



Sudan University of Science and Technology  
College of Graduated Studies



## Measurement of Thoracic Aorta in Adult Sudanese Using Computed Tomography

قياس الشريان الأبهر الصدري للسودانيين باستخدام الأشعة المقطعية  
المحوسبة

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

## الآية

قال تعالى:

(إِنَّهُ لَقَوْلُ رَسُولٍ كَرِيمٍ ﴿٤٠﴾ وَمَا هُوَ بِقَوْلِ شَاعِرٍ قَلِيلًا مَّا تُؤْمِنُونَ ﴿٤١﴾ وَلَا  
بِقَوْلِ كَاهِنٍ قَلِيلًا مَّا تَذَكَّرُونَ ﴿٤٢﴾ تَنْزِيلٌ مِّن رَّبِّ الْعَالَمِينَ ﴿٤٣﴾ وَلَوْ تَقَوَّلَ  
عَلَيْنَا بَعْضَ الْأَقَاوِيلِ ﴿٤٤﴾ لَأَخَذْنَا مِنْهُ بِالْيَمِينِ ﴿٤٥﴾ ثُمَّ لَقَطَعْنَا مِنْهُ  
الْوَتِينَ ﴿٤٦﴾)

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# *Dedication*

*To my parents*

*To my sisters*

*My brothers*

*My friends*

*To everyone whom*

*Gave me a bit of*

*Wise advice*

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## Abstract

The aorta is the main artery in the human body distributes oxygenated blood to all part of the body through the systemic circulation.

The objectives of this study were to evaluate normal thoracic aorta diameter measurements in adult Sudanese using computed tomography and correlate to age.

Computerize tomography scanning was performed in Royal scan for medical services, El- Feisal specialize hospital and Eltamaioz emergency center in Khartoum Sudan during the period from February to April 2016.

The data were collected from 55 normal subjects. Patient's age, gender, ascending aorta diameter, and descending aorta diameter were recorded. The measurements were taken at reproducible anatomic landmarks perpendicular to axis of blood flow.

Data were analyzed as mean and standard deviation (SD) for all of the variables. The correlations were significant at  $P < 0.05$ .

The study revealed that the adult Sudanese thoracic aorta diameter was  $35.11 \pm 7.45$  mm for ascending thoracic aorta and  $23.96 \pm 3.2$  mm for descending thoracic aorta. The measurements were larger than international measurements.

The study showed a significant relation between descending aortic diameter and age. Equation had been established to predict the Sudanese thoracic aorta diameter.

## مستخلص الدراسة

الشريان الأبهر هو الشريان الرئيسي في الجسم البشري يوزع الدم المؤكسد إلى جميع أجزاء الجسم من خلال الدورة الدموية.

الهدف من هذه الدراسة هو قياس قطر الشريان الأبهر الصدري لدى السودانين. تعتبر هذه الدراسة دراسة وصفية تحليلية اجريت في مستشفى رويال سكان, الفيصل التخصصي, والتميز للطوارئ والاصابات في الفترة من فبراير الى ابريل 2016م.

تم اجراء الدراسة على عدد 55 عينة طبيعية خضعت لإجراء فحص أشعة مقطعية للصدر باستخدام جهاز أشعة مقطعية متعددة المقاطع, تم تسجيل العمر, النوع, قطر الشريان الأبهر الصدري الصاعد, وقطر الشريان الأبهر الصدري النازل. أخذت القياسات في المعالم التشريحية الموحدة عموديا على محور تدفق الدم.

أوضحت الدراسة النتائج الآتية: قطر الشريان الأبهر الصدري لعينة السودانين (35,11  $\pm$  7,45 ملم لقطر الشريان الأبهر الصدري الصاعد, و 23,96  $\pm$  3,2 ملم لقطر الشريان الأبهر الصدري النازل) وهذه القياسات اكبر من القياسات العالمية التي وجدت في الدراسات السابقة. يوجد ارتباط معنوي بين قياسات قطر الشريان الأبهر الصدري النازل والعمر. ووضعت معادلات التنبؤ لقياسات قطر الشريان الأبهر الصدري للأفراد معلومي العمر.

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## Abbreviation

A Ao	Ascending aorta
AAoD	Ascending aortic diameter
AR	Aortic regurgitation
AS or AoS	Aortic stenosis
ASVD	Arteriosclerotic vascular disease
BSA	Body surface area
BC	Brachiocephalic Artery
CAC	Coronary artery calcium
Cm	Centimeter
CoA or CoAo	Coarctation of the aorta
CT	Computed tomography
CTA	Computed tomography angiography
D AO	Descending aorta
EDS	Ehlers–Danlos syndrome
FOV	field of view
Fig	Figure
HU	Hounsfield Units
IV	Intravenous
IVC	Inferior vena cava
Kev	kiloelectron volt
LCC	Left Common Carotid
MDCT	Multi-Detector Computed Tomography
Mm	Millimeter
MRA	Magnetic resonance angiography
MRI	Magnetic resonance imaging

PC	Phase contrast
PDA	Patent ductus arteriosus
SC	Subclavian
STP	Standard temperature and pressure
TTE	Transthoracic echocardiogram
TEE	Transeosophageal echocardiogram
TOF	Time-of-flight
T12	Twelfth thoracic vertebra
VS	Versus
2D	Two- dimensional

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# ***Chapter One***

## ***Introduction***

# **Chapter One**

## **Introduction**

The aorta is the main artery in the human body. The aorta distributes oxygenated blood to all part of the body through the systemic circulation. It extends from the heart to about the fourth lumbar vertebra and it divided into thoracic and abdominal sections. The thoracic section divided into four segments: aortic bulb (root), ascending aorta, aortic arch and descending aorta. The bulb or root portion is at the proximal end of the aorta and is the area from which the coronary arteries originate. Extending from the bulb is ascending portion of the aorta, which terminates at approximately second sternocostal joint and becomes the arch. The arch is unique from the other segments of the thoracic aorta because three arterial branches arise from it: the brachiocephalic artery, the left common carotid artery, and the left subclavian artery. The distal end of arch becomes descending aorta which extends from the isthmus to the level of twelfth dorsal vertebra. Numerous intercostals, bronchial, esophageal, and superior phrenic branches arise from the descending aorta. Then continues downward as the abdominal aorta which extends from diaphragm to the aortic bifurcation. It gives rise to lumbar and musculophrenic arteries, renal and middle suprarenal arteries, and visceral arteries (celiac trunk, the superior mesenteric artery and the inferior mesenteric artery). It ends in a bifurcation into the left and right common iliac arteries. (Kenneth, 2012)

Echocardiography better in measure aortic root diameter which provides prognostic information in aortic regurgitation and the Marfan syndrome. (Marco, 2016)

Computed tomography angiography uses an injection of iodine-rich contrast material and CT scanning to help diagnose and evaluate blood

vessels disease or related condition such as aneurysm or blockage. (RadiologyInfo.org, 2016)

Aortography is performed by x-ray with catheters, magnetic resonance imaging, and computed tomography which is usually the most useful technique in imagining of aorta and produce detailed image of vessels. (RadiologyInfo.org, 2016)

## **1.2 problem of the study**

All anatomical organs differ according to race and ethnic groups. The structure may differ also due to diseases and abnormalities. There is no specific characterization of the measurements of the aortic diameter in normal Sudanese. So this study is an attempt to see the effectiveness of the age in the aortic diameter.

## **1.3 Objectives**

### **1.3.1 General objective**

To measure diameter of the thoracic aorta of adult Sudanese people by using computed tomography.

### **1.3.2 Specific objectives are**

- To measure ascending thoracic aorta diameter.
- To measure descending thoracic aorta diameter.
- To correlate ascending and descending aortic measurement with patient age.

## **1.4 Thesis Outline**

This study will be built in five chapters. Chapter one will deal with introduction, problem of the study, objectives, and thesis outline. Chapter

two will highlight the literature review. Chapter three will express the methodology of the study. Chapter four will include the presentation of results. Chapter five will concern with the discussion, conclusion, and recommendations.

# ***Chapter Two***

## ***Literature Review***



## **Chapter Two**

### **Literature Review**

#### **2.1 Anatomical View:**

The aorta is the largest artery in the body. The aorta begins at the top of the left ventricle, the heart's muscular pumping chamber pumps blood from the left ventricle into the aorta through the aortic valve. Three leaflets on the aortic valve open and close with each heartbeat to allow one-way flow of blood. (WebMD, 2013)

The aorta is a tube about a foot long and the size of the aorta is directly proportionate to the patient's height and weight. Its diameter may range from 3cm (more than an inch) to 1.2cm (half an inch). It is typically the largest in the aortic root and smallest in the abdominal aorta. It commences at the upper part of the left ventricle, where it is about 3 cm in diameter, and after ascending for a short distance, arches backward and to the left side, over the root of the left lung; it then descends within the thorax on the left side of the vertebral column, passes into the abdominal cavity through the aortic hiatus in the diaphragm, and ends, considerably diminished in size (about 1.75 cm in diameter), opposite the lower border of the fourth lumbar vertebra, by dividing into the right and left common iliac arteries. Hence it is described in several portions, the ascending aorta, the arch of the aorta, and the descending aorta, which last is again divided into the thoracic and abdominal aorta. (Cedars, 2016)

Variation may occur in the location of the aorta, and the way in which arteries branch of the aorta. The aorta normally on the left side of the body, may be found on the right in dextrocardia, in which the heart is found on the right, or situs inversus, in which the location of all organs are flopped. Variations in the branching of individual arteries may also occur. For

example, the left vertebral artery may arise from the aorta, instead of the left common carotid artery. (Drake, et al 2010)

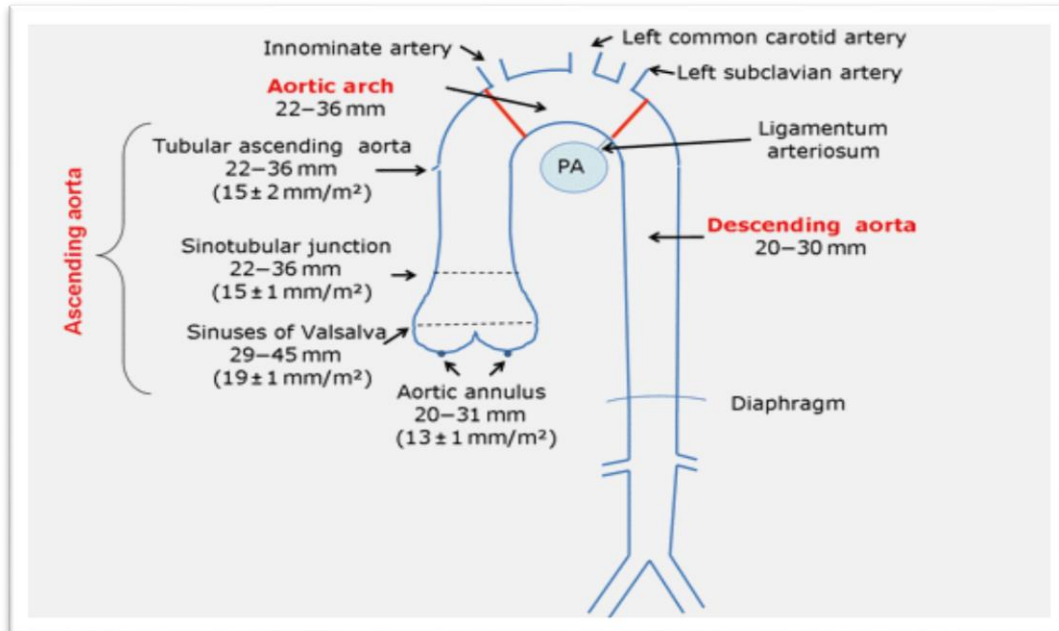


Fig (2.1): Ascending and descending aorta (Erbel et al, 2005)

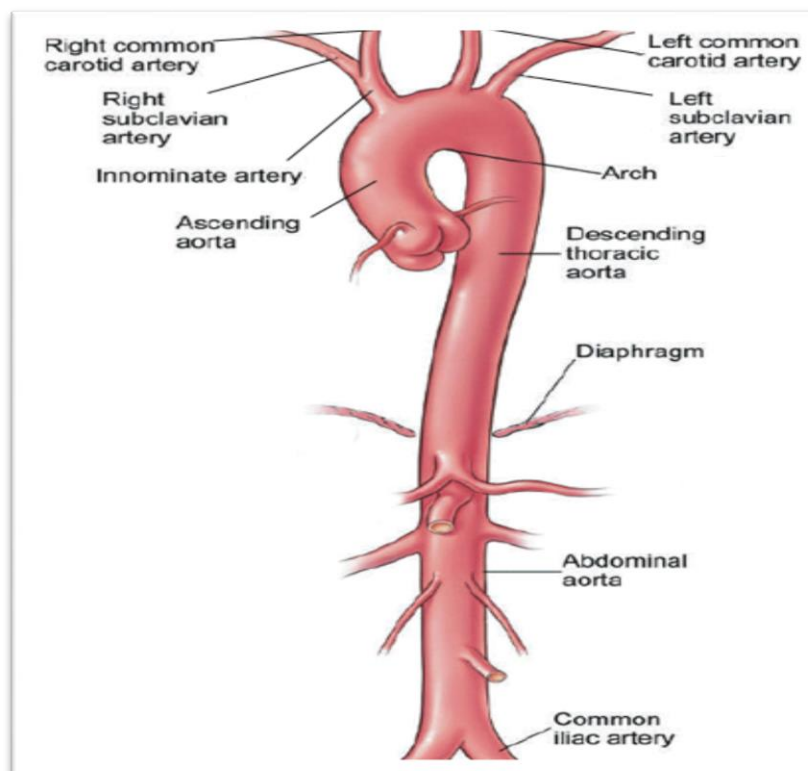


Fig (2.2) The portion of the aorta. (Cleveland Clinic, 2016)

### **2.1.1 Development of the aorta**

Development of the aorta takes place during the third week of gestation. It is a complex process associated with the formation of the endocardial tube (day 21), which lends itself to a variety of congenital variants. Each primitive aorta consists of a ventral and a dorsal segment that are continuous through the first aortic arch. The two ventral aorta fuse to form the aortic sac. The dorsal aorta fuse to form the midline descending aorta. Six paired aortic arches, the so-called branchial arch arteries, develop between the ventral and dorsal aorta. In addition, the dorsal aorta gives off several intersegmental arteries. The vessels derived from each arch are as follows: The first pair contributes to formation of the maxillary and external carotid arteries. The second pair contributes to formation of the stapedia arteries. The third aortic arch constitutes the commencement of the internal carotid artery and is therefore named the carotid arch. Proximal segments of the third pair form the common carotid arteries. Together with segments of the dorsal aorta, the distal portions contribute to formation of the internal carotid arteries. The left arch of the fourth pair forms the segment of normal left aortic arch between the left common carotid and subclavian arteries. The right fourth arch forms the proximal right subclavian artery. The distal right subclavian artery is derived from a portion of the right dorsal aorta and the right seventh intersegmental artery. Rudimentary vessels that regress early develop out of the fifth pair. The left arch of the sixth pair contributes to the formation of the main and left pulmonary arteries and ductus arteriosus; this duct obliterates a few days after birth. The right sixth arch contributes to formation of the right pulmonary artery. With the caudad migration of the heart in the second fetal month, the seventh intersegmental arteries enlarge and migrate cephalad to form the distal subclavian arteries. The left subclavian artery is derived entirely

from the left seventh intersegmental artery, whereas the portions of the right are derived from the right fourth arch and the right dorsal aorta. Malformations of the aortic arch system can be explained by persistence of segments of the aortic arches that normally regress or disappearance of segments that normally remain, or both. Regression of the right dorsal aortic root (between the right subclavian artery and the descending aorta) and the right ductus arteriosus leaves the normal left aortic arch. The classic left aortic arch and descending thoracic aorta are seen in ~70% of individuals. The three main branches of the aortic arch are the brachiocephalic (innominate) artery (dividing into the right subclavian and common carotid arteries), the left common carotid artery, and the left subclavian artery. (Thomas et al, 2007)

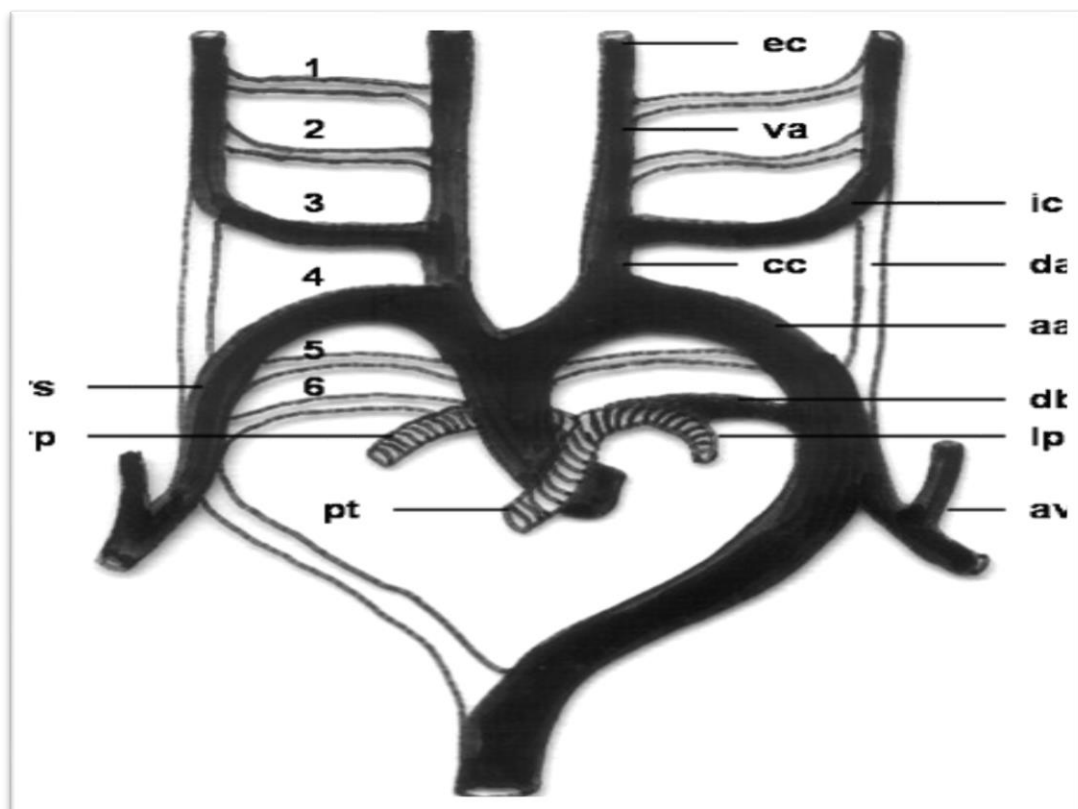


Fig (2.3) Schematic drawing of the development of the aortic arch and its branches. 1, first aortic arch; 2, second aortic arch; 3, third aortic arch; 4, fourth aortic arch; 5, fifth aortic arch; 6, sixth aortic arch; aa, aortic arch; va, ventral aorta; da, dorsal. (Thomas et al, 2007)

### 2.1.2 Histology of the aorta

The aorta is an elastic artery, and as such is quite distensible. The aorta consists of a heterogeneous mixture of smooth muscle, nerves, intimal cells, endothelial cells, fibroblast-like cells, and a complex extracellular matrix. The vascular wall consists of several layers known as the tunica externa, tunica media, and tunica intima. The thickness of the aorta requires an extensive network of tiny blood vessels called vasa vasorum, which feed the tunica externa and tunica media outer layers of the aorta. The aortic arch contains bar receptors and chemoreceptors that relay information concerning blood pressure and blood pH and carbon dioxide levels to the medulla oblongata of the brain. This information is processed by the brain and the autonomic nervous system mediates the homeostatic responses. (Tsamis et al, 2013)

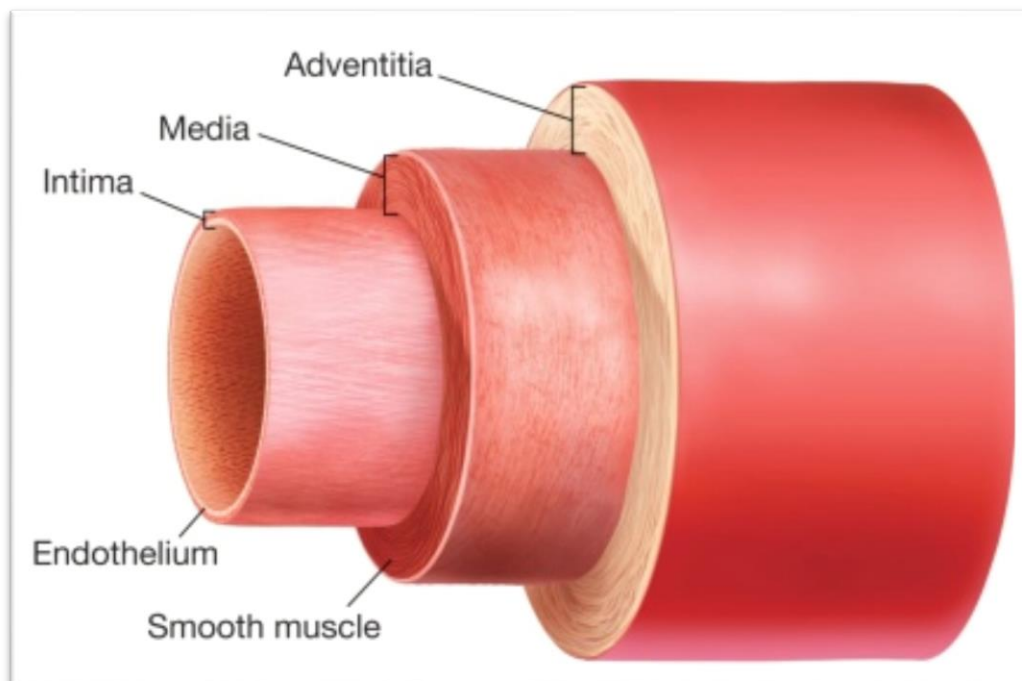


Fig (2.4): The aortic layers. (Aric et al, 2015)

### **2.1.3: Ascending Aorta**

Is about 5 cm in length. It commences at the upper part of the base of the left ventricle, on a level with the lower border of the third costal cartilage behind the left half of the sternum; it passes obliquely upward, forward, and to the right, in the direction of the heart's axis, as high as the upper border of the second right costal cartilage, describing a slight curve in its course, and being situated, about 6 cm. behind the posterior surface of the sternum. At its origin it presents, opposite the segments of the aortic valve, three small dilatations called the aortic sinuses. At the union of the ascending aorta with the aortic arch the caliber of the vessel is increased, owing to a bulging of its right wall. This dilatation is termed the bulb of the aorta, and on transverse section presents a somewhat oval figure. The ascending aorta is contained within the pericardium, and is enclosed in a tube of the serous pericardium, common to it and the pulmonary artery. (Henry, 1918)

#### **2.1.3.1 Relations**

The ascending aorta is covered at its commencement by the trunk of the pulmonary artery and the right auricula, and, higher up, is separated from the sternum by the pericardium, the right pleura, the anterior margin of the right lung, some loose areolar tissue, and the remains of the thymus; posteriorly, it rests upon the left atrium and right pulmonary artery. On the right side, it is in relation with the superior vena cava and right atrium, the former lying partly behind it; on the left side, with the pulmonary artery. (Henry, 1918)

#### **2.1.3.2 Branches**

The only branches of the ascending aorta are the two coronary arteries which supply the heart; they arise near the commencement of the aorta immediately above the attached margins of the semilunar valves. The

coronary arteries divided into right coronary artery and left coronary artery. (Henry, 1918)

#### **2.1.4: The Arch of the Aorta**

The arch of the aorta begins at the level of the upper border of the second sternocostal articulation of the right side, and runs at first upward, backward, and to the left in front of the trachea; it is then directed backward on the left side of the trachea and finally passes downward on the left side of the body of the fourth thoracic vertebra, at the lower border of which it becomes continuous with the descending aorta. It thus forms two curvatures: one with its convexity upward, the other with its convexity forward and to the left. Its upper border is usually about 2.5 cm. below the superior border to the manubrium sterni. (Henry, 1918)

##### **2.1.4.1 Relations**

The arch of the aorta is covered anteriorly by the pleura and anterior margins of the lungs, and by the remains of the thymus. As the vessel runs backward its left side is in contact with the left lung and pleura. Passing downward on the left side of this part of the arch are four nerves; in order from before backward these are, the left phrenic, the lower of the superior cardiac branches of the left vagus, the superior cardiac branch of the left sympathetic, and the trunk of the left vagus. As the last nerve crosses the arch it gives off its recurrent branch, which hooks around below the vessel and then passes upward on its right side. The highest left intercostal vein runs obliquely upward and forward on the left side of the arch, between the phrenic and vagus nerves. On the right are the deep part of the cardiac plexus, the left recurrent nerve, the esophagus, and the thoracic duct; the trachea lies behind and to the right of the vessel. Above are the innominate, left common carotid, and left subclavian arteries, which arise from the convexity of the arch and are crossed close to their origins by the left

innominate vein. Below are the bifurcation of the pulmonary artery, the left bronchus, the ligamentum arteriosum, the superficial part of the cardiac plexus, and the left recurrent nerve. As already stated, the ligamentum arteriosum connects the commencement of the left pulmonary artery to the aortic arch. (Henry, 1918)

### 2.1.4.2 Branches

The branches given off from the arch of the aorta are three in number: the innominate, the left common carotid, and the left subclavian. These vessels supply blood to the head, neck, thorax and upper limbs. (Henry, 1918)

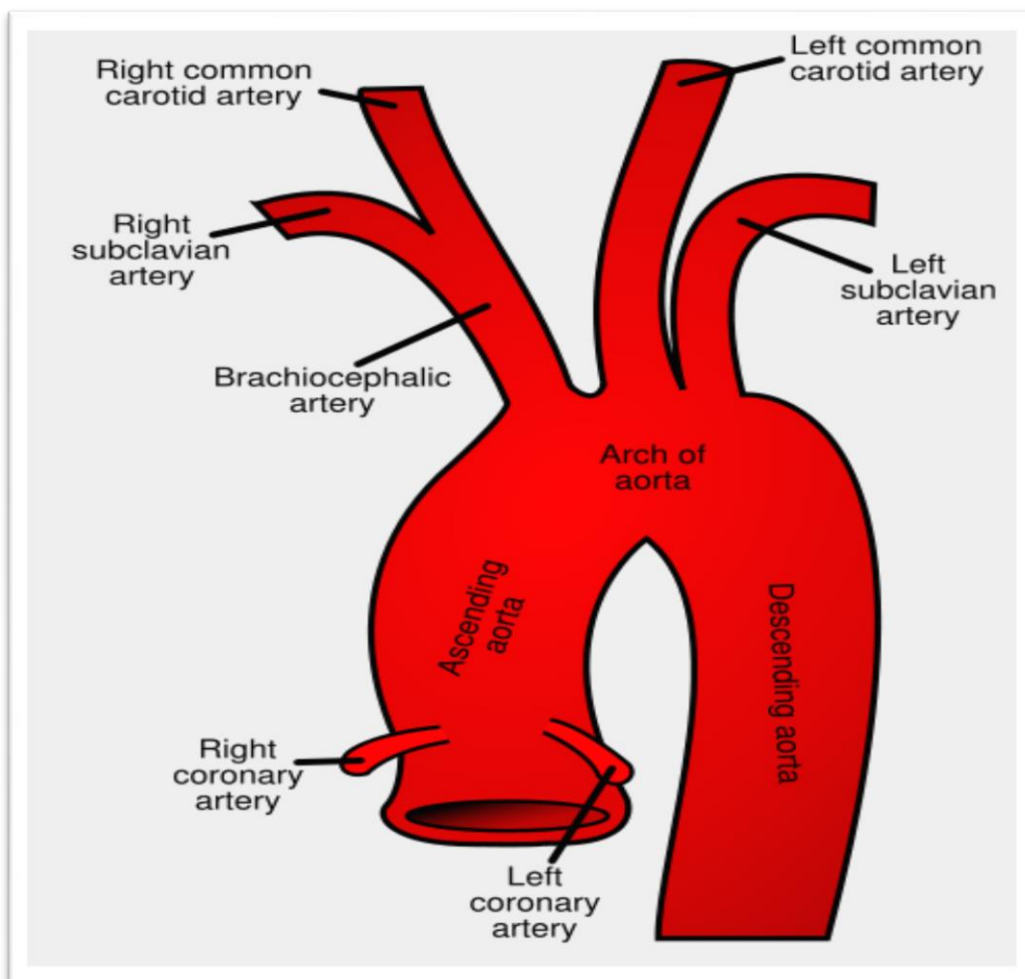


Fig (2.5) The aortic arch and its branches. (Cedars, 2016)



The branches, instead of arising from the highest part of the arch, may spring from the commencement of the arch or upper part of the ascending aorta; or the distance between them at their origins may be increased or diminished, the most frequent change in this respect being the approximation of the left carotid toward the innominate artery. The number of the primary branches may be reduced to one, or more commonly two; the left carotid arising from the innominate artery; or (more rarely) the carotid and subclavian arteries of the left side arising from a left innominate artery. But the number may be increased to four, from the right carotid and subclavian arteries arising directly from the aorta, the innominate being absent. In most of these latter cases the right subclavian has been found to arise from the left end of the arch; in other cases it is the second or third branch given off, instead of the first. Another common form in which there are four primary branches is that in which the left vertebral artery arises from the arch of the aorta between the left carotid and subclavian arteries. Lastly, the number of trunks from the arch may be increased to five or six; in these instances, the external and internal carotids arise separately from the arch, the common carotid being absent on one or both sides. In some few cases six branches have been found, and this condition is associated with the origin of both vertebral arteries from the arch. (Henry, 1918)

#### **2.1.4.2.1 The Innominate Artery (Brachiocephalic Artery)**

The innominate artery is the largest branch of the arch of the aorta, and is from 4 to 5cm in length. It arises, on a level with the upper border of the second right costal cartilage, from the commencement of the arch of the aorta, on a plane anterior to the origin of the left carotid; it ascends obliquely upward, backward, and to the right to the level of the upper

border of the right sternoclavicular articulation, where it divides into the right common carotid and right subclavian arteries. The innominate artery sometimes divides above the level of the sternoclavicular joint, less frequently below it. The position of innominate artery when the aortic arch is on the right side, the innominate is supplies the right side of the head and neck as well as the right arm and chest wall. (Henry, 1918)

#### **2.1.4.2.2: The left Common Carotid Artery**

The left common carotid artery supply the head and neck, springs from the highest part of the arch of the aorta to the left of, and on a plane posterior to the innominate artery, and therefore consists of a thoracic and a cervical portion. The thoracic portion of the left common carotid artery ascends from the arch of the aorta through the superior mediastinum to the level of the left sternoclavicular joint, where it is continuous with the cervical portion. The cervical portions of the common carotids resemble each other so closely that one description will apply to both. Each vessel passes obliquely upward, from behind the sternoclavicular articulation, to the level of the upper border of the thyroid cartilage, where it divides into the external and internal carotid arteries. (Henry, 1918)

#### **2.1.4.2.3 The left Subclavian Artery**

The left subclavian artery arises from the arch of the aorta, behind the left common carotid, and at the level of the fourth thoracic vertebra; it ascends in the superior mediastinal cavity to the root of the neck and then arches lateral ward to the medial border of the scalenus anterior. The left subclavian artery supplies blood to the left arm (Henry, 1918)

### **2.1.5: The descending aorta**

Is the largest artery in the body; it runs from the heart down the length of the chest and abdomen. It is divided into two portions, the thoracic and abdominal, in correspondence with the two great cavities of the trunk in which it sits. Within the abdomen, the descending aorta branches into the two common iliac arteries that provide blood to the pelvis and, eventually, the legs. (David, 2010)

#### **2.1.5.1 The thoracic aorta**

Is contained in the posterior mediastinal cavity, begins at the 4th thoracic vertebra where it is continuous with the aortic arch, and ends in front of the lower border of the twelfth thoracic vertebra, at the aortic hiatus in the diaphragm where it becomes the abdominal aorta. Branches from the thoracic aorta include the bronchial arteries, the mediastinal arteries, the esophageal arteries, the pericardial arteries, the superior phrenic artery which supply the diaphragm, and the subcostal arteries for the twelfth ribs. The thoracic aorta and the esophagus run parallel for most of its length, with the esophagus lying on the right side of the aorta, but at the lower part of the thorax, it is placed in front of the aorta, and, close to the diaphragm, is situated on its left side. (David, 2010)

The thoracic aorta's relation, from above downward, is as follows: anteriorly with the root of the left lung, the pericardium, the esophagus and the diaphragm; posteriorly with the vertebral column; on the right side with the hemiazygos veins and thoracic duct; and on the left side with the left pleura and lung. The esophagus lies on the right side of the aorta for most of its length, but at the lower part of the thorax is placed in front of the aorta and close to the diaphragm, situated on its left side. As it descends in the thorax, the aorta gives off several paired branches. In descending

order these are: the bronchial arteries, the mediastinal arteries, the esophageal arteries, the pericardial arteries, and the superior phrenic artery. The posterior intercostal arteries are branches that originate throughout the length of the posterior aspect of the thoracic aorta. (Drake, et al.2010)

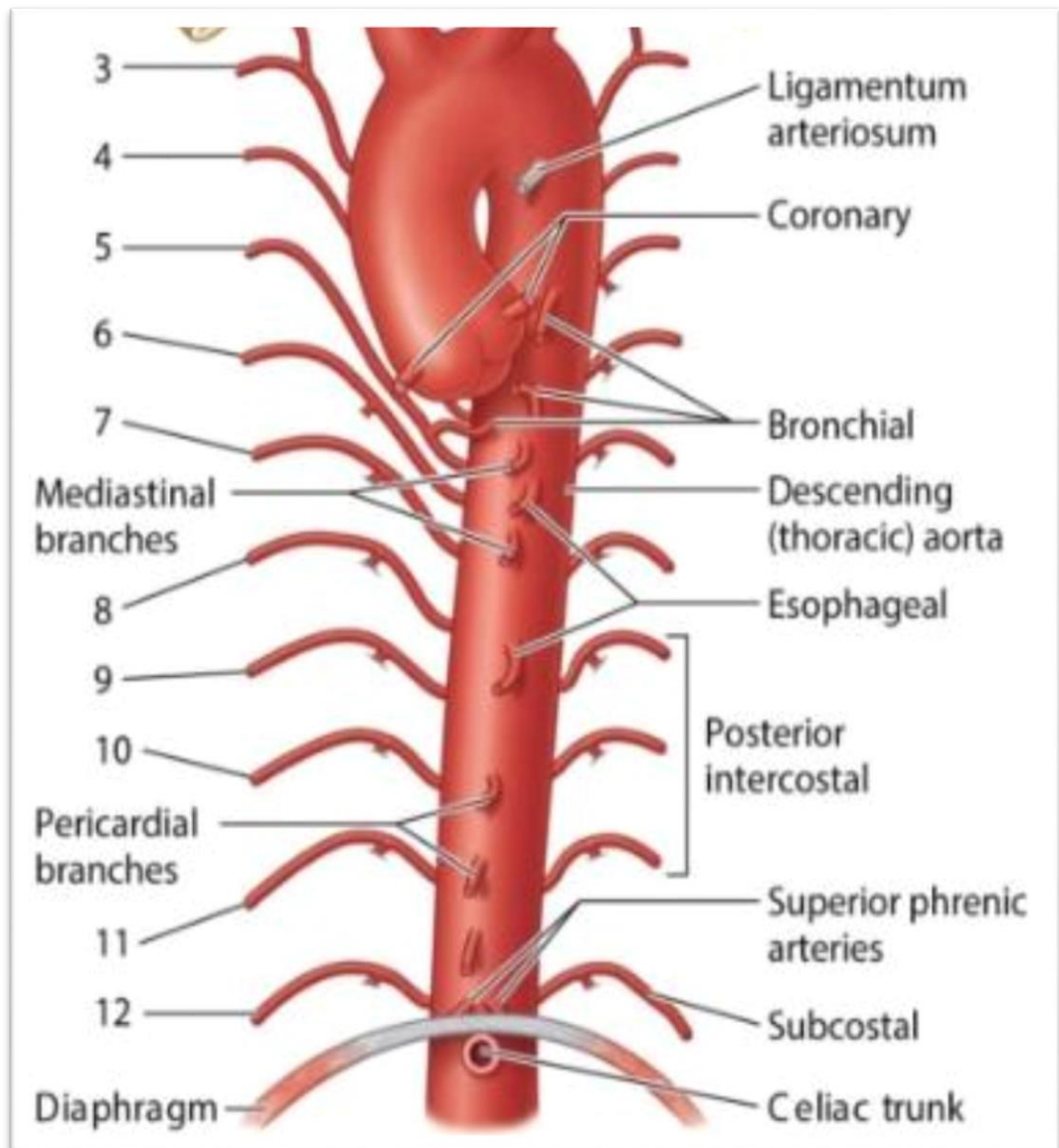


Fig (2.6) Anterior view of thoracic aorta and its branches (Mo, 2014)

### **2.1.5.2: The abdominal aorta:**

Is the largest artery in the abdominal cavity and supplies blood to most of the abdominal organs. It is a direct continuation of the descending aorta. It begins at the level of the diaphragm, crossing it via the aortic hiatus, a hole in the diaphragm that allows the passage of the great vessels, at the vertebral level of T12. It travels down the posterior wall of the abdomen, anterior to the vertebral column, following the curvature of the lumbar vertebrae. The abdominal aorta runs parallel to the inferior vena cava, which is located just to the right of the abdominal aorta. (Drake, et al.2010)

The abdominal aorta lies slightly to the left of the midline of the body. It is covered, anteriorly, by the lesser omentum and stomach. Posteriorly, it is separated from the lumbar vertebrae by the anterior longitudinal ligament and left lumbar veins. (Drake, et al.2010)

The abdominal aorta gives rise to lumbar and musculophrenic arteries, renal and middle suprarenal arteries, and visceral arteries (the celiac trunk, the superior mesenteric artery and the inferior mesenteric artery). It ends in a bifurcation into the left and right common iliac arteries. At the point of the bifurcation, there also springs a smaller branch, the median sacral artery. (Drake, et al.2010)

#### **2.1.5.2 .1 Relationship with inferior vena cava**

The abdominal aorta's venous counterpart, the inferior vena cava (IVC), travels parallel to it on its right side. Above the level of the umbilicus, the aorta is somewhat posterior to the IVC, sending the right renal artery travelling behind it. The IVC likewise sends its opposite side counterpart, the left renal vein, crossing in front of the aorta. Below the level of the umbilicus, the situation is generally

reversed, with the aorta sending its right common iliac artery to cross its opposite side counterpart (the left common iliac vein) anteriorly. (Susan, 2008)

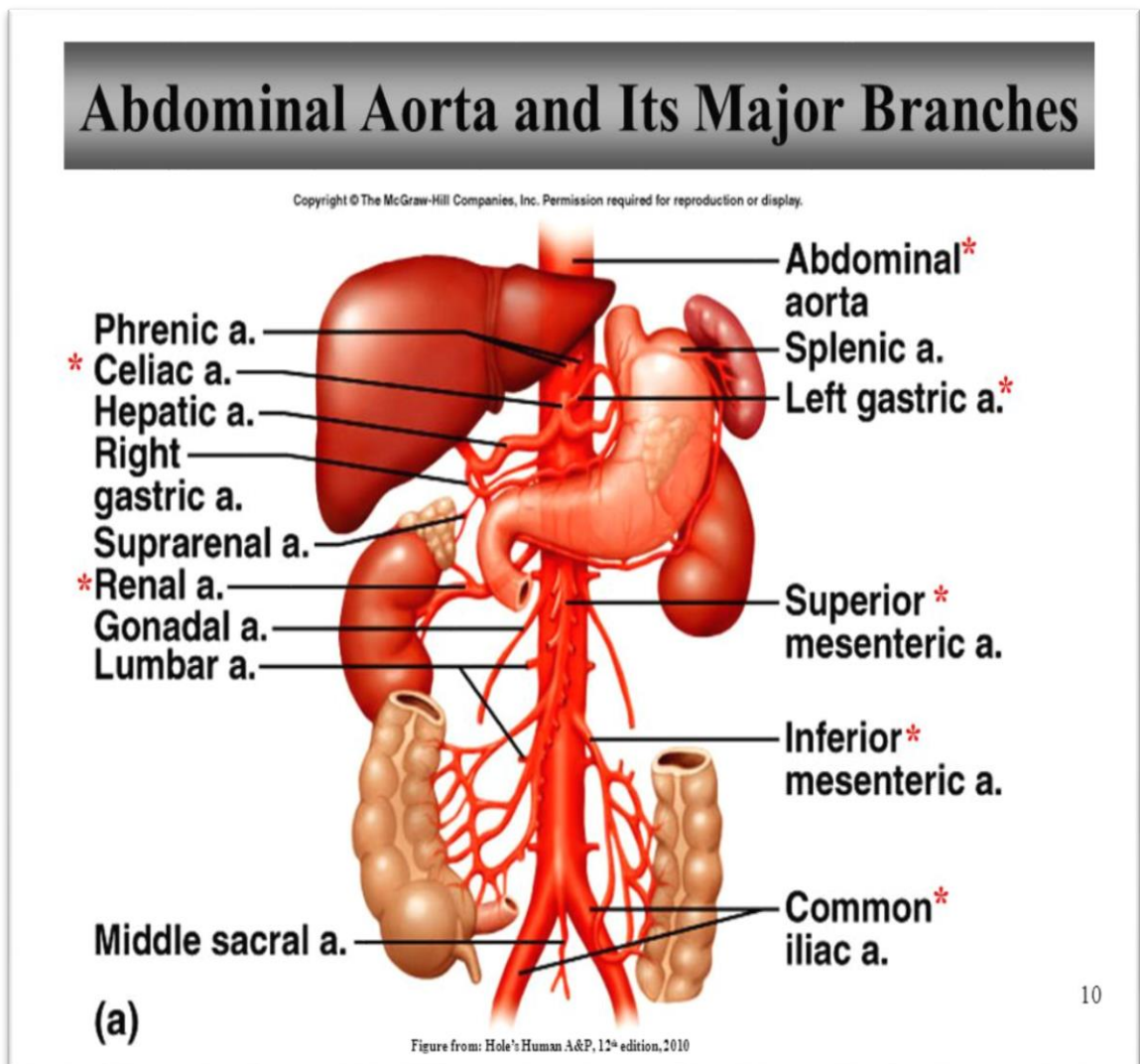


Fig (2.7): Abdominal aorta and its major branches. (David et al, 2010)

## **2.2: Pathology of the aorta**

### **2.2.1: Patent ductus arteriosus (PDA)**

Is a congenital heart defect wherein the ductus arteriosus fails to close after birth. Early symptoms are uncommon, but in the first year of life include increased 'work of breathing' and poor weight gain. An uncorrected PDA may lead to congestive heart failure with increasing age. The ductus arteriosus is a fetal blood vessel that closes soon after birth. In a PDA, the vessel does not close and remains "patent" (open), resulting in irregular transmission of blood between the aorta and the pulmonary artery. PDA is common in newborns with persistent respiratory problems such as hypoxia, and has a high occurrence in premature newborns. Premature newborns are more likely to be hypoxic and have PDA due to underdevelopment of the heart and lungs. A PDA allows a portion of the oxygenated blood from the left heart to flow back to the lungs by flowing from the aorta (which has higher pressure) to the pulmonary artery. If this shunt is substantial, the neonate becomes short of breath: the additional fluid returning to the lungs increases lung pressure, which in turn increases the energy required to inflate the lungs. This uses more calories than normal and often interferes with feeding in infancy. This condition, as a constellation of findings, is called congestive heart failure. In some congenital heart defects (such as in transposition of the great vessels) a PDA may need to remain open, as it is the only way that oxygenated blood can mix with deoxygenated blood. (Tsamis et al, 2013)

### **2.2.2: Coarctation of the aorta (CoA or CoAo)**

Also called aortic narrowing, is a congenital condition whereby the aorta is narrow, usually in the area where the ductus arteriosus

(ligamentum arteriosum after regression) inserts. The word “coarctation” means narrowing. Coarctations are most common where the aorta—the major artery leading away from the heart—arches toward the abdomen and legs (the aortic arch). The arch may be small in babies with coarctations. Other heart defects may also occur when coarctation is present, typically occurring on the left side of the heart. When a patient has a coarctation, the left ventricle has to work harder. Since the aorta is narrowed, the left ventricle must generate a much higher pressure than normal in order to force enough blood through the aorta to deliver blood to the lower part of the body. If the narrowing is severe enough, the left ventricle may not be strong enough to push blood through the coarctation, thus resulting in lack of blood to the lower half of the body. Physiologically its complete form is manifested as interrupted aortic arch. (Groenemeijer et al, 2008)

There are three types of aortic coarctations: Preductal, Ductal and Postductal coarctation. (Valdes, et al, 1999)

### **2.2.3: An aortic aneurysm**

Is enlargement (dilation) of the aorta to greater than 1.5 times normal size. They usually cause no symptoms except when ruptured. Occasionally there may be abdominal, back or leg pain. They are most commonly located in the abdominal aorta, but can also be located in the thoracic aorta. Aortic aneurysms cause weakness in the wall of the aorta and increase the risk of aortic rupture. When rupture occurs, massive internal bleeding results and, unless treated immediately, shock and death can occur. Screening with ultrasound is indicated in those at high risk. Prevention is by decreasing risk factors such as smoking. Treatment is either by open or endovascular surgery. (Kent, 2014)



Aortic aneurysms resulted in about 152,000 deaths in 2013, up from 100,000 in 1990. (G B D, 2013)

Ascending aortic aneurysms are the most common subtype of thoracic aortic aneurysms, and may be true or false injuries. Aneurysmal dilatation is considered with the ascending aorta measures  $>4.0$  cm in diameter. (Aditya et al, 2015)

#### **2.2.4 Aortic dissection**

Occurs when a tear in the tunica intima of the aorta causes blood to flow between the layers of the wall of the aorta, forcing the layers apart. In most cases this is associated with severe characteristic chest or abdominal pain described as "tearing" in character, and often with other symptoms that result from decreased blood supply to other organs. Aortic dissection is a medical emergency and can quickly lead to death, even with optimal treatment, as a result of decreased blood supply to other organs, heart failure, and sometimes rupture of the aorta. Aortic dissection is more common in those with a history of high blood pressure, a known thoracic aortic aneurysm, and in a number of connective tissue diseases that affect blood vessel wall integrity such as Marfan syndrome and the vascular subtype of Ehlers– Danlos syndrome. The diagnosis is made with medical imaging (computed tomography, magnetic resonance imaging or echocardiography). (Kamalakannan et al, 2007)

#### **2.2.5 Aortic regurgitation (AR)**

Another name of aortic insufficiency. Blood regurgitates backward through the incompletely closed aortic valve and into the heart's left ventricle. Valvular abnormalities that may result in AR can be caused by the congenital causes - Bicuspid aortic valve is the most common

congenital cause, and acquired causes: Rheumatic fever Infective endocarditis Collagen vascular diseases Degenerative aortic valve disease Traumatic Postsurgical (including post-transcatheter aortic valve replacement).( Freeman et al, 2011)

### **2.2.6 Aortic stenosis (AS or AoS)**

Is the narrowing of the exit of the left ventricle of the heart, such that problems result. It may occur at the aortic valve as well as above and below this level. It typically gets worse over time. Symptoms often come on gradually with a decreased ability to exercise often occurring first. If heart failure, loss of consciousness, or heart related chest pain occurs due to AS the outcomes are worse. Loss of consciousness typically occurs with standing or exercise. (Czarny et al, 2014)

### **2.2.7 Atherosclerosis**

Also known as arteriosclerotic vascular disease or ASVD is a specific form of arteriosclerosis in which an artery -wall thickens as a result of invasion and accumulation of white blood cells (foam cell) and proliferation of intimal- smooth-muscle cell creating a fibrofatty plaque.(Maton et al, 1993)

### **2.2.8 Ehlers–Danlos syndrome (EDS)**

Is an inherited connective tissue disorder with presentations that have been classified into several primary types. EDS is caused by a defect in the structure, production, or processing of collagen or proteins that interact with collagen, such as mutations in the COL5A or COL3A genes. This is the collagen of granulation tissue, and is produced quickly by young fibroblasts before the tougher type I collagen is synthesized.

Commonly associated with keloid formation, reticular fiber, and found in artery walls, skin, intestines and the uterus. (Voermans et al, 2009)

### **2.2.9 Marfan syndrome**

Is a genetic disorder of connective tissue. It has a variable clinical presentation, ranging from mild to severe systemic disease. The most serious manifestations involve defects of the heart valves and aorta, which may lead to early death if not properly managed. The syndrome also may affect the lungs, eyes, dural sac surrounding the spinal cord, the skeleton, and the hard palate. People with Marfan syndrome tend to be unusually tall, due to the disorder causing people with the condition to have long limbs and long, thin fingers and toes. (Dietz et al, 2005)

### **2.2.10 Major trauma**

Is any injury that has the potential to cause prolonged disability or death. There are many causes of major trauma, blunt and penetrating, including falls, motor vehicle collisions, and gunshot wounds. Depending on the severity of injury, quick management and transport to an appropriate medical facility may be necessary to prevent loss of life. (Yuranga et al, 2008)

## 2.3 Imaging modality of Aorta

### 2.3.1 Aortogram (angiogram)

An angiogram is an X-ray test that uses a special dye and camera (fluoroscopy) to take pictures of the blood flow in an artery (such as the aorta) or a vein (such as the vena cava). An angiogram can be used to look at the arteries or veins in the head, arms, legs, chest, back, or belly. Common angiograms can look at the arteries near the heart (coronary angiogram), lungs (pulmonary angiogram), brain (cerebral angiogram), head and neck (carotid angiogram), legs or arms (peripheral), and the aorta (aortogram). During an angiogram, a thin tube called a catheter is placed into a blood vessel in the groin (femoral artery or vein) or just above the elbow (brachial artery or vein). The catheter is guided to the area to be studied. Then an iodine dye (contrast material) is injected into the vessel to make the area show clearly on the X-ray pictures. This method is known as conventional or catheter angiogram. The angiogram pictures can be made into regular X-ray films or stored as digital pictures in a computer. (WebMD, 2014)

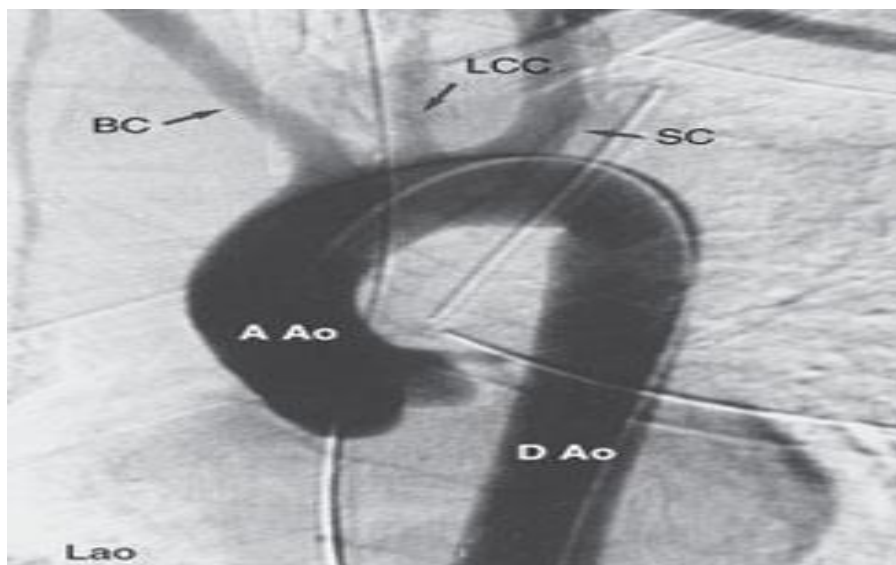


Fig (2.8) angiography of the arch of the aorta. (medicine.academic.ru, 2011)

### **2.3.2 Computed tomography angiography (CTA)**

Is a computed tomography technique used to visualize arterial and venous vessels throughout the body. CTA can be used to examine blood vessels in many key areas of the body, including the brain, kidneys, pelvis, and the lungs. Under some circumstances the coronary arteries may be examined by CTA, but CTA has not replaced invasive catheter coronary angiography. The procedure is able to detect narrowing of blood vessels in time for corrective therapy to be done. This method displays the anatomical detail of blood vessels more precisely than magnetic (MRI) or ultrasound. Today, many patients can undergo CTA in place of a conventional catheter angiogram. CTA is a useful way of screening for arterial disease because it is safer and much less time-consuming than catheter angiography and is a cost-effective procedure. There is also less discomfort because contrast material is injected into an arm vein rather than into a large artery in the groin. (American College of Chest Physicians and American Thoracic Society, 2013)

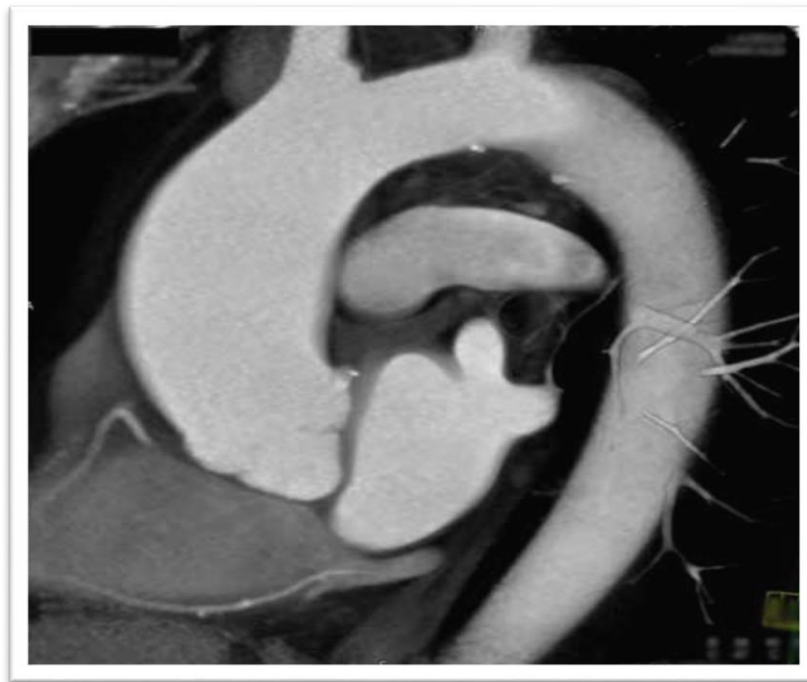


Fig (2.9) 3-D image of the aorta in the CT chest (RadiologyInfo.org, 2016)

### **2.3.3 Magnetic resonance angiography (MRA)**

Is a group of techniques based on magnetic resonance imaging (MRI) to image blood vessels. Magnetic resonance angiography is used to generate images of arteries (and less commonly veins) in order to evaluate them for stenosis (abnormal narrowing), occlusions, aneurysms (vessel wall dilatations, at risk of rupture) or other abnormalities. MRA is often used to evaluate the arteries of the neck and brain, the thoracic and abdominal aorta, the renal arteries, and the legs. A variety of techniques can be used to generate the pictures of blood vessels, both arteries and veins, based on flow effects or on contrast (inherent or pharmacologically generated). The most frequently applied MRA methods involve the use intravenous contrast agents, particularly those containing gadolinium to shorten the  $T_1$  of blood to about 250 ms, shorter than the  $T_1$  of all other tissues (except fat). Short-TR sequences produce bright images of the blood. However, many other techniques for performing MRA exist, and can be classified into two general groups: 'flow-dependent' methods and 'flow-independent' methods. Flow-dependent angiography is based on blood flow. They take advantage of the fact that the blood within vessels is flowing to distinguish the vessels from other static tissue. That way, images of the vasculature can be produced. Flow dependent MRA can be divided into different categories: There is phase-contrast MRA (PC-MRA) which utilizes phase differences to distinguish blood from static tissue and time-of-flight MRA (TOF MRA) which exploits that moving spins of the blood experience fewer excitation pulses than static tissue. (Eur Radiol, 2013)



Fig (2.10) Contrast-enhanced (CE-MRA) of the aorta. (Matthias et al, 2014)

### **2.3.2 Echocardiography**

Is a sonogram of the heart, uses standard two-dimensional, three-dimensional, and Doppler ultrasound to create images of the heart. A standard echocardiogram is also known as a transthoracic echocardiogram (TTE), or cardiac ultrasound. In this case, the echocardiography transducer (or probe) is placed on the chest wall (or thorax) of the subject, and images are taken through the chest wall. This is a non-invasive, highly accurate and quick assessment of the overall health of the heart. The alternative way to perform an echocardiogram is a transesophageal echocardiogram, or TOE. A specialized probe containing an ultrasound transducer at its tip is passed into the patient's esophagus. This allows image and Doppler evaluation from a location directly behind the heart. Transesophageal echocardiograms are most often utilized when transthoracic images are

suboptimal and when a more clear and precise image is needed for assessment. This test is performed in the presence of a cardiologist, registered nurse, and ultrasound technician. Conscious sedation and/or localized numbing medication may or may not be used in order to make the patient more comfortable during the procedure. (Journal of American College of Cardiology, etrieved August 17, 2012)

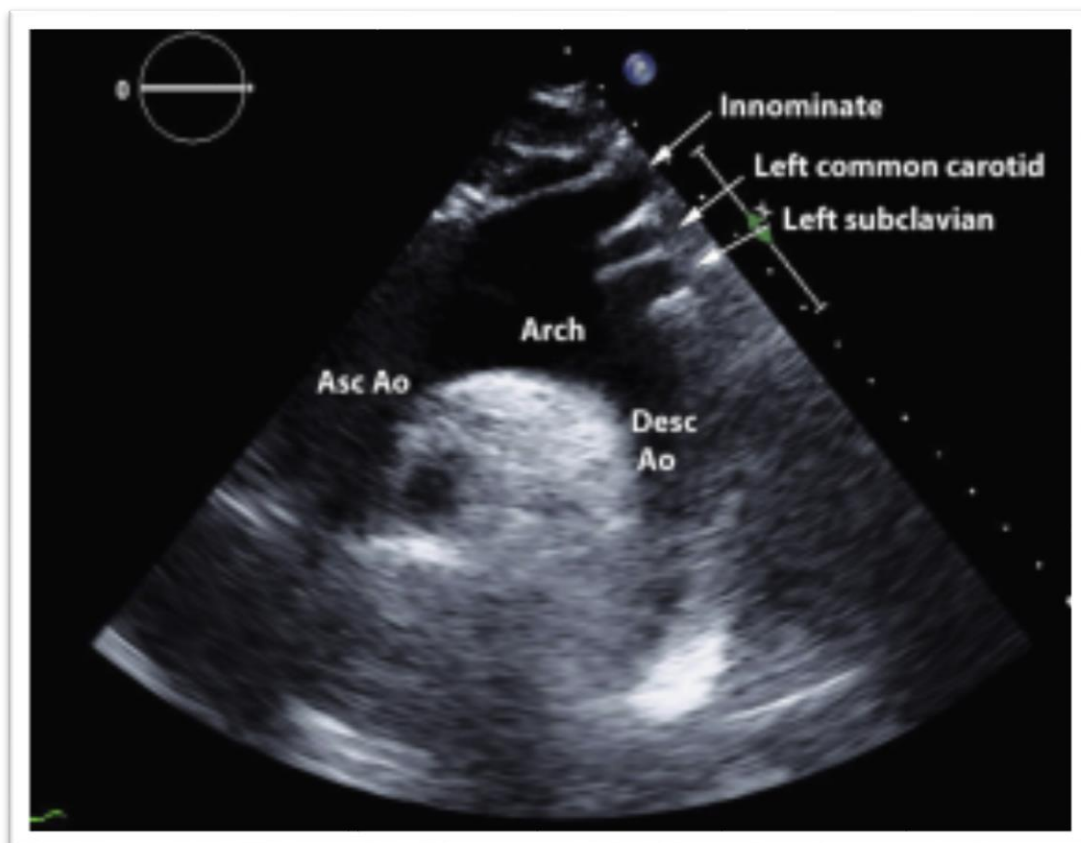


Fig (2.11) Transthoracic echocardiographic suprasternal notch view of the distal ascending aorta (Asc Ao), aortic arch, supraaortic vessels (arrows), and proximal descending thoracic aorta (Desc Ao). (Journal of the American Society of Echocardiography February 2015)



## **2.4 Computerized Tomography Scanning**

Computed tomography (CT scan or CAT scan) is a noninvasive diagnostic imaging procedure that uses a combination of X-rays and computer technology to produce horizontal, or axial, images (often called slices) of the body. A CT scan shows detailed images of any part of the body, including the bones, muscles, fat, and organs. CT scans are more detailed than standard X-rays. In standard X-rays, a beam of energy is aimed at the body part being studied. A plate behind the body part captures the variations of the energy beam after it passes through skin, bone, muscle, and other tissue. While much information can be obtained from a standard X-ray, a lot of detail about internal organs and other structures is not available. In computed tomography, the X-ray beam moves in a circle around the body. This allows many different views of the same organ or structure. The X-ray information is sent to a computer that interprets the X-ray data and displays it in a two-dimensional (2D) form on a monitor. CT scans may be done with or without "contrast." Contrast refers to a substance taken by mouth or injected into an intravenous (IV) line that causes the particular organ or tissue under study to be seen more clearly. Contrast examinations may require you to fast for a certain period of time before the procedure. (Jiang, 2009)

### **2.4.1 Basic principle of CT**

CT is based on the fundamental principle that the density of the tissue passed by the X-ray beam can be measured from the calculation of the attenuation coefficient. So, CT allows the reconstruction of the density of the body, by two dimensional section perpendiculars to the axis of the acquisition system. The emitter of X-rays (typically with energy levels between 20 and 150 keV), emits photons per unit of time. The

beam passes through the layer of biological material thickness. A detector placed at the exit of the sample, measures photons, number of photons smaller than 0. So, the X-rays interacted with the object and the beam has been attenuated. There are basically two processes of the absorption: the photoelectric effect and the Compton. This phenomenon is represented by a single coefficient. In the specific case of the CT, the emitter of X-rays rotates around the patient and the detector, placed in diametrically opposite side, picks up the image of a body section (beam and detector move in synchrony). Unlike X-ray radiography, the detector of the CT scanner does not produce an image. They measure the transmission of a thin beam (1-10mm) of X-rays through a full scan of the body. The image of that section is taken from different angles and this allows retrieving the information on the depth (in the third dimension). In order to obtain tomographic images of the patient from the data in "raw" scan, the computer uses complex mathematical algorithms for image reconstruction. (Goldman, 2008)

If the X-ray at the exit of the tube is made monochromatic or quasi-monochromatic with the proper filter, one can calculate the attenuation coefficient corresponding to the volume of irradiated tissue by the application of the general formula of absorption of the X-rays in the field. The outgoing intensity of the beam of photons measured will depend on the location. In fact, the intensity is smaller where the body is more radioopaque. (Goldman, 2008)

The image of the section of the object irradiated by the X-ray is reconstructed from a large number of measurements of attenuation coefficient. It gathers together all the data coming from the elementary volumes of material through the detectors. Using the computer, it presents the elementary surfaces of the reconstructed image from projection of the

data matrix reconstruction, the tone depending on the attenuation coefficients. The image by the CT scanner is a digital image and consists of square matrix of elements (pixel), each of which represents a voxel (volume element) of the tissue of the patient. In conclusion, a measurement made by a detector CT is proportional to the sum of the attenuation coefficients. (Lukáš et al, 2014)

The typical CT image is composed of 512 rows, each of 512 pixels, i.e., a square matrix of  $512 \times 512 = 262144$  pixels (one for each voxel). In the process of image, the value of attenuated coefficient for each voxel corresponding to these pixels needs to be calculated. Each image point is surrounded by a halo-shaped star that degrades the contrast and blurs the boundary of the object. To avoid this, the method of filtered back projection is used. The action of the filter function is such that the negative value created is the filtered projection, when projected backwards, is removed and an image is produced, which is the accurate representation of the original object. (Lukáš et al, 2014)

Before the data are presented on the screen, the conventional rescaling was made into CT numbers, expressed in Hounsfield Units (HU), which define as a quantity commonly used in computed tomography (CT) scanning to express CT numbers in a standardized and convenient form. Hounsfield units, created by and named after Sir Godfrey Hounsfield, are obtained from a linear transformation of the measured attenuation coefficients. The radiodensity of distilled water at standard temperature and pressure (STP) 0 HU, and the radiodensity of air at STP -1000 HU. So, the signal transmitted by the detector is processed by the PC in the form of the digital information, the CT image reconstruction. (Lukáš et al, 2014)

### **2.4.2 The pitch**

Is a term used in helical CT. It has two terminologies depending on whether single slice or multislice CT scanners are used. Is defined as table distance traveled in one 360° gantry rotation divided by beam collimation. For example, if the table traveled 5 mm in one rotation and the beam collimation was 5 mm then pitch equals  $5 \text{ mm} / 5 \text{ mm} = 1.0$ . (Silverman et al, 2011)

### **2.4.3 The field of view (FOV)**

The parameter that determines how much anatomy is scanned. The FOV should exceed the dimensions of the anatomy. Its value can be selected by the operator and generally lies in the range between 12 and 50 cm. The choice of a small FOV allows increased spatial resolution in the image, because the whole reconstruction matrix is used for a smaller region than is the case with a larger FOV; this results in reduction of the pixel size. In any case, the selection of the FOV must take into account not only the opportunity for increasing the spatial resolution but also the need for examining all the areas of possible disease. If the FOV is too small, relevant areas may be excluded from the visible image. If raw data are available the FOV can be changed by post-processing. (Willi, 2006)

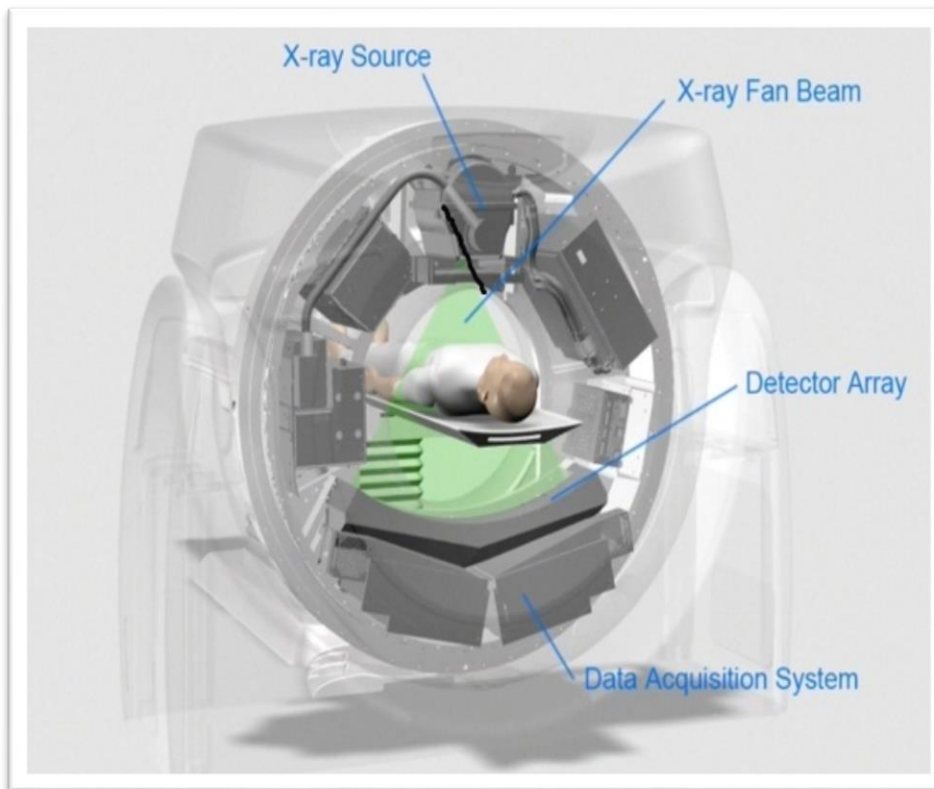


Fig (2.12): CT scan unit. (Lukáš et al, 2014)

#### **2.4.4 CT chest**

CT chest (computed tomography) is an imaging method that uses x-rays to create cross-sectional pictures of the chest and upper abdomen. (Gerald et al, 2013)

Chest CT scans are used for a multitude of reasons. They may be done to check for certain cancers in various different ways including to detect abnormal tumors, can also be ordered after a mammogram exam, Some chest CT scans are tailored to look for heart disease, aneurysms of the aorta or pulmonary emboli, can be used to guide doctors or surgeons during a procedure, such as a biopsy, can be used to detect cysts or infections in the body, They can also identify the bone structures within the body and can accurately measure the density of bone, and is often

used to quickly inspect a patient after an accident in order to identify traumatic internal injuries. (Gerald et al, 2013)

The technologist begins by positioning patient on the CT examination table, usually lying flat on his back. Straps and pillows may be used to help you maintain the correct position and to help you remain still during the exam. Many scanners are fast enough that children can be scanned without sedation. In special cases, sedation may be needed for children who cannot hold still. Motion will cause blurring of the images and degrade the quality of the examination the same way that it affects photographs. If a contrast material is used, it will be injected into a vein shortly before scanning begins. Next, the table will move quickly through the scanner to determine the correct starting position for the scans. Then, the table will move slowly through the machine as the actual CT scanning is performed. Depending on the type of CT scan, the machine may make several passes. You may be asked to hold his breath during the scanning. Any motion, whether breathing or body movements, can lead to artifacts on the images. This loss of image quality can resemble the blurring seen on a photograph taken of a moving object. When the examination is completed, you will be asked to wait until the technologist verifies that the images are of high enough quality for accurate interpretation. The actual CT scanning takes less than 30 seconds and the entire process is usually completed within 30 minutes. (Gerald et al, 2013)

Certain CT scans require a special dye, called contrast, to be delivered into the body before the test starts. Contrast highlights specific areas inside the body and creates a clearer image. If your doctor requests a CT scan with intravenous contrast, you will be given it through a vein (IV) in your arm or hand. A blood test to measure your kidney function

may be done before the test. This test is to make sure your kidneys are healthy enough to filter the contrast. Some people have allergies to IV contrast and may need to take medications before their test to safely receive this substance. Contrast can be given in several ways, depending on the type of CT being performed. It may be delivered through a vein (IV) in your hand or forearm, it may be given through the rectum using an enema, and you might drink the contrast before your scan. When you actually drink the contrast depends on the type of exam being done. The contrast liquid may taste chalky, although some are flavored to make them taste a little better. The contrast eventually passes out of your body through your stool. If contrast is used, you may also be asked not to eat or drink anything for 4 to 6 hours before the test. (Gerald et al, 2013)

## **2.4.5 The benefits vs. risks of CT**

### **Benefits**

- CT is fast, which is important for patients who have trouble holding their breath.
- CT scanning is painless, noninvasive and accurate.
- A major advantage of CT is its ability to image bone, soft tissue and blood vessels all at the same time.
- Unlike conventional x-rays, CT scanning provides very detailed images of many types of tissue as well as the lungs, bones, and blood vessels.
- CT examinations are fast and simple; in emergency cases, they can reveal internal injuries and bleeding quickly enough to help save lives.
- CT has been shown to be a cost-effective imaging tool for a wide range of clinical problems.

- CT is less sensitive to patient movement than MRI.
- CT can be performed if you have an implanted medical device of any kind, unlike MRI.
- CT imaging provides real-time imaging, making it a good tool for guiding minimally invasive procedures such as needle biopsies and needle aspirations of many areas of the body, particularly the lungs, abdomen, pelvis and bones.
- A diagnosis determined by CT scanning may eliminate the need for exploratory surgery and surgical biopsy.
- No radiation remains in a patient's body after a CT examination.
- X-rays used in CT scans should have no immediate side effects.
- Low-dose CT scans of the chest use a lower dose of radiation than conventional chest CT.( RadiologyInfo.org,2016)

## **Risks**

- There is always a slight chance of cancer from excessive exposure to radiation. However, the benefit of an accurate diagnosis far outweighs the risk.
- The effective radiation dose for this procedure varies. See the Safety page for more information about radiation dose.
- Women should always inform their physician and x-ray or CT technologist if there is any possibility that they are pregnant. See the Safety page for more information about pregnancy and x-rays.
- CT scanning is, in general, not recommended for pregnant women unless medically necessary because of potential risk to the baby in the womb.
- The risk of serious allergic reaction to contrast materials that contain iodine is extremely rare, and radiology departments are well-equipped to deal with them.



- In some patients with reduced kidney function, the dye used in CT scanning may worsen kidney function.
- Because children are more sensitive to radiation, they should have a CT exam only if it is essential for making a diagnosis and should not have repeated CT exams unless absolutely necessary. CT scans in children should always be done with low-dose technique.(  
RadiologyInfo.org,2016)

## 2.5 Previous Studies

Arik, et al 2008 had done statistical study about aortic size assessment by noncontrast cardiac computed tomography to determine normal limits for ascending and descending thoracic aorta diameters in a large population of asymptomatic, low risk adult subjects. Their methods were done in 4,039 adult patients undergoing coronary artery calcium (CAC) scanning during the period from July 2004 to March 2007, systematic measurements of the ascending and descending thoracic aorta diameters were made at the level of the pulmonary artery bifurcation. The final analysis groups for ascending and descending thoracic aorta included 2,952 and 1,931 subjects, respectively. Subjects were then regrouped by gender, age, and body surface area (BSA) for ascending and descending aorta, separately. The mean diameters for the final analysis group were  $33 \pm 4$  mm for the ascending and  $24 \pm 3$  mm for the descending thoracic aorta.

Mao, et al 2008 had done study about normal thoracic aorta diameter on cardiac computed tomography in healthy asymptomatic adult to establish the normal criterion of ascending aortic diameter (AAOD) measured by 64 Multi-Detector Computed Tomography and Electron Beam Computed Tomography based on gender and age. 1442 consecutive subjects who were referred for evaluation of possible coronary artery disease underwent coronary CT angiography and coronary artery calcium scanning (55+11 years, 65% male) without known coronary heart disease, hypertension, chronic pulmonary and renal disease, diabetes and severe aortic calcification. The ascending aortic diameter, descending aortic diameter, pulmonary artery and chest anteroposterior diameter, posterior border of sternal bone to anterior border of spine, were measured at the slice level of mid right pulmonary

artery. The linear correlation analysis was done between AAOD and all parameters. Their result AAOD had significant linear association with age, gender, descending aortic diameter and pulmonary artery diameter. The mean Intra-luminal AAOD was  $31.1 \pm 3.9$  mm and  $33.6 \pm 4.1$  mm in females and males respectively. They concluded with the ascending aortic diameter increases with age and male gender.

FY, et al 2008 had done study to establish reference values for thoracic aortic diameters MDCT in adults without evident cardiovascular disease. Their method was done in 103 (43% women, age  $51 \pm 14$  years) adults free of cardiac or aortic structural disease underwent MDCT examination to determine aortic dimensions. Their results were at the end-diastolic diameter 95% confidence intervals were 2.5-3.7 cm for the aortic root, 2.1-3.5 cm for the ascending aorta, and 1.7-2.6 cm for the descending thoracic aorta. Aortic diameters were significantly greater at end systole than end diastole, Aortic root and ascending aortic diameter increased significantly with age and body surface area.

Alfred, et al 2002 their aim is the use of helical computed tomography is well established in the evaluation of the thoracic aorta. They planned to set up normal diameters for the thoracic aorta of adults obtained by helical computed tomography. Their study was done on seventy adults, 17 to 89 years old, without any signs of cardiovascular disease were investigated with helical computed tomography. Aortic diameters were measured at seven predefined thoracic levels, Their results are Aortic diameters (mean  $\pm$  SD) were  $2.98 \pm 0.46$  cm at the aortic valve sinus,  $3.09 \pm 0.41$  cm at the ascending aorta,  $2.94 \pm 0.42$  cm proximal to the innominate artery,  $2.77 \pm 0.37$  cm at the proximal transverse arch,  $2.61 \pm 0.41$  cm at the distal transverse arch,  $2.47 \pm 0.40$  cm at the

isthmus, and  $2.43 \pm 0.35$  cm at the diaphragm. Men had slightly longer diameters than did women. All diameters increased with age.

Garcier et al, 2003 they were done study to determine the evolution of the diameter of the thoracic aorta with age in order to detect dilatation more reliably by imaging. They performed a retrospective analysis of the MRI examinations of the normal thoracic aorta of 66 subjects aged  $44.1 \pm 19.1$  years (range 19.1–82.4 years) obtained between 1991 and 2000 used T1-weighted spin echo sequences. Sixteen measurements were made in the axial plane, the oblique sagittal plane in the axis of the aortic arch, and the oblique frontal plane perpendicular to the latter at the level of the ascending aorta, the arch and the descending thoracic aorta. They found an increase in the thoracic aorta diameter and a significant relationship between this diameter and the age of their subjects, wherever the measure was performed.

Anthony et al, 1994 they used transesophageal echocardiography to assessment the effects of age, gender, and hypertension on thoracic aortic wall size, thickness, and stiffness. In 83 patients undergoing transesophageal echocardiography for clinical indications, recordings of the descending thoracic aorta were made. There were 53 normotensive subjects (33 men and 20 women, mean age 46 years, range 14 to 79 years) and 25 hypertensive subjects (8 men and 17 women, mean age 67 years, range 50 to 80 years). Their result is aging significantly increases aortic thickness and stiffness. Women have significantly higher relative aortic wall thickness than men but a similar stiffness. Hypertension increases aortic thickness and stiffness.

Anne et al, 2013 study was done on 484 subjects (230 male, 254 female), age 19-70 years without identifiable cardiac risk factors underwent MRI to determine aortic diameter at three levels namely; the

ascending aorta, proximal descending aorta ( pulmonary artery level), and the abdominal aorta. In addition, 208 of the subjects had aortic root measurements performed at the aortic valve annulus, aortic sinuses and sino-tubular junction. Their results are with increasing BSA, aortic root diameter increased at all levels measured, No gender difference in the degree of dilatation with increasing BSA was seen and aortic diameters at the more distal aortic levels also increased with increasing BSA.

# ***Chapter Three***

## ***Material and Methods***

## **Chapter Three**

### **Material and Methods**

#### **3.1 Study design**

This was descriptive analytical study. It was achieved at radiology department Royal Scan for medical services, El- Faisal specialize Hospital and El-tamaioz emergency center Khartoum- Sudan during the period from February2016 to April 2016.

#### **3.2 Sample**

##### **3.2.1 Inclusion Criteria**

A total of fifty five patients were included in this study, their age from 21 to 80 years old, without any signs of cardiovascular disease. Patients were in both genders were selected for chest CT. Patients age, gender, ascending thoracic aorta diameter, and descending thoracic aorta diameter was recorded.

##### **3.2.2 Exclusion criteria**

Patients having pathological changes such as pulmonary embolism, aortic aneurysm, aortic atherosclerosis, aortic regurgitation, aortic dissection, aortic stenosis and aortitis.

#### **3.3 Method**

##### **3.3.1 Scanning Protocol**

55 Sudanese subject who were scanned for chest CT and were diagnosed as normal mediastenium and had no history of cardiovascular diseases. Axial images were obtained using Toshiba 64 slice CT scanner and Toshiba 4slice, Tokyo, Japan, 2010.

CT scans were obtained with the patient in supine position during full inspiration. The scan range was from 1 cm above lung apices to the diaphragm. The exposure parameters were 120 kVp, 50-300 mA and 5 mm slice.

### 3.3.2 Method of Thoracic Aorta Measurement

The measurements were taken from the operator console of the CT machine; the axial images were obtained at the level of pulmonary artery bifurcation, ascending and descending thoracic aortic diameter measurements perpendicular to the axis of rotation of aorta made in (mm), and used as a reference applied by Arik, et al 2008. The diameter of ascending aorta and descending aorta were measured at the same slice images.

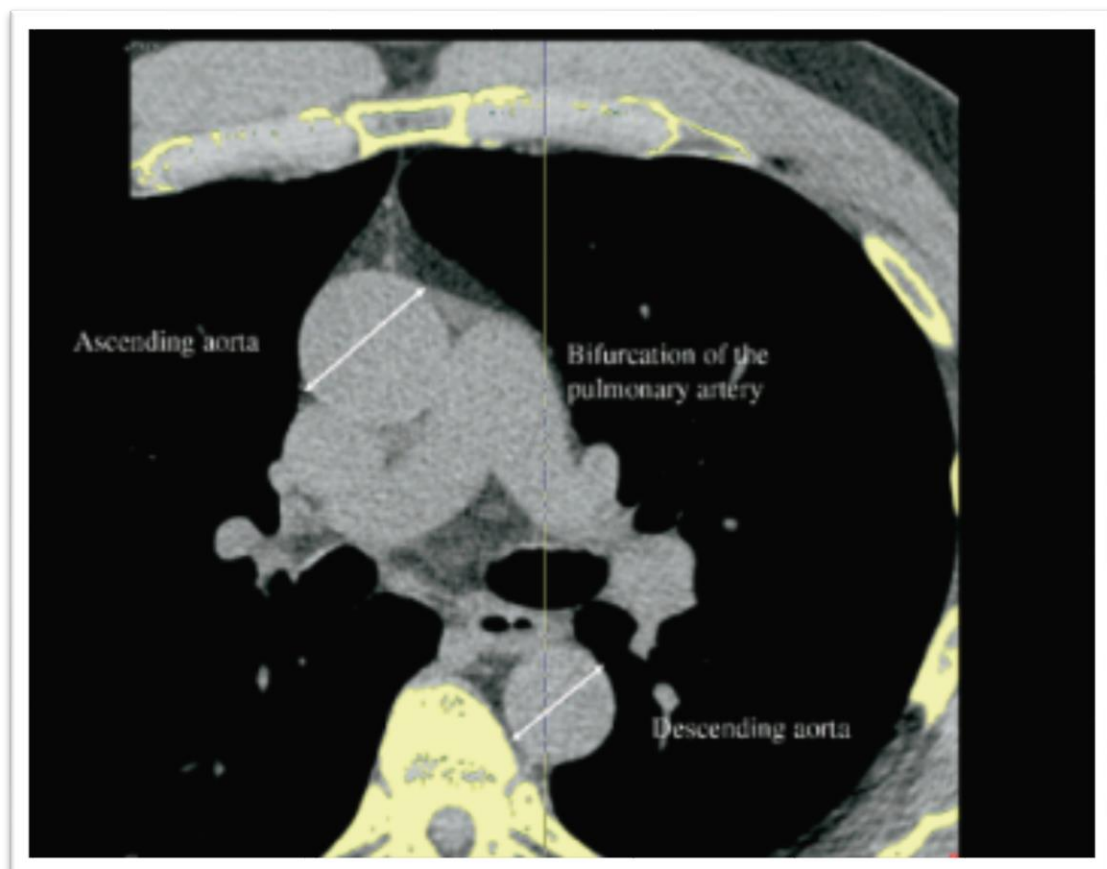


Fig (3.13) Show the method of aorta measurement. (Arik et al, 2008)



### **3.4 Statistical Analysis**

The data collected in master data sheet and were analyzed using SPSS program version 16. Data were presented as mean and standard deviation (SD) for all of variables. The results were significant at  $p < 0.05$ . Detailed results are shown in the tables and figures.

# ***Chapter Four***

## ***Results***

## **Chapter Four**

### **Results**

Computerized Tomography Scanning was performed in the radiology department Royal Scan for medical services, El- Faisal specialize Hospital and El-tamaioz emergency center Khartoum- Sudan.

The data was collected from 55 normal subjects, 27 females and 28 males with age from 21 years old up to > 60 years old. Patient's age, gender, ascending thoracic aorta diameter, and descending thoracic aorta diameter was recorded. Data were presented as mean and standard deviation (SD) for all variables. The results were significant at  $p < 0.05$ . Detailed results are shown in the tables and figures below.

Table (4.1): Distribution of sample size according to gender

Gender	Frequency	Percent
Female	27	49.1
Male	28	50.9
<b>Total</b>	<b>55</b>	<b>100.0</b>

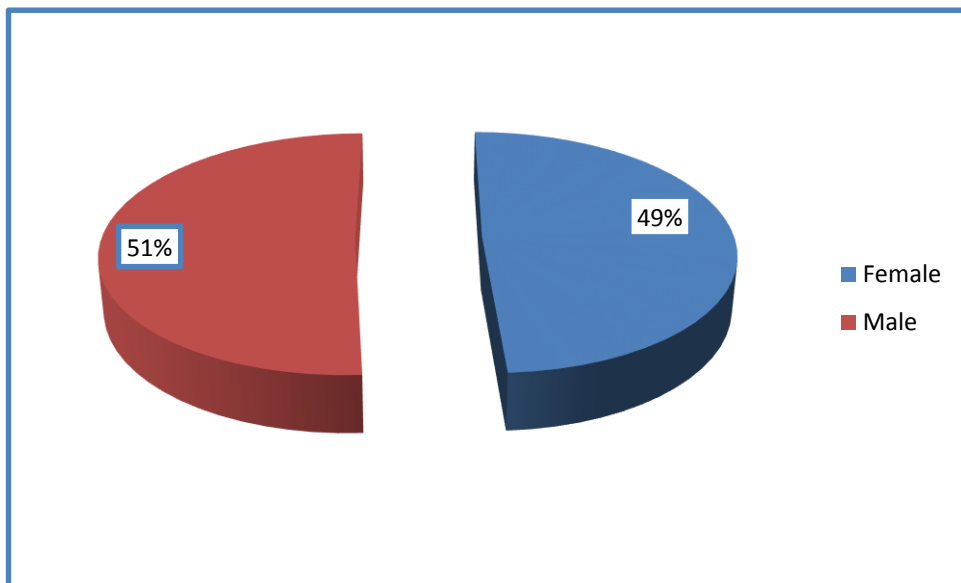


Fig (4.1): Distribution of sample size according to gender

Table (4.2): Distribution of sample size according to age

Age	Frequency	Percent
21-30	9	16.4
31-40	7	12.7
41-50	7	12.7
51-60	11	20.0
>60	21	38.2
<b>Total</b>	<b>55</b>	<b>100.0</b>

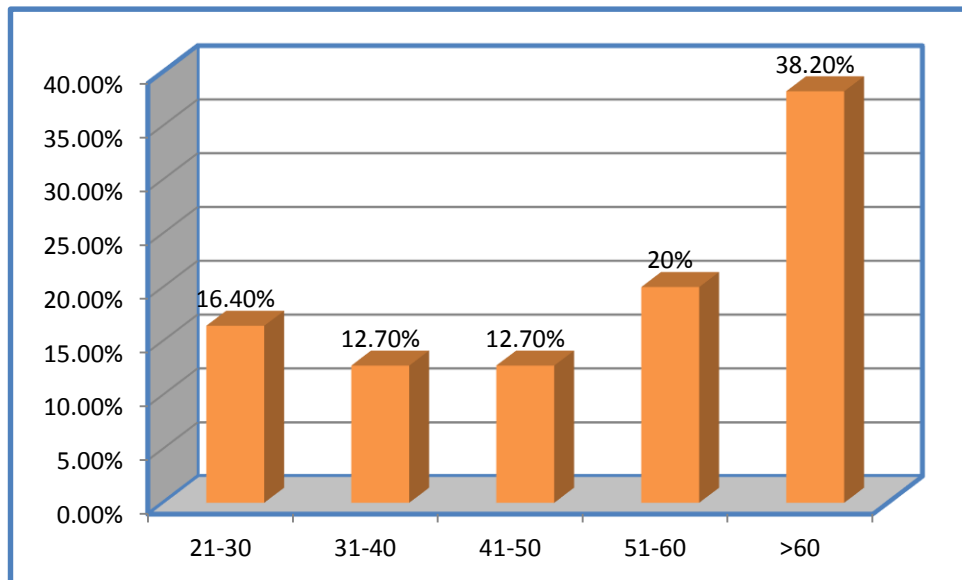


Fig (4.2): Distribution of sample size according to age.

Table (4.3) Descriptive Statistics (mean and SD) of the variables

<b>Statistics</b>			
	Descending thoracic aorta diameter	Ascending thoracic aorta diameter	Age
Mean	23.9545	35.1055	53.1273
Std. Deviation	3.20063	7.45347	17.70337

Table (4.4): Difference between ascending and descending aorta diameter.

<b>Group Statistics</b>				
	N	Mean	Std. Deviation	P-value
Descending thoracic aorta diameter	55	23.9545	3.20063	.044
Ascending thoracic aorta diameter	55	35.1055	7.45347	

Table (4.5): The correlation between Descending thoracic aorta diameter and age

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.716	1.247		15.813	.000
	Age	.080	.022	.441	3.580	.001

a. Dependent Variable: Descending thoracic aorta diameter

Descending thoracic aorta diameter = 19.716 + 0.080 Age

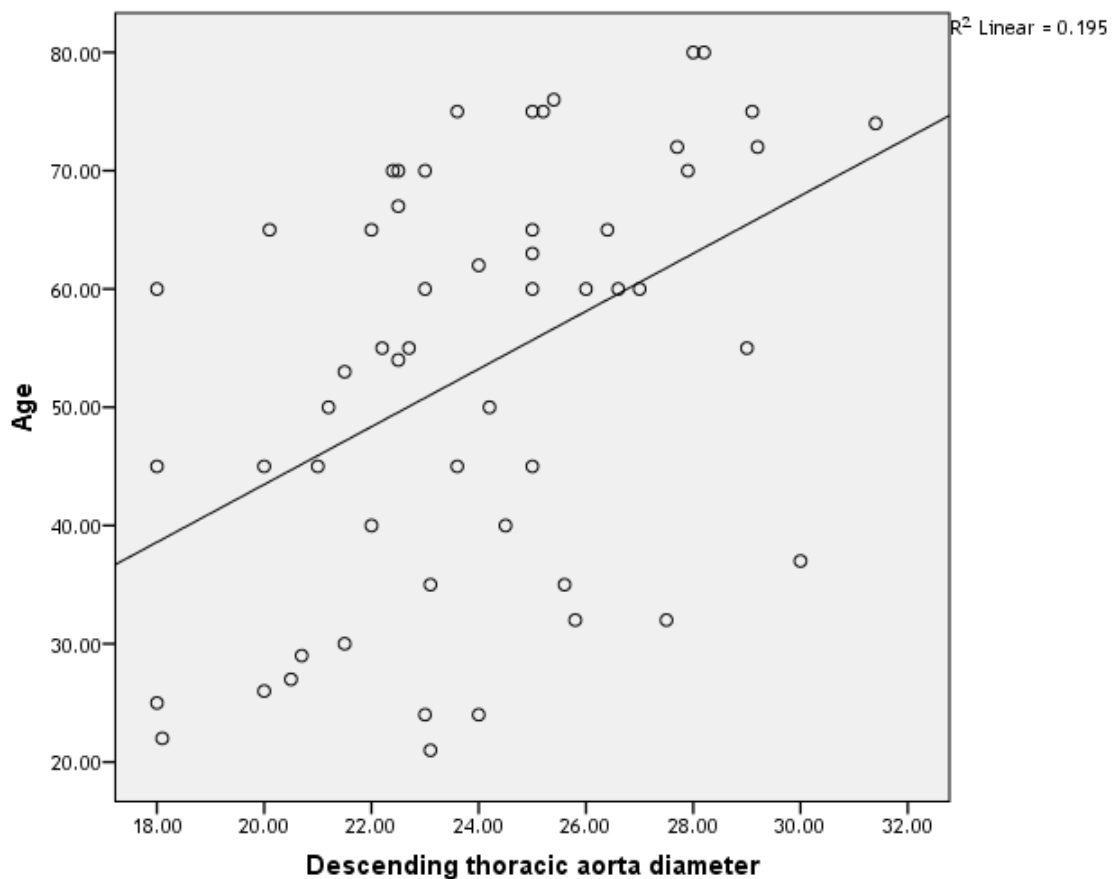


Fig (4.3): A scatter plot diagram shows the linear relationship between Descending thoracic aorta diameter and age

Table (4.6): The correlation between Ascending thoracic aorta diameter and age

Coefficients <sup>a</sup>					
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
1	(Constant)	14.694	17.315	.849	.400
	Age	.384	.309	1.241	.220

a. Dependent Variable: Ascending thoracic aorta diameter

Ascending thoracic aorta diameter = (14.694 + 0.384) Age

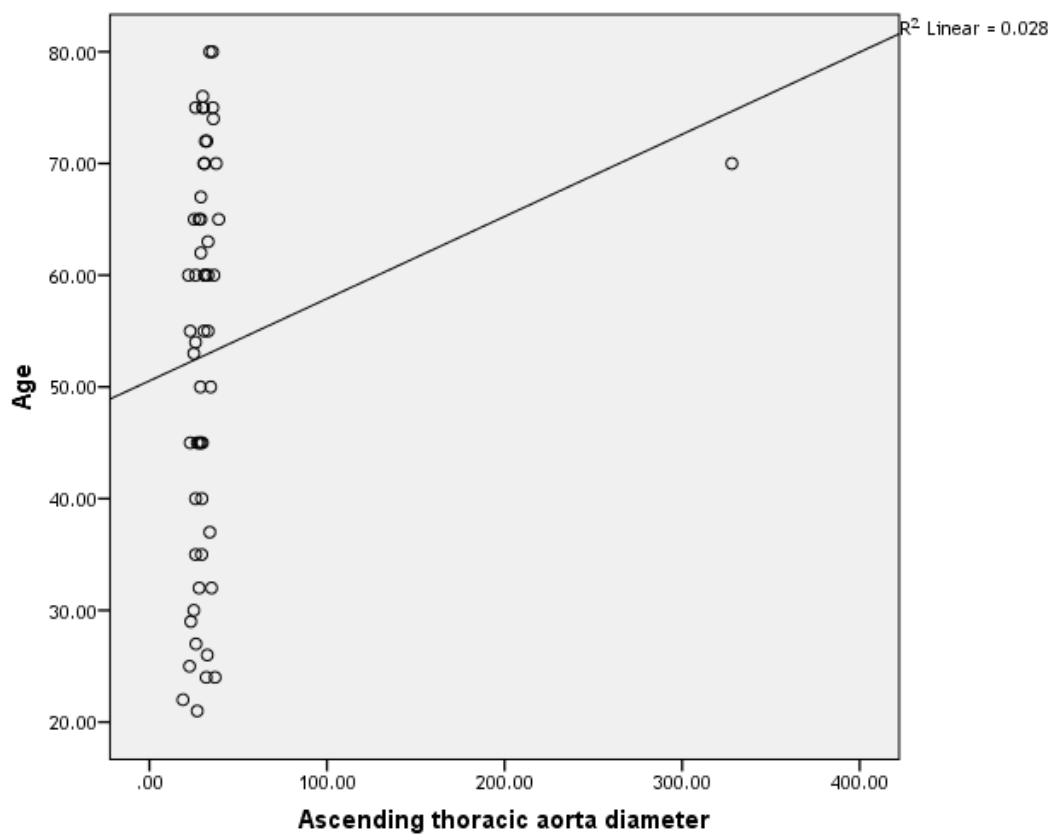


Fig (4.4) A scatter plot diagram shows the linear relationship between Ascending thoracic aorta diameter and age



# ***Chapter Five***

## ***Discussion, Conclusion, and Recommendations***

## **Chapter Five**

### **Discussion, Conclusion, and Recommendations**

#### **5.1 Discussion**

The objectives of this descriptive study were to measurement the thoracic aorta diameter in Sudanese population by using CT scan and to evaluate the aorta diameter regarding to age.

The sample of this study consisted of 55 subjects with different genders, 27 were female (49%) and 28 were male (51%) (Table 4.1).

The sample was classified according age starting from 21 to >60, this was presented in table 4.2.

Descriptive statistics mean and SD of the variables which includes age, descending thoracic aorta diameter, and ascending aorta diameter presented in table 4.3.

There was a significant difference between ascending and descending aorta diameter this was presented in table 4.4. This difference was normal in all anatomical organs and presented in all references.

As represented in table 4.5 the correlation between descending thoracic aorta diameter and age there are significant relation between age and descending thoracic aorta diameter p value at level .001. As the age increase the descending thoracic aorta diameter increase. For descending thoracic aorta diameter predicted the measurement if the age was known by using the following equation:

$$\text{Descending thoracic aorta diameter} = 19.716 + 0.080 \times \text{Age}$$

For ascending thoracic aorta diameter predicted the measurement if the age was known by using the following equation:

$$\text{Ascending thoracic aorta diameter} = 14.694 + 0.384 \times \text{Age}$$

There are no significant relation between ascending thoracic aorta diameter and age this was presented in table 4.6. The study should that there was no relation between ascending thoracic aorta diameter and age.

Our result disagree with studies done by (FY et al, 2008 and Mao et al, 2008) reported that the ascending aortic diameter increased significantly with age.

In this study the mean values of normal ascending thoracic aorta diameter was found to be up to  $35.11 \pm 7.45$  and  $23.95 \pm 3.2$  for descending thoracic aorta diameter, this results were differ from international previous studies done by Aric et al, 2008 said that the normal ascending thoracic aorta diameter was  $33 \pm 4$  and for descending thoracic aorta diameter was  $24 \pm 3$ , also FY et al, 2008 measured the normal ascending and descending thoracic aorta diameter and found that 21- 35mm and 17- 26 mm respectively.

## 5.2 Conclusion

This study was done in normal Sudanese people to measure the thoracic aorta diameter and showed the relation between measurement and age.

Thoracic aorta diameter measurement was found to be  $35.11 \pm 7.45$  mm for ascending thoracic aorta and  $23.96 \pm 3.2$  mm for descending thoracic aorta.

The measurement of descending thoracic aorta diameter had significant relation with age and no effect of age to ascending thoracic aorta diameter. New equations established to predict thoracic aorta diameter for patient with known age (Descending thoracic aorta diameter =  $19.716 + 0.080 \times \text{Age}$  & Ascending thoracic aorta diameter =  $14.694 + 0.384 \times \text{Age}$ ).

### **5.3 Recommendations**

- Measurement of aortic diameter should be taken at reproducible anatomic landmarks, perpendicular to the axis of blood flow if measurements taken by CT, MRI or echocardiography.
- Abnormal morphology should be recognized when aortic diameter within normal limits.
- Further descriptive analytic studies are needed using another imaging method as MRI or echocardiography to confirm these result that presented in the index so as to help in diagnosis of aortic problem which lead to enlargement or decreasing its size.
- As the morphology differs regarding the race and ethnicity factor a similar local research is recommend in different Sudanese tribes.

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# ***Appendices***

## Appendix one

### Data collection sheet

Sudan University of Science and Technology

College of Graduated Studies

Measurement of Thoracic Aorta of Adult Sudanese People by Using  
Computed Tomography

Patients Data			Aortic Data	
NO	Gender	Age	Ascending thoracic aorta diameter	Descending thoracic aorta diameter

## Appendix Two

