

Sudan University of Science and Technology
College of Graduate Studies

**Measurement of Splenic Volume in Adult Sudanese
Population Using Computed Tomography**

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A thesis Submitted for the Partial Fulfillment of the M.Sc Degree in
Diagnostic Radiology

Prepared by:

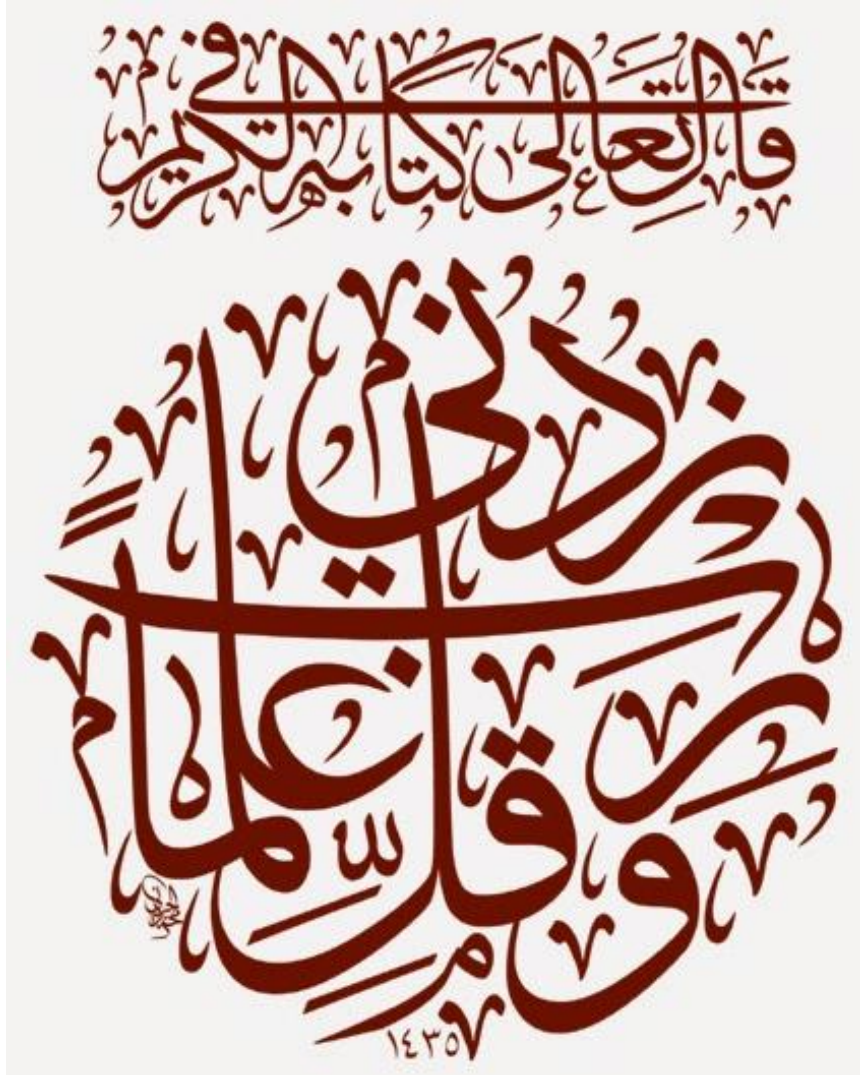
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2018

الاية



صدق الله العظيم

طه (114) سورة

Dedication

The tender man . . .

My Father

The Kindest woman . . .

My Mother , Brothers and Sisters

Acknowledgement

This research project would not have been possible without the support of many people, the author wishes to express high graduated to my supervizer **Dr. Asma Ibraheem Ahmed ALameen**.

Special thanks to (**Mujahed Zaidan**) for helping me.

Special thanks also to all my friend specially the group of Radiology Department in Alzaytona Hospital . Not forgetting to my best friend who always being there.

Abstract

This was descriptive analytic study aim to measure splenic volume in Sudanese population using abdominal computed tomography scan (Toshiba aquilion 64 slices in al zayton specialist hospital) and (Toshiba aquilion 64 slices in royal care hospital) in Khartoum state during the period from February 2018 To June 2018. The study sample included 60 abdominal scan (30 male and 30 female), mean age was 51.8 ± 14.7 years; patients having any splenic disorders were excluded. The patient's body weight and height were recorded at the time of examination. The measurements of spleen were calculated manually. The average of splenic volume for male $166.33 \pm 24.67 \text{ cm}^3$ and female $198.3 \pm 17.54 \text{ cm}^3$, the average of splenic volume for all population was $182.12 \pm 21.9 \text{ cm}^3$. This study provides normative data for evaluating patients with splenic enlargement.

The results showed significant difference in two genders, the spleen volume in female higher than spleen volume male and this may due to genetic factor or other reasons.

As conclude recommended the radiologist and physician to use the splenic volume in diagnosis the splenic abnormalities.

Keywords: measurement, spleen volume and computed tomography.

الخلاصة

الهدف من الدراسة هو قياس حجم الطحال في السكان السودانيين باستخدام التصوير المقطعي بالكمبيوتر. اجريت هذه الدراسة في مستشفى الزيتونه التخصصي ومستشفى رويال كير العالمي في ولاية الخرطوم في الفتره من فبراير 2018 حتى يونيو 2018 .

شملت عينة الدراسة 60 حاله تصوير للبطن (30 رجل و30 امراه)، متوسط العمر ان 51.8 ± 14.7 سنه.

تم استبعاد المرضى اللذين يعانون من اي اضرابات في الطحال.

تم تسجيل وزن المريض وطوله في وقت الفحص .

تم حساب قياسات الطحال يدويا . [بلغ متوسط حجم الطحال للذكور 166.33 ± 24.67

والنساء 198.3 ± 17.54 cm^3 ومتوسط حجم الطحال لجميع السكان 182.12 ± 21.9 cm^3 .

توفر الدراسة البيانات المعيارية لتقييم المرضى اللذين يعانون من تضخم الطحال .

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List of abbreviations

AP	Anterio Posterior
BMI	Body mass index
CT	Computed Tomography
FOV	Field of View
GIT	Gastro intestinal tract
IGM	Immunoglobulin M
IGG	Immunoglobulin G
IV	Intra venous
KVP	Kilo Volt Penetration
MRI	Magnetic Resonance Imaging
MDCT	Multi Detector Computed Tomography
MAS	Mile Ampere Second
S LE	Spleen length
S TH	Spleen thickness
S WI	Spleen width
S CT	Single Computed Tomography

Chapter One

1.1 Introduction:

Spleen is a reticulo-endothelial and lymphoid organ and sometimes works as hemopoietic organ. Spleen is never palpable till it is enlarged two-three times of its own size. There are many modes of investigation to identify the enlarged spleen plane radiograph, sonography, computed tomography, MRI and radionuclide scan. Out of these modalities sonography and computed tomography are most reliable for intra-abdominal organs (Adel Asghar et al 2011).

Various studies were done by sonography to study the linear dimension of spleen – length, width, and thickness. dimensions determined by 2-D ultrasound are limited predominantly by the variable, irregular contour of spleen but also by the difficulty in completely scanning the entire organ or visualizing complete contours as because of the presence of overlying structures such as bone, bowel gas or kidney, CT imaging is more accurate than ultrasonography because this drawback is not seen with computed tomography (Lamb PM et al 2002).

1.2 Problem of study:

There is no stander measurement of spleen volume for Sudanese using to diagnosis spleen abnormality.

1.3 Objective of the study:

1.3.1 General objective:

To measure the spleen volume for Sudanese using computed tomography.

1.3.2 Specific objectives:

1. To determine the correlation of spleen volume with body weight and height.
2. To determine the correlation of spleen volume with gender.
3. To determine the correlation of spleen volume with age.

1.4 Research Overview:

The study will fall into five chapters , chapter one consists of introduction that about spleen , objectives , significant of the study and over view of the study .chapter two included the literature review , chapter three detailed the material and methods , chapter four included the presentation of the result , and finally chapter five included the discussions , conclusion , recommendation .

Chapter Two

Theoretical Background and Previous studies

2.1: Theoretical Background:

2.1.1 Anatomy of the Spleen:

The spleen starts to develop in the fourth week of gestation as a mesenchymal condensation in the dorsal mesogastrium of the lesser sac. In the following weeks these early mesenchymal cells differentiate to a vascular lymphatic pedicle that eventually forms the spleen. Smaller condensations that develop near the hilum of the spleen form accessory spleens. When the embryo is about 10 cm in length the dorsal mesogastrium can be divided into a posterior part and an anterior part. The posterior part, from the posterior abdominal wall to the spleen, is eventually invaded by the pancreatic bud, which grows as far as the hilum and later fuses with the peritoneum of the posterior abdominal wall ventral to the left kidney to the splenorenal ligament. In this dorsal structure the splenic artery and vein develop. The anterior part of the dorsal mesogastrium develops into the gastrosplenic ligament and contains the short gastric vessels. It is now clear that the spleen is of mesenchymal origin and does not originate from the embryonic endodermal gut.

The splenic condensation forms a trabecular structure resulting in a mesh and ending up in the connective supportive structure of the spleen. The isolated free cells in this network differentiate into hematopoietic cells in the next months of gestation. Other cells derived from the sinusoids of the splenic artery specialize to participate in the reticuloendothelial system (Mollit DL et al 2000).

The spleen is located in the left hypochondria between the fundus of the stomach and the diaphragm, behind the maxillary line opposite the 9th, 10th, and

11th ribs. Its long axis lies parallel to the long axis of the 10th rib. It moves a bit in living during respiration(Vishram. S 2014).

The spleen is a wedge-shaped soft organ with purple color. The size of the spleen roughly corresponds to the first of the subject.

Normal Measurements of the spleen are 1 inch Thickness, 3 inches width, 5 inches Length and about 7 ozWeight.The spleen is marked on the surface on the left side of the back of the trunk. Its long axis corresponds to that of the 10th rib. Its upper border corresponds to the upper border of the 9th rib, and its lower border corresponds to the lower border of the 11th rib. Its medial end lies about 5 cm from the posterior midline of the body at the level of spine of T10 vertebra and lateral end at the mid axillary line (Richard s 2012).

The features of the spleen are External features two ends (anterior and posterior) the anterior end (lateral end/lower pole) is broad and is more like a border. It is directed downward, forward, and to the left. It is related to the left colic flexure in front and phrenic colic ligament below. The posterior end (medial end/upper pole) is blunt and rounded. It is directed upward, backward, and medially towards the vertebral column. It is related to the upper pole of the left kidney (Vishram. S 2014).

Three borders (superior, inferior, and intermediate).The superior border of the spleen is thin and convex. It separates the visceral surface (gastric impression) from the diaphragmatic surface. It characteristically presents one or two notches near its anterior end. These notches indicate that the spleen develops by the fusion of separate masses of lymphoid tissue (lobulated development).The inferior border of the spleen separates the visceral surface (renal impression) from the diaphragmatic surface. It is rounded and corresponds to the lower border of the 11th rib. The intermediate border is rounded and separates the gastric impression from the renal impression on the visceral surface (Vishram. S 2014).

Concave and irregular. It presents four impressions: gastric, renal, colic, and pancreatic. The gastric impression is produced by the fundus of the stomach. It is the

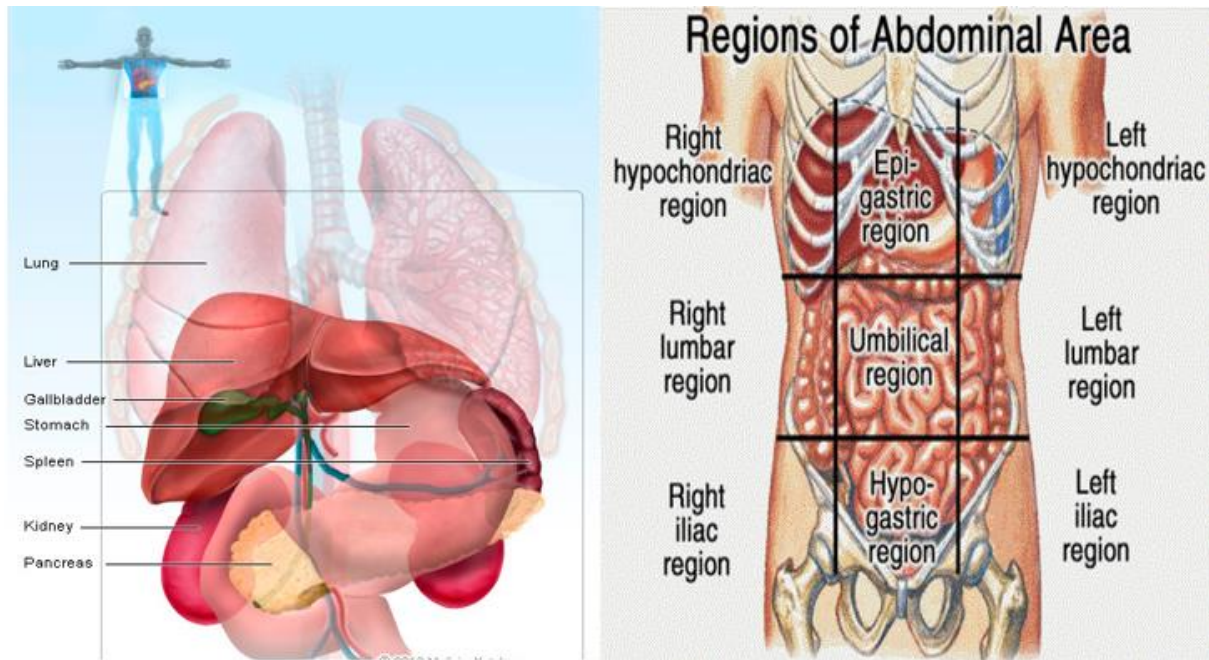


Fig (2.1) shows spleen is location in the abdominal cavity Vishram. S 2014)

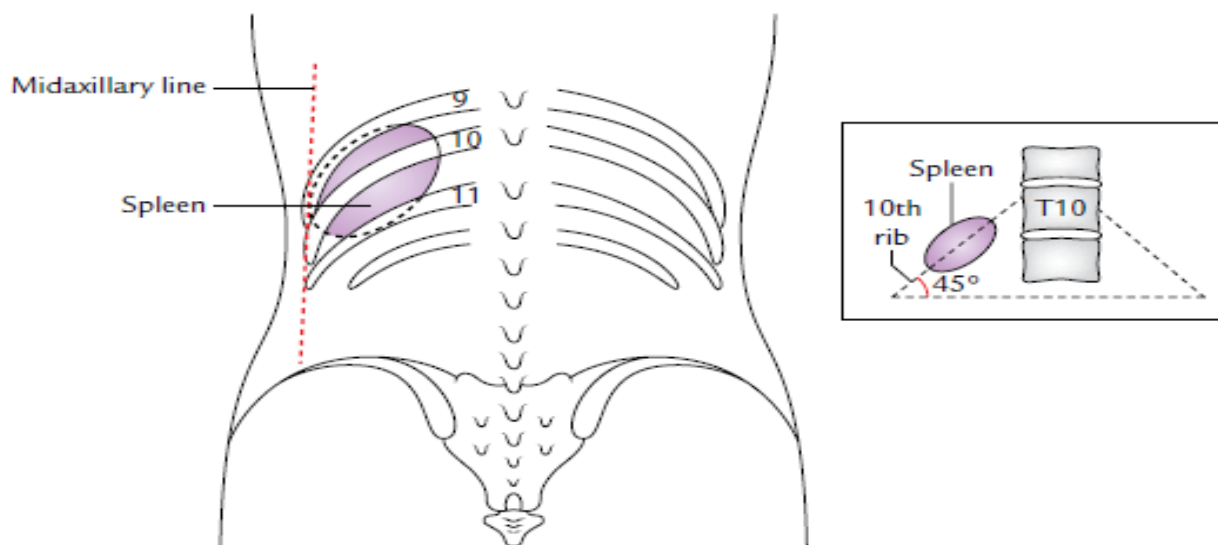


Fig (2.2) shows the relation of the spleen with the ribs Richard s 2012

Largest impression and lies between the superior and intermediate borders. The hilum of spleen is located in the lower part of this impression. The renal impression is produced by the left kidney and lies below and behind the gastric impression between the intermediate and inferior borders. The colic impression is produced by the left colic flexure. It is triangular in shape and situated in front of the lateral end. The pancreatic impression (occasional) is produced by the tail of the pancreas. It is located between the hilum and the colic impression (Vishram. S 2014).

2.1.1.2 Relation of spleen:

The Peritoneal Relations spleen is completely enclosed in the peritoneum except at its hilum, from where two peritoneal folds extend one to the stomach and one to the left kidney, called gastrosplenic and lienorenal ligaments, respectively. Gastrosplenic ligament extends from the hilum of the spleen to the upper one-third of the greater curvature of the stomach. It contains short gastric vessels (Ashwin P 2014).

Lien renal ligament extends from the hilum of the spleen to the anterior surface of the left kidney. It contains the Tail of the pancreas, splenic vessels, and pancreatic splenic lymph nodes. The visceral surface of the spleen is related to the following viscera Fundus of the stomach, anterior surface of the left kidney, Left colic flexure and Tail of pancreas (Ashwin P 2014).

These viscera produce impressions on this surface. The diaphragmatic surface of the spleen is related to the diaphragm, which separates it from the costophrenic recess of the pleura, lung, and 9 to 11 ribs (Ashwin P 2014).

2.1.1.3 Blood supply:

The blood supply of the spleen is splenic artery is, along with the gastric and common hepatic arteries, one of the three main branches of the celiac artery. The celiac artery branches from the abdominal aorta, the largest artery in the abdomen. The splenic artery is responsible for supplying oxygenated blood to the spleen, but also has several branches that deliver blood to the stomach and pancreas. The

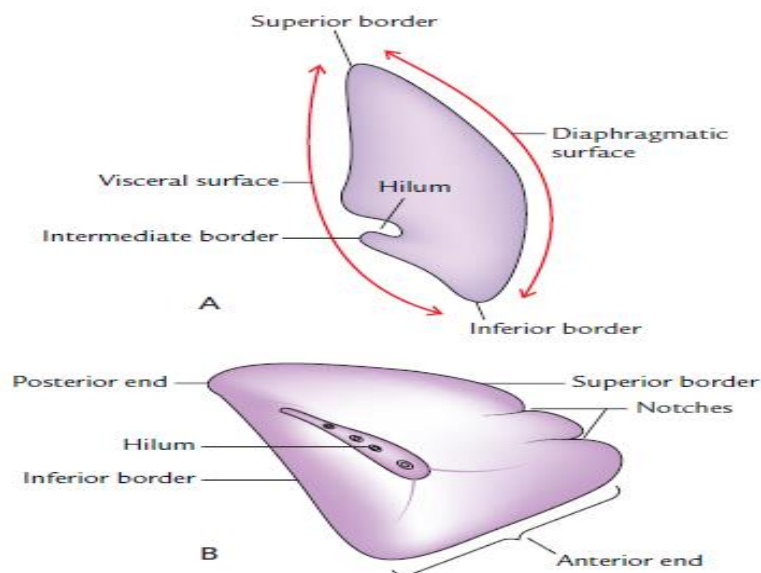


Fig (2.3): A, External features of the spleen: A, as seen in the transverse section; B, as seen from the visceral surface.(Ashwin P 2014).

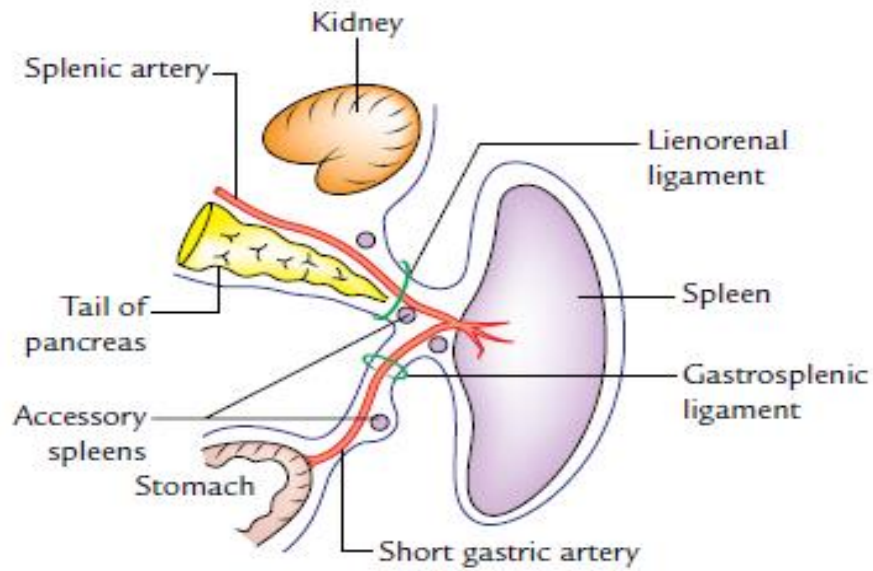


Fig (2.4): peritoneal relations of the spleen.(Ashwin P 2014).

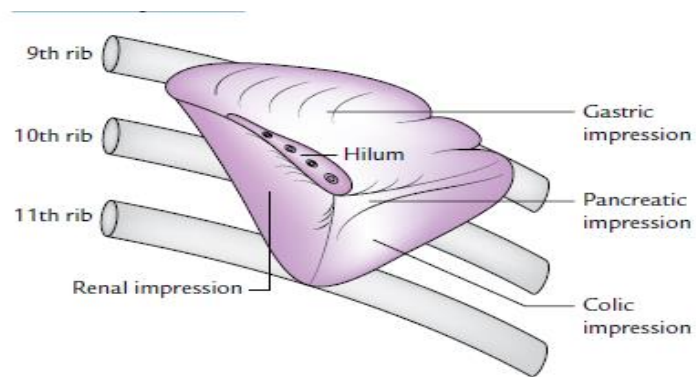


Fig (2.5): Visceral surface of the Spleen showing different impressions.(Ashwin P 2014).

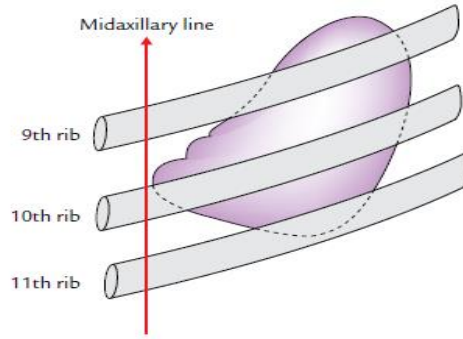


Fig (2.6): Diaphragmatic surface of the Spleen showing relation to 9th, 10th, and 11th ribs.(Ashwin P 2014).

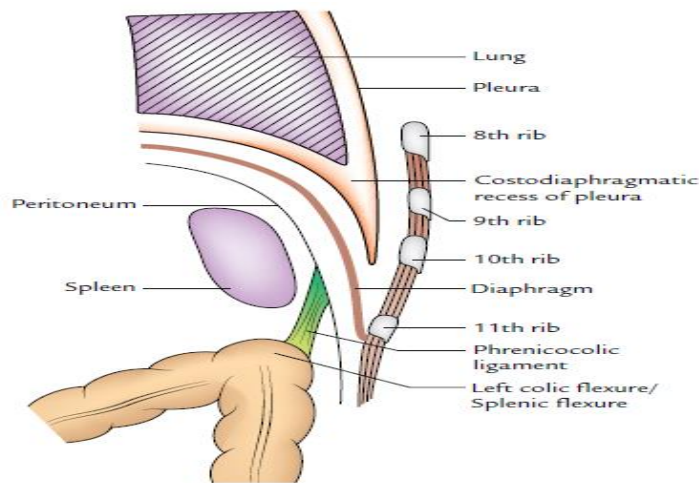


Fig (2.7): longitudinal section through the mid axillary line to show the relation of diaphragmatic surface of the spleen.(Ashwin P 2014).

Branches of the splenic artery are the short gastric, the left gastroepiploic, the posterior gastric, and the branches to the pancreas. The short gastric arteries consist of five to seven small branches that run along the greater curvature of the stomach. The left gastroepiploic artery is the largest branch of the splenic artery and runs toward the interior of the stomach through the greater omentum, a large membrane

that hangs down from the stomach. The branches to the pancreas consist of numerous, small, blood vessels that run behind the upper border of the pancreas, supplying it with blood (Healthline Media 2016). The venous blood from the spleen is drained by the splenic vein, which is formed at the hilum by the union of five or more tributaries which emerge from the splenic substance. The splenic vein runs a straight course from left to right behind the body of pancreas. Behind the neck of pancreas it joins the superior mesenteric vein to form the portal vein its tributaries are: Short gastric veins, Left gastroepiploic vein, pancreatic veins and Inferior mesenteric vein (Healthline 2016).

The splenic tissue proper has no lymphatics the tissue fluid formed in the spleen freely enters the venous sinusoids. The splenic lymphatics are confined to its trabecular, capsule, and visceral peritoneum. They drain along the splenic vessels into the pancreaticolienal lymph nodes (Vishram. S 2014).

The spleen is supplied by the sympathetic fibers derived from the coeliac plexus. They supply blood vessels (vasomotor) and smooth muscle fibers present in the trabecular and capsule (Vishram. S 2014).

The splenic artery within the spleen usually gives two branches superior and inferior. These branches usually do not anastomose and each branch supplies its own territory (segment). Thus, an avascular zone exists between these two territories. Thus, the spleen presents two segments, superior and inferior, separated by an avascular plane passing perpendicular to the long axis of the spleen .

The Knowledge of

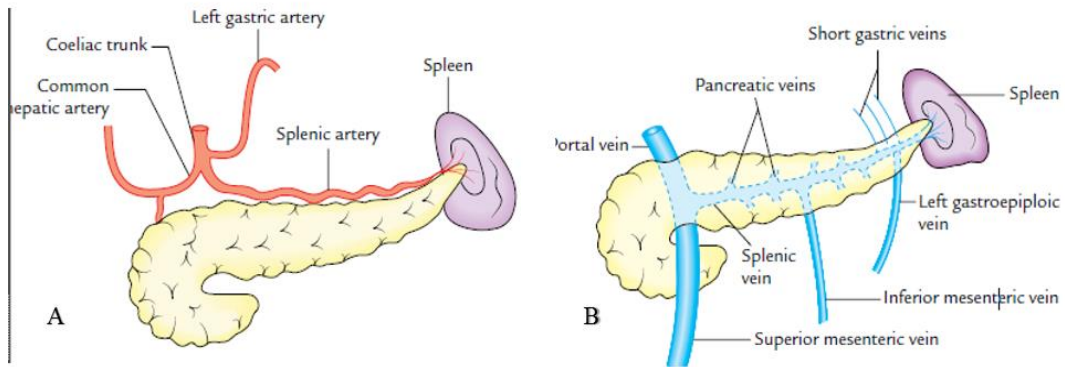


Fig (2.8): A. Shows the Arterial supply of the spleen, B. venous drainage of the spleen.

(Healthline2016)

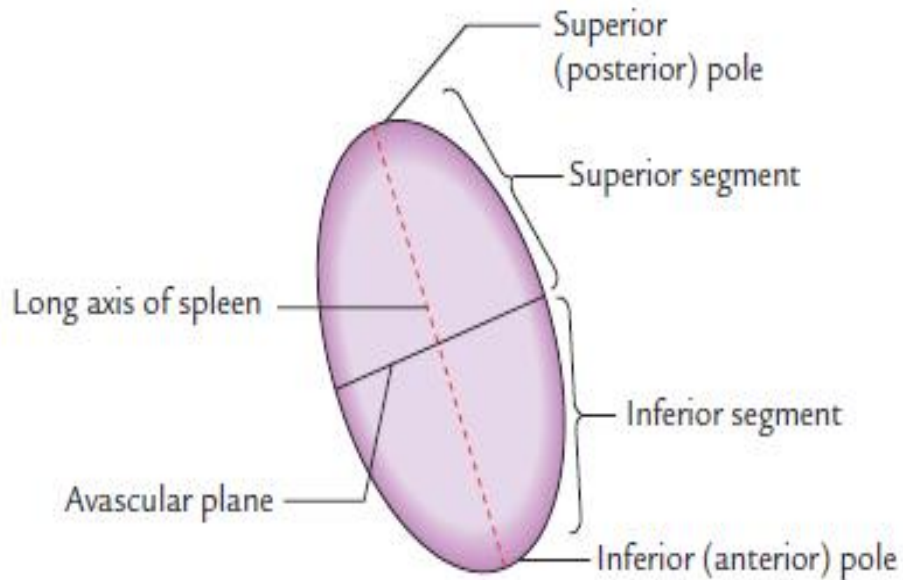


Fig (2.9): vascular segment of the spleen

These vascular segments is essential for segmental resection of the spleen to preserve the splenic tissue if required (Vishram. S 2014).

2.1.2 Physiology of Spleen:

The spleen has multiple functions, some of which remain poorly understood. Its most important functions are its ability to act as a blood filter and its role in the immunologic process of the body (Genevieve C 2015).

1. Filtering functions. Splenic blood flow is approximately 350 L/day of blood most blood elements pass through rapidly and uneventfully. A. Removal of old or abnormal red blood cells the spleen removes about 20 mL/day of aged or abnormal red blood cells. The Cells that have immunoglobulin G (IgG) on their surfaces are removed by monocytes in the spleen. This removal of cells may be the mechanism of increased cell destruction in some diseases, such as idiopathic thrombocytopenic Purport and autoimmune haemolyticanaemia. Removal of abnormal white blood cells, normal and abnormal platelets, and cellular debris(Genevieve C 2015).

2. Immunologic functions opsonicproduction. The entire reticuloendothelial system is capable of removing well-opsonized bacteria from the circulation, but the spleen, with its highly efficient filtering mechanism, is particularly suited to removing poorly opsonized or encapsulated pathogens (Genevieve C 2015).Antibody synthesis. This synthesis occurs mainly in the white pulp, where soluble antigens stimulate the production of immunoglobulin M (IgM).Protection from infection. It is well established that splenectomy leaves some patients more susceptible to infection(GenevieveC2015).

3. Storage functions. Approximately one third of the body's platelets are stored in the spleen. In some pathologic states, the percentage is increased(Genevieve C 2015).

2.1.3 Pathology of the spleen:

2.1.3.1 Congenital Malformations:

Accessory spleen: A section of spleen with attached pancreas and omentum. In the mass of tissue arising from the hilum, there is a small nodule (approximately 2 cm) of dark red purple tissue. This is an accessory spleen. (Malley 2013).

Intrapancreatic spleen: Is a rare finding associated with embryologic abnormality. Small fragments of spleen tissue are entrapped within a portion, usually distal, of the pancreas although these can vary in size, they are usually quite small. (Malley 2013).

Polysplenia: In this case, the primordial separate lobes of splenic tissue do not fuse to make a single unified organ. Rather, they are partly fused or remain separated by fibrous bands (Malley 2013).

2.1.3.2 Primary benign splenic neoplasms:

Hemangioma: Hemangioma is the most common benign neoplasm of spleen and most splenic hemangiomas are found incidentally on imaging. (Wijaya et al 2001). **Lymphangioma:** Splenic lymphangiomas are rare, benign, slow-growing neoplasms usually seen in childhood. Similar to hemangioma. (Wijaya et al 2001). **Hamartoma:** Splenic hamartoma is a rare benign lesion composed of malformed splenic red pulp elements without organized lymphoid follicles, the exact cause of which is uncertain. (Yu RS et al 2004).

Littoral cell angioma: Littoral cell angioma is a rare vascular tumor arising from the littoral cell, which lines the sinuses of splenic red pulp. (Levy AD et al 2004).

Inflammatory pseudo tumor: Splenic inflammatory pseudo tumor is a rare benign lesion of uncertain cause, likely resulting from an unusual inflammatory reparative response to injury such as infection (Levy AD et al 2004).

Uncommon primary splenic neoplasms:

Primary mesenchyme tumors such as lipoma, angiomyolipoma, fibroma, fibrosarcoma, leiomyosarcoma and malignant fibrous histiocytoma have been reported to occur in the splenic parenchyma but are quite rare (Warshauer DM, et al 2006).

2.1.3.3 Primary malignant neoplasms of the spleen:

Lymphoma: Primary involvement of the spleen by lymphoma is much less common than secondary involvement, accounting for less than 1% of all lymphomas. Primary splenic lymphoma usually represents non-Hodgkin lymphoma of B cell origin. Secondary involvement of the spleen is much more common and is seen in association with enlarged lymph nodes in the rest of abdomen (Levy AD et al 2004).

Angiosarcoma: Although rare, angiosarcoma is the most common primary non-hematopoietic malignant tumor of the spleen (Lucey BC et al 2000).

2.1.3.4 Metastatic lesions:

Splenic involvement by metastasis is relatively uncommon and is thought to be secondary to lack of afferent lymphatics. Hematogeneous spread is considered the most probable route of spread resulting in splenic metastases. Tumors that most commonly metastasize to the spleen include melanoma, and tumors of the breast, lung, ovary, colon, stomach and pancreas, most metastases to the spleen are seen as solitary or multiple masses and diffuse infiltration is a rare phenomenon (Lam KY et al 2000).

2.1.3.5 Traumatic:

Rupture of the spleen can often be managed non-operatively. Splenectomy is reserved for those patients who are unstable or who have additional, massive injuries (Genevieve C 2015).

2.1.4 Principles of Computed tomography (CT):

Computed tomography (CT) was first introduced as a clinical tool in 1971 when Drs. Godfrey Hounsfield and James Ambrose successfully diagnosed a brain tumor in a 41-year-old woman. In its most basic form, a rotating X-ray beam emits ionizing radiation of a defined thickness, which is used to irradiate the patient from numerous projections. Detectors located on the other side of the patient, opposite the source of the beam, register the amount of radiation that has penetrated through the patient. By calculating these values for numerous projections, a two-dimensional image of a specified thickness is generated. These images possess contrast resolution that is far superior to conventional radiography, demonstrating the ability to distinguish substances of only slightly different densities. Once such a 2-D image is acquired, the patient is advanced through the CT gantry for a predefined distance, and then the process is repeated. This is known as “step-and-shoot” technology (G. Bongartz et al .2004).

2.1.4.1 Spiral CT imaging:

Method of CT imaging was allowing for uninterrupted scanning during continuous patient advancement through the gantry, thus describing a spiral or helical pattern of data acquisition .With the introduction of spiral CT came the need to start thinking differently (G. Bongartz et al .2004).

2.1.4.2 Generation OF CT:

First Generation: The CT scanners (early 1970s) have single detector and the combination of both translate and rotate motions, scan times were very long: of the order of a few minutes (Greg 2001).

Second Generation: The Second generation CT scanners (fig2:11) were developed to decrease scan times. They had a narrow fan-beam of x-rays and a small number of detectors. Multiple projections were acquired simultaneously (one per detector) during each translation and therefore the number of translations required was reduced accordingly (Greg 2001).

Third Generation: The Third generation is that shown in (fig2:12), i.e. the fan beam of x-rays is wide enough to cover the full width of the patient and therefore no translation motion is required. The x-ray tube and detector arc rotate only. The arc of detectors may contain up to 1000 individual detectors (Greg 2001).

Fourth Generation: The Fourth generation scanners the detectors form a complete ring around the patient and only the x-ray tube has to rotate. These scanners may use up to nearly 5000 individual detectors. A fourth generation CT scanner is depicted in (fig2:13) (Greg 2001)

Fifth Generation: The fifth generation of CT scanners has eliminated all mechanical motion by using an x-ray tube with an anode that forms a circular arc of about 210° around the patient. The scanning motion is achieved by using magnetic fields to sweep the electron beam along the anode. This Scanner can acquire a

complete set of projection data in as little as 50 MS and is designed specifically for cardiac imaging (fig 2:14) (Greg 2001).

Helical CT: The conventional way in which CT is used is to keep the patient stationary during the scanning process. Scanning is then halted while the patient is positioned, using a motorized table-top, for the next scan (Greg 2001).

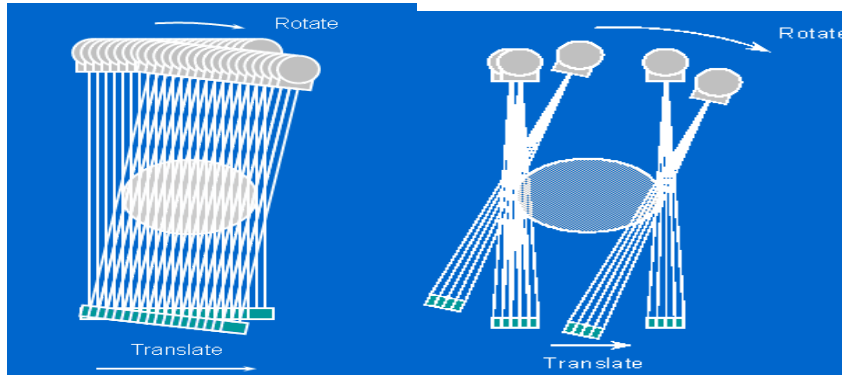


Fig (2:10) Shows First generation

Fig (2:11) Shows second

generation

(Greg 2001).

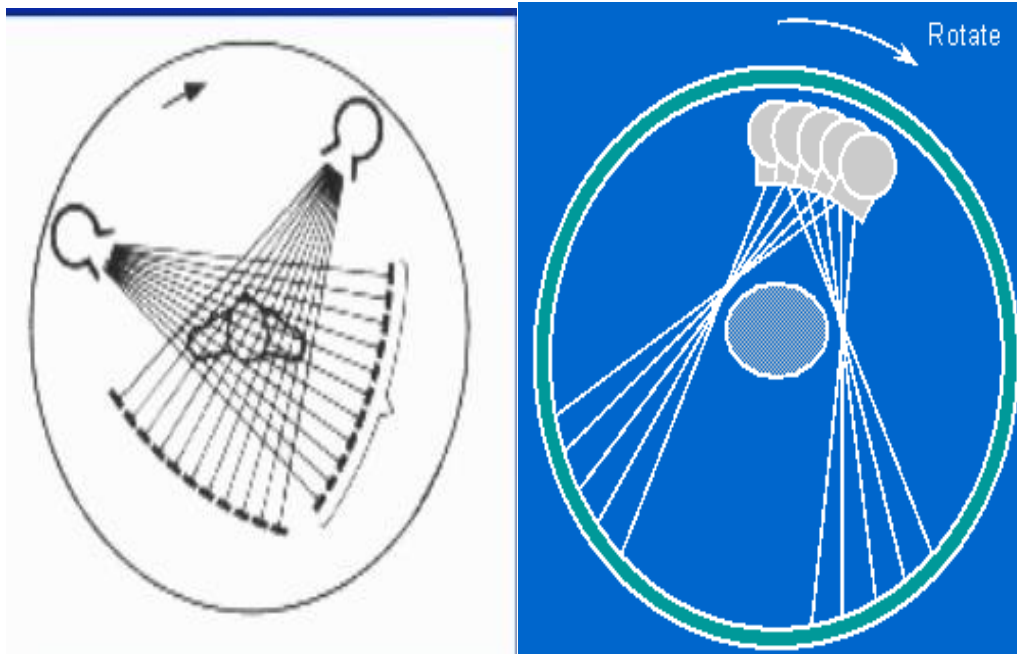


Fig (2:12) Shows third generation Fig (2:13) Shows fourth generation

(Greg 2001).

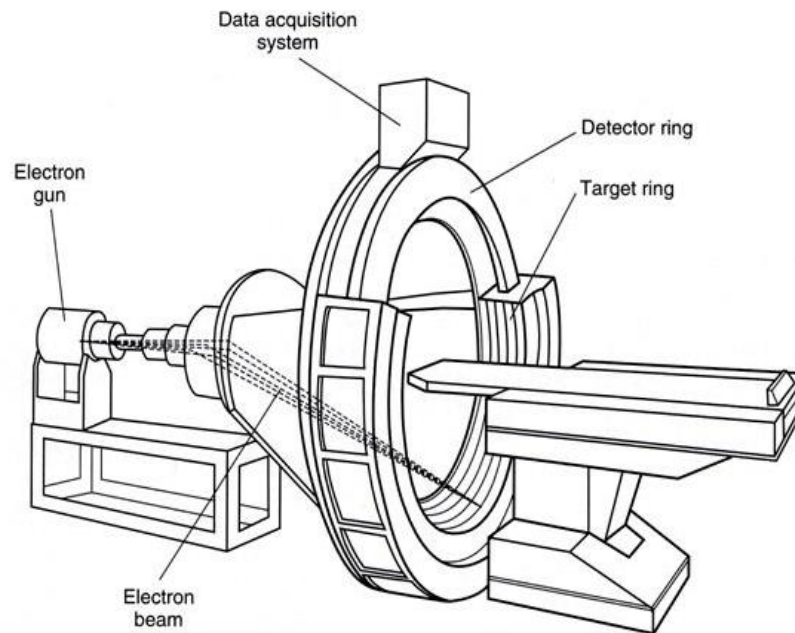


Fig (2:14) Shows fifth generation

(Greg 2001)

2.1.5 Technique of abdomen and spleen:

2.1.5.1 Patient's preparation:

For adequate examination of the abdomen and pelvis by CT, sometimes we need to opacity the gastrointestinal tract by an orally administered contrast material (gastrographin 38%). (D Karthikeyan 2005).

The contrast material is diluted by water to a concentration of 2-4% and taken orally by the patient at intervals to opacity the GI tract from the stomach to the anus. The amount of contrast material and the intervals of intake are subject to great variations. Patient should be fasting 4-6 hours before the examination. Patients indicated for IV contrast injection are injected with 4-5 ampules (20 ml each) as a

bolus just before The start of examination, flow rate 1.5-2 ml/sec, scan delay 75-80 sec. Non contrast scans should be obtained before contrast Injection when examining specific organs such as the liver, spleen, kidney and urinary bladder(D Karthikeyan 2005).

2.1.5.2 Patient position:

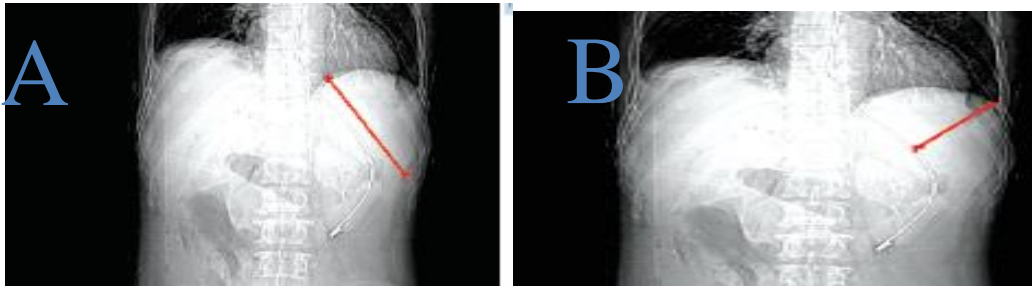
Patient in supine position, feet first on scanner table, the arms are raised and placed behind the patients head, out of scan plane. Median sagittal plane is perpendicular to the center of the table top and the coronal plane is parallel to it. The scanner table height is adjusted to ensure that the coronal plane alignment light is at the level of the mid-axillary line(M .Mahfouz 2007). A Tomogram is obtained to include the diaphragm and pubis, the scans are performed during normal inspiration Gantry angle zero, for general abdomen 10 mm slice thickness and 10 mm table increments are selected through the entire abdomen for the spleen use less slice thickness 5 mm 5 mm table increments. In the multidetector CT (MDCT) facilities we may obtain reconstructed images in the sagittal and coronal planes which are very helpful in the diagnosis especially in cases of spleen pathology(M.Mahfouz 2007).

2.1.6 Measurement of spleen:

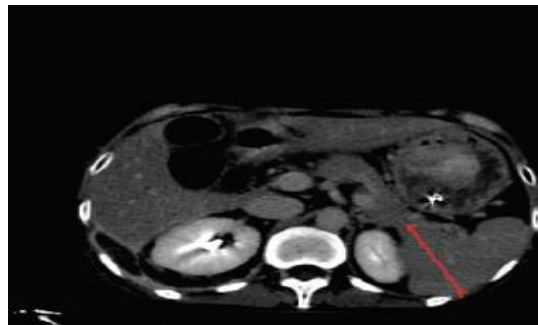
CT-scan DICOM images of each patient were observed in Able- 3D-doctor software. Spleen was identified in each cross section and longitudinal section of CT-scan images. The length of spleen was recorded in longitudinal section along 10th rib in cephalocaudal direction (Fig2:15A). Width of spleen was also recorded in longitudinal direction (Fig2:15B) and thickness measured in cross-section image (Fig2:16). All dimensions were recorded maximum appreciated in sections for better accuracy.

2.1.7 Calculation of spleen volume method:

The CT volumes, means and ranges of calculated volumes, and SDs using ellipsoid methodology. The ellipsoid formulas were then adjusted for bias such that CT volume = $(0.524 \times W \times T \times L)$ (Ellen M. 2003)



(Fig2:15) Shows A-Measurement of splenic length (cephalo-caudal length Along 10th rib) and B- Measurement of splenic width



(Fig2:16) Shows Measurement of splenic thickness

2.2 Previous Studies:

SitthipongSrisajakul In 2011 was measured the width (W), length (L), thickness (T) and splenic volume from 426 patients who underwent CT for various indications. The relationship between splenic volume and age, gender and body habitus were also examined. And he found the average splenic volume was $124.1 \pm 51.8 \text{ cm}^3$. Adel Asghar *et al* In 2011 measured splenic volume using volumetric software in north Indian adult population and found it out to be $192 \pm 54.91 \text{ cm}^3$ in males, $118.39 \pm 47.7 \text{ cm}^3$ in females and over all $161.57 \pm 90.2 \text{ cm}^3$. Researcher found the splenic size in males to be $196.95 \pm 46.81 \text{ cm}^3$ and in females to be $121.45 \pm 26.97 \text{ cm}^3$. They found a significant difference in two sexes.

Mustapha *et al* In 2010 measurement of spleen for adult African people by ultrasonography and found out the mean splenic volume to be 120 cm^3 . Harris *et al* In 2010 measure of splenic volume using volumetric software in 230 patients who underwent CT scan for various reasons. They reported splenic volume in Japanese people to be $127 \pm 62.9 \text{ cm}^3$ in all subjects. Loftus *et al* In 2009 calculated splenic volume by water displacement and reported Normal size to be $110 \pm 70 \text{ cm}^3$.

Ahmed Musa *et al*. 2016 measured splenic volume using prolate ellipsoid equation in Sudanese adult population and found it out to be $182.4 \pm 25.8 \text{ cm}^3$ in males, $148.5 \pm 37.9 \text{ cm}^3$ in females and over all $165.46 \pm 34.4 \text{ cm}^3$.

2-2 Previous study:

Chapter three

Materials and methods

3.1 Materials:

3.1.1 Subject:

This study intended to measure spleen in normal adult Sudanese population.

The data used in this study was collected from two hospitals in Khartoum state:

AlzytounSpecialist Hospital, Royal care international hospital.

The data collected from February2018 to JUNE 2018.

CT scans of 60 patients (30 male and 30 female) are used to measure the volume of spleen. The age of patients ranged from 20 to 80 years.

3.1.2 CT Machine:

Two CT machines were used to collect data during this study. This machines are installed in two radiological departments.

Hospital	Manufacture	Model	Instillation	Detector type
Al-zaytouna Hospital	Toshiba	Aquilion 64	2010	64 Rows
Royal care international hospital	Toshiba	Aquilion 64	2012	64 Rows

3.2 Methods:

3.2.1 Technique used:

	Al-Zytouna hospital	Royal care hospital
Scouts	AP and lateral	AP and lateral
Scan type	Helical	Helical
Start location	above to the diaphragm	above to the diaphragm
End location	below symphysis pubis	below symphysis pubis
Breath-hold	Inspiration	Inspiration
Reconstruction	Slice Thickness and Interval 5 mm/5 mm	Slice Thickness and Interval 5 mm/5 mm
KVp	120	120
Mas	≥230	≥200
I.V. contrast	3.5 - 4 ml/sec, 100-150 ml	4 - 4.5 ml/sec, 100-150 ml
Scan delay	1. non-contrast 2. Arterial 20 sec. 3. Portal 20 sec. 4. delay after 5 min	1. non-contrast 2. Arterial 25 sec. 3. Portal 25 sec. 4. delay after 5 min

3.2.2 Measurement:

CT-scan DICOM images of each patient were observed in Radiant DICOM Viewer software. Spleen was identified in each cross section and longitudinal section of CT-scan images. The length of spleen was recorded in longitudinal coronal section along 10th rib from superior border of the spleen (appendix A.1). Width of spleen was also recorded in coronal section from the hilum of the spleen to the lateral border of spleen (appendix A.2) and thickness measured in axial section (appendix A.3). All dimensions were recorded maximum appreciated in sections for better accuracy.

The splenic volume calculated by multiplying the splenic width, thickness and length and then by multiplying in 0.52.

3.2.3 Data Collection and analysis:

Data were collected using a sheet for all patients in order to maintain consistency of the information from display (appendix B). A data collection sheet was designed to obtain patient gender, age, spleen length, spleen thickness, spleen width, spleen volume, patient Weight, and height was calculated.

Microsoft excel for analysis.

4. The Results

Table (4.1) demonstrates the distribution of the gender:

Gender	Frequencies	Percentage
Male	30	50%
Female	30	50%
Total	60	100%

Table (4.2) demonstrates the mean and stander deviation of the age, body weight, body height and splenic volume.

	Age /years	Body weight/Kg	Body highest/cm	Splenic volume/cm³
Mean ±SD	51.8±14.7	75±15	168.2±8.7	182.12±21.9

Table (4.3) demonstrates the mean and standard deviation of the splenic volume in males and females.

	Male	Female
Splenic volume /cm³	166.33±24.67	198.3±17.54

Table (4.4) demonstrates the splenic volume according to age groups in males.

Age group/years	Splenic volume /cm³
20-40	230
41-60	183.59
61-80	174.0

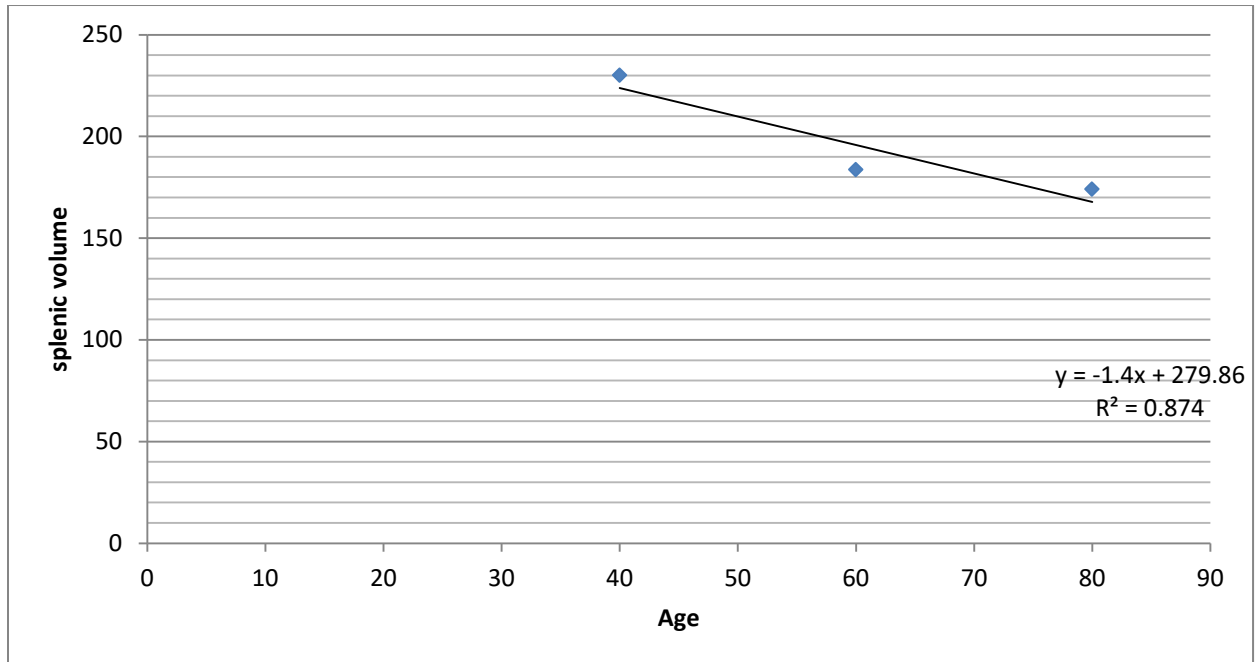


Fig (4.1) shows correlation between age and spleen volume in males

Table (4.5) demonstrates the splenic volume according to age groups in females.

Age group/years	Splenic volume /cm ³
20-40	150.15
41-60	138.33
61-80	106

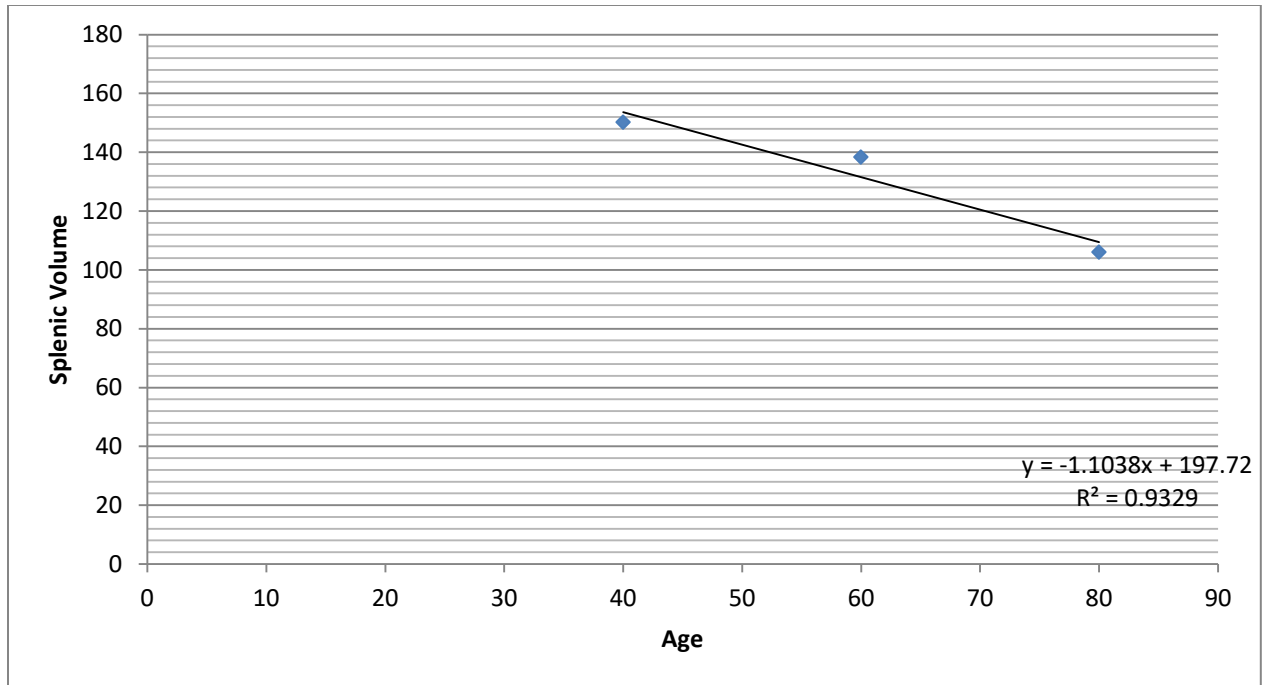


Fig (4.2) shows correlation between age and spleen volume in females.

Table (4.6) demonstrates the splenic volume according to body highest in males.

Body height\cm	Splenic volume /cm³
150-160	195.76
161-170	169.68
171-180	210
181-190	231

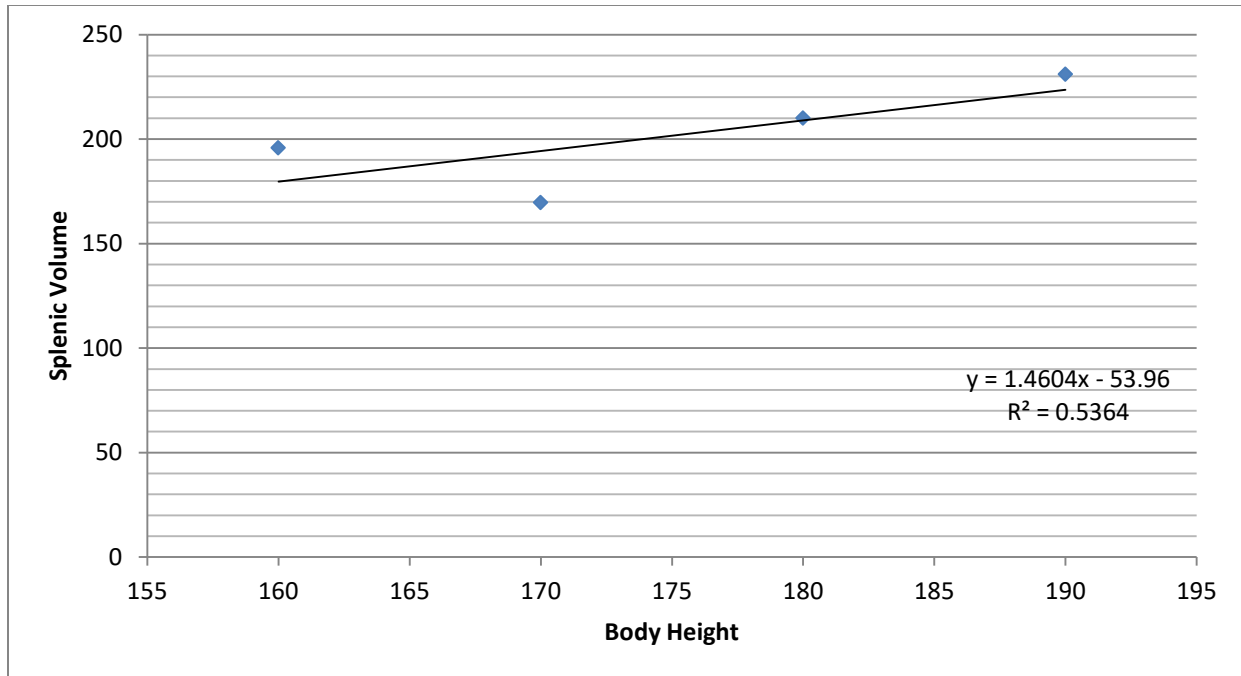


Fig (4.3) shows correlation between body highest and spleen volume in males.

Table (4.7) demonstrates the splenic volume according to body highest in females.

Body height\cm	Splenic volume /cm³
150-160	120.23
161-170	186.35
171-180	200.8
181-190	279

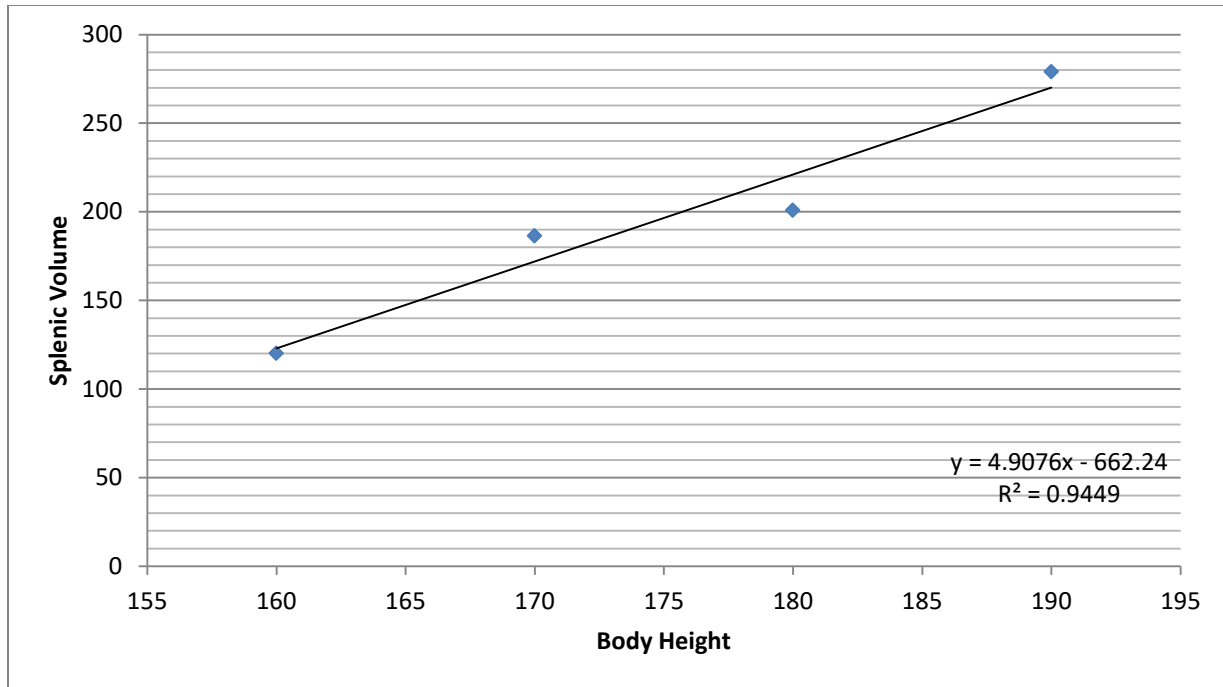


Fig (4.4) shows correlation between body highest and spleen volume in females.

Table (4.8) demonstrates the splenic volume according to body weight in males.

Body weight \kg	Splenic volume /cm³
40-60	190.3
61-80	197
81-100	259.5
101-120	199.4

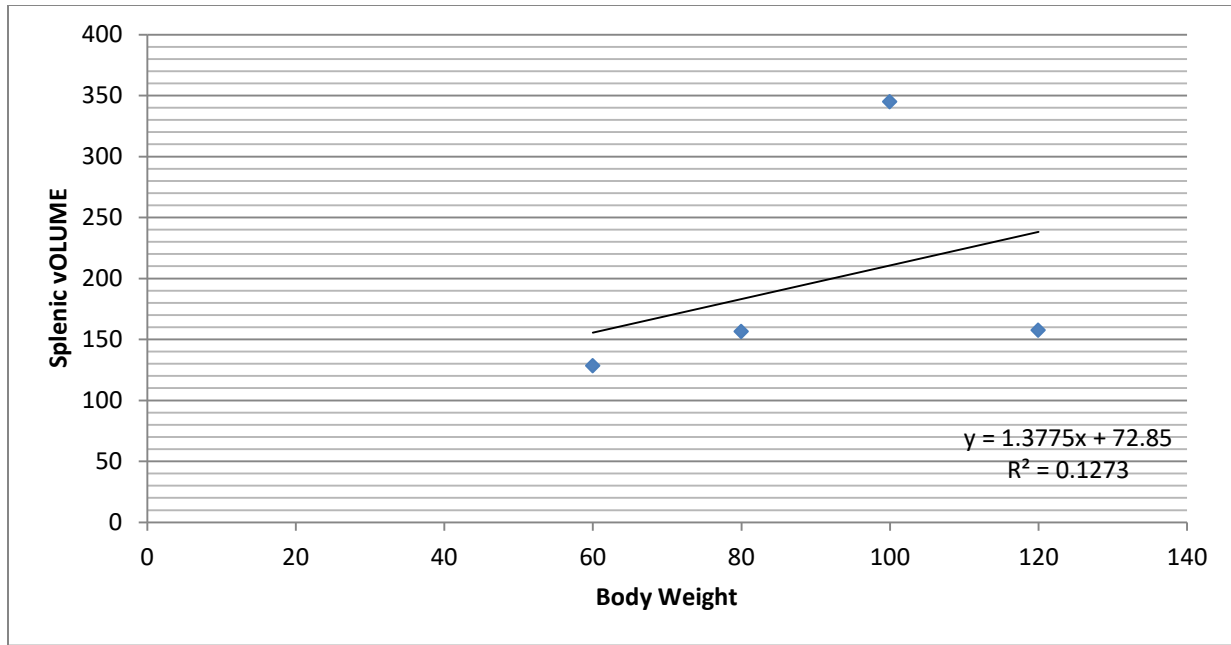


Fig (4.5) shows correlation between body weight and spleen volume in males.

Table (4.9) demonstrates the splenic volume according to body weight in females.

Body weight \kg	Splenic volume /cm³
40-60	128.4
61-80	156.5
81-100	345
101-120	157.4

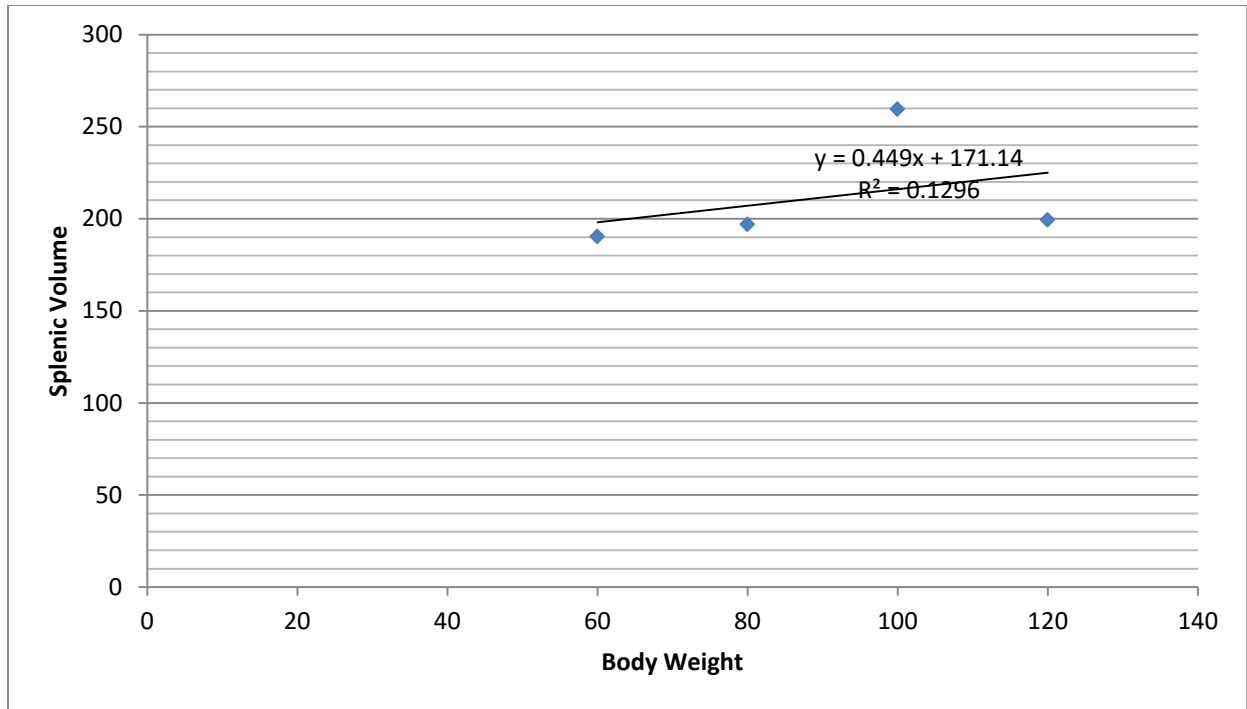


Fig (4.6) shows correlation between body weight and spleen volume in females.

5.1 Discussion:

Splenomegaly is a well-known manifestation of several diseases that may involve the liver, immune system, and hematopoietic system. Accurate noninvasive assessment of splenic volume is used in the clinical treatment of patients with these diseases.

The data used in this study were collected from cases admitted to various hospitals in Khartoum state (Al-Zytouna specialist hospital, Royal care international hospital) during the period from February 2018 to JUNE 2018, 60 CT scans of consecutive adult patients (30 male and 30 female) , mean age was 51.8 ± 14.7 years table 4.2 , having no splenic disorders, The patient's body weight and height were recorded at the time of the Computed tomography (CT) examination. Computed tomography (CT) examinations was done by using CT machine Toshiba- aquilion 64 slices. The technical parameters were 120 kvp, 200 mas, and 5 mm slice width with identical reconstruction index and rotation time of 0.6 secs.

Tables 4.4,4.5 and figure 4.1,4.2 showed the relation between the splenic volume and age in both gender groups , according to this results in figure 4.1, 4.2 there is a reverses relation between the age and splenic volume this could be due to the shrink of the splenic size due to increase of age.

This result was similar to findings of Adel Asghar et al and Ahmed Musa et al.

Table 4.6 and Table 4.7 demonstrate the splenic volume according to body highest in both gender, the results showed that the splenic volume increased with increasing in body highest , but there is slightly decrease in both gender in body highest between 161 to 171 cm ,then the splenic volume rapidly increase again.

Table 4.8 , 4.9 showed the relation between splenic volume and body weight in both males and females the results showed that there is a proportional relation between the splenic volume and body weight.

Table 4.3 showed the mean of splenic volume in female was $198.3 \pm 17.5 \text{ cm}^3$ and a male was $166.33 \pm 24.6 \text{ cm}^3$ and over all $182.12 \pm 21.9 \text{ cm}^3$, the difference between male and female could be due to body habits. AdilAsghar et al. 2011, measured splenic volume using volumetric software in north Indian adult population and found it out to be $192 \pm 54.91 \text{ cm}^3$ in males, $118.39 \pm 47.7 \text{ cm}^3$ in females and over all $161.57 \pm 90.2 \text{ cm}^3$.

Ahmed Musa et al. 2016 measured splenic volume using prolate ellipsoid equation in Sudanese adult population and found it out to be $182.4 \pm 25.8 \text{ cm}^3$ in males, $148.5 \pm 37.9 \text{ cm}^3$ in females and over all $165.46 \pm 34.4 \text{ cm}^3$. Current study showed there is slightly difference compare to ahmedmusa this difference could be due to sample size and adilasghar also this difference my due to the body habits in Sudanese population and north India population.

5.2 Conclusion:

The volume of the spleen was measure with help of CT in 30 males and 30 female's patient, any patient with splenic abnormality was excluded. The basis of the above study, the following conclusion was drown.

In female and male there is no relation between splenic volumes with the age, Spleen volume, have direct relation with body weight and Volume of the spleen increase with increase the body height in both gender . The results showed significant difference in two genders, the spleen volume in female higher than spleen volume male and this may due to genetic factor or other reasons. The results showed the mean splenic volume for Sudanese population is $182.12 \pm 21.9 \text{ cm}^3$.

5.3 Recommendations:

The study recommended to:

- Recommend to measure the spleen volume by using small slice thickness to make the measurement more accurate.
- Using more advance method to measure the splenic volume.
- Recommend the radiologist and physician to use the splenic volume in diagnosis the splenic abnormalities.
- Further studies in measuring spleen with larger sample of population.
- Further imaging modalities like Ultrasound and MRI should be used for measuring the spleen volume.

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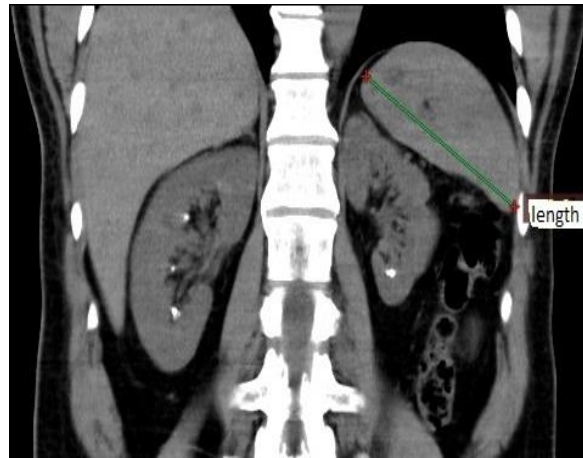
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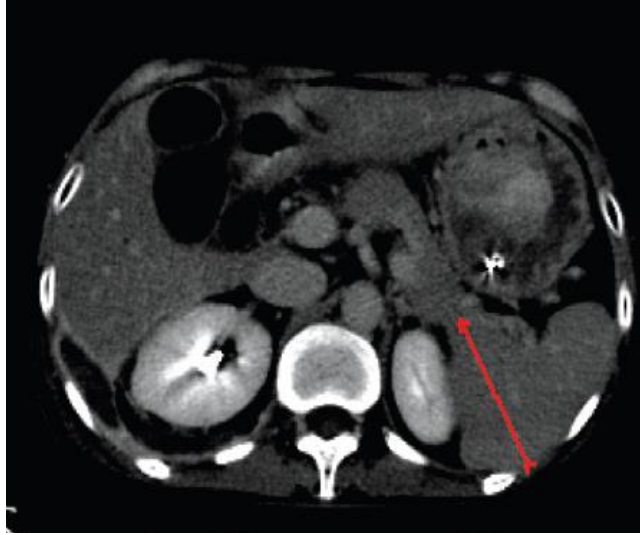
Appendices
Appendix (A)



Appendix (A1) shows the Measurement of splenic length in coronal section.



Appendix (A2) shows the Measurement of splenic width in coronal section.



Appendix (A3) shows the thickness measured in axial section.

Appendix B:

Data Sheet Collecting

age	gender	Body height	Body weight	Spleen length	Spleen width	Spleen thickness	volume

