

بسم الله الرحمن الرحيم



**Sudan University of Science and Technology**

**College of Graduate Studies**



**Thesis title:**

**Evaluation of Sudanese Abdominal Aorta using  
Ultrasonography**

**تقويم الابهر البطني لدي السودانيين باستخدام الموجات فوق الصوتيه**

A Thesis submitted in partial fulfillment requirements of M. Sc. Degree in Medical Diagnostic  
ultrasound

M.Sc. in Diagnostic Radiology

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# الآية

بسم الله الرحمن الرحيم

(يَا أَيُّهَا الَّذِينَ آمَنُوا إِذَا قِيلَ لَكُمْ تَفَسَّحُوا فِي الْمَجَالِسِ فَافْسَحُوا يَفْسَحِ اللَّهُ لَكُمْ وَإِذَا قِيلَ انشُرُوا فَانشُرُوا يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

الآية (11) من سورة المجادلة

# *Dedication*

*To My Family*

*To my father and mother*

*To my sister and brothers*

# *Acknowledgment*

*I would like to specify my  
acknowledgment to my supervisor Dr.  
Caroline Edward Ayad*

*My thanks extend also to all the staff  
in hospitals whom help me in this  
research*

*To my colleague Dr. Azeza babiker*

*To my brother Mohammed*

*To any person help me to complete this  
study*

## Abstract

This study was performed to measure the normal abdominal aorta in adult Sudanese population without history of vascular disease by using grey scale ultrasound. The aim of this study was to determine the normal range of diameter of abdominal aorta among Sudanese population and to develop local standard measurements by ultrasound.

Gray scale ultrasound was done for abdominal aorta and the measurements was taken in three different level at aortic hiatus, infrarenal and just above the bifurcation.

This study was performed in Khartoum state in many hospitals and clinics center at Omdurman Islamic University Clinic, Alrebat Universal hospital and Tayba hospital. The study was included 105 adult normal subjects were 55 males (52.4%) and 50 females (47.6%) with different age from 17 years to 74 years.

This study was carry out over period of six months from 2016 to May 2017.

The results of the study was showed that the abdominal aortic measurements were 22 mm  $\pm$  3 Std in aortic hiatus, 18.5 mm  $\pm$  2.5 Std in infrarenal and 16 mm  $\pm$  2.2 Std above the bifurcation. with multivariate analysis including the age, body size (height, weight, and body mass index). The study was demonstrated significant correlation between aortic measurements (at the three levels) with age and correlated to height, weight and body mass index.

This study was notes different between gender measurements 23/21 mm ( $r=0.87$ ,  $p=.000$ ) for aortic hiatus, 19/17 mm ( $r=0.74$ ,  $p=.000$ ) for infrarenal and 16/15 mm ( $r=0.74$ ,  $p=.000$ ) for bifurcation. The males have the largest abdominal aortic diameter than females at the three levels.

## مستخلص البحث

أُجريت هذه الدراسة لتقويم القياس الطبيعي لقطر الشريان الأبهري البطني لدى السودانيين البالغين الذين لم يتعرضوا لأمراض القلب والأوعية الدموية. تهدف هذه الدراسة لتحديد المعدل الطبيعي لقطر الشريان الأبهري البطني بين السكان السودانيين وتطوير قياس معياري محلي بواسطة الموجات فوق الصوتية.

أُجريت هذه الدراسة بواسطة الموجات فوق الصوتية الرمادية على ثلاث مستويات هي بعد دخول الشريان منطقة البطن تحت الحجاب الحاجز، تحت الشريان الكلوي، وقبل انقسام الشريان الأورطي.

أُجريت هذه الدراسة في ولاية الخرطوم في عيادات و مستشفيات متعددة هي مستوصف جامعة أم درمان الإسلامية ومستشفى الرباط الجامعي ومستشفى طيبة، كان عدد العينات 105 من السكان البالغين بعدد 55 رجلا (52.4%) و 50 أنثى (47.6%) بأعمار مختلفه من 17 سنة إلى 74 سنة.

تم جمع واكمال هذه الدراسة على مدى ستة أشهر من 2016 حتى مايو 2017.

أوجدت الدراسة أن القياسات للشريان الأبهري البطني بمقياس 22 مم + 3 عند دخوله البطن تحت الحجاب الحاجز، و18.5 مم + 2.5 تحت الشريان الكلوي، و16 مم + 2.2 قبل انقسامه، تضمنت الدراسة متغيرات متعددة هي العمر، الطول، الوزن ومؤشر كتلة الجسم اوجدت الدراسة ان هنالك ارتباط قوى بين قياسات الشريان الأبهري (في المستويات الثلاثة) مع تقدم العمر ومع ارتفاع الطول، وزيادة الوزن ومؤشر كتلة الجسم.

وقد لوحظ في هذه الدراسة اختلافا كبيرا بين القياسات لدى الذكور والإناث (21/23 م (r=.87, p=.000) عند دخوله البطن تحت الحجاب الحاجز، و17/19 مم (r=.74, p=.000) تحت الشريان الكلوي، و15/16 مم (r=.74, p=.000) قبل انقسامه ولوحظ في هذه الدراسة أن الذكور لديهم قطر اكبر للشريان الأبهري في البطن من الإناث على المستويات الثلاثة.

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### List of Abbreviations:

<b>AAA</b>	Abdominal Aortic Aneurysm
<b>ASIS</b>	Anterior Superior Iliac Spine
<b>CHA</b>	Common Hepatic Artery
<b>HAP</b>	Hepatic Artery Proper
<b>SMA</b>	Superior Mesenteric Artery
<b>IMA</b>	Inferior Mesenteric Artery
<b>EIA</b>	External Iliac Artery
<b>IIA</b>	Internal Iliac Artery
<b>RCIA</b>	Right Common Iliac Artery
<b>LCIA</b>	Left Common Iliac Artery
<b>RRA</b>	Right Renal Artery
<b>LRA</b>	Left Renal Artery
<b>GDA</b>	Gastroduodenal Artery
<b>LGA</b>	Left Gastric Artery
<b>IVC</b>	Inferior vena cava
<b>AP</b>	Anteroposterior
<b>CT</b>	Computed tomography
<b>OTO</b>	Outer to Outer
<b>ITI</b>	Inner to Inner
<b>LELE</b>	Leading Edge to Leading Edge
<b>LDL</b>	Low Density lipoprotein

# **CHAPTER ONE**

## **Introduction**

# CHAPTER ONE

## **1-1-Introduction:**

Today nearly every hospital and medical clinic has some form of ultrasound instrumentation to provide the diagnostic information of the soft tissue structures within the body. (Sandra L et al, 2012)

The circulatory system, along with the heart and lymphatics, is transport gases, nutrient materials, and other essential substances to the tissues, and subsequently to transport waste products from the cells to appropriate sites for excretion. Blood is carried away from the heart by the arteries and is returned from the tissues to the heart by the veins. (Sandra L et al, 2012)

The aorta is the largest principal artery of the body It divided into five sections the root of the aorta, ascending aorta and arch, descending aorta, abdominal aorta and abdominal aortic branches and bifurcation of the aorta into iliac arteries. (Sandra L et al, 2012)

The aorta passes through the diaphragm at the level of the 12th thoracic vertebral body. It lies slightly to the left of the midline and bifurcates at the level of the 4th lumbar vertebral body. The surface anatomy landmarks corresponding to these two points are the xiphoid process and the umbilicus. The length of the abdominal aorta is about 13 cm (6 inches) which is less than the length of iliac arteries from the bifurcation to the inguinal ligament. Most scanning of the aorta will therefore take place in the short distance between the sternum and the umbilicus. (Sandra L et al, 2012)

The abdominal aorta is usually one of the easiest abdominal structures to image with ultrasound because of the marked change in acoustic impedance between its elastic walls and blood-filled lumen. The Sonography provides the diagnostic information needed to create an image of the entire abdominal aorta, to assess its diameter, and to visualize the presence of aneurysm, thrombus, calcification, or dissection within the walls. (Sandra L et al, 2012)

## **1-2 Study Problem:**

The aorta is affected by many disorders, any dilation may diagnose as aneurysm, no standard measurements was done for Sudanese by ultrasound for normal value.

## **1-3 Objective:**

### **1-3-1 General Objective:**

The general objective of this study is to evaluate the normal measurements of abdominal aorta diameter in normal Sudanese subjects.

### **1-3-2 Specific objective:**

The specific objective of this study are:

- 1-To correlate the normal aortic measurements with age and gender.
- 2-To correlate the height and weight of subjects with the aortic measurements.
- 3- To correlate the body mass index of subjects with the aortic measurements.

# **CHAPTER TWO**

## **Literature Review**

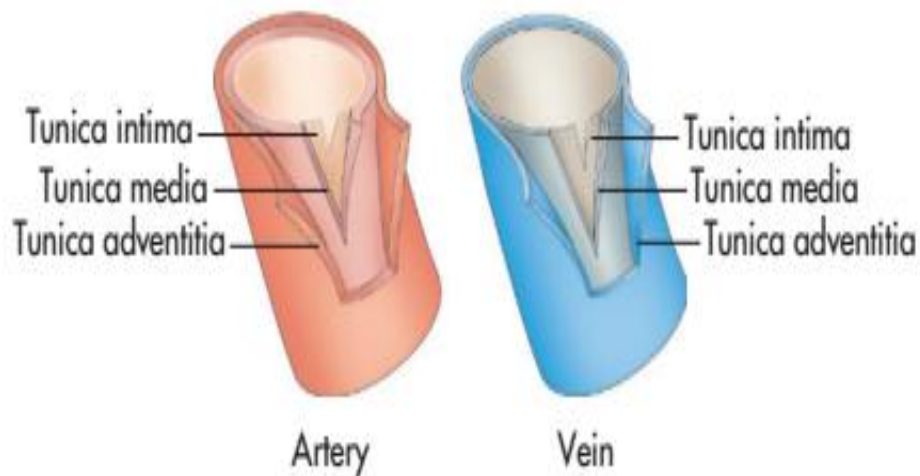
# CHAPTER TWO

## Literature Review

### 2-1 Anatomy:

#### Artery in cross section consists of the following three layers:

- Tunica intima (inner layer), which itself consists of the following three layers: a layer of endothelial cells lining the arterial passage (lumen), a layer of delicate connective tissue, and an elastic layer made up of a network of elastic fibers.
- Tunica media (middle layer), which consists of smooth muscle fibers with elastic and collagenous tissue.
- Tunica adventitia (external layer), which consists of loose connective tissue with bundles of smooth muscle fibers and elastic tissue. The vasa vasorum comprises the tiny arteries and veins that supply the walls of blood vessels. (Sandra Let al,2012)





**Figure 2-1 Cross section of an artery and vein showing the distinctions among the three layers of each vessel. (Sandra Let al,2012)**

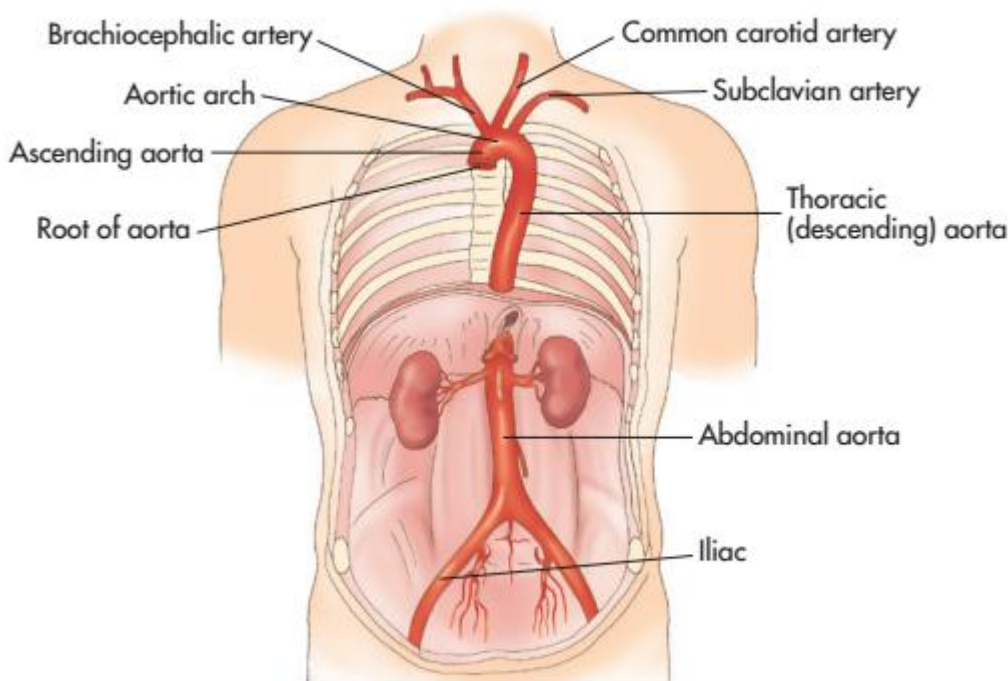
Although arteries and veins have the same three layers, each layer is thicker in the arteries. Veins usually have larger diameters than the corresponding arteries; for example, the splenic vein has a larger diameter than the splenic artery. Blood flow in an artery is faster than in a vein since the flow is dependent upon the strength of the heart's contractions. Since arteries originate from the heart they are therefore closer to the source of the contractions. Blood flow in veins can be sluggish, especially in peripheral areas of the body such as the legs. Other factors that influence blood flow are the strength of the vessel wall contractions and the effects of gravity. Arteries have thicker muscle layers and can propel blood more effectively than the thinner walled veins. Blood flow is reduced whenever it has to flow against the influence of gravity; conversely, it is increased whenever it flows with the forces of gravity. Veins also have valves that permit flow only in the direction of the heart. (Devin-Deen2005)

**2-1-1 Root of the aorta:**

The aorta, the largest artery in the body, originates at the left ventricle of the heart. The subdivision of the aorta within the chest is referred to as the thoracic aorta. As it passes through the aortic hiatus of the diaphragm, it is referred to as the abdominal aorta. It is retroperitoneal in location and positioned anterior to the spine, just left of the midline. (Sandra L et al,2012)

The systemic circulation leaves the left ventricle of the heart by way of the aorta. The root of the aorta arises from the left ventricular outflow tract in the heart. The aortic root has three semilunar cusps that prevent blood from flowing back into the left ventricle. These cusps open with ventricular systole to allow blood to be

ejected into the ascending aorta; the cusps are closed during ventricular diastole. The coronary arteries arise superiorly from the right and left coronary cusps to form the right and left coronary arteries, respectively. These coronary arteries further bifurcate to supply the vasculature of the cardiac structures. After the aorta arises from the left ventricle, it ascends posterior to the main pulmonary artery to form the ascending aorta. (Sandra L et al,2012)



**Figure 2-2 The aorta is divided into five sections. (Sandra L et al,2012)**

### **2-1-2 Ascending and Arch of Aorta:**

The ascending aorta arises a short distance from the ventricle and arches superiorly to form the aortic arch at the level of the sternoclavicular junction. Three arterial branches arise from the superior border of the aortic arch to supply the head, neck,

and upper extremities: the brachiocephalic, left common carotid and left subclavian arteries. (Sandra L et al,2012)

### **2-1-3 Descending Aorta:**

From the aortic arch, the aorta descends posteriorly along the back wall of the heart through the thoracic cavity, where it pierces the diaphragm to become the abdominal aorta. The descending (thoracic) aorta enters the abdomen through the aortic opening of the diaphragm anterior to the twelfth thoracic vertebra in the retroperitoneal space. (Sandra L et al,2012)

### **2-1-4 Abdominal Aorta:**

The abdominal aorta is the largest artery in the body that supplies blood to all visceral organs and to the legs. The aorta continues to flow in the retroperitoneal cavity anterior and slightly left of the vertebral column. The aorta lies posterior to the left lobe of the liver, the body of the pancreas, the gastroesophageal junction, the pylorus of the stomach, and the splenic vein, the diaphragmatic crura surround the aorta as it projects through the diaphragm into the abdominal cavity. (Sandra L et al,2012)

Many branches arise from the abdominal aorta (i.e., celiac axis, superior mesenteric, inferior mesenteric, renal, suprarenal, and gonadal arteries). At the level of the fourth lumbar vertebra (near the umbilicus), the aorta bifurcates into the right and left common iliac arteries. (Sandra L et al,2012)

### **2-1-5 Relationships of the Aorta:**

#### **2-1-5-1 Anterior superior to inferior**

Esophagus, Crura, Celiac Trunk and Branches, Omental Bursa (lesser sac), Superior Mesenteric Artery (SMA), Left Renal Vein (between aorta and SMA), Body of pancreas and splenic vein (anterior to SMA and left renal vein), Uncinate process of pancreatic head (variable), Gonadal arteries and horizontal part of duodenum, Inferior mesenteric artery, Mesentery, Normal lymph nodes - these nodes encircle the aorta and are NOT normally visible. (Devin-Deen 2005)

### **2-1-5-2 Posterior**

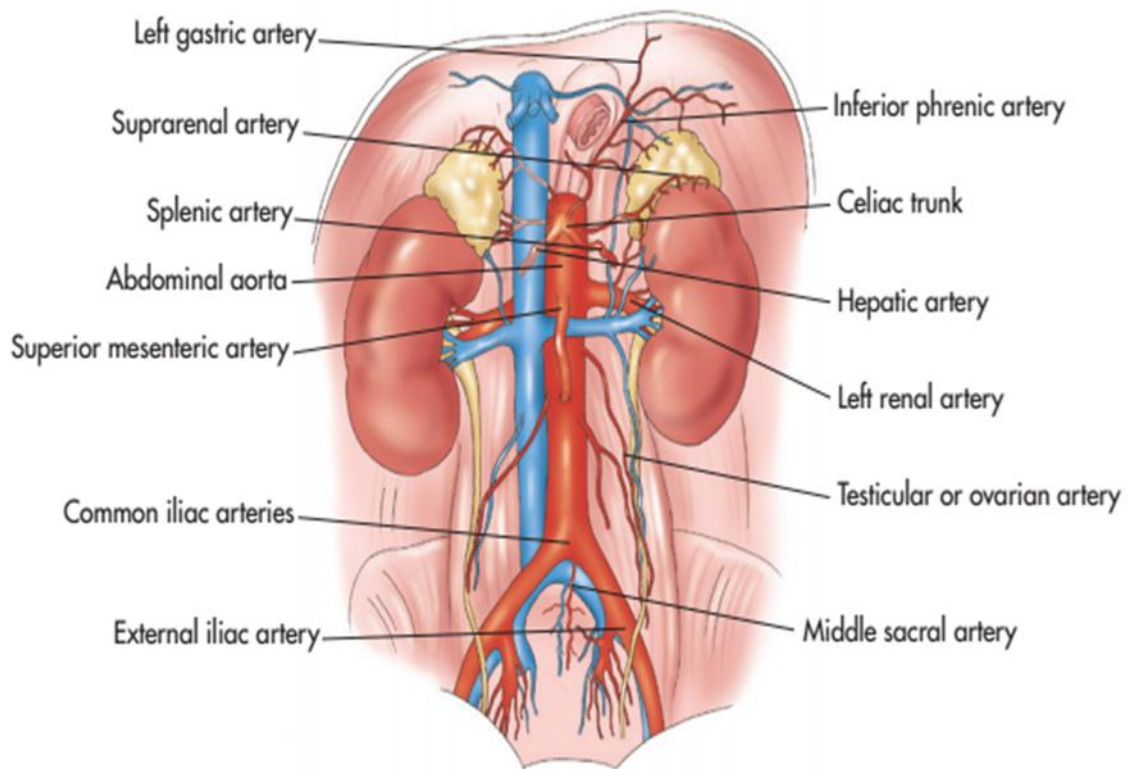
Upper 4 lumbar vertebrae and discs. In the elderly, osteoarthritis resulting in degenerative osteophytic lipping from the vertebrae, displaces the aorta anteriorly. This is the most common cause of anterior displacement of the aorta in the elderly. Anterior longitudinal ligament (The aorta is usually separated from the spine by no more than 0.5 to 1 cm. of soft tissue.). (Devin-Deen 2005)

### **2-1-5-3 Right Side:**

above L2: the right crus and below L2: in contact with the IVC.

### **2-1-5-4 Left Side:** - from superior to inferior:

Left crus and esophagus, Left adrenal gland, Duodenum, Inferior mesenteric artery. (Devin-Deen 2005)



**Figure 2-3 The abdominal arterial vascular system and its tributaries.**  
(Sandra L et al,2012)

### **2-1-6 Abdominal Aortic Branches:**

The small phrenic arteries arise from the lateral walls of the aorta to supply the undersurface of the diaphragm. (Sandra L et al,2012)

#### **2-1-6-1 The celiac Trunk:**

The first anterior branch of the aorta, arising 1 to 2 cm inferior to the diaphragm. The median arcuate ligament surrounds the aorta and has been known to compress the celiac trunk. The short celiac trunk gives rise to three smaller vessels: the splenic, hepatic, and left gastric arteries. (Sandra L et al,2012)

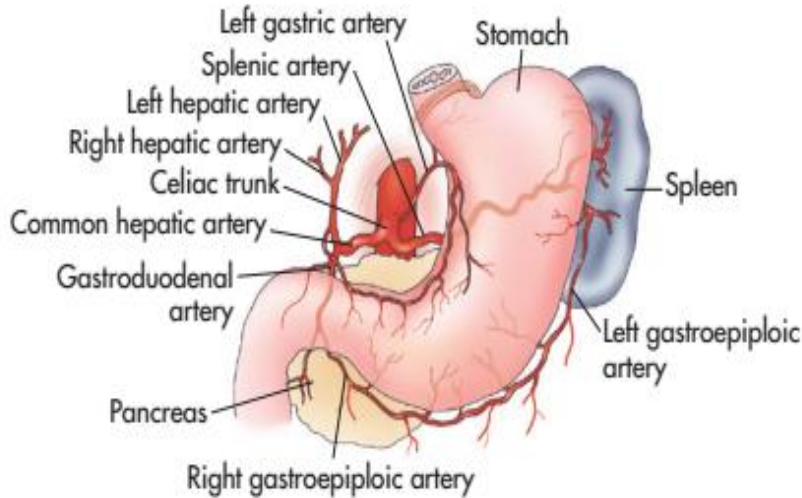
##### **2-1-6-1-1 Left Gastric Artery (LGA):**

This small branch passes superiorly and to the left towards the cardia of the stomach. It anastomoses with the lower esophageal arteries to supply the lower

esophagus. The LGA then proceeds to supply the lesser curvature of the stomach. It also anastomoses with the splenic artery and right gastric artery to aid in supplying blood to both surfaces of the stomach. (Devin Deen 2005)

### **2-1-6-1-2 Common Hepatic Artery (CHA):**

The CHA passes transversely to the right along the superior border of the pancreatic body, neck and head. Superior to the pancreatic head, the CHA bifurcates into the gastroduodenal artery (GDA) and the hepatic artery proper (HAP). Just prior to its bifurcation, the CHA passes anterior to the main portal vein. Hepatic Artery Proper: ascends to the porta hepatis within the folds of the hepatoduodenal ligament (one portion of the lesser omentum). It divides into left and right hepatic arteries within the porta hepatis. Left and Right Hepatic Arteries: These vessels supply 20% of the blood supply to the liver. The remaining 80% is supplied by the portal vein. Cystic Artery: is a branch of the right hepatic artery. It supplies the gallbladder, hepatic bile ducts and part of the common bile duct. (Devin Deen 2005)



**Figure 2-4 The celiac trunk and its branches. (Sandra L et al,2012)**

## **2-1-6-1-2 Branches of the CHA:**

### **2-1-6-1-2-1 The Right Gastric Artery:**

It arises either from the common hepatic artery or from the hepatic artery proper. It descends to the pyloric end of the stomach in the lesser omentum and anastomoses with the left gastric artery. The right gastric artery supplies the lesser curve of the stomach. (Devin Deen, 2005)

### **2-1-6-1-2-2 The Gastroduodenal Artery (GDA):**

It descends between the superior part of the duodenum and the neck or head of the pancreas. The GDA supplies the pylorus, head of the pancreas, and part of the duodenum. (Devin Deen, 2005)

### **2-1-6-1-3 The Splenic Artery:**

This is the largest branch of the celiac trunk. It is accompanied by the splenic vein which lies posterior and inferior to the splenic artery. The splenic artery is a tortuous vessel that passes to the left horizontally behind the stomach and the lesser

sac, along the superior border of the pancreas. It crosses anterior to the left suprarenal gland and upper part of the left kidney. Near the spleen it divides into 5 or more branches which enter the hilus of the spleen. (Devin Deen, 2005)

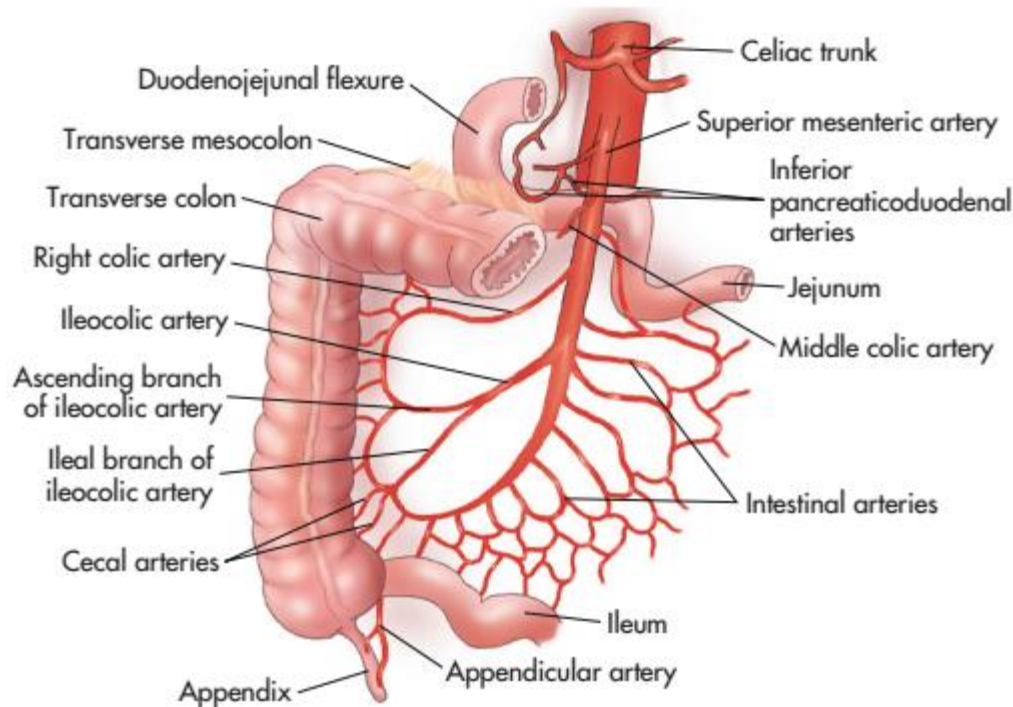
### **The splenic artery supplies:**

- The neck, body and tail of the pancreas.
- The fundus of the stomach (after anastomosing with the left gastric artery).
- The greater curve of the stomach.
- Part of the greater omentum.
- The spleen. (Devin Deen, 2005)

### **2-1-6-2 Superior Mesenteric Artery:**

The second main branch of the abdominal aorta is the superior mesenteric artery (SMA). The SMA typically originates along the anterior aspect of the abdominal aorta, just distal to the origin of the celiac trunk. It supplies blood to parts of the small intestines, some of the colon, and the pancreas. Sonographically, the SMA is readily identified by the echogenic fat layer surrounding it. It is located posterior to the splenic vein and pancreas and left lateral to the superior mesenteric vein. The left renal vein should be noted posterior to the SMA and anterior to the abdominal aorta. (Steven M et al, 2011)





**Figure 2-5 The Superior Mesenteric Artery and it branches. (Sandra L et al,2012)**

### **2-1-6-3 Renal Arteries:**

The third main visceral branches of the abdominal aorta are the paired renal arteries. They arise just below the level of the SMA. The right renal artery originates from the right anterolateral aspect of the aorta and travels posterior to the IVC on its way to the right renal hilum. The left renal artery originates from the left anterolateral aspect of the aorta and travels posterior to the left renal vein as it progresses to the left renal hilum. Duplication of the renal arteries is common. (Steven M, 2011)

The Right Renal Artery is longer than the left because of the left sided position of the aorta. The RRA passes posterior to the IVC, right renal vein, head of pancreas

and descending duodenum. The Left Renal Artery is slightly higher in the body than the RRA. The LRA lies posterior to the left renal vein, body of pancreas and splenic vein. Just prior to the hilus of the kidney the LRA and RRA divide into 4 or 5 branches. (Devin Deen, 2005)

#### **2-1-6-4 Gonadal Arteries:**

These arise from the aorta anterolaterally, a little inferior to the origins of the renal arteries. They pass obliquely downwards and laterally, anterior to the psoas major muscles. The testicular arteries go through the inguinal canals and are part of the spermatic cords leading to the testes which they supply. The ovarian arteries enter the pelvic cavity and supply the ovaries. (Devin Deen, 2005)

#### **2-1-6-5 Inferior Mesenteric Artery:**

The inferior mesenteric artery (IMA) arises from the anterior surface of the abdominal aorta. It arises 3-4 cm superior to the aortic bifurcation. It supplies the left third of the transverse colon and the entire descending and sigmoid colon and rectum. The IMA is rarely demonstrated on ultrasound scans due to the overlying bowel gas; however, when it is demonstrated it has a similar longitudinal appearance to the SMA. (Devin Deen, 2005)

#### **2-1-6-6 Common Iliac Arteries:**

The aorta bifurcates on the left side of the body of L4 (approximately the level of the umbilicus) into the right and left common iliac arteries. The maximum diameter of the common iliac artery (outer -to-outer) generally is about 1 cm. The common iliac arteries diverge as they descend and bifurcate at the L5-S1 level into the external and internal iliac arteries. (Devin Deen, 2005)

### **2-1-6-6-1 The Right Common Iliac Artery (RCIA):**

The RCIA is about 5 cm. long. It descends obliquely towards the right side of the body.

#### **Relationships:**

- Anterior to the RCIA is the ureter.
- Posterior to the RCIA are the terminal parts of the two common iliac veins and the origin of the IVC.
- Lateral to the RCIA is the origin of the IVC and the right common iliac vein.
- Medial to the RCIA is the left common iliac vein. (Devin Deen, 2005)

### **2-1-6-6-2 The Left Common Iliac Artery (LCIA):**

The LCIA is about 4 cm. long.

#### **Relationships:**

- Anterior to the LCIA are the left ureter and bowel.
- Posterior to the LCIA are the L4 and L5 vertebral bodies.
- Medial to the LCIA is the left common iliac vein.
- Lateral to the LCIA is the psoas major muscle. (Devin Deen, 2005)

### **2-1-6-6-1-1 The Internal Iliac Arteries (IIA):**

These are about 4 cm. long and arise from the bifurcation of the common iliac arteries. (Devin Deen, 2005). The internal iliac artery enters the pelvis anterior to the sacroiliac joint, at which point it is crossed anteriorly by the ureter. It divides into anterior and posterior branches to supply the pelvic viscera, peritoneum, buttocks, and sacral canal. (Sandra L et al,2012)

## **Relationships:**

- Anterior to the IIA is the ureter and in the female, anterior to the ureter is the ovary.
- Posterior to the IIA is the internal iliac vein.
- Lateral to the IIA is the external iliac vein.
- Medial to the IIA is the bowel. (Devin Deen. 2005)

## **2-1-6-6-1-2 The External Iliac Arteries (EIA):**

The EIA's are larger than the internal iliac arteries. They run obliquely downward and laterally along the medial border of the psoas major muscle from the bifurcation of common iliac artery to a point midway between the anterior superior iliac spine (ASIS) and the symphysis pubis. Here the vessels enter the thighs behind the inguinal ligaments to become the femoral arteries. The femoral arteries supply the lower limbs. (Devin Deen 2005) The portion of the femoral artery posterior to the knee is the popliteal artery. This artery further divides into the anterior and posterior tibial arteries. (Sandra L et al,2012) The maximum diameter of the external iliac arteries (outer-to-outer) is slightly less than 1cm. (Devin Deen, 2005)

## **2-1-7 Dorsal Aortic Branches (Lumbar Artery):**

Four lumbar arteries are usually present on each side of the aorta. The vessels travel lateral and posterior to supply muscle, skin, bone, and spinal cord. The midsacral artery supplies the sacrum and rectum. (Sandra L et al, 2012)

## **2-2 Physiology:**

The function of the circulatory system, along with the heart and lymphatics, is to transport gases, nutrient materials, and other essential substances to the tissues, and subsequently to transport waste products from the cells to appropriate sites for excretion. Blood is carried away from the heart by the arteries and is returned from the tissues to the heart by the veins. Arteries divide into progressively smaller branches, the smallest of which are the arterioles. These lead into the capillaries, which are minute vessels that branch and form a network where the exchange of materials between blood and tissue fluid takes place. After the blood passes through the capillaries, it is collected in the small veins, or venules. These small vessels unite to form larger vessels that eventually return the blood to the heart for recirculation. Functions of the blood is responsible for a variety of functions, including transportation of oxygen and nutrients, defense against infection, and maintenance of PH. (Sandra L et al,2012)

## **2-3 Pathology:**

### **2-3-1 Atherosclerosis:**

Atherosclerosis is a vascular wall disorder in which fat cells accumulate beneath the intima and may be covered later by fibrous tissue. These deposits are called plaques. Atherosclerosis is associated with cigarette smoking, diabetes mellitus and increased levels of the low density lipoprotein (LDL) fraction of serum cholesterol. The incidence of atherosclerosis increases with age and is more common in men. It affects the aorta, iliac vessels and aortic branch arteries. Stenotic or occlusive disease most often occurs in the infrarenal portion of the aorta. Sonographically atherosclerosis is demonstrated by luminal irregularities (caused by the plaque), narrowing of the vessel lumen, tortuosity and wall calcification. Intraluminal thrombus is demonstrated by the presence of low levels of echogenicity within the vessel lumen. (Devin Deen, 2005)

#### **2-3-1-1 Effects of Atherosclerosis:**

- Hypertension - caused by rigid vessel walls.
- Functional disturbances caused by ischemia - Angina pectoris, which is chest pain radiating up to the neck, jaw and down the left arm, is due to partially occluded coronary arteries. Intermittent claudication is spasm of the calf muscles which subsides once the patient stops walking. This too is caused by partially obstructed leg vessels.
- Distraction of organs - gradual obstruction of the vessel lumen leads to ischemia. Ischemic renal arteries can result in shrunken, poorly functioning kidneys.

- Thromboembolus formation - Stasis of blood and the formation of eddy currents around lumen irregularities result in clot formation.
- Thromboemboli may subsequently result if the clot (thrombus) becomes detached from the wall.
- Ulceration formation - If the fibrous covering of the plaque becomes detached, the intima can ulcerate.
- Calcification - The fatty material in the plaque undergoes degenerative changes resulting in calcium deposition. The calcification is readily seen with ultrasound and if in large enough deposits there may be shadowing posterior to the calcification.
- Ectasia and aneurysm formation - The atherosclerotic plaque causes atrophy of the underlying media resulting in weakened walls which either dilate diffusely called aortic ectasia if less than 3 cm in diameter or dilate focally into an aneurysm if aorta is greater than 3 cm in diameter. The most common cause of abdominal aortic aneurysms is atherosclerosis. (Devin Deen, 2005)

### **2-3-2 Abdominal Aortic Aneurysm:**

The abdominal aorta slowly tapers from the diaphragmatic hiatus to the aortic bifurcation. Most of the tapering occurs in the proximal abdominal aorta as its largest branches (celiac, superior mesenteric, and renal arteries) arise. The normal size of the supraceliac abdominal aorta ranges from 2.5 to 2.7 cm in men and 2.1 to 2.3 cm in women. The normal diameter of the infrarenal aorta ranges from 2.0 to 2.4 cm in men and 1.7 to 2.2 cm in women. (Coral M et al, 2011)

The normal ultrasound diameter of the aorta as it enters the abdomen to be 23 mm, above the level of the renal arteries it is 20 mm, and just below the level of the

renal arteries it is 18 mm. At the bifurcation it measures 15 mm. (Devin Deen, 2005)

The size of the aorta will vary slightly according to body mass index; the larger the body size, the greater is the width of the aorta. It is also important to note that the aorta does change in size as we grow older. (Sandra L et al, 2012)

An aneurysm is defined as a permanent localized dilation of an artery, with an increase in diameter of greater than 1.5 times its normal diameter. The normal diameter for an artery depends on several factors, including age, gender, and blood pressure. The diagnosis of an aneurysm depends on a comparison of the aortic diameter of the suspicious area versus that of the normal area of the vessel above and below that area. Assessment is often made by physical examination of the abdomen, where a pulsatile mass slightly to the left of the midline, between the umbilicus and the xiphoid process, may be palpated. Risk factors that contribute to the development of an aneurysm include tobacco use, hypertension, and vascular disease. Other risk factors include chronic obstructive pulmonary disease and positive family history for abdominal aortic aneurysm. Abdominal aortic aneurysm studies suggest a 5% to 10% prevalence in men over the age of 60 in the United States. (Sandra L et al, 2012)

### **2-3-2-1 Factors may cause the development of an aortic aneurysm:**

- Atherosclerosis
- Trauma (following transection).
- Congenital defects (aortic sinus, post coarctation of the aorta, ductus diverticulum).
- Syphilis (involving the ascending aorta and arch).
- Mycosis (fungal dissection).



- Cystic medial necrosis (e.g., Marfan’s syndrome).
- Inflammation of media and adventitia (e.g., rheumatic fever, polychondritis, ankylosing spondylitis).
- Increased pressure (systemic hypertension, aortic valve stenosis).
- Abnormal volume load (severe aortic regurgitation). (Sandra L et al, 2012)

### **2-3-2-2 Clinical Symptoms:**

Symptoms may vary in the patient with an abdominal aneurysm. Approximately 30% to 60% of patients with an abdominal aortic aneurysm are asymptomatic, and the enlarged vessel is found during routine physical examination or during an unrelated radiologic or surgical procedure. Symptoms of the aortic aneurysm may result from rupture or expansion of the vessel. The enlarged vessel may produce symptoms by impinging on adjacent structures, or it may occlude a vessel by direct pressure or thrombus with resulting embolism. The large aneurysm may rupture into the peritoneal cavity or the retro peritoneum, causing intense back pain and a drop in hematocrit. Patients may present with satiety (becoming full easily) or nausea and vomiting. Abrupt onset of severe, constant pain in the abdomen, back, or flank that is unrelieved by positional changes is characteristic of rapid expansion or rupture of an aneurysm. Other complications may include dissection, thrombosis, distal embolism, infection, and obstruction and invasion of adjacent structures. Commonly, branch artery occlusions or stenosis may be seen in the inferior mesenteric artery or renal arteries. (Sandra L et al, 2012)

### **2-3-2-3 Features of Abdominal Aortic Aneurysms:**

- Most are true aneurysms—involve all three layers.
- 95% are infrarenal.
- Measure anteroposterior (AP) diameter on sagittal views.

- Mural thrombus is common with larger aneurysm.
- Atherosclerosis—tortuosity, folding.
- Aortic pseudoaneurysm—trauma.
- Mycotic aneurysm—infection.
- Surgery should be considered when >5 cm.
- Aneurysms that measure less than 4 cm in diameter are followed every 6 months, with intervention if the patient becomes symptomatic.
- In patients with aneurysms ranging from 4 to 5 cm in diameter, surgical intervention may be suggested if the patient is in good health.
- Patients with aneurysms ranging from 5 to 6 cm may benefit from surgical repair, especially if they have other factors for rupture (e.g., hypertension, smoking, chronic obstructive pulmonary disease).
- Patients at highest risk are those with aneurysms larger than 6 to 7 cm. The risk increases with age and other medical problems. (Sandra L et al, 2012)

#### **2-3-2-4 Three primary factors are related to the growth rate of abdominal aneurysms:**

The initial size of the aortic aneurysm, the presence of cardiac disease, and the presence of beta-adrenergic blockade (blood pressure– lowering medications). (Sandra L et al,2012)

#### **2-3-2-4 Classification of Aneurysms:**

Histologically, the aneurysm may be classified as a true aneurysm (lined by all three layers of the aorta) or as a false aneurysm (pseudoaneurysm) (not lined by all three layers). (Sandra L et al, 2012)

#### **2-3-2-4-1 True Aneurysm:**

Forms when the tensile strength of the wall decreases. A small percentage of true aneurysms occur secondary to underlying diseases such as Marfan's syndrome, Ehlers-Danlos syndrome, familial aortic dissection, annulo-aortic ectasia, and intimomedial mucoid degeneration. In the pseudoaneurysm, blood escapes through a hole in the intima of the vessel wall, but is contained by the deeper layers of the aorta or by adjacent tissue. (Sandra L et al, 2012)

#### **2-3-2-4-2 Pseudoaneurysm:**

Is a pulsatile hematoma that results from leakage of blood into the soft tissue abutting the punctured artery, with subsequent fibrous encapsulation and failure of the vessel wall to heal. With color Doppler, blood can be seen to flow into the protuberance during systole and out during diastole. These events can occur after trauma to the vessel as a result of accident or surgery, or after an interventional cardiac catheterization or angiography procedure. (Sandra L et al, 2012)

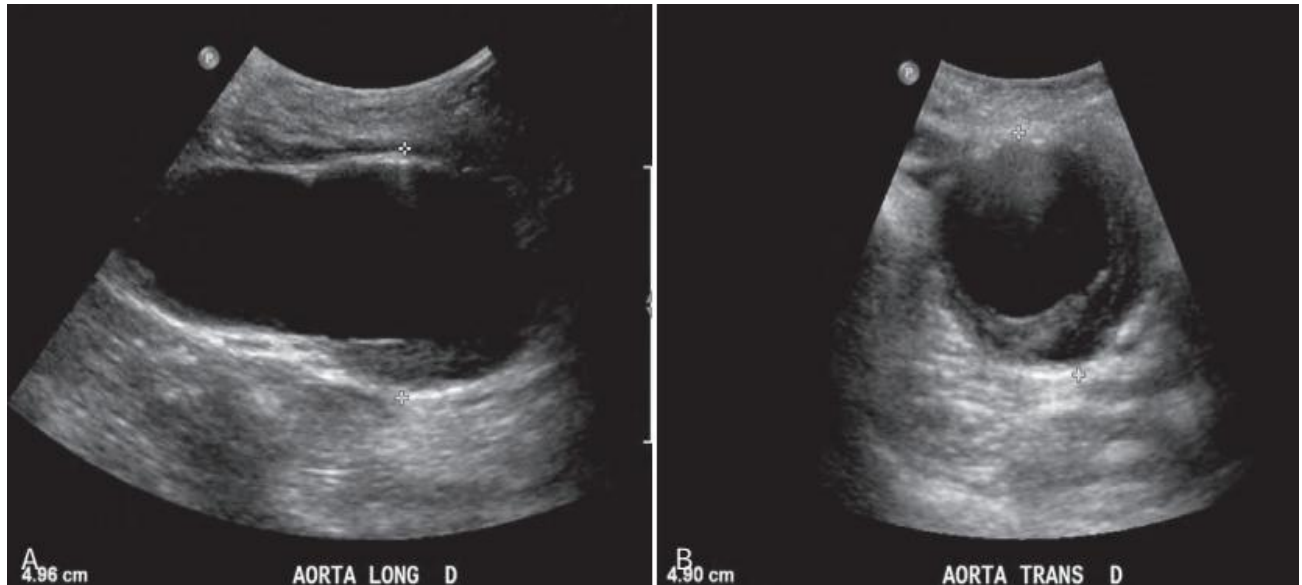
#### **2-3-2-5 Type of an Abdominal Aortic Aneurysm:**

An aneurysm may be described as fusiform, bulbous, saccular, or dumbbell. The idiopathic abdominal aneurysm is a true aneurysm that most commonly develops inferorenally (in more than 95% of patients). It usually begins below the renal arteries (inferior to the superior mesenteric artery) and extends to the bifurcation of the aorta at the iliac arteries. (Sandra L et al, 2012)

#### **2-3-2-5-1 Fusiform Aneurysm:**

The most common presentation of an atherosclerotic aneurysm is a fusiform aneurysm of the distal aorta at the aortic bifurcation. The fusiform aneurysm represents a gradual transition between normal and abnormal and extends over the

length of the aorta to resemble a “football-like” shape. These aneurysms often extend into the iliac vessels in the pelvis. (Sandra L et al, 2012)



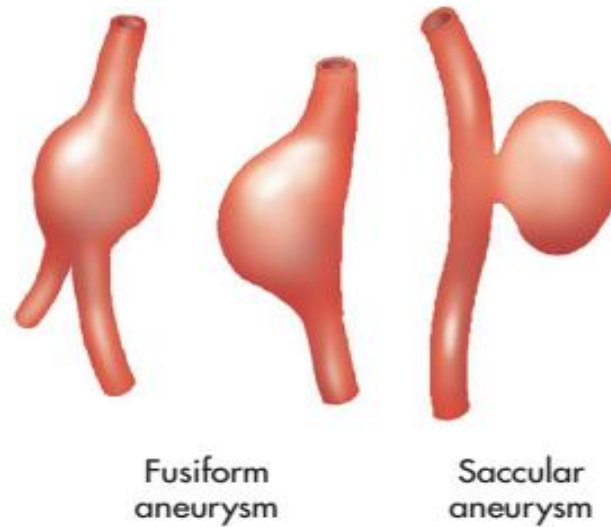
**Figure 2-6 Fusiform abdominal aortic aneurysms. (Sandra L et al, 2012)**

### **2-3-2-5-2 Bulbous Aneurysm:**

The term bulbous describes a sharp junction between normal and abnormal. An aneurysm may be bulbous and saccular. (Sandra L et al, 2012)

### **2-3-2-5-3 Saccular Aneurysm:**

A saccular aneurysm shows a sudden transition between normal and abnormal and is somewhat spherical and larger (5 to 10 cm) than fusiform aneurysms. This type of aneurysm is connected to the vascular lumen by a mouth that varies in size but may be as large as an aneurysm. It may be partially or completely filled with mural thrombus. The sonographer must carefully follow the course of such an aneurysm to differentiate it from a retroperitoneal mass or lymphadenopathy. Pulsations are usually diminished secondary to clot formation. (Sandra L et al,2012)



**Figure 2-7 Type of aneurysm. (Sandra L et al, 2012)**

#### **2-3-2-5-4 Dumbbell aneurysm:**

The term dumbbell applies to the figure-of-eight appearance of the aneurysm, where one may see more than one protrusion of the vessel. The aneurysm may extend into the iliac arteries. (Sandra L et al, 2012)

#### **2-3-2-6 Inflammatory Aortic Aneurysm:**

This type of aneurysm is a variant in which the wall of the aneurysm is thickened and surrounded by fibrosis and adhesions of a type similar to those found in retroperitoneal fibrosis. These patients present with a higher surgical risk. Clinically, they present with pain that may mimic a retroperitoneal hemorrhage. (Sandra L et al,2012)

### **2-3-2-7 Rupture of Aortic Aneurysm:**

The rupture of an aortic aneurysm is catastrophic, with a mortality rate of 50%. An aneurysm measuring greater than 5 cm in anteroposterior diameter has a 25% cumulative incidence of rupture over 8 years. The classic symptoms of a ruptured aortic aneurysm are excruciating abdominal pain, shock, and an expanding abdominal mass. The rupture may extend into the perirenal space with displacement of renal hilar vessels, effacement of the aortic border, and silhouetting of the lateral psoas border at the level of the kidney. The most common site for rupture is the lateral wall inferior to the renal vessels. Hemorrhage into the posterior pararenal space accounts for loss of visualization of the lateral psoas muscle merging inferior to the kidney and may also displace the kidney. A large aneurysm may compress its neighboring structures. Compression of the common bile duct may cause obstruction; compression of the renal artery can cause hypertension and renal ischemia. Retroperitoneal fibrosis with an aneurysm may involve the ureter, causing hydronephrosis. The left kidney is more frequently affected than the right. The iliac aneurysm may rupture into the rectosigmoid colon, iliac vein, or ureter. (Sandra L et al,2012)

The sonographer should note the maximum length, width, and transverse dimension of the aortic aneurysm. Documentation of the shape (fusiform, bulbous, saccular, or dumbbell) and location of the aneurysm in relation to the renal arteries is important. Extension of the aneurysm into the iliac arteries should also be noted. Measurements of length  $\times$  width  $\times$  height should be included in the report. A description of wall thickening, the presence of calcification, blood flow, soft plaque, or calcified plaque should also be included in the report. Careful evaluation of the presence or absence of an aortic dissection should be noted. Because the aneurysm may often affect the renal vessels, both kidneys should be analyzed.

(Measure the size, and exclude pelvocaliectasis.) If hypertrophy of one or both kidneys occurs, a full Doppler evaluation of the renal vessels should be conducted to rule out renal stenosis. A rare condition is the development of a mycotic aneurysm secondary to infection. The most common infections result from septic emboli, streptococci, staphylococci, and Salmonella. The infection may produce a focal abscess that appears as a complex fluid collection with irregular borders. (Sandra L et al,2012)



**Figure 2-8 Abdominal aortic aneurysm with thrombus. (Sandra L et al, 2012)**

### **2-3-2-8 Dissecting Aneurysm:**

May be detected by ultrasound and usually displays one or more clinical signs and symptoms. The typical patient is 40 to 60 years old and hypertensive; males predominate over females. The patient is usually known to have an aneurysm, and sudden, excruciating chest pain radiating to the back may develop as the result of a dissection. These patients may go into shock very quickly, and CT is generally

ordered to obtain the most information in the shortest amount of time. However, the patient who presents with some of these symptoms and is stable may have a slow leak aneurysm. These patients are appropriately imaged with sonography. The sonographer should look for a dissection “flap” or recent channel, with or without frank aneurysmal dilation. This flap is well demonstrated with M-mode as a fluttering within the lumen at different phases of the cardiac cycle. The dissection of blood occurs along the laminar planes of the aortic media with formation of a blood-filled channel within the aortic wall. Color Doppler will demonstrate flow in both channels (true and false lumens) with the flow rate differing between the channels. When the dissection develops, hemorrhage occurs between the middle and outer thirds of the media. An intimal tear is considered if the tear is found in the ascending portion of the arch. This type of dissection extends proximally toward the heart and distally, sometimes to the iliac and femoral arteries. A small number of dissections do not have an obvious intimal tear. Extravasation may completely encircle the aorta or may extend along one segment of its circumference, or the aneurysm may rupture into any of the body cavities. underlying media resulting in weakened walls which either dilate diffusely (called aortic ectasia if less than 3 cm in diameter) or dilate focally into an aneurysm (if aorta is greater than 3 cm in diameter). The most common cause of abdominal aortic aneurysms is atherosclerosis. (Sandra L et al,2012)

### **2-3-3 Aortic Dissection:**

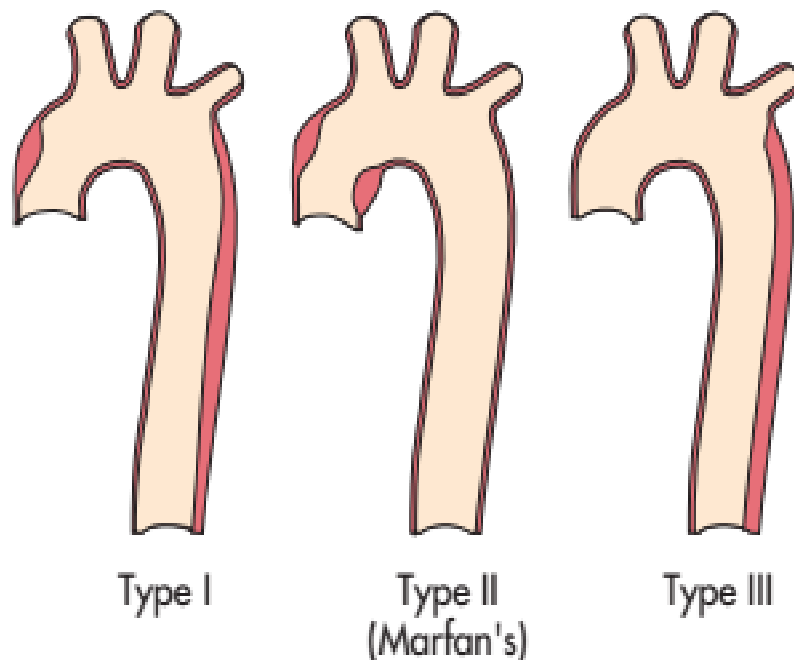
IS defect in the vessel intimal wall must exist along with internal weakness for a dissection to occur. Dissection of the aorta (Type II) may occur secondary to cystic medial necrosis (weakening of the arterial wall), to hypertension, or to the inherited disease Marfan’s syndrome. (Individuals with this disorder are extremely tall, lanky, and double-jointed; a progressive stretching disorder exists in all



arterial vessels, especially in the aorta, causing abnormal dilation, weakened walls, and eventual dissection, rupture, or both, Color flow Doppler may be used to detect flow into the false channel. (Sandra L et al,2012)

### **2-3-3-1 Three classifications of aortic dissection are based on the DeBakey model:**

Types I and II involve the ascending aorta and the aortic arch; Type III involves the descending aorta at a level inferior to the left subclavian artery. A high incidence of mortality is associated with Type I and II dissections because of possible obstruction at the origin of the coronary arteries and possible obstruction of blood into the head and neck vessels. The lowest mortality rate is associated with the Type III dissection, which begins inferior to the left subclavian artery with possible extension into the abdominal aorta. The Type I dissection begins at the root of the aorta and may extend the entire length of the arch, descending to the aorta and into the abdominal aorta. This is the most dangerous, especially if the dissection spirals around the aorta, cutting off the blood supply to the coronary, carotid, brachiocephalic, and subclavian vessels. The third type of dissection (Type III) begins at the lower end of the descending aorta and extends into the abdominal aorta. This may be critical if the dissection spirals around to impede the flow of blood into the renal vessels. Less than 5% of dissections occur primarily in the abdomen. (Sandra L et al,2012)



**Figure 2-9 Aortic dissection: Types I, II, and III. (Sandra L et al,2012)**

### **2-3-4 Arteriomegaly and Aortic Ectasia:**

Arteriomegaly is diffuse arterial dilation involving several arteries, each with an increased diameter of at least 50% compared with the normal diameter. Ectasia refers to diffuse or focal dilation that is less than 50% increased in diameter. (Coral M et al, 2011)

This dilatation is considered part of the normal aging process. Generally aortic measurements of up to 3 cm. are ectasia and greater than 3 cm. are aneurysmal. However, another approach is to consider the aorta aneurysmal “when the dilated segment is 1.5 times greater in diameter than an adjacent normal segment. (Devin Deen, 2005)

The size of the aorta will vary slightly according to body mass index; the larger the body size, the greater is the width of the aorta. It is also important to note that the aorta does change in size as we grow older; therefore an aorta in a younger adult measuring 1.8 cm may be increased to 2.27 cm by the time the adult reaches 60 years of age. (Sandra L et al,2012)

### **2-3-5 Penetrating Ulcer:**

Penetrating ulcer has been recognized for approximately 20 years. It is believed to result when an atherosclerotic ulceration penetrates the media, allowing an intramural hematoma to form. (Coral M et al, 2011)



**Figure 2-10 Longitudinal image shows an outpouching of the aorta with an otherwise relatively normal abdominal aorta (Penetrating Ulcer). (Coral M et al, 2011)**

This outpouching into the media can either develop or maintain flow, forming an aneurysmal-type structure. Penetrating ulcers occur more frequently in the thoracic aorta but are also seen in the abdominal aorta. (Coral M et al, 2011)

### **2-3-6 Tortuosity of aorta:**

This refers to a vessel that has many twists and turns. It is a normal aging feature. The caliber is often normal but may be associated with ectasia or aneurysm. Tortuous aortas usually deviate to the left of the spine, but some may deviate anteriorly. (Devin Deen, 2005)

### **Assessment of a Tortuous Aorta:**

Tortuosity of vessels often develops in the elderly. In order to define the actual size of the vessel you must identify the long axis of the vessel and then turn the transducer 90 degrees so you are in the true transverse plane of the vessel (although it may be in an oblique plane of the abdomen). Alternatively scan in the AP and coronal planes, thus avoiding the possibility of measuring off axis. (Devin Deen, 2005)

### **2-3-7 Stenotic Disease of the Abdominal Aorta:**

Stenosis or occlusion of the abdominal aorta can be congenital or may be caused by atherosclerosis, vasculitis (arteritis), trauma, or embolus. Dissection may also result in stenosis. Mid aortic syndrome is a rare congenital stenosis that is also called abdominal coarctation. Symptoms of aortic stenosis or occlusion may include intermittent claudication and impotence. These symptoms, along with the finding of decreased femoral pulses, are called Leriche syndrome, although the term is often used more broadly to refer to all the signs and symptoms that may result from aortic occlusive disease or even the occlusion itself. (Coral M et al, 2011)

In the great majority of patients with aortic stenosis or occlusion, the disease is caused by atherosclerosis. However, certain clinical settings suggest other causes. the majority of emboli to the abdominal aorta come from the heart. Having an arterial embolism of any type is similar to having a pulmonary embolism; having one means that the patient is at risk for having more. If the origin of the embolus was cardiac, the next one that forms may go to some less favorable place, such as the cerebral circulation, resulting in stroke, or to the mesenteric circulation, resulting in intestinal infarction. (Coral M et al, 2011)

Takayasu arteritis is a cause of aortic stenosis and is of particular note because it may occur in younger patients. It can affect the abdominal aorta or its branches. Takayasu arteritis can present with symptoms resulting from aortic stenosis or branch vessel stenosis. (Coral M et al, 2011)

Posttraumatic aortic stenosis can occur in patients of any age, including younger patients. The initial aortic injury results from a forceful, nonpenetrating injury to the abdomen. The resulting intimal injury can cause subintimal fibrosis, which can result in stenosis. (Coral M et al, 2011)

## **2-4 Normal Sonographic Appearances:**

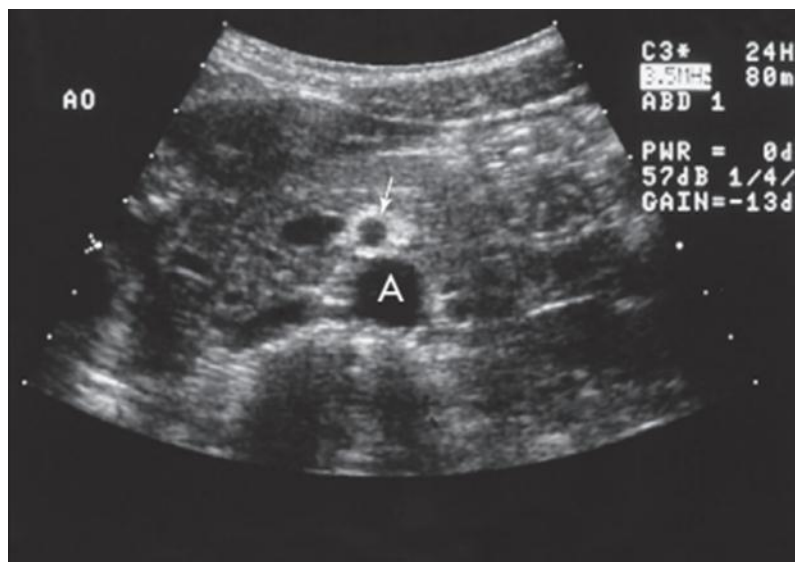
The abdominal aorta is usually one of the easiest abdominal structures to image with ultrasound because of the marked change in acoustic impedance between its elastic walls and blood-filled lumen. Sonography provides the diagnostic information needed to create an image of the entire abdominal aorta, to assess its diameter, and to visualize the presence of thrombus, calcification, or dissection within the walls. The anterior and posterior walls of the aorta should be easily seen as two thin pulsatile parallel lines. This facilitates measuring the anteroposterior diameter of the aorta, which in most institutions is done from the leading outer

edge of the anterior wall to the leading inner edge of the posterior wall. (Sandra L et al,2012)

In the transverse plane, the aorta is imaged as a circular structure anterior to the spine and slightly to the left of the midline.

In the longitudinal plane, the aorta is imaged as a long tubular structure just anterior to the spine. The landmarks of the left lobe of the liver and the gastroesophageal junction may be seen anterior to the aorta.

The celiac trunk may be visualized sonographically on transverse or longitudinal images. It is usually seen as a small vascular structure, arising anteriorly from the abdominal aorta just below the diaphragm. Because it is only 1 to 2 cm long, it is sometimes difficult to record unless the area near the midline of the aorta is carefully examined. Sometimes the celiac trunk can be seen to extend in a cephalic rather than a caudal presentation. The superior mesenteric artery is just inferior to the origin of the celiac trunk. The superior mesenteric artery may be used as a landmark in locating the celiac trunk. (Sandra L et al,2012)



**Figure 2-11 Transverse image of the high abdominal aorta (A) at the level of the superior mesenteric artery. (Sandra L et al,2012)**



**Figure 2-12 Longitudinal image of the aorta (A) with celiac axis (ca) and superior mesenteric artery (sma). (Sandra L et al,2012)**

Transversely, one can differentiate the celiac trunk as the “wings of a seagull,” arising with its short trunk before dividing into the “wings” of the hepatic and splenic arteries. The splenic artery may be seen to flow directly from the celiac trunk toward the spleen. (Sandra L et al,2012)



**Figure 2-13 Transverse image of the celiac trunk and branches into splenic and hepatic artery. (Steven M et al, 2011)**

## **2-5 Previous Studies:**

Ultrasound measurement of the luminal diameter of the abdominal aorta and iliac arteries in patients without vascular disease in north american during 1993 done by ole martin et al.

The luminal diameters of the proximal and distal abdominal aorta and the common iliac arteries were measured by ultrasonography in 160 patients (15 to 89 years) who were without known vascular disease.

his study found the patients above 50 years of age the distal aorta, which most often is involved in aneurysmatic dilations, measured  $16.8 \pm 2.9$  mm in men and  $14.6 \pm 1.9$  mm in women ( $p < 0.001$ ). The diameter of the iliac artery in these patients was  $10.1 \pm 2.0$  mm in men and  $9.2 \pm 1.3$  mm in women ( $p < 0.001$ ). The usually present gradual narrowing of the aorta toward the bifurcation was replaced by a slight increase (1 to 2 mm) in 5% of the men and 6% of the women.

Ole martin et al use in his study multivariate analysis, including age, height, body weight, and sex, the distal aortic diameter was significantly correlated only to age ( $r = 0.46$ ;  $p < 0.001$ ) and sex ( $r = -0.29$ ;  $p < 0.001$ ). With aging the mean of the proximal and distal aortic diameters increased by 0.08 and 0.05 mm/yr, respectively. Also correlated with age was a linear reduction in systolic expansion ( $r = -0.73$ ;  $p < 0.001$ ). ( Ole Martin et al, 1993)

Other study done by Joh JH, et al about reference diameters of the abdominal aorta and iliac arteries in the Korean population during 2013. His study collected from three cities in Korea for the abdominal aortic aneurysm (AAA) screening. By measured the diameter of the aorta and iliac arteries and analyzed the reference



diameter of the population without AAA. The results were analyzed by Student's t-test and ANOVA on SPSS version 19. A p value  $<0.05$  was considered to be statistically significant. One thousand two hundred and twenty-nine people were enrolled. 478 men and 751 women, with a mean age of  $63.9 \pm 10.1$  years (range 50 to 91) were examined. Eleven out of 1229 (0.89%) were diagnosed with AAA. In the population of 1218 people without AAA, the mean diameters (cm) of male/female were 2.20/2.11 ( $p<0.001$ ) at suprarenal, 2.04/1.90 ( $p<0.001$ ) at renal, 1.90/1.79 ( $p<0.001$ ) at infrarenal, 1.22/1.17 ( $p<0.001$ ) at right iliac and 1.47/1.15 ( $p=0.097$ ) at the left iliac, respectively. There was a significantly larger diameter in the male population. The diameter of each level increased with age. The conclusion of his found that the normal reference diameter of the infrarenal abdominal aorta in the Korean population is 1.9 cm in males and 1.79 cm in females. The diameter of the abdominal aorta increases with age. (Joh JH, et al 2013)

Another Study done by B. Sonesson et al about compliance and diameter in the human abdominal aorta and influence of age and sex of the distal abdominal aorta in healthy female. Females develop cardiovascular diseases and abdominal aortic aneurysms later in life than males. The results were compared with those obtained previously from healthy males in order to assess potential sex-related differences in the aging process of the abdominal aorta. An ultrasound phase-locked echo-tracking system was used to determine differences in diameter and pulsatile diameter change of the distal abdominal aorta in 69 Caucasian females from 4 to 74 years. Pressure strain elastic modulus ( $E_p$ ) and stiffness ( $\beta$ ) were calculated from diameter, pulsatile diameter change and blood pressure obtained by the auscultatory method. Compliance was defined as the inverse of  $E_p$  and  $\beta$ . The pressure dependence of  $E_p$  and  $\beta$  was evaluated in 10 females with intraarterial

blood pressure measurement at rest and during isometric exercise. His investigation demonstrates age and sex-related differences in diameter and compliance in the normal human abdominal aorta and implies that degenerative changes appear later in females than in male. (B. Sonesson et al, 1993)

Other study done by Bjorn Sonesson et al about8 Infrarenal aortic diameter in the healthy person during 1994. His study done in order to determine the normal aortic diameter and its relation to age, sex and body size (height, weight, body surface area). The diameter of the infrarenal aorta was measured in 146 healthy males and females 4–74 years old with ultrasonography and the influence of the aforesaid factors on aortic diameter was analysed by means of a multiple stepwise regression model. The infrarenal aorta was found to increase steadily in diameter throughout life. From about 25 years the diameter was larger in males than in females ( $p < 0.01$ ) though this difference vanished if corrected for differences in body surface area. Significant correlations were found between aortic diameter and weight ( $r = 0.84$ ,  $p < 0.001$ ), height ( $r = 0.77$ ,  $p < 0.001$ ) and body surface area ( $r = 0.83$ ,  $p < 0.001$ ). Age followed by body surface area were the factors most influencing aortic diameter in both males ( $r = 0.92$ ,  $p < 0.001$ ) and females ( $r = 0.94$ ,  $p < 0.001$ ). Nomograms predicting aortic diameters in relation to age, sex and body surface area are presented. (Bjorn Sonesson et al,1994)

Other study done by Mark I et al about the relationship between aortic diameter and body habits during 1992

His study included nine hundred and six men between the ages of 65 and 74 years were screened to determine whether there was a correlation between abdominal aortic diameter and body size. There was no correlation between aortic diameter and weight or obesity but there was a significant correlation with height and age. Sequential enlargement of the aorta was observed in 57 men with aortic diameters

above the normal range, none of these were characterised by one particular body habitus: it is suggested that patients in this group should be rescanned regularly. (Mark I et al, 1992)

Other study done by Marcelo Lagos and Carlos Manterola about the normal ranges of the infrarenal aortic diameters during 2016.

The aim of his study is to determine the normal range of the diameter of the infrarenal AA according 2D ultrasonography in patients with no history of vascular disease. Cross-sectional study, conducted in Hospital Regional of Temuco and Pitrufquen in 399 subjects over 15 years, with no history of vascular disease, who consulted for abdominal pain cadres were studied.. The outcome variables were anteroposterior diameters (DAP) and transverse (TD) of AA. Other variables of interest were: sex, age index weight / height and body surface.

DAP average was  $16.1 \pm 2.2$  mm (9-23 mm) and DT average was  $19.4 \pm 2.7$  mm (11-26 mm). DAP and DT was significantly higher in the subgroup age > 50 and in men. There was a positive correlation between weight / height-DAP ( $p=0.0321$ ) and index weight / height-DT ( $p=0.0052$ ), the more relevant in the female subgroup index. Moreover, positive correlation between DAP and body surface area ( $p<0.0001$ ) and DT and body surface area ( $p<0.0001$ ) was demonstrated. Sex, age and body surface area are associated with higher DAP and DT. Apparently his study found lower average diameter aortas that described in international literature. (Marcelo Lagos, 2016)

Other study done by M. Gürtelschmid about Comparison of three ultrasound methods of measuring the diameter of the abdominal aorta during 2014

The outer-to-outer (OTO) method, where callipers are placed on the outer layer of the aortic wall; the inner-to-inner (ITI) method, where callipers are placed on the inner layer of the aortic wall; and the leading edge-to-leading edge (LELE)

method, where callipers are placed on the outer layer of the anterior wall and the inner layer of the posterior wall. The aim of his study was to determine the variability of the three methods, differences between them, and the consequences on prevalence estimates. Some 127 consecutive patients with a small abdominal aortic aneurysm (AAA) were included. The maximal anteroposterior diameter was measured using the OTO, ITI and LELE methods by two vascular sonographers who were blinded to each other's measurements. The variability was described as the standard deviation. The variability was 2.7 (95 per cent limits of agreements  $\pm 5.4$ ) mm for the OTO, 2.3 ( $\pm 4.6$ ) mm for the ITI and 2.0 ( $\pm 4.0$ ) mm for the LELE method. The corresponding coefficients of variability were 6.4, 6.1 and 5.0 per cent. The difference was 4.1 mm between ITI and OTO ( $P < 0.001$ ), 2.0 mm between ITI and LELE ( $P < 0.001$ ), and 2.1 mm between LELE and OTO ( $P < 0.001$ ).

The LELE measurement was found as the most reproducible method of measuring the abdominal aorta. All methods showed a high degree of variability. (M. Gürtelschmid et al 2014 )

# **CHAPTER THREE**

## **Materials and Methods**

# CHAPTER THREE

## Materials and Methods

### 3-1 Materials:

#### 3-1-1 Type of study:

This study was descriptive cross-sectional study was conducted in sonographic measurement of normal abdominal aorta diameter in adult population.

#### 3-1-2 Study area:

This study was conducted in many hospital:

- Omdurman Islamic University Clinic:
  - Abd-Alaal Aledreese Clinic.
  - Althora Clinic Centre.
- The Alrebat Universal Hospital.
- Tayba Hospital.

#### 3-1-3 Study duration:

This study was carried out over period of six months from December 2016 to May 2017.

#### 3-1-4 Study variable:

The variables study in healthy population with different age, sex, height and weight.

#### 3-1-5 Sample size:

The sample was collected from 105 healthy adult populations with different age ranging from 17 to 74 years and different sex.

#### 3-1-6 Data collection:

Data was collect by:

- Data collection sheets.
- Ultrasound images.

### **3-1-7 Inclusion criteria:**

All patients come to ultrasound department with normal abdominal ultrasound finding and with no history of cardiovascular disease.

### **3-1-8 Exclusion criteria:**

Adult population with history of cardiovascular disease, hypertension, and pregnant women.

### **3-1-9 Data collection instrumentation:**

Different type of ultrasound machines was used:

- Aloka curvilinear probe 3.5 MHz frequency.
- FF sonic UF-4100 curvilinear probe 3.5 MHz frequency.
- Seimans curvilinear probe 2-6 MHz frequency.
- Medison curvilinear probe.

### **3-1-10 Ethical consideration:**

The volunteer scan as a part of routine medical ultrasound scan.

## **3-2 Methods:**

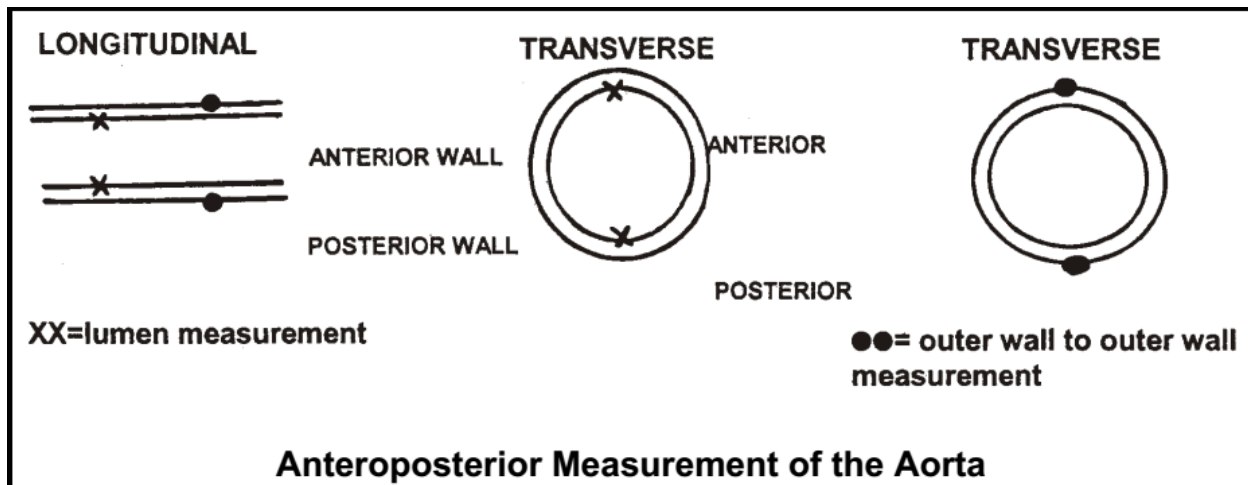
### **3-2-1 Vessels measurement:**

The measurement taken perpendicular to the vessel from outer layer-to-outer layer walls. (Sandra L et al,2012)

Measurements taken along the long axis of the sound beam are more accurate than those taken at right angles to the sound beam. In other words measurements are most accurate if they utilize axial resolution rather than lateral resolution. Least accurate are transverse measurements of the vessels taken in the anteroposterior plane. (Devin Deen, 2005)

The scanning protocol used in each department differs. Some measure only the lumen of the vessel while another department may measure to include the outer

vessel wall. Surgeons usually prefer the outer wall to outer wall measurement. (Devin Deen, 2005)



**Figure 3-1 Anteroposterior measurement of aorta. (Devin Deen 2005)**

### **3-2-2 Ultrasound techniques:**

- Patient preparation: Nothing by mouth for 6 hours.
- Patient position: Supine.
- low to medium gain was used to demonstrate the walls of the aorta without artifactual internal echoes. These weak echoes may result from increased gain, reverberation from the anterior abdominal wall fascia or musculature, or poor lateral resolution
- Different breathing techniques was used. (This method as same with Sandra L et al,2012)

#### **3-2-2-1 Longitudinal plane:**

The longitudinal scans was obtained beginning at the midline with a slight angulation of the transducer to the left—from the xiphoid to the level of bifurcation. The measurements taken perpendicular to the vessel from outer layer-to-outer layer walls at three levels. The anterior and posterior borders are often



better imaged than the lateral borders. (This method mentioned in Sandra L et al,2012)

### **3-2-2-2 Transverse plane:**

Transverse scans was obtained by title the transducer in transverse plane (pointer to 9 o'clock), high in the epigastrium, using the liver as a sonic window. Identify the aorta on the patient's left, and the IVC (patient's right) above the vertebral body on the ultrasound image. (Anthony J. et al 2016)

Anteroposterior measurement was taken at three levels of the abdominal aorta at the aortic hiatus, just inferior to the renal vessels, and just above the level of the bifurcation, to confirm the anteroposterior measurements that was taken in longitudinal plane.

### **3-2-2-3 Coronal Plane:**

This plane was taken in left flank position with the patient in right lateral decubitus position, to demonstrated middle and distal abdominal aorta in this position in obese patient. (This method mentioned in Coral M et al, 2011)

# **CHAPTER FOUR**

## **Results**

# CHAPTER FOUR

## RESULTS

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Female	50	47.6	47.6	47.6
Male	55	52.4	52.4	100.0
Total	105	100.0	100.0	

**Table (4.1) Frequency distribution of gender.**

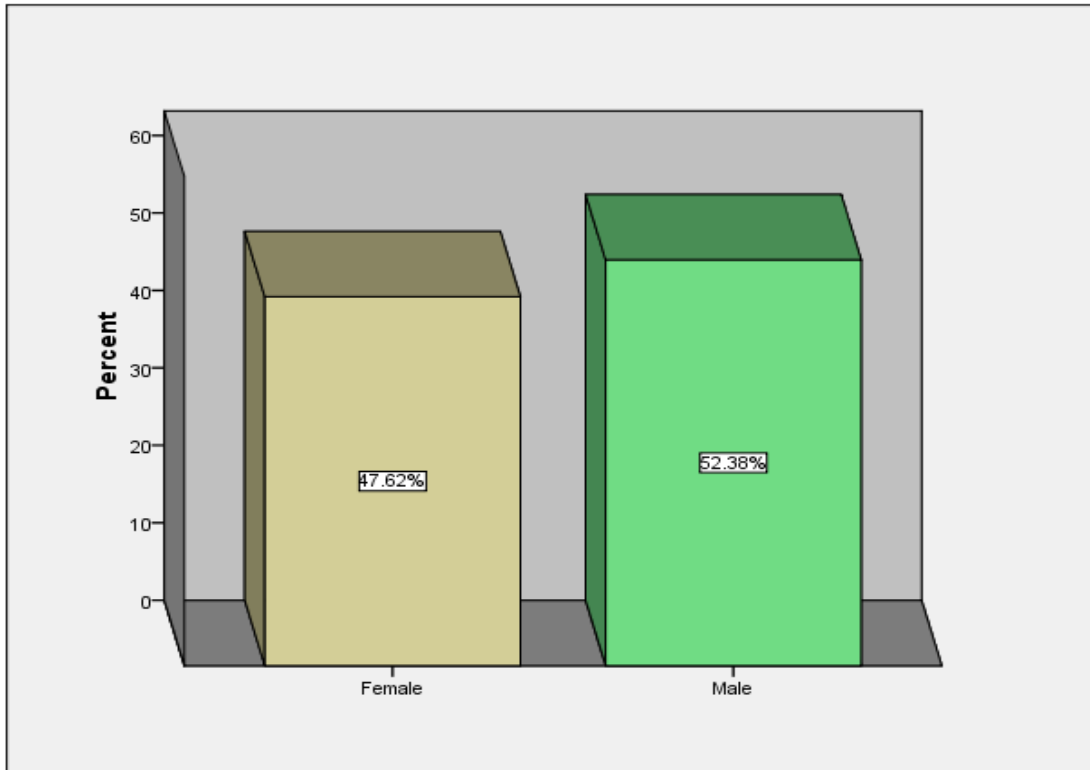


Figure (4.1) Frequency distribution of gender

**Table (4.2) Frequency distribution of age group**

Age group	Frequency	Percent	Valid Percent	Cumulative Percent
15-30 years	38	36.2	36.2	36.2
31- 45 yeas	30	28.6	28.6	64.8
46-60 years	27	25.7	25.7	90.5
61-75 years	10	9.5	9.5	100.0
Total	105	100.0	100.0	

Figure (4.2) Frequency distribution of age group

**Table (4.3) descriptive statistic of age , height, weight, BMI.**

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Height (cm)	105	150	188	167.70	8.367
Weight (kg)	105	41.00	109.00	66.6476	14.81487
BMI (kg/m <sup>2</sup> )	105	15.00	34.00	23.5714	4.78752
Age	105	17	74	39.87	15.358
Valid N (listwise)	105				

**Table (4.4) descriptive statistic of measurement of hiatus ,infrarenal and aortic bifurcation**

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Measurement of aortic Hiatus (mm)	105	17.00	29.00	22.0857	3.01635
Infrarenal aortic measurement (mm)	105	14.00	26.00	18.4762	2.55740
Bifurcation aortic measurement (mm)	105	10.00	21.00	16.0190	2.24885
Valid N (listwise)	105				

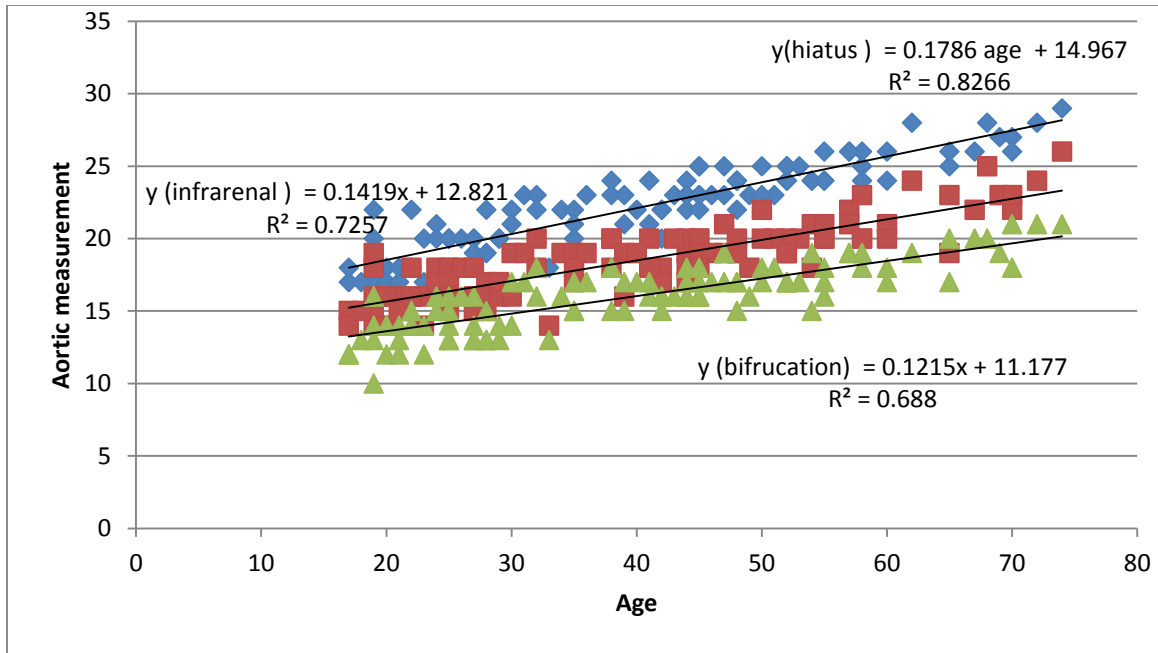


Figure (4.3) scatter plot shows correlation between aortic measurements and age

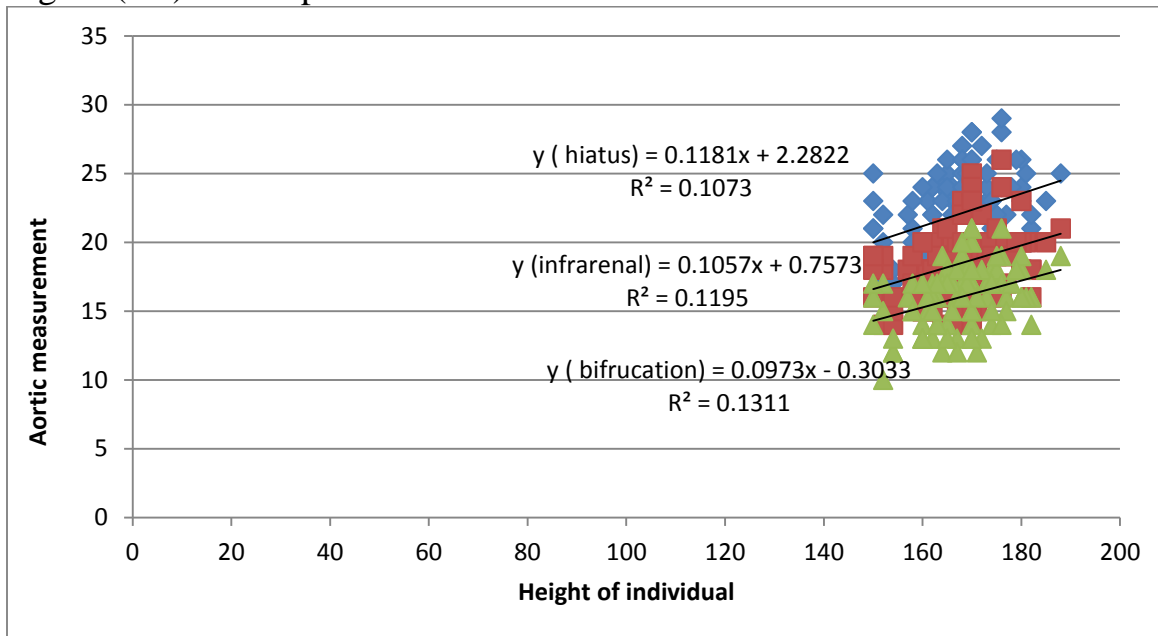


Figure (4.4) scatter plot shows correlation between aortic measurements and height

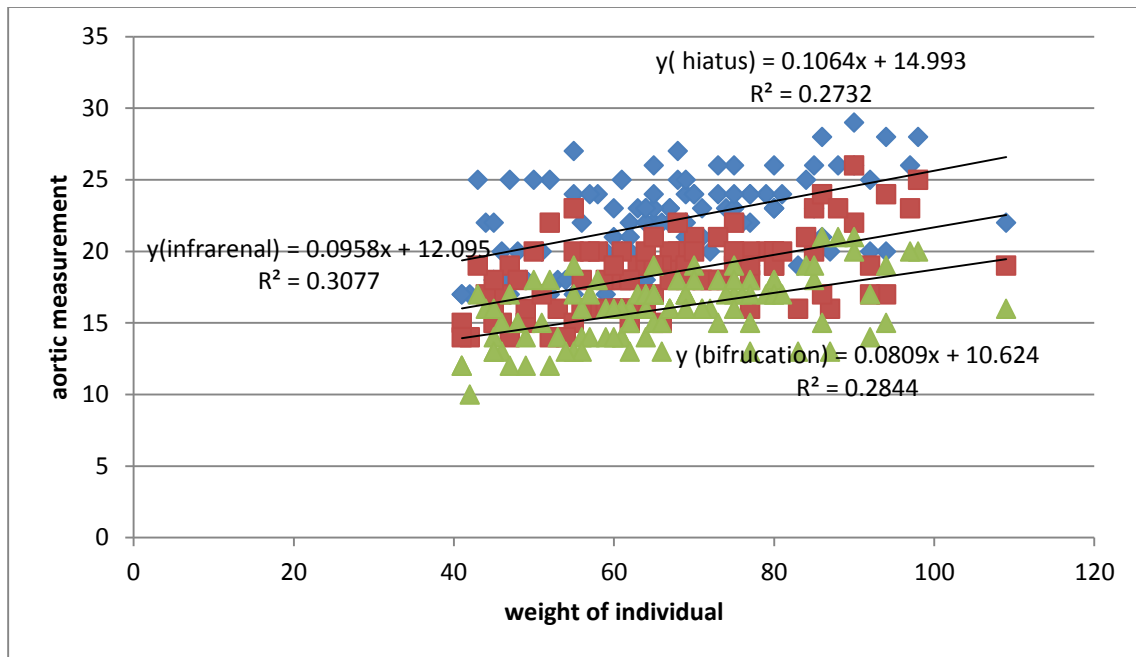


Figure (4.5) scatter plot shows correlation between aortic measurements and weight

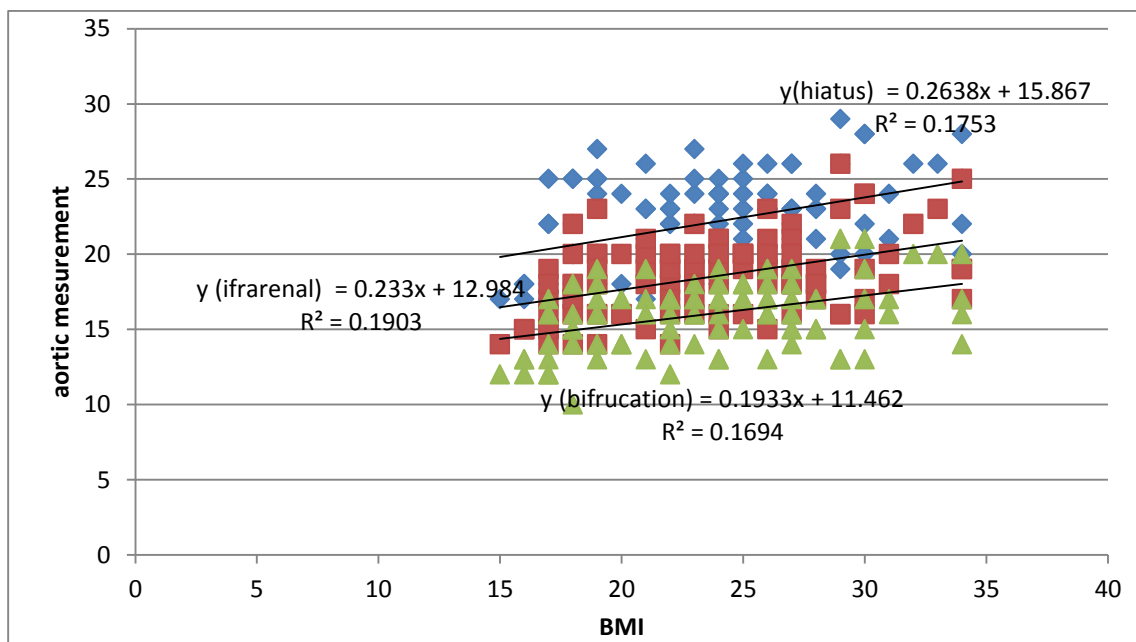


Figure (4.6) scatter plot shows correlation between aortic measurements and BMI



**Table (4.5) correlation between age , height, weight, BMI and measurement**

		age	height	weight	BMI	Hiatus	Infrarenal	Bifurcation
Hiatus	Pearson Correlation	.909**	.328**	.523**	.419**	1	.936**	.918**
	Sig. (2-tailed)	.000	.001	.000	.000		.000	.000
	N	105	105	105	105	105	105	105
Infrarenal	Pearson Correlation	.852**	.346**	.555**	.436**	.936**	1	.946**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000
	N	105	105	105	105	105	105	105
Bifurcation	Pearson Correlation	.829**	.362**	.533**	.412**	.918**	.946**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	
	N	105	105	105	105	105	105	105

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

**ofhiatus ,infrarenal and aortic bifurcation.**

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Height	55	162	188	172.78	6.223
Weight	55	47.00	109.00	69.1455	13.56796
BMI	55	16.00	34.00	23.0727	4.24637
Age	55	17	74	40.55	16.067

**Table (4.6) descriptive statistic of minimum, maximum, means and Std of age , height, weight, BMI for male.**

**Table (4.7) descriptive statistic of minimum, maximum, means and Std of measurement of hiatus ,infrarenal and aortic bifurcation for male.**

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Hiatus	55	18.00	29.00	23.0545	2.85721
Infrarenal	55	15.00	26.00	19.3636	2.42184
Bifurcation	55	12.00	21.00	16.8182	1.88651
Valid N (listwise)	55				

**Table (4.8) descriptive statistic of minimum, maximum, means and Std of age , height, weight, BMI for female.**

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Height (cm)	50	150	174	162.10	6.701
Weight (Kg)	50	41.00	97.00	63.9000	15.75611
BMI(Kg/m <sup>2</sup> )	50	15.00	34.00	24.1200	5.30937
Age	50	17	70	39.12	14.664
Valid N (listwise)	50				

**Table (4.9) descriptive statistic of minimum, maximum, means and Std of measurement of hiatus ,infrarenal and aortic bifurcation for female.**

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Hiatus (mm)	50	17.00	26.00	21.0200	2.84634
Infrarenal (mm)	50	14.00	23.00	17.5000	2.35822
Bifurcation (mm)	50	10.00	21.00	15.1400	2.30359
Valid N (listwise)	50				

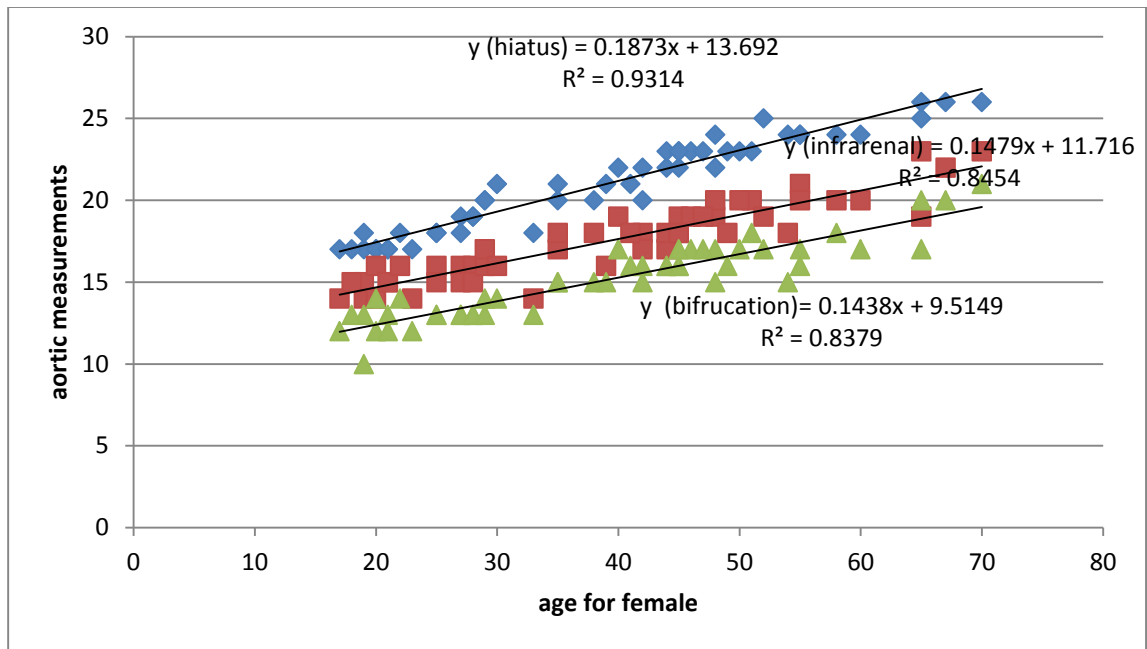


Figure (4.7) scatter plot shows correlation between aortic measurements and age for female

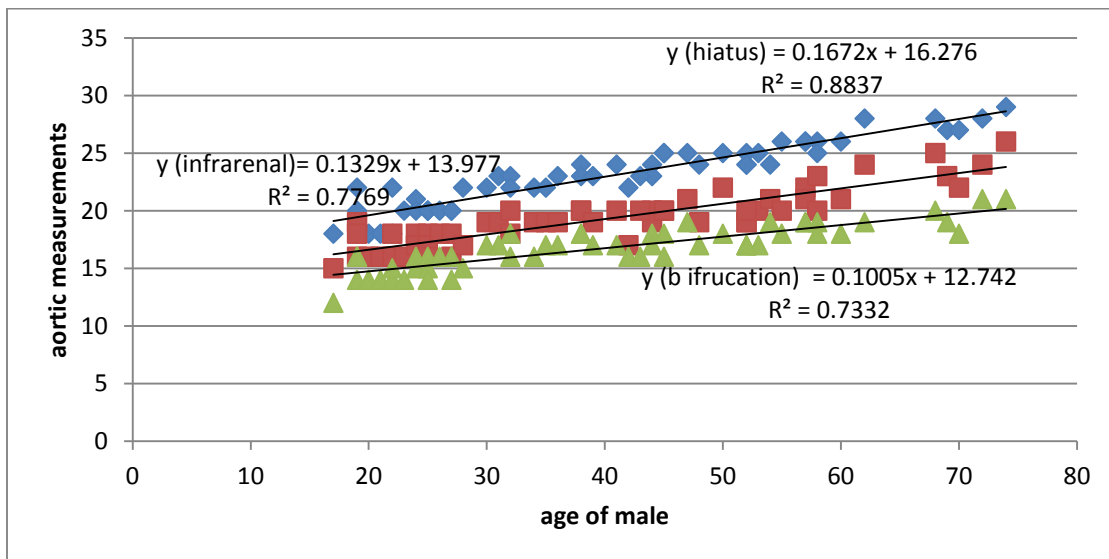


Figure (4.8) scatter plot shows correlation between aortic measurements and age for female

**Table (4.10) correlation between measurement of hiatus ,infrarenal and aortic bifurcation for female and male.**

		Hiatus male	Infrarenal male	Bifurcation male
Female hiatus measurement	Pearson Correlation	.876**	.817**	.782**
	Sig. (2-tailed)	.000	.000	.000
	N	50	50	50
Female infrarenal measurement	Pearson Correlation	.794**	.742**	.701**
	Sig. (2-tailed)	.000	.000	.000
	N	50	50	50
Female bifurcation measurement	Pearson Correlation	.803**	.768**	.740**
	Sig. (2-tailed)	.000	.000	.000
	N	50	50	50
**. Correlation is significant at the 0.01 level (2-tailed).				

## 5-1 Discussion:

The diameter of abdominal aorta was obtained by measured the aorta anteroposterior measurements at the level of aortic hiatus, infrarenal, and at bifurcation of abdominal aorta.

Table (4-1) figure (4-1) shows the distribution of genders with percentage of male higher than female.

The distribution of age group show in table (4-2) figure (4-2) the highest frequency between (15-30) years represent 36.2% followed by (31-45) years represent 28.6%.

According to table (4-4) the mean of aortic hiatus measurements(mm) was 22.08  $\pm$  3.01 std. The infrarenal measurement mean 18.47  $\pm$  2.5 std ( not agree with (Marcelo Lagos, 2016) his study lower from average diameter described in international literature ). The bifurcation measurement mean 16.01  $\pm$  2.24 std.

According to figure (4-3) demonstrate highly significant correlation between aortic hiatus, infrarenal and bifurcation and age  $R=.82$   $R=.72$   $R=.69$  respectively . the aortic hiatus correlated to age more than other measurements. (agree with (Ole Martin et al, 1993), (Bjorn Sonesson et al,1994)and (Mark I et al, 1992) )

According to figure (4-4) table ( 4-5) show there was correlation between aortic hiatus, infrarenal and bifurcation measurement and height of the patients  $R=.107$   $R=.119$   $R=.131$  respectively and p value .000. (agree with (Bjorn Sonesson et al,1994 ) and (Mark I et al, 1992) )

According to figure (4-5) table (4-5) show there was correlation between the aortic hiatus, infrarenal and bifurcation measurements and weight of the patients  $R=.27$   $R=.307$   $R=.28$  respectively and p value .000.(agree with Bjorn Sonesson et al,1994)

According to figure (4-6) table (4-5) show there was correlation between aortic measurements and BMI at the aortic hiatus, infrarenal and bifurcation  $R=.17$   $R=.19$   $R=.16$  respectively, and p value .000. (agree with Sandra L et al)

According to table (4-5) there was significant correlation between age , height, weight, BMI and measurement of aortic hiatus ,infrarenal and aortic bifurcation(as same with Ole Martin et al, 1993)), the strong correlation is between age and measurements  $R=.909$  for hiatus , $R=.852$  for infrarenal,  $R=.829$  for bifurction. (agree with Bjorn Sonesson et al,1994))

According to table (4-7) the means and Std of measurement of aortic hiatus ,infrarenal and aortic bifurcation for male. aortic hiatus mean  $23.05 \pm 2.8$  Std ,  $19.3 \pm 2.4$  Std for infrarenal(agree with Joh JH, et al 2013 ),  $16.8 \pm 1.88$  Std for aortic bifurcation ( agree with Ole Martin et al, 1993)

According to table (4-9) the means and Std of measurement of aortic hiatus ,infrarenal and aortic bifurcation for female. aortic hiatus mean  $21 \pm 2.84$  Std ,  $17.5 \pm 2.35$  Std for infrarenal (agree with Joh JH, et al 2013),  $15.1 \pm 1.3$  Std for aortic bifurcation ( disagree with (Ole Martin et al, 1993) small difference  $14.6 \pm 1.9$ ).

By compered table (4-7) with table (4-9) the means and Std of measurement of aortic hiatus, infrarenal and aortic bifurcation for male and female , the male has largest measurement than female (agree with ( Joh JH, et al 2013) and (Bjorn Sonesson et al,1994)).

According to figure 4-7 shows strong correlation between aortic measurements and age for female  $R=.93$   $R=.84$   $R=.83$  for aortic hiatus ,infrarenal and aortic bifurcation respectively.

According to figure 4-8 shows strong correlation between aortic measurements and age for males  $R=.88$   $R=.77$   $R=.73$  for aortic hiatus ,infrarenal and aortic bifurcation respectively .

By compare figure 4-7 with figure 4-8 the females aortic measurements in the three levels effect by age more than males (agree with B. Sonesson et al, 1993) and the aortic hiatus effect by age more than other measurements in both males and females.

According to table (4-10) demonstrated correlation between measurement of aortic hiatus ,infrarenal and aortic bifurcation for females and males shows significant different between males measurements and females measurements p value .000.

The reference diameter in Sudanese subjects by this study was same with international literature.

The diameter of abdominal aorta increase with age to provide the blood supply to the all organs of the body that increase with the age



## **5-2 Conclusion:**

The study done in Sudanese subject to evaluate the normal anteroposterior diameter of abdominal aorta by gray scale ultrasound, the abdominal aorta diameter was measured in three level at aortic hiatus, infrarenal and just above the aortic bifurcation, with different gender, different age, weight, height, and BMI.

The normal anteroposterior diameter for 105 Sudanese subject was found as 22 mm at aortic hiatus, 18.5 mm at infrarenal and 16 mm above the bifurcation.

The study determines there was significant different between males and females aortic measurements, the males have the largest measurements than females.

The normal anteroposterior diameter in males were 23 mm at aortic hiatus, 19.3 mm at infrarenal , 16.8 mm above the bifurcation.

The normal anteroposterior diameter for females were 21 mm at aortic hiatus, 17.5 mm at infrarenal, 15.1 mm above the bifurcation.

The study determines there was significant correlation between age, height, weight, and BMI and anteroposterior diameter measurements of each level, but the strong correlation with age followed by weight.

The abdominal aortic diameter influence by age in three level in females more than effect of age in males measurements.

### **5-3 Recommendations:**

-The diameter of abdominal aorta differs for individual therefore is important to know the normal diameter of abdominal aorta in Sudanese population.

-Is important to know the normal diameter of abdominal aorta to diagnose abdominal aortic disease.

-In future for using this topic the researcher record in his study suprarenal measurement, iliac artery measurement and body surface area as study variables.

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# **APPENDICES**

# Appendix 1

## Images

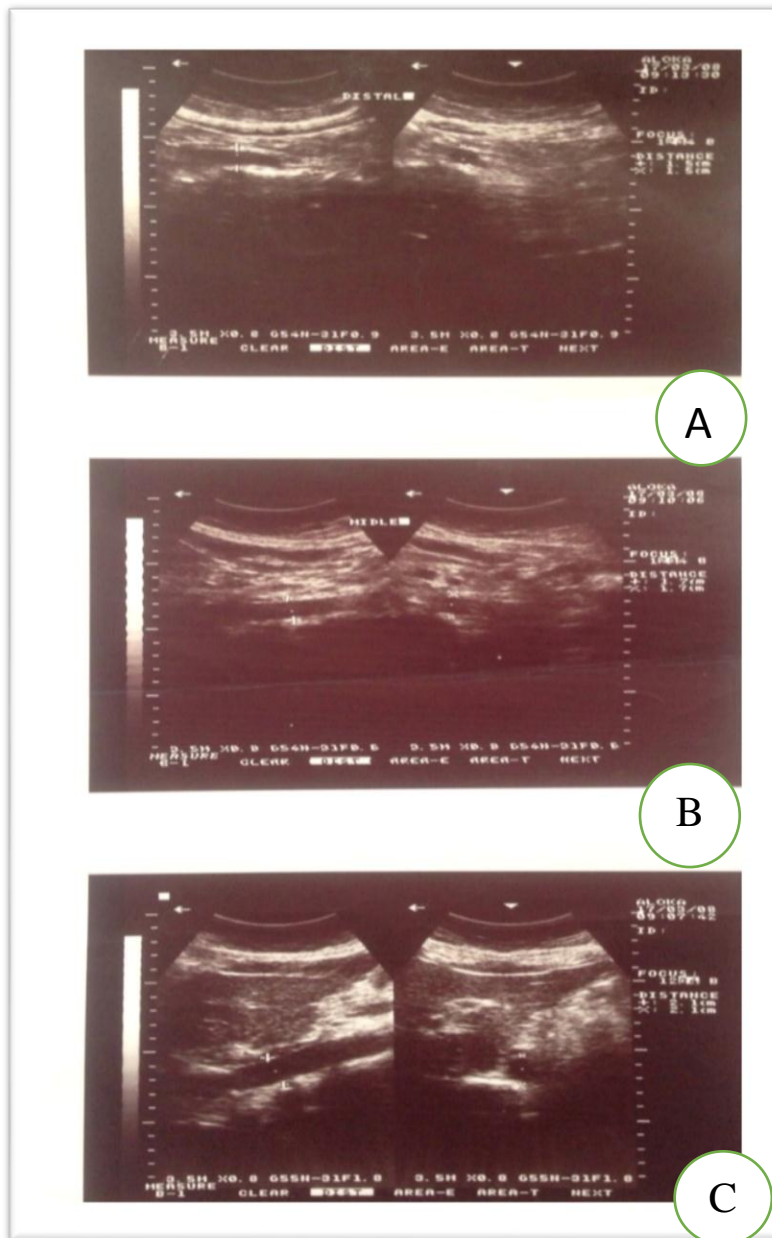
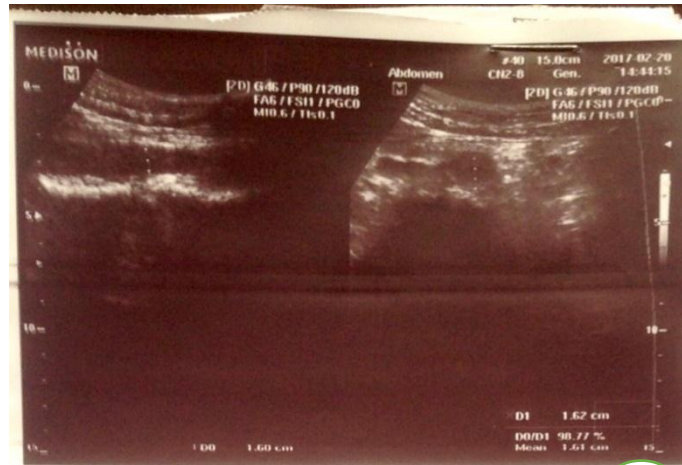
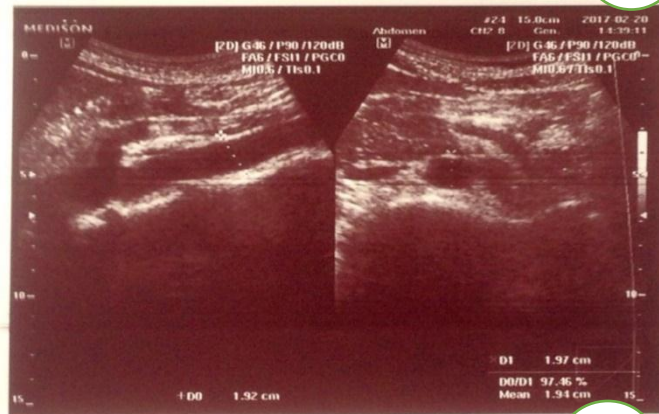


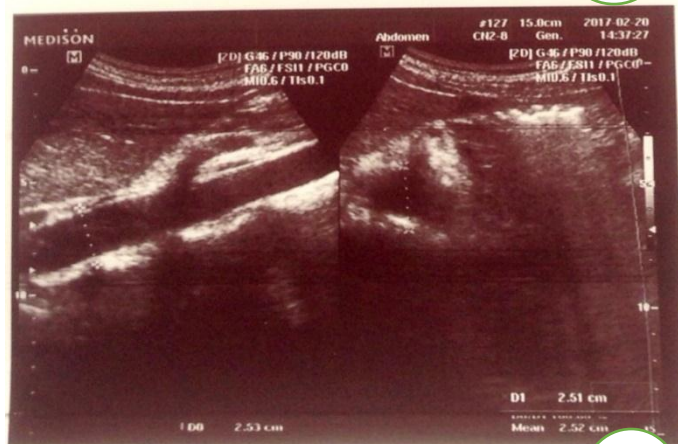
Image A, B and C for 35 years female A demonstrate distal aorta above the bifurcation 15 mm. B demonstrate infrarenal measurement 17 mm. C demonstrate aortic hiatus 21mm.



A

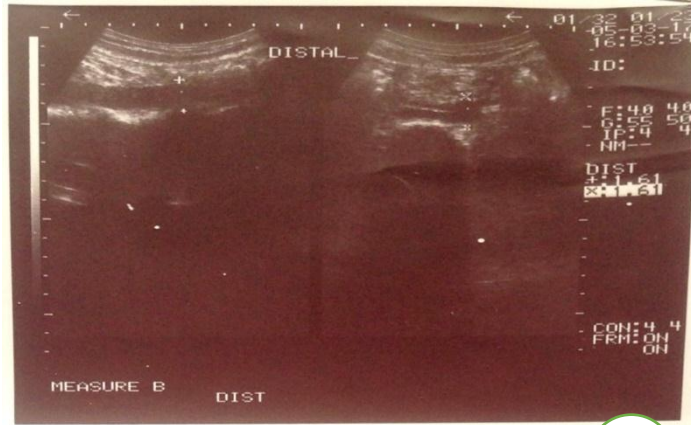


B



C

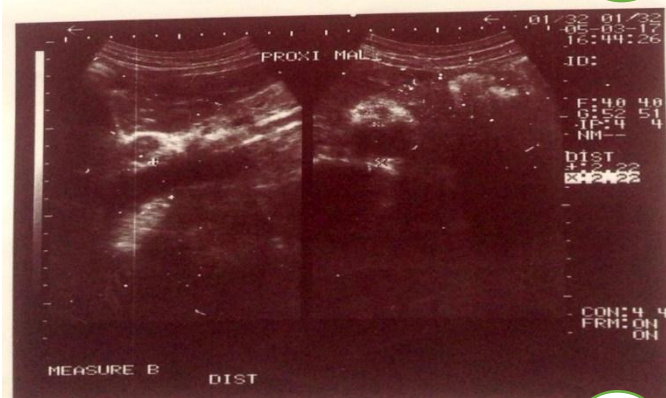
Image A, B and C for 45 years male, A demonstrate distal aorta above the bifurcation 16 mm. B demonstrate infrarenal measurement 19mm. C demonstrate aortic hiatus 25 mm.



A



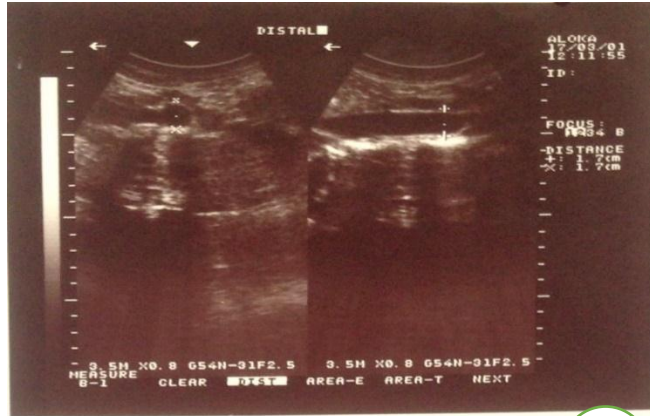
B



C

Image A, B and C for 45 years female. A demonstrate distal aorta above the bifurcation 16 mm. B demonstrate infrarenal measurement 18 mm. C demonstrate aortic hiatus 22 mm.

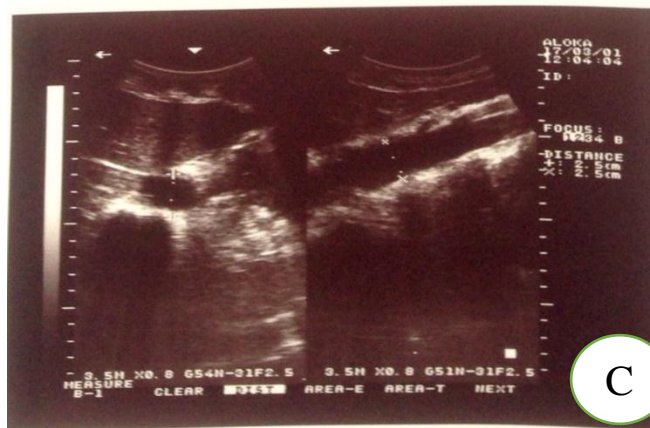




A

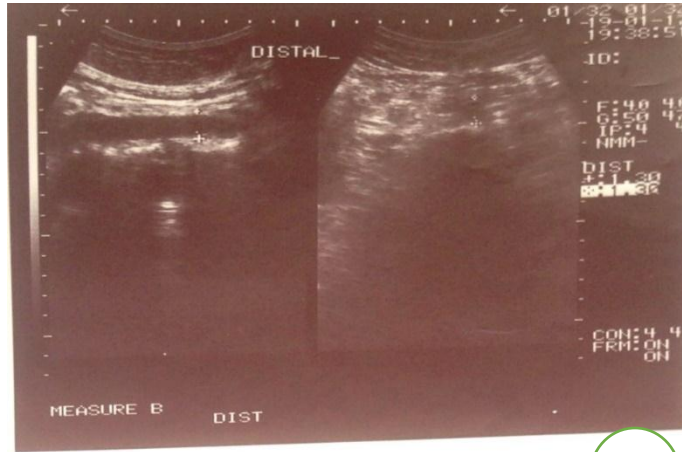


B

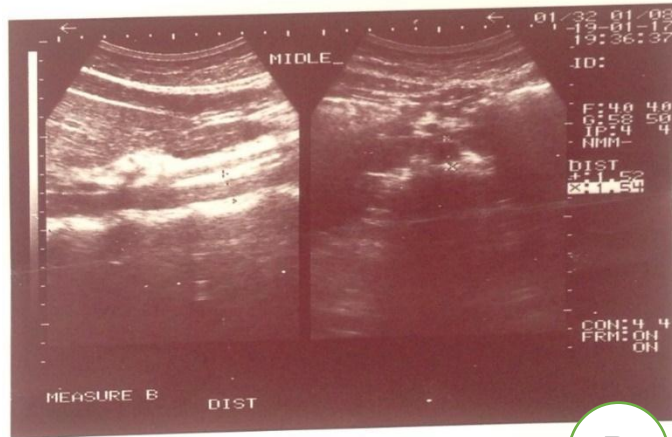


C

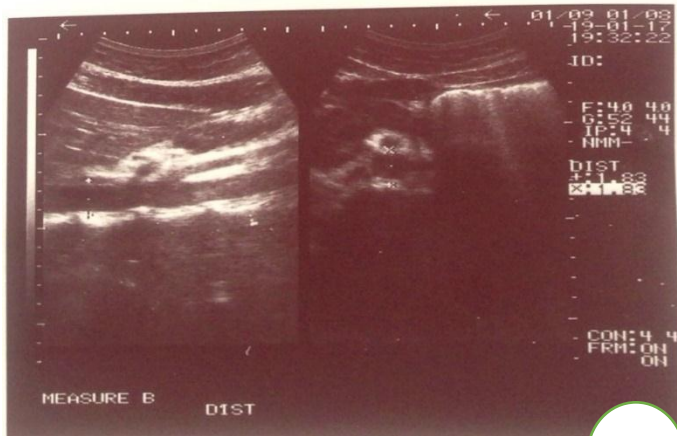
Image A, B and C for 52 years male. A demonstrate distal aorta above the bifurcation 17 mm. B demonstrate infrarenal measurement 19 mm, C demonstrate aortic hiatus 25 mm.



A



B

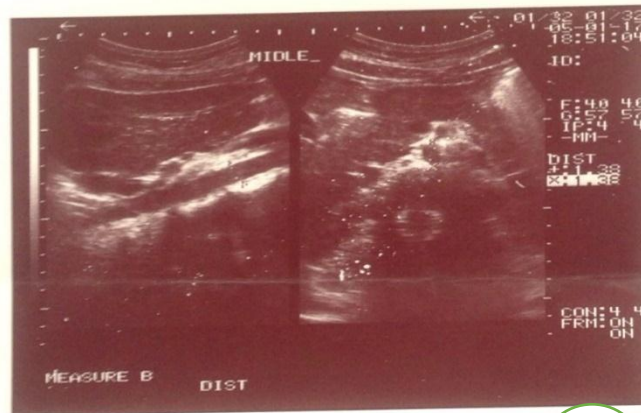


C

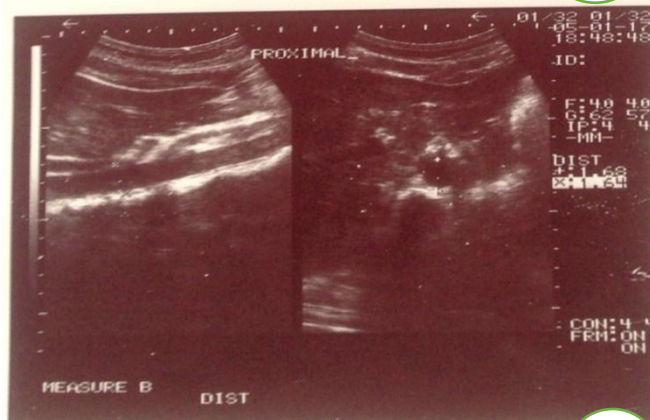
Image A, B and C for 27 years female A demonstrate distal aorta above the bifurcation 13mm. B demonstrate infrarenal measurement 15mm. C demonstrate aortic hiatus 18mm.



A



B

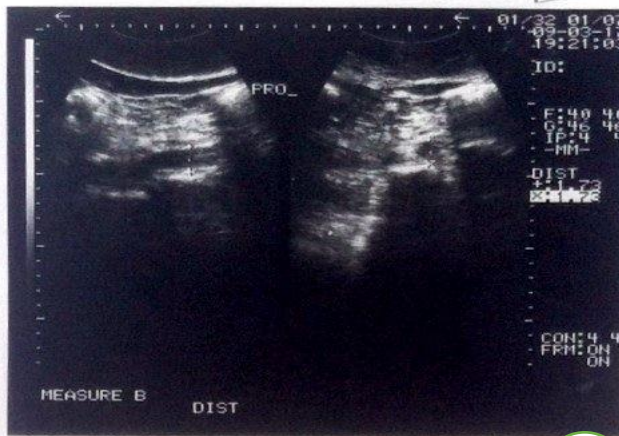


C

Image A, B and C for 20 years female A demonstrate distal aorta above the bifurcation 12 mm. B demonstrate infrarenal measurement 13mm. C demonstrate aortic hiatus 16 mm.







A



B



C

Image A, B and C for 45 years female A demonstrate distal aorta above the bifurcation 17 mm. B demonstrate infrarenal measurement 18 mm. C demonstrate aortic hiatus 22 mm.



A



B



C

Image A, B and C for 24 years male A demonstrate distal aorta above the bifurcation 15 mm. B demonstrate infrarenal measurement 17mm. C demonstrate aortic hiatus 20 mm.



A



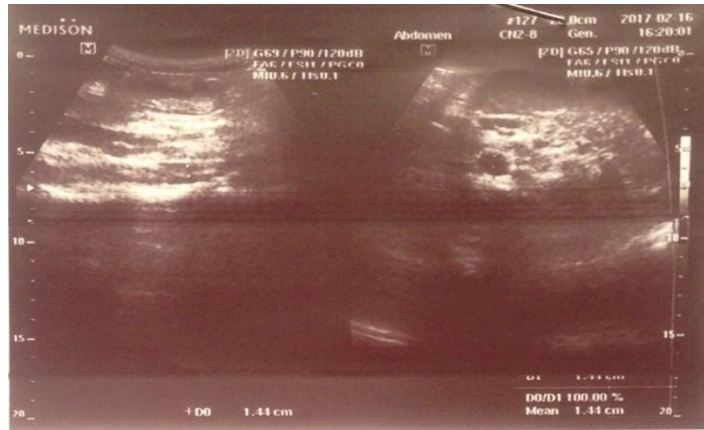
B



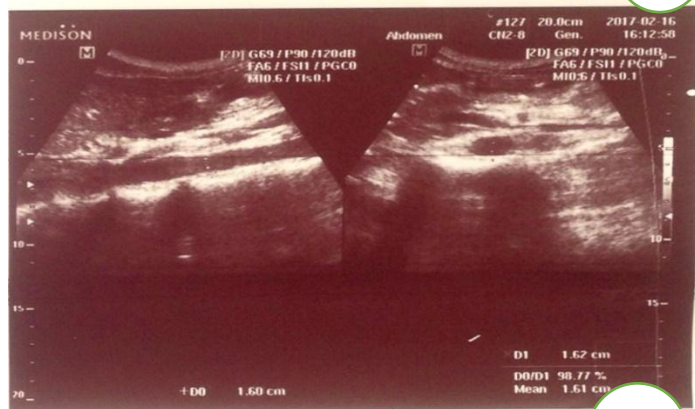
C

Image A, B and C for 36 years male A demonstrate distal aorta above the bifurcation 18 mm. B demonstrate infrarenal measurement 20 mm. C demonstrate aortic hiatus 24 mm.

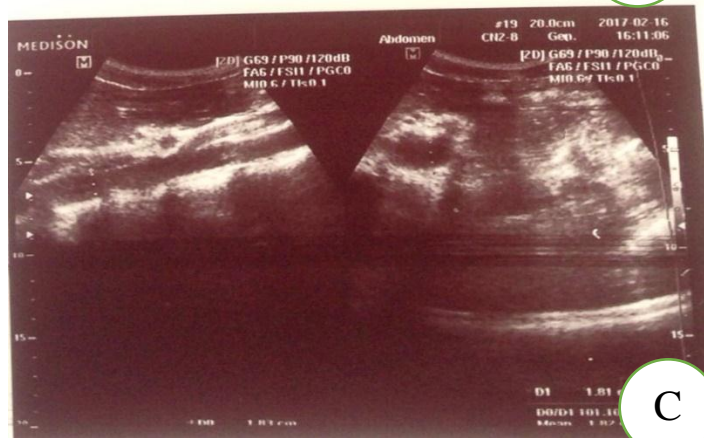




A



B



C

Image A, B and C for 19 years male A demonstrate distal aorta above the bifurcation 14 mm. B demonstrate infrarenal measurement 16 mm. C demonstrate aortic hiatus 18 mm.



**Appendix 2**

**Sudan University of Science and Technology**

**Faculty of Graduate Studies**

**Data Collection Sheet**

**EVALUATION OF SUDANESE ABDOMINAL AORTA USING  
ULTRASONOGRAPHY**

2017

Date: .....

Serial No:

1- Patient gender:

2- Patient age:

3- Height of patient:

 Cm

4- Weight of patient:

 kg

5- Body mass index:

**Ultrasound Measurements of abdominal aorta:**

6- aortic hiatus:

 mm

7- Below the level of renal artery:

 mm

8- At the Bifurcation:

 mm