- Portal vein obstruction Thrombosis, stenosis, atresia; cavernous malformation; arteriovenous aneurysm; obstructive lesions at porta hepatis.
- Splenic vein obstruction. Thrombosis, stenosis, atresia; angiomatous malformation; obstruction by pancreatic disease, splenic arterial aneurysm and retroperitoneal fibrosis.
- Hepatic vein occlusion. Budd-Chiari syndrome.

- Cardiac. Acute, chronic or recurrent congestive cardiac failure; constrictive pericarditis (Banti's syndrome).

2.1.3.2.5 HEMATOLOGICAL DISORDERS

- Hemolytic disorders.
- Hereditary red blood cell membrane disorders; thalassemia; sickle-thalassemia; sickle cell disease (early stages); hemoglobin-SC disease.
- Myeloproliferative disorders. Primary (agnogenic myeloid metaplasia); polycythemia vera (variable); essential thrombocythemia (variable).
- Miscellaneous. Primary splenic hyperplasia; megaloblastic anemias; iron deficiency.

2.1.3.2.6 NEOPLASM

- Hematolymphoid. Acute leukemias; chronic leukemias; prolymphocytic leukemia; hairy cell leukemia; malignant lymphoma; dendritic cell tumors; systemic mastocytosis; plasma cell myeloma.
- Metastatic. Carcinoma, especially lung and breast; melanoma; neuroblastoma; malignant teratoma; choriocarcinoma.
- Benign. Hamartoma (single, multiple); hemangioma (capillary, cavernous); lymphangioma; lipoma

2.1.3.2.7 MISCELLANEOUS

- Storage diseases. Gaucher's disease; Neimann-Pick disease; ceroid histiocytosis; 0Tangier disease; Hurler's syndrome; Hunter's syndrome.

- Cysts. Pseudocyst; epidermoid (epithelial) cyst; echinococcal (hydatid) cyst.
- Others. Amyloidosis; Albers-Schonberg disease; hereditary hemorrhagic telangiectasia; hyperthyroidism. (The Complete Spleen, 2002)

2.2 Previous Studies:

- **Harris A. et al 2009** : this study established normal splenic volume measurement in 230 consecutive patients who underwent computed tomography (CT) scans for various indications, The average splenic volume of all the subjects was 127.4+/-62.9 cm3, ranging from 22 to 417 cm3. The splenic volume correlated with age ($r=-0.33$, $p<0.0001$), body weight ($r=0.35$, $p<0.0001$), body mass index ($r=0.24$, $p<0.0001$) and body surface area (BSA) ($r=0.31$, $p<0.0001$). The age-adjusted splenic volume index correlated with gender ($p=0.0089$).

- **V. Caglar et al (2014)**: this study established normal splenic volume measurement in 212 adults between the ages of 20 and 88 years. The spleen volume (SV) measurements using abdominal CT images of each patient on the Image Information Systems were performed with Cavalieri principle. The mean SV and splenic length (SL), width (SW), and thickness (ST) for the total study population of 212 patients was 198 ± 88 cm3, 9.96 ± 2.1 cm, 8.87 ± 1.6 cm and 4.58 ± 0.8 cm, respectively. There was a strong correlation between SV and ST ($r = 0.752$, $p < 0.001$), SL ($r = 0.735$, $p < 0.001$), SW ($r = 0.681$, $p < 0.001$) mean values of total study population. Comparison between mean splenic dimension parameters for males and females showed a

statistically significant difference ($p = 0.032$ for SV, $p = 0.04$ for ST) but no statistically significant difference with SL and SW. Also there was a positive correlation between SV and body height in mean of total groups and female groups, there was no correlation in males.

- **M. A. Siddiqui et al (2013):** this study established normal splenic volume measurement in 34 adult patients (male and female) aged between 20 - 70 years, having no splenic disorders, were collected from department of radio-diagnosis King Khalid Hospital Al-Kharj, KSA. Splenic volume was measured by two methods—by volumetric software and the prolate ellipsoid formula. The average splenic volume of all subjects was 161.42 ± 54.91 cm3 with a range of 106 - 319 cm3. The average splenic volume of males was 196.95 ± 48.70 cm3 and that of female was 196.95 ± 26.97 cm3.

- **Prassopoulos P. et al (1997):** this study established normal splenic volume measurement in 140 patients who underwent CT for indications unrelated to splenic disease. Splenic volume did not vary significantly ($-0.04 < r < 0.05$, $p > 0.10$) with the patient's age, gender, height, weight, body mass index or the diameter of the first lumbar vertebra, the latter considered as representative of body habitus on CT. The mean value of the measured splenic volume (SV) was 214.6 cm3 with a range from 107.2 to 314.5 cm3. S Vol correlated well with all the linear and the maximal cross-sectional area measurements and could be calculated using the formula: S Vol = 30 + 0.58 (W x L x Th.).

Table 2.1 shows similar previous studies done for Splenic Volume (SV) measurement:

Author	Race	Mean SV (cm^3)	Modality
Harris A., 2009	Japanese	127.4 ± 62.9	CT
V. Caglar ,2014	Turkish	198 ± 88	CT
M. A. Siddiqui ,2013	Saudi Arabian	161.42 ± 54.91	CT
Prassopoulos P., 1997	Greek	214.6	CT

Chapter Three

Materials and Methods

3.1 Materials:

All studies were obtained with a dual-detector row helical scanner (dual fast, GE systems). Abdominal CT images (section thickness 10 mm) were examined retrospectively

3.2 Sampling:

3.2.1 Inclusion Criteria:

Adult patients of age ranged between18 and 70 Y.

3.2.2 Exclusion Criteria:

Patients with previous splenectomy, difficult identification of splenic margins, splenic tumours, and focal lesions were excluded from the study

3.3 Area of the study:

This study was conducted at Khartoum state, Almodaris Medical Center.

3.4 Duration of the study:

This study was conducted during the period from September to December 2015.

3.5 Methods:

3.5.1 Data collection:

The SV was calculated manually by using the standard clinical prolate ellipsoid equation for spleen [0.524 × splenic index (length × width × thickness)] to CT scans of 50 adult patients referred for abdominal CT for various reasons. The radiologist's report for each CT examination was reviewed. There were 26 males and 24 females, whose age ranged between 18 to 70 years.

3.5.2 Data analysis:

Data were analyzed using Excel program and SPSS version 22 for significance of tests.

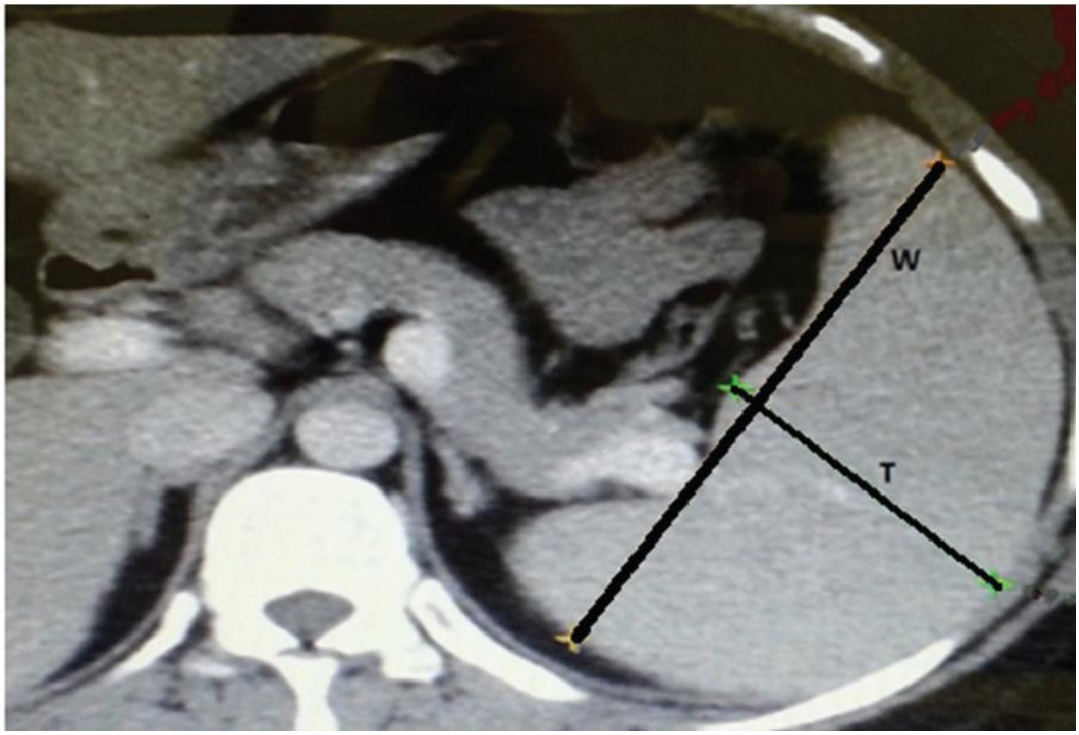

Fig 3.1: Estimation of Splenic Width (W), & Splenic Thickness (T).

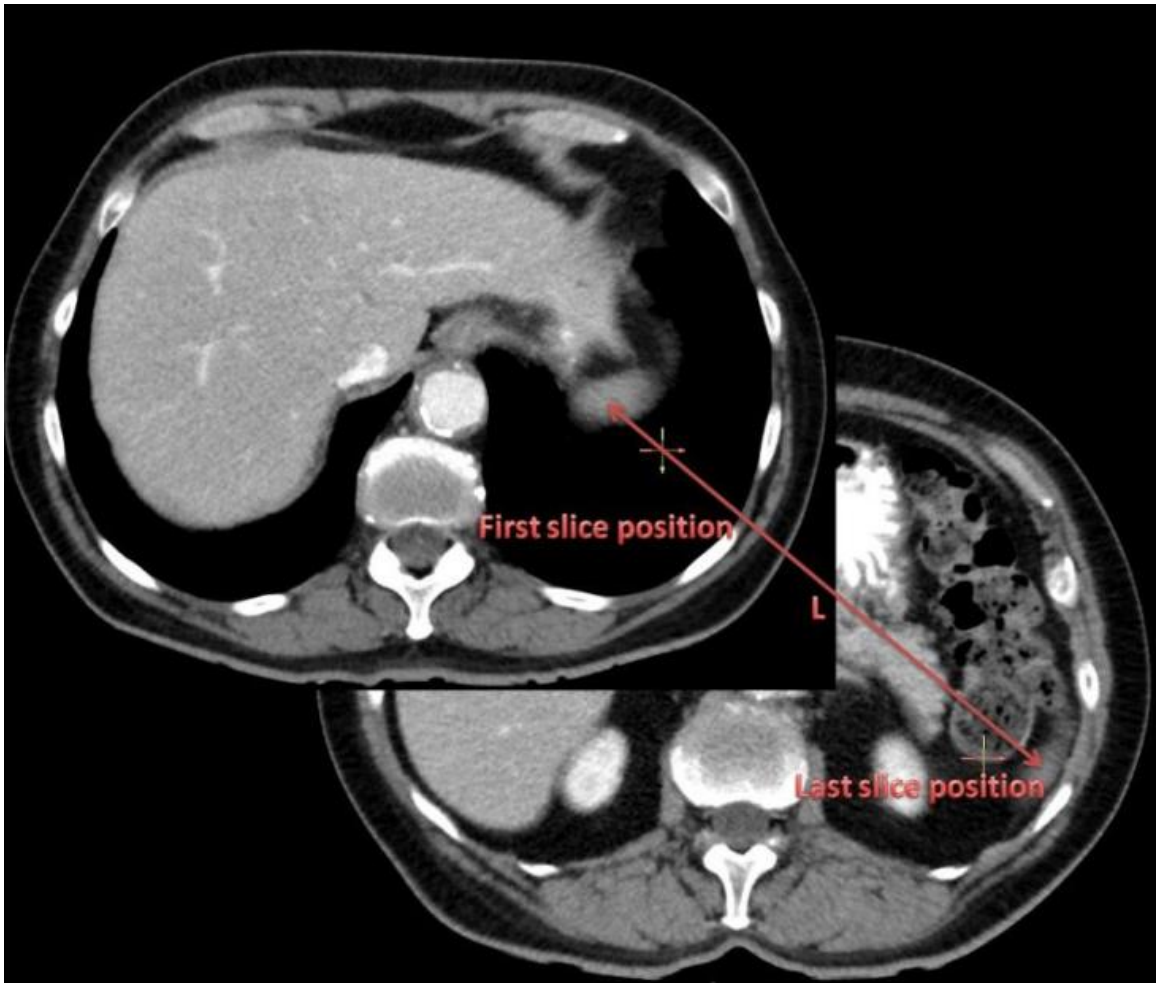

Fig 3.2: Estimation of Splenic Length (L)

Chapter Four

Results

The following tables and figures presented the data obtained from 50 patients who were examined for axial CT abdomen. The spleen length, width & thickness were measured. Patient's age, weight, height, body mass index (BMI), & 1st lumber vertebra diameter, were also measured. The data were analyzed using Excel program and SPSS version 22 for significance of tests. Frequency tables, means and standard deviations were presented.

Table 4.1: Characteristics of subjects enrolled in computed tomography imaging studies of the spleen

Variables	Total	Male	Female
N	50	25	25
Age	44.22 ± 15.5	46.08 ± 17.32	42.36 ± 13.53
Body Weight	67.94 ± 14.54	65.40 ± 12.91	70.48 ± 15.86
Body Height	165.90 ± 8.56	169.92 ± 8.57	161.88 ± 6.52
SL	10.88 ± 2.30	10.72 ± 2.1	11.04 ± 2.52
SW	8.98 ± 1.68	8.92 ± 1.2	9.03 ± 2.07
ST	4.15 ± 0.92	4.16 ± 0.57	4.14 ± 1.19
BMI	24.83 ± 5.59	22.72 ± 4.36	26.93 ± 5.97
SV	211.9 ± 72.5	209.73 ± 62.74	214.06 ± 82.38

Values are means ± standard deviation; **SL**: Splenic Length, **SW**: Splenic Width, **ST**: Splenic Thickness, **BMI**: Body Mass Index, **SV**: Splenic Volume.

Table 4.2: Relationship between the parameters used and splenic volume

Parameters	Splenic Volume					
	Total (n=50)		Female (n=25)		Male (n=25)	
	R	p	r	P	R	P
Age(years)	-0.286	0.05	NS		-0.624	0.01
Height(cm)	NS		NS		0.532	0.05
Weight(Kg)	NS		0.597	0.01	NS	
BMI(Kg/m^3)	0.331	0.05	0.533	0.01	NS	
SL(cm)	0.597	0.01	0.598	0.01	0.596	0.01
SW(cm)	0.688	0.01	0.700	0.01	0.676	0.01
ST(cm)	0.378	0.01	NS		0.659	0.01

Values are means ± standard deviation; **r**: value is the correlation coefficient; **p**: value is the probability; **NS** — non significant ($p > 0.05$); rest abbreviations as in Table 4.1

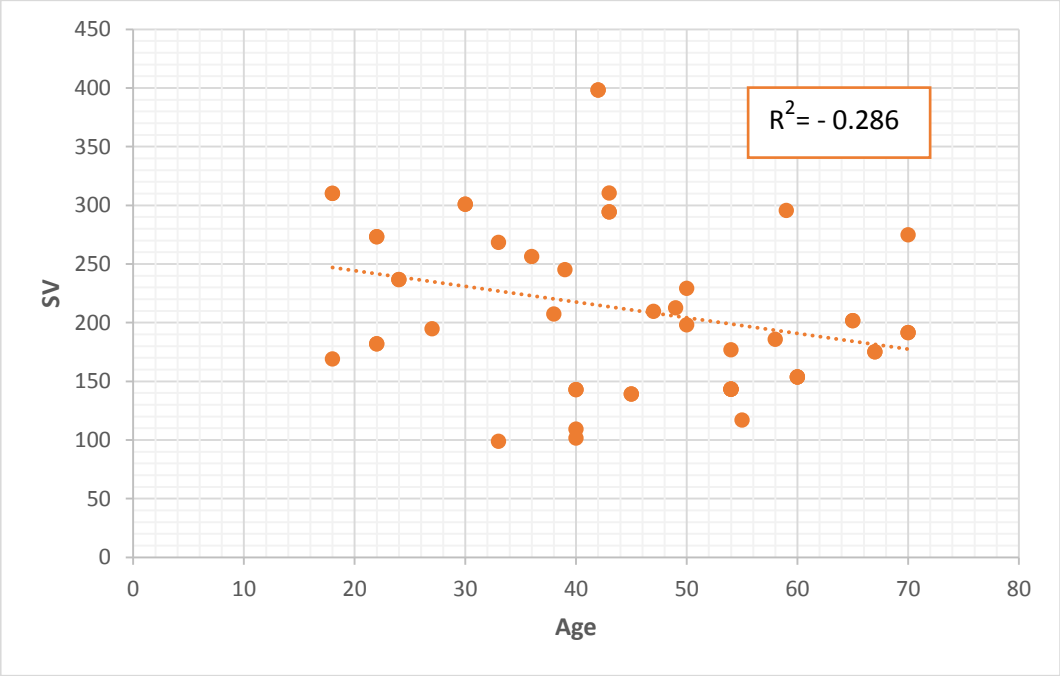

Figure 4.1 A scatter plot diagram shows a linear relationship between the **SV** and the **Age** of the subjects, $\mathbf{R^2}$=- 0.286.

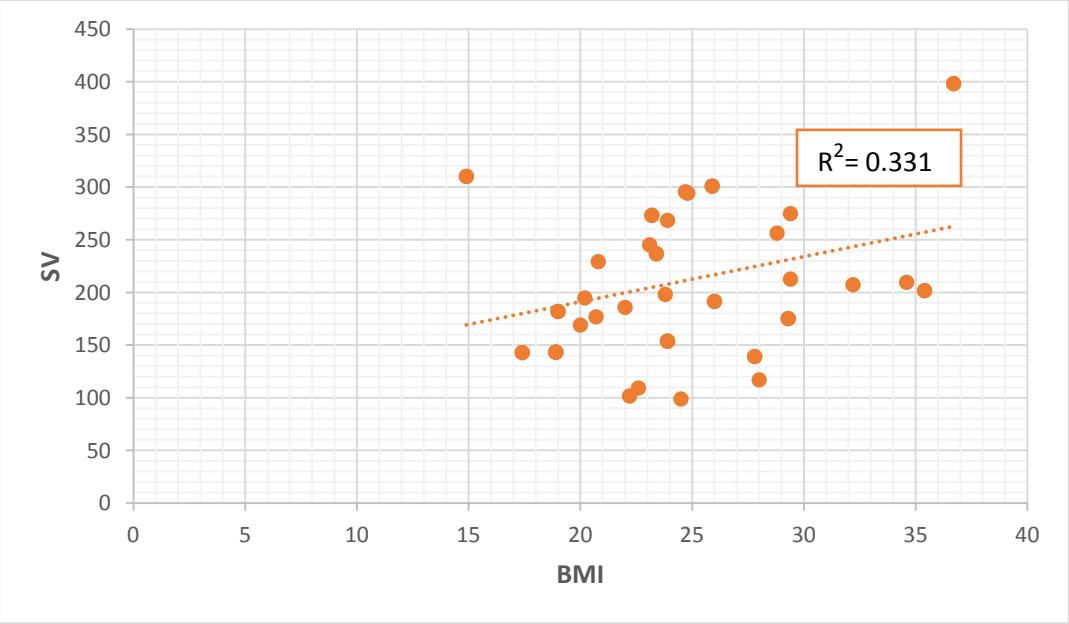

Figure 4.2 A scatter plot diagram shows a linear relationship between the **SV** and the **BMI**, $\mathbf{R^2}$=0.331.

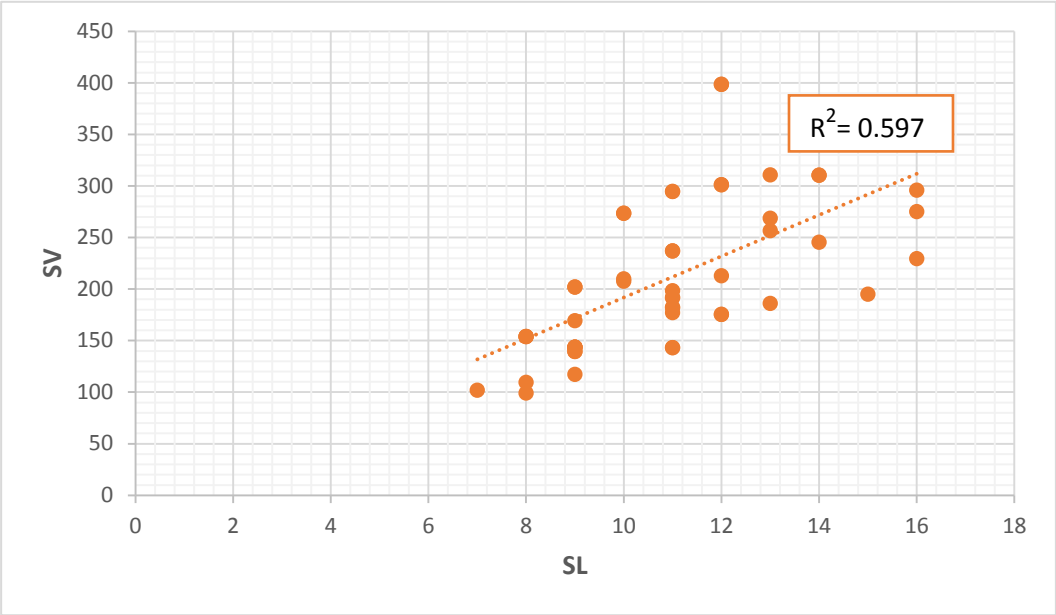

Figure 4.3 A scatter plot diagram shows a linear relationship between the **SV** and the **SL**, $\mathbf{R^2}$=0.597.

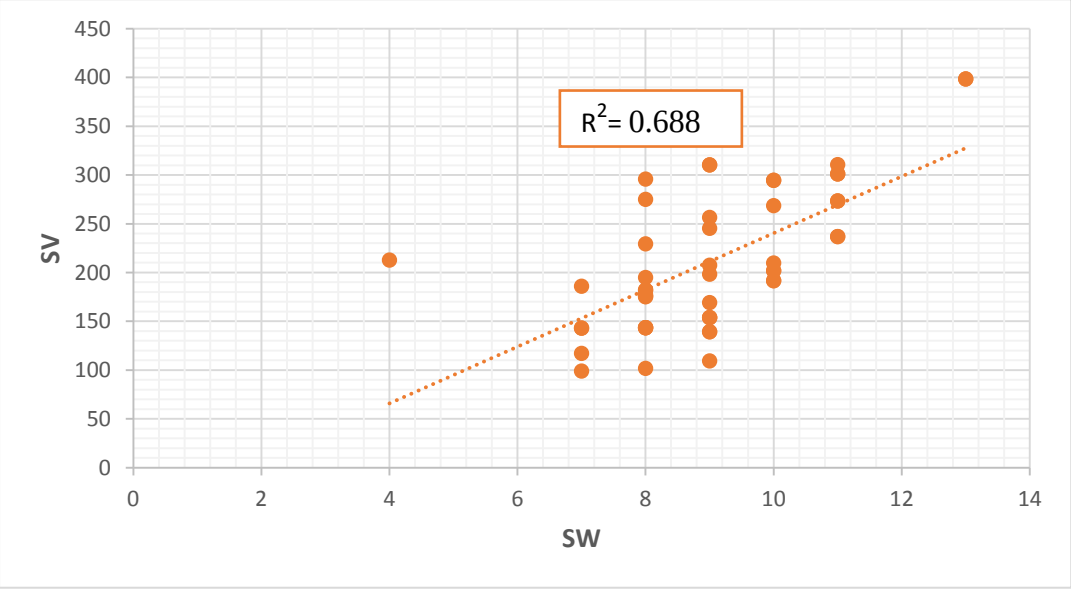

Figure 4.4 A scatter plot diagram shows a linear relationship between the **SV** and the **SW**, $\mathbf{R^2}$=0.688.

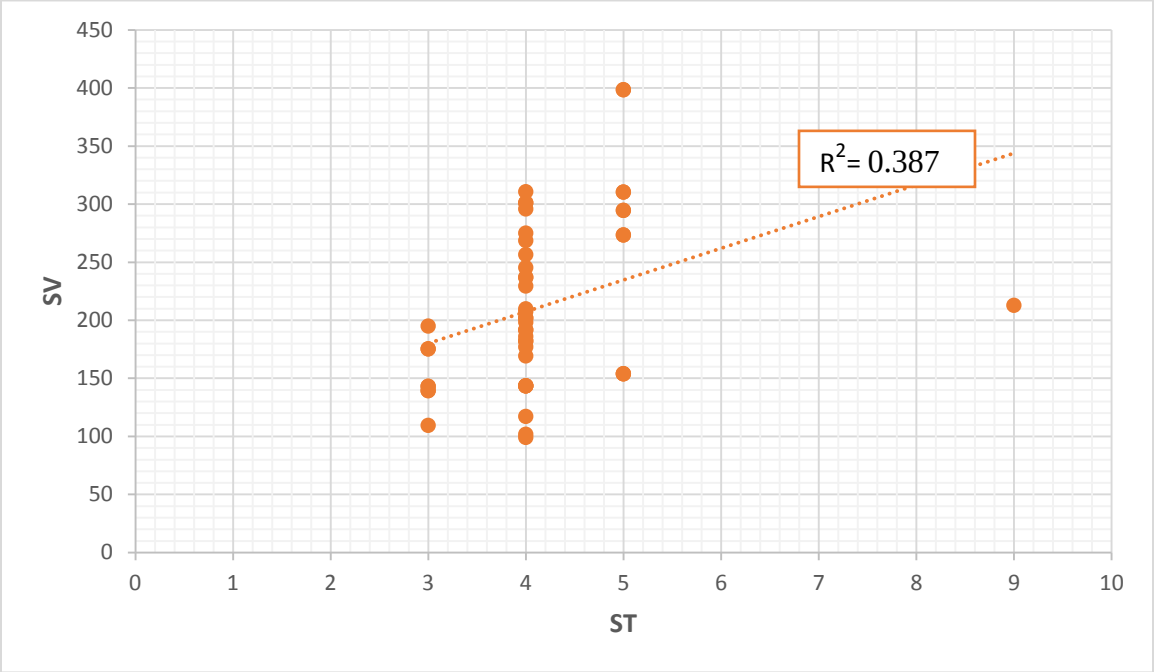

Figure 4.5 A scatter plot diagram shows a linear relationship between the **SV** and the **ST**, $\mathbf{R^2}$=0.387.

Chapter Five

Discussion, Conclusion and Recommendations

5.1 Discussion:

In the present study, the range of SV and SS in patients and the relationship between SS and parameters such as age, height, weight, BMI, gender were examined. The SV and SS vary from person to person. Besides, a number of disorders are accompanied by altered SS, including liver disease, portal hypertension, splenic vein thrombosis, lymphoma and other neoplastic processes, and haematologic entities. (V. Caglar et al 2014).

In addition, chronic formaldehyde exposure can cause morphometric alterations in the follicles and marginal zone of the spleen. Assessment of SV and SS without radiologic examination is subjective and known to be inaccurate, therefore evaluation with radiologic imaging is common. The use of imaging techniques is receiving increasing attention to estimate SV and SS, particularly for diagnosis of and follow-up of splenomegaly. Current literature recommends that CT can identify changes in SV and SS with the highest sensitivity and specificity. (V. Caglar et al 2014)

The objective of this study was to establish normal splenic volume in the Sudanese patient and it’s relation to age, gender, height, weight, and body mass index (BMI).

This study was performed on 50 patients. The data collected form patients of ages ranged between 18-70 years old. The results showed

that the normal splenic volume was correlated with patient age and body mass index (BMI).

5.1.1 Splenic volume, age and gender:

The mean SV for the total study population of 50 patients was 212.4 ± 62.8 cm^3. The SV ranged from 101.65 to 398.24 cm^3. There was a general decrease in SV as age increased. There was a significant negative correlation between SV and age for total study population (r = –0.307, p = 0.05) (Fig 4.1), and male group (r = –0.583, p = 0.01), in female there was no significant (Table 4.2).

The average SV was higher in females (219.8 ± 67.4 cm^3) than in males (205.6 ± 58.7 cm^3).

5.1.2 Splenic volume and dimensions:

The mean SL, SW, and ST for the total study population of 50 patients was 10.9 ± 2.1 (range 7–16) cm, 8.8 ± 1.5 (range 3.6–13.2) cm and 4.2 ± 0.9 (range 2.9–9.4) cm, respectively.

There was a significant correlation between SV and ST (r = 0.302, p = 0.05) (Fig 4.5), SL (r = 0.580, p = 0.01) (Fig 4.3), SW (r = 0.640, p = 0.01) (Fig 4.4), in mean values of total study population. The SL, SW and ST correlations for male and female groups are shown in Table 4.2.

5.1.3 Splenic volume and body habitus

The mean body weight of the patients was 67.2 ± 14 kg and the height was 166.1 ± 9.3 cm. On average, the SV increases with an increase in body weight and height.

The BMI was 25 ± 5 kg/m^2 for the total study population. The BMI for male patients was 23 ± 3 kg/m2 and that for female patients was 27 ± 5 kg/m^2. A statistically significant relationship was observed between the SV and BMI (r = 0.291, p = 0.05) (Fig 4.2).

These measurements were compared to study done by Harris A. et al 2009, in Japanese population by CT found the mean SV for total population was 127.4 ± 62.9 cm3, which was lower than this study by 85 cm^3. This difference may be due to racial differences and patient habits, also present of tropical diseases like malaria affects splenic size among Sudanese people.

Another study done by V. Caglar et al 2014 in Turkish population by CT found the mean SV for total population was 198 ± 88 cm3, which was lower than this study by 14.4 cm^3. This difference may be due to smaller sample size in this study, racial differences and patient habits, also present of tropical diseases like malaria affects splenic size among Sudanese people.

Another study was done by M. A. Siddiqui et al 2013 in Saudi Arabian population by CT found the mean SV for total population was 161.42 ± 54.91 cm3, which was lower than this

study by 51 cm^3. This difference may be due to smaller sample size in their study, racial differences and patient habits, also present of tropical diseases like malaria affects splenic size among Sudanese people.

Another study done by Prassopoulos P. et al 1997 in Greek population by CT found the mean SV for total population was 214.6 cm^3, which was more than this study by 2.2 $cm^{3.}$ This difference may be due to smaller sample size in this study, racial differences and patient habits, also present of tropical diseases like malaria affects splenic size among Sudanese people.

In this study there was a negative correlation between SV and age ($r = –0.307$, $p = 0.05$) as age increased SV decreased (Fig 4.3), there was a significant correlation between SV and BMI ($r = 0.291$, $p = 0.05$) as BMI increased SV increased (Fig 4.4).

5.2 Conclusion:

The study concluded that the mean normal SV in Sudanese patients according to the findings of CT images was found to be 212.4 ± 62.8 cm^3.

The SV significantly correlates with age, subject height, weight, and body habitus. The normal reference ranges for SV and SS given in this study can serve as a standard to judge whether splenomegaly is present in patients and the size of abnormality. The SV in female was higher than in male, possibly because Sudanese females tend to weigh more than males. Sudanese SV was different from the previous studies mentioned in this research.

5.3 Recommendations:

Further study in evaluation of SV with larger sample of Sudanese population for more accurate results is needed.

Using of other imaging modalities like ultrasound and MRI is recommended to confirm the results.

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Data Collection Sheet:

No	Age	Gender	Body Height	Body Weight	1st lumber vertebra diameter
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
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