Sudan University of Science and Technology

College of Graduate Studies

Establishing Reference Diameters of Abdominal Aortic and Inferior Vena Cava of Sudanese Using Computed Tomography

تأسيس اقطار مرجعية للشريان الأورطي البطني والوريد الأجوف السفلي للسودانيين باستخدام التصوير المقطعي المحوسب

A Thesis Submitted For Fulfillment of the Requirements

Of Ph.D. Degree in Diagnostic Radiologic Technology

By:

SALAH ELBAGIR AHMAD

Supervisor:

Dr. Mohamed Mohamed Omer Mohamed Yousef

Associate Professor

Co- Supervisor:

Dr.Ikhlas Abdelaziz

Associate Professor

2018

الآيـة

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

(وَلَقَدْ خَلَقْنَا الْإِنْسَانَ وَنَعْلَمُ مَا تُوَسْوِسُ بِهِ نَفْسُهُ وَنَحْنُ أَقْرَبُ إِلَيْهِ مِنْ حَبْلِ الْوَرِيدِ)

صدق الله العظيم

سورة ق الآية (16)

Dedication

I proudly dedicate thesis to:

The soul of my beloved Father Who passed away recently, his words of inspiration and Encouragement in pursuit of excellence.

My Mother...

My Brothers and Sisters...

My wife…

To my kind kids…

And my friends…

Acknowledgement

*I would like to express my sincere gratitude to **Dr. Mohamed Mohamed Omer Mohamed Yousef and Dr. Ikhlas Abdelaziz Hassan** who has given me great advice and help in the whole process of my thesis for their fruitful day to day supervision, guidance, endless help and encouragement that built confidence in my work for their valuable and continuous help, their patience through all the years that made this work possible for giving this opportunity of study, and for endless encouragement and unlimited support.*

My thanks extend also to colleagues in Royal Care International Hospital radiology staff, Khartoum, Sudan, colleagues in College Medical Radiologica l Sciences for contributing in the sample collections.

*Thanks are also extended to **Dr. Mohammed Abdelwahab Idris Salih** and College Medical Radiological Science-Sudan University of Science and Technology and all staff of the College of Medical Radiological Sciences for their endless moral support and encouragement.*

I would like to thank everyone who assisted by one way or another to bring this study to the light.

Abstract

Computerized angiography (CTA) is a standard tool for investigating vascular diseases .The aims of this study were to study Reference Diameters of Abdominal Aortic and Inferior Vena Cava of Sudanese Using Computed Tomography and to study the variation in aortic diameters with age and gender. A total of 200 patients (108 males and 92 females) with a mean age of 48.6 years consecutive adults free of cardiac or aortic structural disease or arrhythmia who referred for abdominal CT scanning in the radiology department of Royal Care Hospital in Khartoum- Sudan during the period from August 2015 to May 2018.

This study revealed that the mean internal diameters of the suprarenal and infrarenal abdominal aorta were measured at T12 and L3 vertebral levels and tabulated according to various age groups for both men and women. The results revealed that the mean diameter of the suprarenal abdominal aorta, measured at T12 vertebral level was19.44±1.51 mm in women and 20.97±1.74mm in men. The mean diameters of the infrarenal abdominal aorta, measured at L3 vertebral level were 14.13±1.34 mm. in women and 17.34±1.36 mm. in men.

The mean± standard deviation (SD) of the anteroposterior (AP) diameter of the IVC in men measured was 25.47±1.69 mm, 24.15±1.58 in women **.** The mean± standard deviation (SD) of the transverse (TV) diameters, measured were 14.11±1.46 mm. in women and 15.3112±1.49919mm in men.

It concluded that normal dimensions abdominal aorta by CT scan was established and correlated with age and gender which is similar to previously published studies, that normal dimensions IVC by CT scan was established and correlated with age and gender, The information provided in this study will allow radiologists to detect and accurately characterize IVC abnormalities to guide clinical decision making and improve patient care. Recognition of IVC processes is essential to patient treatment.

مستخلص الدراسه

تصوير الأوعية الدموية المحوسبة (CTA) هو أداة قياسية للتحقيق في أمراض الاوعية الدموية البطنية هدفت هذه الدراسة معرفة أقطار مرجعية من الشريان الأورطي البطني و الوريد الأجوف السفلي في السودانيين باستخدام التصوير المقطعي ودراسة الاختلاف في الأبهري مع العمر والجنس. ما مجموعه 200 مريض (108 ذكور و 92 إناث) بمتوسط عمر 48.6 سنة من غير أمراض القلب أوالأورطى أوعدم انتظام ضربات القلب الذين أجروا صور مقطعيه للبطن في قسم الأشعة بمستشفى رويال كير في الخرطوم- السودان خلال الفترة من أغسطس 2015 إلى مايو 2018.

كشفت هذه الدراسة أن متوسط القطرالداخلي للشريان الأبهرالبطني فوق الكلوي واسفل الكلوي قد تم قياسه عند مستويات الفقرتينT12 و L3 وتم حسابه طبقًا لمجموعات عمرية مختلفة لكل من الرجال والنساء. أظهرت نتائج هذه الدراسة أن متوسط قطرالشريان الأورطي البطني فوق الكلوي الذي تم قياسه عند مستوىT12 الفقري كان1.51± 19.44 مم في النساء و 1.74±20.97 مم لدى الرجال. بلغ متوسط أقطارالشريان الأورطي البطني تحت الكلى،والذي تم قياسه عند مستوىL3 الفقري 1.34±14.13 مم. في النساء و 17.34± 1.36. مم لدى الرجال.

كان متوسط القياس الامامي الخلفي ±الانحرافالمعياري للوريد الأجوف السفلي عند الرجال 1.69±25.47 مم و 1.58±24.15 عند النساء. وبلغ متوسط القياس المستعرض ±الانحرافالمعياري للوريد الأجوف السفلي 1.46±14.11 مم. في النساء و 1.49919±15.3112مم في الرجال.

وخلصت الدراسة إلى أن الأبعاد الطبيعية للشريان الأبهر البطني عن طريق الأشعة المقطعية قد تم تأسيسها وترتبط بالعمر والجنس الذي يشبه الدراسات المنشورة سابقًا ، وأن الأبعاد العادية للوريد الأجوف السفلي بواسطة الأشعة المقطعية قد تم تأسيسها وترتبط بالعمر والجنس ، وستسمح المعلومات المقدمة في هذه الدراسة علماء الأشعة لاكتشاف وتمييز بدقة تشوهات للوريد الأجوف السفلي لتوجيه صنع القرار السريري وتحسين رعاية المرضى. يعتبر الاعتراف بعمليات للوريد الأجوف السفلي أمرًا ضروريًا للعلاج .

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AA	Abdominal aortic
AAA	Abdominal aortic aneurysm
CT	Computed Tomography Angiography
CTA	Computed Tomography Angiography
IVC	Inferior vena cava
AAS	Abdominal aortic stenosis
AR	Aortic regurgitation
LV	Left ventricle
3-D	Three-dimensional
CA	Coronary artery
LAD	Left anterior descending
CAD	Coronary artery disease
PACS	Picture archiving and communication system
MIP	Maximum Intensity Projection
VR	Volume Rendering
MIP	Maximum intensity projection
MDCT	Multidetector computed Tomography
ATA	Ascending thoracic aorta
DTA	Descending thoracic aorta
SPSS	Statistical Package for Social Sciences
BMI	Body mass index
BSA	Body surface area

Chapter One

Chapter One

1.1Introduction:

Knowledge of normal abdominal aortic size in patients without vascular disease is an important criterion to diagnose abdominal aortic aneurysms (AAA) (Norman et al 2011). Abdominal aortic aneurysm (AAA) is a dilatation of the abdominal aorta. There are several definitions of an AAA. A diameter in excess of 30 mm based on the angiographic study is the most accepted definition(Wanhainen et al 2008).Some definitions relate to the infrarenal aortic diameter to the suprarenal aortic diameter (Sterpetti et al 1987).

The International Society for Cardiovascular Surgery/Society for Vascular Surgery Ad Hoc Committee proposed that an AAA is defined as the maximum infrarenal aortic diameter being at least 1.5 times larger than the expected normal infrarenal aortic diameter (Johnston et al 1991).

With this standard definition, it is important to know the normal diameter of the abdominal aorta so that clinicians will be able to determine when an aorta becomes aneurysmal. The mean diameters at the level of the infrarenal aorta were 16 to 23 mm in males and 15 to 19 mm in females((Sariosmanoglu et al 2002),(Ouriel et al 1992),(Al-Zahrani 1996)). However, a practical working definition of an AAA is a transverse diameter of 3 cm or greater based on average values for normal individuals(Hirsch et al 2006).

Nowadays Computed Tomography Angiography (CTA) is one of the main noninvasive medical tests that provides detailed information about the aorta and its branches, this is due to the fact that the method is highly informative, reliable and safe. Currently, only a few published articles have devoted to the study of the infrarenal aortic size without pathology(Wolak et al 2008).The relevance of the investigation of these indicators comes from the dependence of changes in aortic measurements on the anthropometric indicators, such as age and other risk factors for the development of aneurysms of the infrarenal aorta (Rogers et al .2013).

The determination of the aneurysmal sac became used recently. The method of determining the volume of the aneurysmal expansion may play a key role in the observation of small abdominal aneurysms and follow-up of endovascular repair of abdominal aortic aneurism (Lee et al 2003) , (Hendy et al.2015) ,(Parr et al 2011).

Restoring intravascular volumeisa therapeutic goal in the treatment of patients suffering from traumatic shock. The end points of resuscitation in trauma patients are difficult to define yet under-resuscitated patients continue to have a higher incidence of cardiovascular collapse and multi-organ failure (Meregalli and Oliveira 2004;8,Porter and Ivatury 1998).

1.2. Problem of the study:

Knowledge of the normal Abdominal Aorta diameter in Sudan would be useful in management of patients presenting with aortic aneurysms. There is paucity of Sudan data on the aortic diameter according to which clinical decisions regarding management of aortic aneurysms i.e., whether to follow up the patients, institute medical therapy or to go for surgery can be made. Most of the data available in literature is based on Western demographic data and treatment in Sudan is still guided by the aortic sizes End points of resuscitation in trauma patients are difficult to define. The size of the inferiorvena cava (IVC) on CT scan may accurately indicate volume status and guide resuscitation efforts. There is no specific characterization of the morphology and dimensions of the Abdominal Aorta changes due to age, gender, tribe, circumference as standard in Sudanese population; so this study is obtain to study the anatomical variation of the Abdominal Aorta for forensics and anthropologic and surgical purposes.

1.3. Objectives:

1.3.1 General objective:

To study the Normative Reference Values of Abdominal Aortic Diameters of Sudanese Using Computed Tomography.

1.3.2 Specific objectives:

- To assess the abdominal aorta normal dimensions, and signal intensity (CT number).
- To correlate and determine the abdominal aorta variations related with age and gender in Sudanese population.
- To generate an index for Sudanese and compare it to standard index.

1.4. Thesis outline:

This research in five chapters:

Chapter one, shows the introduction, study problems, and objectives of the study.

Chapter two, highlighted literature review in two sections, section one shows (anatomy, physiology and pathology of the abdominal aorta, instrumentations and techniques). Section two shows previous studies.

Chapter three discusses the materials and methods.

Chapter four, include presentation of the results and finally.

Chapter five, deal with the discussion, conclusions, recommendations, of the study performed as well as future work.

Chapter Two

Chapter Two

Theoretical Background and Literature review

2.1Theoretical Back Ground

2.1.1Aorta Anatomy:

The aorta is the main blood vessel in the human body. As blood is pumped from the heart, it passes across the aortic valve, and then through the aorta, where it is then distributed through a system of smaller arteries. As the aorta travels through the body, each portion has a different name based on its location and each section supplies different organ systems or areas of the body. The aorta first leaves the heart and brings blood towards the head as the ascending aorta. As the aorta turns towards the left side of the body, it gives off branches to the upper body and the brain as the aortic arch. The aorta next travels down the chest, where it is called the descending aorta. The descending aorta continues through the abdomen as the abdominal aorta, where it supplies the abdominal organs before dividing to provide arteries for each leg (the iliac arteries)(Ashley et al 2011).

2.1 .1.1 Aortic root:

The aortic root may be defined as the portion of the left ventricular outflow tract which supports the leaflets of the aortic valve, delineated by the sinotubular ridge superiorly and the bases of the valve leaflets inferiorly. It comprises the sinuses, the aortic valve leaflets, the commissures, and the inter leaflet triangles. The sinuses are expanded portions of the aortic root which are confined proximally by the attachments of the valve leaflets and distally by the sinotubular junction. They are named according to the coronary arteries arising from them—right, left, and non-coronary. (Underwood et al,2000)

2.1 .1.2 Ascending aorta:

Is the first part of the aorta, and begins at the aortic valve - located obliquely just to the left of the midline at the level of the third intercostal space. It terminates as it exits the fibrous pericarium and reaches the sternomanubrial joint, where it becomes the aortic arch. It normally has only two branches, the right coronary artery and the left coronary artery. These arise from the right and left aortic sinuses (of Valhalla) respectively, which are out-pouchings of the aortic wall above each cusp of the aortic valve. Immediately above the three aortic sinuses, the normal tubular configuration of the aorta is attained - at the sinotubular junction. (Standring et al, 2008)

2.1 .1.3 Aortic arch:

The most common aortic arch branching pattern in humans consists of 3 great vessels originating from the arch of the aorta. The first branch is the in nominate artery, which branches into the right subclavian artery and the right common carotid artery. The second branch in the most common pattern is the left common carotid artery, and the last branch is the left subclavian artery. The final configuration of the aortic arch and its branches is probably related to different growth rates in the various arteries and the associated “migration” and “merging” of the branches. left common carotid artery origin is moved to the right and merges with the origin of the in nominate artery.(Lippert et al,1985)

2.1 .1.4 Thoracic aorta:

Is contained in the posterior meditational cavity. It begins at the lower border of the fourth 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. At its commencement, it is situated on the left of the vertebral column; it approaches the median line as it descends; and, at its termination, lies directly in front of the column. It is in relation, anteriorly, from above downward, with the root of the left lung, the pericardium, the esophagus, and the diaphragm; posteriorly, with the vertebral column and the azygos vein; on the right side, with the hemiazygos veins and thoracic duct; on the left side, with the left pleura and lung. The esophagus, with its accompanying plexus of nerves, lies on the right side of the aorta above; but at the lower part of the thorax it is placed in front of the aorta, and, close to the diaphragm (Atlas et al,2006).

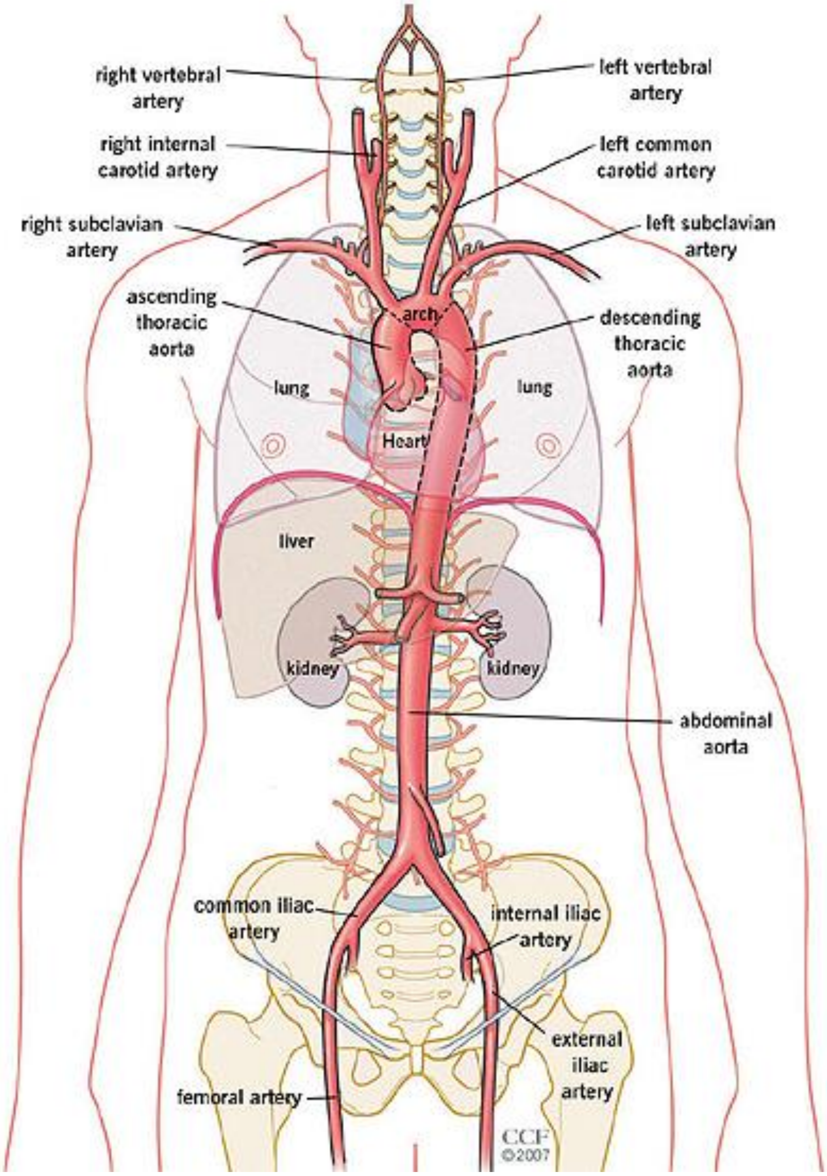


Figure (2-1): Abdominal aorta and its branches

2.1 .1.5 Abdominal aorta:

The abdominal aorta lies slightly to the left of the midline of the body. It is covered, anteriorly, by the lesser omentum and stomach, behind which are the branches of the celiac artery and the celiac plexus; below these, by the lienal vein (splenic vein), the pancreas, the left renal vein, the inferior part of the duodenum, the mesentery, and aortic plexus. Posteriorly, it is separated from the lumbar vertebræ and intervertebral fibrocartilages by the anterior longitudinal ligament and left lumbar veins. On the right side it is in relation above with the azygos vein, cisterna chyli, thoracic duct, and the right crus of the diaphragm—the last separating it from the upper part of the inferior vena cava, and from the right celiacganglion;theinferiorvenacavaisincontactwiththeaortabelow.Ontheleft side are the left crus of the diaphragm, the left celiac ganglion, the ascending part of the duodenum, and some coils of the small intestine. (enwikipedia.org /wiki /abdominal aorta)

2.1 .1.5.1 Branches of the Abdominal Aorta:

2.1 .1.5.1.1 Celiac Artery:

The celiac also known as the celiac trunk, or truncuscoeliacus The first major branch of the abdominal aorta, the celiac trunk is responsible for supplying oxygenated blood to the stomach, spleen, liver, esophagus, and also parts of the pancreas and duodenum. Along with the superior and inferior mesenteric arteries, it is one of three anterior branches of the abdominal aorta, the largest artery in the abdominal cavity. The celiac trunk is one of the most important arteries in the abdominal area as it is essential for the proper functioning of many major organs that would otherwise be unable to receive sufficient quantities of blood from other arteries. This is because the three anterior arteries of the abdominal aorta are separate and cannot substitute for each other There are three main divisions of the celiac trunk: the left gastric artery, the common hepatic artery, and the splenic artery. (Ayushetal, 2003)

2.1 .1.5.1.2 Superior Mesenteric Artery (SMA):

Is a large vessel which supplies the whole length of the small intestine, except the superior part of the duodenum; it also supplies the cecum and the ascending part of the colon and about one-half of the transverse part of the colon. It arises from the front of the aorta, about 1.25 cm. below the celiac artery, and is crossed at its origin by the lienal vein and the neck of the pancreas. It passes downward and forward, anterior to the process susuncinatus of the head of the pancreas and inferior part of the duodenum, and descends between the layers of the mesentery to the right iliac fossa, where, considerably diminished in size, it anastomoses with one of its own branches, viz., the ileocolic.

In its course it crosses in front of the inferior vena cava, the right ureter and Psoas major, and forms an arch, the convexity of which is directed forward and downward to the left side, the concavity backward and upward to the right. It is accompanied by the superior mesenteric vein, which lies to its right side, and it is surrounded by the superior mesenteric plexus of nerves.(Gray et al,1918)

2.1 .1.5.1.3 Middle Suprarenal Artery:

Are two small vessels which arise, one from either side of the abdominal aorta, opposite the superior mesenteric artery. They pass laterally and slightly upward, over the crura of the diaphragm, to the suprarenal glands, where they an astomose with suprarenal branches of the inferior phrenic and renal arteries. (Gray et al, 1918)

2.1 .1.5.1.4 Renal Artery:

Are two large trunks, which arise from the side of the aorta, immediately below the superior mesenteric artery. Each is directed across the crus of the diaphragm, so as to form nearly a right angle with the aorta. The right is longer than the left, on account of the position of the aorta; it passes behind the inferior vena cava, the right renal vein, the head of the pancreas, and the descending part of the duodenum. The left is somewhat higher than the right, it lies behind the left renal vein, the body of the pancreas and the lienal vein, and is crossed by the inferior mesenteric vein. Before reaching the hilus of the kidney, each artery divides into four or five branches, the greater number of the selie between the renal vein and ureter, the vein being in front, the ureter behind, but one or more branches are usually situated behind the ureter.(Gray et al, 1918).

2.1 .1.5.1.5 Gonadal Artery:

The term gonadal artery is a generic term for a paired artery, with one arising from the abdominal aorta for each gonad. Specifically, it can refer to the testicul arartery in males and the ovarian artery in females.(Gray et al, 1918)

2.1 .1.5.1.6 Lumbar Artery:

Are in series with the intercostals. They are usually four in number on either side, and arise from the back of the aorta, opposite the bodies of the upper four lumbar vertebræ. A fifth pair, small in size, is occasionally present: they arise from the middle sacral artery. They run lateral ward and backward on the bodies of the lumbar vertebræ, behind the sympathetic trunk, to the intervals between the adjacent transverse processes, and are then continued into the abdominal wall. The arteries of the right side pass behind the inferior vena cava, and the upper two on each side run behind the corresponding crus of the diaphragm. The arteries of both sides pass beneath the tendinous arches which give origin to the Psoas major, and are then continued behind this muscle and the lumbar plexus. They now cross the Quadratuslumborum, the upper three arteries running behind, and the last usually in front of the muscle. At the lateral border of the Quadratuslumborum they pierce the posterior aponeurosis of the Transversus abdominis and are carried forward between this muscle and the Oblique usinternus. (Gray et al, 1918).

2.1 .1.5.1.7 Inferior Mesenteric Artery:

Supplies the left half of the transverse part of the colon, the whole of the descending and iliac parts of the colon, the sigmoid colon, and the greater part of the rectum. It is smaller than the superior mesenteric, and arises from the aorta, about 3 or 4 cm. above its division into the common iliacs and close to the lower border of the inferior part of the duodenum. It passes downward posterior to the peritoneum, lying at first anterior to and then on the left side of the aorta.(Gray et al, 1918)

2.1 .1.5.1.8 Common Iliac:

The common iliac artery originates from the abdominal aorta. The aorta is the main trunk of the systemic arteries in the cardiovascular system. This system carries oxygenated blood from the heart to the other areas of the body and back. At the fourth lower lumbar vertebral body the aorta ends by dividing into the right and left common iliac arteries. The two arteries travel below and to one side for about four to five centimeters towards the edge of the pelvis. It splits into an internal and external iliac artery at the level of the pelvic inlet. The internal iliac artery supplies the pelvic organs including the urinary bladder, the man's prostate gland, and the woman's uterus and vagina. The external iliac artery through - the femoral artery supplies the thigh - the popliteal artery supplies the knee area and the anterior and posterior tibial arteries supply the area below the knee including the feet and toes. The common iliac artery is a paired structure, meaning there is one on the right and one on the left of the body.(Avenue et al,2006).

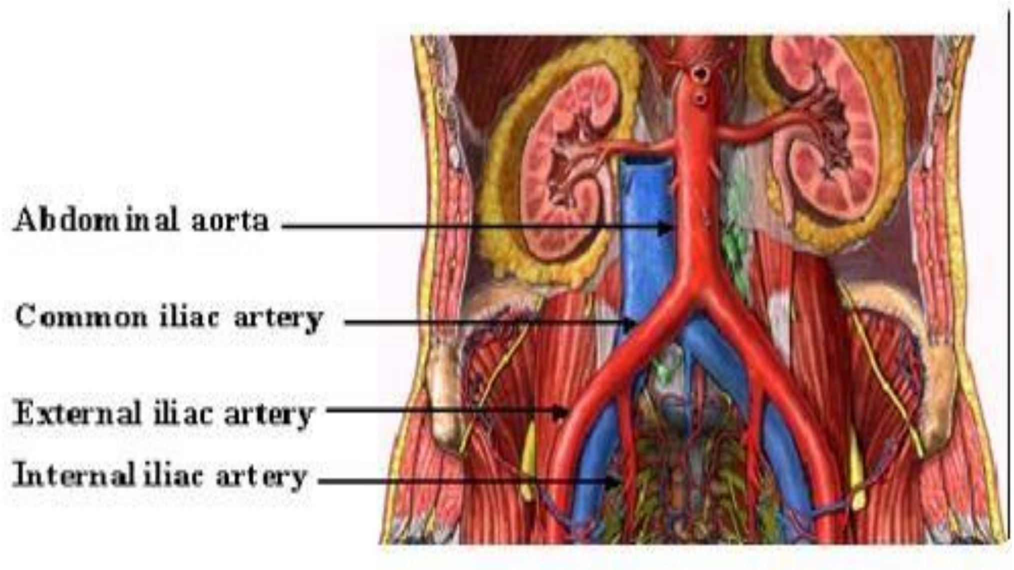


Figure 2-2 Show inferior branches abdominal aorta

2.1.2. Physiology:

The double circulatory system of blood flow refers to the separate systems of pulmonary circulation and the systemic circulation in amphibians, birds and mammals (including humans.) In contrast, fishes have a single circulation system. For instance, the adult human heart consists of two separated pumps, the right side with the right atrium and ventricle (which pumps deoxygenated blood into the pulmonary circulation), and the left side with the left atrium and ventricle (which pumps oxygenated blood into the systemic circulation). Blood in one circuit has to go through the heart to enter the other circuit. Blood circulates through the body two to three times every minute.

2.1.2.1The Pulmonary Circuit:

Pulmonary circulation is the movement of blood from the heart to the lungs for oxygenation, then back to the heart again . Oxygen-depleted blood from the body leaves the systemic circulation when it enters the right atrium through the superior and inferior venae cavae. The blood is then pumped through the tricuspid valve into the right ventricle. From the right ventricle, blood is pumped through the pulmonary valve and into the pulmonary artery. The pulmonary artery splits into the right and left pulmonary arteries and travel to each lung. At the lungs, the blood travels through capillary beds on the alveoli where respiration occurs , removing carbon dioxide and adding oxygen to the blood. The alveoli are air sacs in the lungs that provide the surface for gas exchange during respiration. The oxygenated blood then leaves the lungs through pulmonary veins, which returns it to the left atrium, completing the pulmonary circuit. Once entering the left heart, the blood flows through the bicuspid valve into the left ventricle. From the left ventricle, the blood is pumped through the aortic valve into the aorta to travel through systemic circulation, delivering oxygenated blood to the body before returning again to the pulmonary circulation.(www.boundless.com)

2.1.2.2 The Systemic Circuit:

Systemic circulation is the movement of blood from the heart through the body to provide oxygen and nutrients, and bringing deoxygenated blood back to the heart. Oxygen-rich blood from the lungs leaves the pulmonary circulation when it enters the left atrium through the pulmonary veins. The blood is then pumped through the mitral valve into the left ventricle. From the left ventricle, blood is pumped through the aortic valve and into the aorta, the body's largest artery. The aorta arches and branches into major arteries to the upper body before passing through the diaphragm, where it branches further into arteries which supply the lower parts of the body. The arteries branch into smaller arteries, arterioles, and finally capillaries. Waste and carbon dioxide diffuse out of the cell into the blood, while oxygen in the blood diffuses out of the blood and into the cell. The deoxygenated blood continues through the capillaries which merge into venules, then veins, and finally the venae cavae, which drain into the right atrium of the heart. From the right atrium, the blood will travel through the pulmonary circulation to be oxygenated before returning gain to the system circulation. Coronary circulation, blood supply to the heart muscle itself, is also part of the systemic circulation. (www.boundless.com)

2.1.3. Pathology:

2.1.3. 1Abdominal aortic stenosis (AAS):

Abdominal aortic stenosis (AAS) refers to abnormal narrowing of the aorta anywhere along its course in the abdomen. The aorta enters the abdomen through the thoracic hiatus at the level of the 12th thoracic vertebra in front of the spinal cord and terminates as the right and left iliac arteries. Stenosis can result from congenital or acquired lesions. AAS produces a bottleneck effect, where there is hypertension above the lesion and hypotension below and can often be diagnosed based on the difference in blood pressure between the upper and lower extremities. Symptoms can be divided into three categories based on the major groups of arteries supplied by the abdominal aorta. (Heather,2011)

2.1.3. 2 Atherosclerosis:

Atherosclerosis appears to play a major role in diseases of the aortic arch, descending thoracic and abdominal aorta. Atherosclerosis can result in weakening of the aortic wall, making it prone to aneurysm formation or dissection. The development of aortic atherosclerosis is associated with traditional cardiac risk factors of smoking, hypertension, hyperglycemia, and atherogenic lipoproteins.

Atherosclerosis can also lead to the formation of complex atheromatous plaques, which are prone to embolization, resulting in cerebral and peripheral arterial occlusive events.(Mary et al,2014)

2.1.3. 3 Aortic regurgitation:

Aortic regurgitation (AR) is the diastolic flow of blood from the aorta into the left ventricle (LV). Regurgitation is due to incompetence of the aortic valve or any disturbance of the valvular apparatus (e.g. leaflets, annulus of the aorta) resulting in the diastolic flow of blood into the left ventricular chamber. Aortic regurgitation may be a chronic disease process or it may occur acutely, presenting as heart failure. The most common cause of chronic aortic regurgitation used to be rheumatic heart disease, but presently it is most commonly caused by bacterial end ocarditis. In developed countries, it is caused by dilation of the ascending aorta (eg, aortic root disease, aortoannularectasia). Acute aortic regurgitation is associated with significant morbidity, which can progress from pulmonary edema to refractory heart failure and cardiogenic shock. (Stanley et al,2014)

2.1.3. 4 Aortic dissection

Aortic dissection is defined as separation of the layers within the aortic wall. Tears in the intimal layer result in the propagation of dissection (proximally or distally) secondary to blood entering the intima-media space. Mortality is still high despite advances in diagnostic and therapeutic modalities. ortic dissection can be rapidly fatal, with many patients dying before presentation to the emergency department or before diagnosis is made in the ED. Acute aortic dissection can be treated surgically or medically. In surgical treatment, the area of the aorta with the intimal tear is usually resected and replaced with a Dacron graft. Endovascular repair is emerging as the preferred treatment for descending aortic dissection. (Mary,2014)

2.1.3. 5Abdominal aortic aneurysm (AAA):

Abdominal aortic aneurysm (also known as AAA, pronounced "triple-a") is a localized dilatation(ballooning) of the abdominal aorta exceeding the normal diameter by more than 50 percent, and is the most common form of aortic aneurysm. Approximately 90 percent of abdominal aortic aneurysms occur infrarenally (below the kidneys), but they can also occur pararenally (at the level of the kidneys) or suprarenally (above the kidneys). Such aneurysms can extend to include one or both of the iliac arteries in the pelvis.(Upchurch et al,2006).

Abdominal aortic aneurysms occur most commonly in individuals between 65 and 75 years old and are more common among men and smokers. They tend to cause no symptoms, although occasionally they cause pain in the abdomen and back (due to pressure on surrounding tissues) or in the legs (due to disturbed blood flow). The major complication of abdominal aortic aneurysms is rupture, which is life-threatening, as large amounts of blood spill into the abdominal cavity, and can lead to death within minutes.(Upchurch et al, 2006)

Surgery is recommended when the aneurysm is large enough (>5.5 cm in diameter). With newer procedures, surgical risk is minimal – much less than the risk of rupture. Open surgery is a viable option to stents, particularly when one chooses to avoid the issues associated with routine stent replacement or early failure. A stent consists of a stainless steel mesh liner inserted through the groin and put in place with endoscopic tools, then spread with a balloon-like device to hold the stent in place. Yearly CT scans are necessary to determine if the mesh tube stents have failed and require replacement.(Chadi et al,2012)

2.1.3. 5.1Classification:

Abdominal aortic aneurysms are commonly divided according to their size and symptomatology. An aneurysm is usually defined as an outer aortic diameter over

3 cm (normal diameter of the aorta is around 2 cm). If the outer diameter exceeds 5.5 cm, the aneurysm is considered to be large. A ruptured AAA is a clinical diagnosis involving the presence of the triad of abdominal pain, shock and a pulsatile abdominal mass. If these conditions are present, indicating AAA rupture, no further clinical investigations are needed before surgery. (Bown et al,2002).

2.1.3. 5.2 Signs and symptoms:

The vast majority of aneurysms are asymptomatic. However, as abdominal aortic aneurysms expand, they may become painful and lead to pulsating sensations in the abdomen or pain in the chest, lower back, or scrotum. The risk of rupture is high in a symptomatic aneurysm, which is therefore considered an indication for surgery. The complications include rupture, peripheral embolization, acute aortic occlusion, and aortocaval (between the aorta and inferior vena cava) or aortoduodenal (between the aorta and the duodenum) fistulae. On physical examination, a palpable abdominal mass can be noted. Bruits can be present in case of renal or visceral arterial stenosis. (Fauci et al,2008).

The clinical manifestation of ruptured AAA usually includes excruciating pain of the lower back, flank, abdomen and groin. The bleeding usually leads to a hypovolemic shock with hypotension, tachycardia, cyanosis, and altered mental status. The mortality of AAA rupture is up to 90%. 65–75% of patients die before they arrive at hospital and up to 90% die before they reach the operating room. The bleeding can be retroperitoneal or intraperitoneal, or the rupture can create an aortocaval or aortointestinal (between the aorta and intestine) fistula.(Brown LC et al,1999)

2.1.3. 5.3 Risk factors for an AAA:

It's not known exactly what causes the aortic wall to weaken, although increasing age and being male are known to be the biggest risk factors. One study found that people aged over 75 are seven times more likely to be diagnosed with an AAA than people under 55 years old. Men are around six times more likely to be diagnosed with an AAA than women. Described below other risk factors.

2.1.3. 5.3.1 Smoking:

Research has found that smokers are seven times more likely to develop an AAA than people who have never smoked. The more you smoke, the greater your risk of developing an AAA. People who regularly smoke more than 20 cigarettes a day may have more than 10 times the risk of non-smokers. The risk may increase because tobacco smoke contains harmful substances that can damage and weaken the wall of the aorta.(Jonothan et al.2014)

2.1.3. 5.3.2 Atherosclerosis:

Atherosclerosis is a potentially serious condition where arteries become clogged up by fatty deposits, such as cholesterol. An AAA is thought to develop because these deposits (called plaques) cause the aorta to widen in an attempt to keep blood flowing through it. As it widens, it also gets weaker. Smoking, eating a high-fat diet and high blood pressure all increase your risk of developing atherosclerosis.(Jonothan et al.2014)

2.1.3. 5.3.3 High blood pressure:

As well as contributing to atherosclerosis, high blood pressure (hypertension) can place increased pressure on the aorta's wall.(Jonothan et al.2014).

2.1.3. 5.3.4 Family history:

Having a family history of AAAs means that you have an increased risk of developing one. One study found that people who had a brother or sister with an AAA were eight times more likely to develop one than people whose siblings were unaffected.(Jonothan et al.2014)

2.1.4. Overview of Computed Tomography

The development of computed tomography (CT), resulting in widespread clinical use of CT scanning by the early1980s, was a major breakthrough in clinical diagnosis. The primary advantage of CT was the ability to obtain thin cross-sectional axial images, with improved spatial resolution over echocardiography, nuclear medicine, and magnetic resonance imaging. This imaging avoided super position of three-dimensional (3-D) structures onto a planar 2-D representation, as is the problem with conventional projection X-ray (fluoroscopy). The increased contrast resolution of CT is the reason for its increase insensitivity for atherosclerosis and coronary artery disease (CAD). Localization of structures (in any plane) is more accurate and easier with tomography than with projection imaging like fluoroscopy. Furthermore, the images, which are inherently digital and thus quite robust, are amen able to 3-D computer reconstruction, allowing for ultimately nearly an infinite number of projections (MetinAkay et al 2013).

The basic principle of CT is that a fan-shaped, thin x ray beam passes through the body at many angles to allow for cross-sectional images. The corresponding X-ray transmission measurements are collected by a detector array. Information entering the detector array and X-ray beam itself is collimated to produce thin sections while avoiding unnecessary photon scatter (to keep radiation exposure and image noise to a minimum). The data recorded by the detectors are digitized into picture elements (pixels) with known dimensions. The gray-scale information contained in each individual pixel is reconstructed according to the attenuation of the X-ray beam along its path using a standardized technique termed “filtered back projection.” (Metin Akay et al 2013).

Gray-scale values for pixels within the reconstructed tomogram are defined with reference to the value for invention of the CT scanner in the late 1960s. Since CT uses X-ray absorption to create images, the differences in the image brightness at any point will depend on physical density and the presence of atoms with a high difference in anatomic number like calcium, and soft tissue and water. The absorption of the X-ray beam by different atoms will cause differences in CT brightness on the resulting image. Blood and soft tissue (in the absence of vascular contrast Enhancement) have similar density and consist of similar proportions of the same atoms (hydrogen, oxygen, carbon). (Metin Akay et al 2013).

Bone has an abundance of calcium. Fat has an abundance of hydrogen. Lung contains air which is of extremely low physical density. The higher the density, the brighter the structure on CT. Calcium is bright white, air is black, and muscle or blood is gray. Computed tomography, therefore, can distinguish blood from air, fat and bone but not readily from muscle or other soft tissue. The densities of blood, myocardium, thrombus, and fibrous tissues are so similar in their CT number, that non-enhanced CT cannot distinguish these structures. Thus, the ventricles and other cardiac chambers can be seen on non-enhanced CT, but delineating the wall from the blood pool is not possible .Investigators have validated the measurement km bn xc4of “LV size” with cardiac CT, which is the sum of both left ventricle (LV) mass and volume . Due to the thin wall which does not contribute significantly to the total measured volume, the left and right atrial volumes can be accurately measured on non-contrast CT (Matthew J.et al 2010).

The higher spatial resolution of CT allows visualization of coronary arteries both with and without contrast enhancement. The ability to see the coronary arteries on anon-contrast study depends upon the fat surrounding the artery (of lower density, thus more black on images), providing a natural contrast between the myocardium and the pericardial artery. Usually, the entire course of each coronary artery is visible on non-enhanced scans. The major exception is bridging, when the coronary artery delves into the myocardium and cannot bed is distinguished without contrast. The distinction of blood and soft tissue (such as the left ventricle, where there is no air or fat to act as a natural contrast agent) requires injection MSCT is a highly accurate diagnostic modality for congenital heart diseases, obviating the need for invasive modalities. Beside its noninvasive nature, the advantage of MSCT over the angiography is its ability to provide detailed anatomical information about the heart, vessels, lungs and intra-abdominal organs.

2.1.4.1 MDCT Methods

Sub-second MDCT scanners use a rapidly rotating X-ray tube and several rows of detectors, also rotating. The tube and detectors are fitted with slip rings that allow them to continuously move through multiple 360° rotations. The “helical” or “spiral” mode is possible secondary to the development of this slip-ring interconnect. This allows the X-ray tube and detectors to rotate continuously during image acquisition since no wires directly connect the rotating and stationary components of the system (i.e. no need to unwind the wires). This slip-ring technology was a fund a mental breakthrough in conventional CT performing (Carr JJ, Nelson JC, Wong ND, et al2005).

A contrast-enhanced CT of the coronary arteries, with excellent visualization of a high grade stenosis in the mid-portion of the left anterior descending (LAD). A large collateral vessel is seen from the right coronary artery (RCA), but this is quite rare, as usually the collaterals are too small to be well seen on cardiac CT.A large ramus intermedius is well visualized, and the dominant RCA is present. This is but one view of many that can be visualized with cardiac CT, allowing for near-complete visualizations of the coronary tree (Nieman K, Rensing BJ, van Geuns RJ, et al.2008).

2.1.4.2 Post processing Technique

The interpretation of cardiac CT angiographic studies performed with multidetector scanners requires real-time interaction with the volumetric data set that is generated. Consequently, radiologists must become proficient with workstation applications and post processing techniques. At our institution, interpretation of the cardiac CT angiographic data is accomplished using a combination of the post processing techniques described in the following sections. Nieman K, Rensing BJ, van Geuns RJ, et al.2008).

2.1.4.2.1 Multiplanar Reformation

MPR is the basic tool used to interpret cardiac CT angiographic studies. With use of retrospective electrocardiographic gating, data from specific phases of the cardiac cycle are retrospectively referenced to the electrocardiogram for reconstruction. Once the reconstruction is complete, the data are transferred directly to the workstation. The radiologist then interfaces with the reconstructed series in real time at the workstation. Because of variations in the orientation of the heart in the thorax, it is often useful to evaluate cardiac structures along the cardiac planes. The multiplanar capabilities of the workstation allow images of the heart and coronary arteries to be manually rotated for optimal evaluation of the cardiac anatomy. Most workstations with cardiac analysis capabilities can automatically orient volumetric image data sets along the cardiac axes and into the traditionally used cardiac planes (ie, short-axis, horizontal long-axis, vertical long-axis) with the click of a button. This feature is especially useful for evaluating the cardiac chambers and left ventricular (LV) function. Selected reformatted images are sent to the picture archiving and communication system (PACS) for review by the referring clinicians and for long-term storage (Ropers D,BaumU,PohleK,et al.2003).

2.1.4.2.2 Maximum Intensity Projection:

MIP is a post processing technique that takes the highest-attenuation voxel in a predetermined slab of data and projects it from the user toward the viewing screen, resulting in a two-dimensional image. MIP images are similar to traditional angiograms, which display intraluminal opacity values (Ropers D,Baum,et al.2003). Only the highest attenuation objects, typically contrast material and bone, are preferentially displayed and retained in the image. The limitation of MIP images is that they lack depth and spatial information regarding relationships to adjacent structures (Lawler LP, Pannu HK 2005, Gruden JF.2005).

However, they can allow quick assessment for significant coronary artery stenosis. At our institution, MIP images of each coronary artery are created and transferred to the PACS for every study.

2.1.4.2.3Volume Rendering

VR is a 3D technique in which the CT attenuation values for each voxel can be assigned a specific color (Lawler LP, Pannu HK 2005), thereby producing an overall image of the heart. VR is the only true 3D technique and provides the depth and spatial information that is lacking with MIP (Lawler LP, Pannu HK 2005, Gruden JF.2005).

VR techniques facilitate surface evaluation of the heart and coronary arteries. With respect to diagnosis, we have found this technique to be the most useful for evaluating complex anatomy, including coronary artery anomalies, bypass grafts, and fistulas. At our institution, VR images of each coronary artery are transferred to the PACS. Our referring physicians have found that these images allow them to communicate the major findings of a study to the patient in an easily understandable format. (Lawler LP, Pannu HK 2005)

2.1.4.2.4 Curved Reformation

Because normal coronary arteries are often tortuous, accurate evaluation requires assessment of the entire vessel along its center line. Curved reformatted images provide this capability by sampling a given volume (ie, artery) along a predefined curved anatomic plane (Gruden JFet al.2005).

Most cardiac workstations have software capable of automatically determining the center line of each coronary artery and display the entire length of the artery on a single curved reformatted image (Cody DD et al, 2002).

This type of reformation is especially helpful in patients with bypass grafts and highly tortuous coronary arteries.

2.1.4.5 The need for Multi slice CT:

The detector configuration in which a single row of a detector is irradiated by the x-ray beam. Although helical (spiral) CT has significantly improved volume coverage, many clinical applications demand even greater volume coverage and thinner slices. A good example is CT angiography. (Cody DD et al, 2002).

For this application, a rapid volume acquisition is needed during the plateau phase of contrast enhancement. For thoraco-abdominal aorta studies, the volume includes the whole chest and abdomen, which can reach between 45 and 60 cm along the patient (z) axis. A more demanding case is the runoff study of the abdominal aorta and the legs, which covers the area from the celiac artery to the calves, coverage between 90 and 120 cm. (Cody DD et al, 2002).

To ensure optimal contrast enhancement and minimal patient respiratory motion, an entire study should be completed in less than 20 sec. For instance, to cover 40 cm in 20 sec, the patient table must travel at a speed of 2 cm/sec. With a single-slice scanner rotating at 0.5 sec per revolution, it is difficult to obtain a slice thickness of 5 mm or less at this coverage. For example, consider a likely scanning protocol of 5-mm collimation at a 2:1 helical pitch. (Cody DD et al, 2002).

The effective slice thickness of a reconstructed image increases quickly with an increase in helical pitch. If we use a thinner collimation or slower helical pitch, the time to cover the same volume increases, which leads to several complications. First, we may lose the optimal timing for contrast enhancement. When the scan time is significantly lengthened, the contrast washout effect becomes significant. Although we can partially compensate for the effect by prolonging the contrast injection time, we often run into limitations such as the total amount of allowable contrast administered to the patient. (Cody DD et al, 2002).

Prolonged scan time and contrast injection also preclude the examination of organs in their arterial (free of venous) phase. (Cody DD et al, 2002).

The second problem with a thinner collimation or slower helical pitch is patient motion. This is particularly important for chest and abdominal studies. A typical patient can hold his or her breath for approximately 20 to 30 sec. For studies that extend beyond this range, multiple breath-holds are required. (Cody DD et al, 2002).

Although images reconstructed within each breath-hold are free of respiratory motion artifacts, misregistration between breath-holds is often unavoidable (it is nearly impossible for a patient to repeat exactly the same breath-holding level). Since many studies are viewed in 3D (multiplanar reformat, MIP, or VR), misregistration between adjacent volumes is highly objectionable. (Cody DD et al, 2002).

Clinical example illustrate the clinical benefits of multislice CT. Figure (2-3) show VR image of abdominal CT angiogram study to visualize the fine vascular structures, the slice thickness must be small while the entire abdomen area must be covered in a short period of time to produce the best contrast. Such a level of image quality would be very difficult to obtain with a single-slice scanner. Although this particular study was performed on a 64- slice scanner, the clinical benefits of the multislice concept can be clearly demonstrated even on older vintage scanners. (Cody DD et al, 2002).

Figure (2.3): Showing Volume-rendered image of CTA abdominal study

2.1.6 CT Angiography of Aorta

During the past decade CT angiography (CTA) has become a standard noninvasive imaging modality for the depiction of vascular anatomy and pathology. The quality and speed of CTA examinations have increased dramatically as CT technology has evolved from one-channel spiral CT systems to multichannel (4-, 8-, 10- and 16-slice) spiral CT systems. Sixty-four multi detector row CT (MDCT) became available in 2004 ((Schoenhagen et al 2004), (Lepor et al 2005). (Flohr et al 2003) (Kuettner et al 2005).

The imaging modality most commonly used for diagnosis of aortic disease is CT, followed by transesophageale chocardiography, MR imaging, and aortography. If multiple imaging is performed, the initial imaging technique most frequently used is CT (Suzuki et al 2003).

2.1.6.1. CT techniques (Examination protocols)

CTA of the aorta using four-slice scanners produces images with a lower spatial resolution and a relatively longer scan time than those produced using scanners with 16 or more slices. The spatial resolution needed to render diagnostic images of the smaller branches of the aorta and of in timal tears becomes feasible with the latter scanners. The scan should cover the area from a level 3 cm above the aortic arch to the level of the femoral heads. (Suzuki et al 2003).

Typical protocols for 4-, 16- and 64-slice scanners for aortic CTA Currently the standard tube voltage for CTA is120 kV. The tube current should be approximately120 mAs, and automated dose modulation should be used. A tube voltage of 100 kV increases the contrast-to-noise ratio because of effective X-ray absorption by iodine at lower tube voltages, which improves the quality of images and reduces the radiation exposure to patients by 35% in comparison with 120 kV at a constant tube current (Wintersperger et al 2005).

CTA of the abdominal aorta performed at a low voltage results in higher attenuation in the aorta with reduced radiation dose and without degrading the diagnostic image quality. The volume of iodinated contrast medium can be reduced by lowering the voltage during CTA (Kalva et al 2006), (Strocchi et al 2006).

The beating of the heart results in both circular and perpendicular motion of the aorta that is most pronounced near the heart. Pseudodis section of the thoracic aorta, a well-known pitfall, occurspre dominantly at the right anterior and left posterioraortic circumference (Fig. 2-4) (Roos et al 2002).

Multiplan are reconstruction of images from contrast-enhancedor unenhanced helical CT provides evidence of motion artifacts (Yoshida et al 2003).

Hofmann and colleagues (Hofmann et al, 2004)recommended the use of retrospective ECG gating for imaging of the heart, the aortic root, and the ascending aorta, especially when motion artifacts may influence the diagnosis critically (eg, when aortic dissection is suspected); however, an ECG-gated scan increases the radiation dose to the patient. (Yoshida et al 2003).

Morgan-Hughes and colleagues [Morgan-Hughes 2003] suggested that in patients who have slower heart rates (% 70beats per minute), a reconstruction window should be centered at 75% of the R-R interval and that in patients who have faster heart rates(> 70 beats per minute) the construction window should be centered at 50% of the R-R interval.

ECG-assisted MDCT shows a significant reduction of motion artifacts for the entire thoracic aorta compared with non–ECG-assisted MDCT.

Protocols for administration of contrast medium High-quality CTA of the aorta requires sufficient contrast enhancement. An intra-arterial target threshold higher than 200 Hounsfield units(HU) produces adequate aortic enhancement fora diagnostic study (Macari et al 2001).

As blood and the contrast media travel downstream, gradual mixing of the central and peripheral parts of the lumen occurs to compensate for this dilution effect, a high contrast delivery rate should be used to reach the target threshold. In addition, the reduction in the volume of contrast material for a given iodine dose may reduce adverse hemodynamic effects, especially in large patients (Shigeki, et al 2005). Therefore, contrast media with a high iodine concentration (350–400 mg/mL) should be used at a flow rate of 3 to 4 mL/s to reach the target threshold.

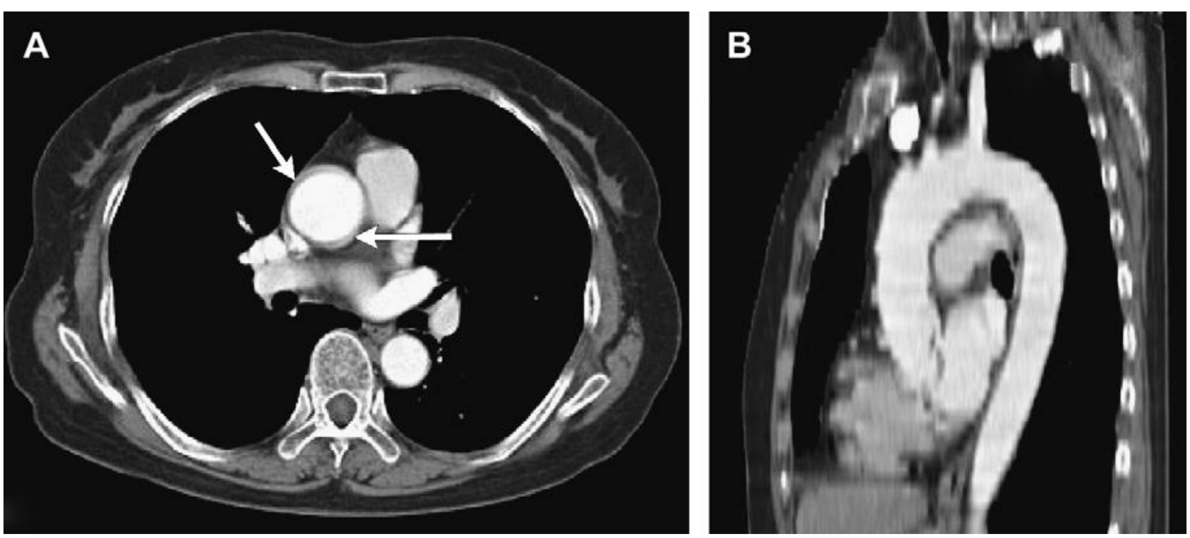


Figure (2-4): (A) The motion of the heart transfers motion to the right anterior and left posterior walls of the ascending aorta (white arrows), which mimics aortic dissection. (B) Sagittal multiplanar reformation reconstruction shows evidence of motion artifact.

Uniform vascular contrast enhancement with a reduced volume of contrast medium, which is desirable in CTA and essential for steady-state quantification of blood volume, can be achieved by using an exponentially decelerated method for injecting contrast medium (Bae et al 2003).

Another challenge of aortic CTA is scan synchronization, which is determined by several factors including the transit of contrast medium bolus in the aorta, the start of the scan, and the table feed.

Factors that influence the pattern of the arterial enhancement include the volume of contrast medium, the injection rate, and the iodine concentration (Brink et al 2003,Feyter et al 2005). Adjusting the volume of contrast medium according to the patient's weight can result in a predictable degree of aortic enhancement, bu tin clinical practice a fixed amount is applied (Cademartiri et al 2003).

A saline chaser usually is used in CTA performed by 16-row CT, especially in CTAs examining the vessels of the thorax. A saline chaser can facilitate the use of a smaller volume of contrast medium, decrease the streak artifacts in the superior venacava, and produce a uniform enhancement pattern without affecting the maximal enhancement in the main arteries [(Hopper et al 1997)., (Cademaritiri et al 2004), (Tatsugami et al 2006)]. The time to peak aortic enhancement depends mainly on the injection rate; increasing the injection rate leads to a proportion al increase in arterial enhancement regardless of the iodine concentration and volume of the contrast medium [Han et al 2000]. Effective opacification of the thoracic aorta is achieved better by injecting a contrast medium with a high iodine concentration at injection rates of 3 mL/s or more (Fenchel et al 2004).

The start of the scan can be determined by one of three methods: using a fixed delay time, using a delay time determined by a peak enhancement time obtained from a test bolus, or triggered by bolus tracking. Awai and colleagues (Awai et al 2004)showed that in a protocol using a fixed injection duration, the time of arterial phase CT scanning may remain unchanged; thus, the scanning protocol can be specified easily because the aortic peak enhancement time and the period during which contrast enhancement is 200 HU or greater are almost constant. The authors did not specify the time value for fixed injection duration, however (Awai et al 2004). Because scan times become shorter with the use of faster MDCT scanners, bolus timing is essential to make the full use of the contrast media. Automated bolus tracking is used more often than the test-bolus technique because it is easier to use, is more efficient, and reduces the total contrast medium dose (Thomas et al . 2005).

Also, with the bolus-tracking protocol, scanning is performed during the plateau of attenuation, which may offer a more homogenous enhancement in the aorta and less pooling of contrast material in the right side of the heart (Cademartiri et al 2004). Another important consideration with regards to synchronization of the contrast bolus and the scan is the table feed. The table feed of 64-slice scanners, sometimes up to 7 cm/s,may result in the scan overriding the bolus if a proximal stenosis is present. A lower table feed may result in the bolus overtaking the scan if there is peripheral vasodilatation. These two circumstances will affect the quality of the aortic CTA. Thomas and Bernhard (Thomas et al . 2005) recommend using a fixed table feed of 40 to 48 mm/s combined with bolus tracking to perform aortic CTA.

Post processing techniques CTA of the aorta using modern CT scanners produces several hundred images per study. This volume of data makes a comprehensive review of all axial images virtually impossible, and post processing techniques providing three-dimensional volumetric images are a prerequisite for efficient interpretation of the CTA and for reporting the findings to referring physicians. An important point for all post processing techniques is that they should not be rendered from the entire data set, because doing so would reduce the spatial resolution substantially.The aorta should be divided into segments to exploit the high Z-axis resolution inherent in the data set.

Volume rendering is not without its disadvantages, however: skeletal structures may overlap vessels, and vessel wall calcifications may obscure underlying stenotic lesions. Maximum intensity projection (MIP) is a projection without depth information.

MIP images of vessels are similar to digital subtraction angiography images, with the advantage that any desired projection can be visualized from a single data acquisition set. Overlapping bones that completely obscure the view of the artery may be resolved by thin-slab MIP images or bone-removal techniques. Thin-slab MIP images are performed in a short time and depict a particular vascular segment but lack a comprehensive overview of the entire vascular bed. A threshold of 200 to 300 HU is selected for bone removal, and a few reference points are set in bones at different positions. Despite the relatively long post processing time, the authors of this article consider MIP with bone removal the best way of displaying CTAs because of the excellent image quality. Curved multiplanar reformation is a technique that can be used if the vascular lumen travels along the long axis. Curved multiplanar reformation is an excellent adjunct to MIP reconstructions whenever extensive calcifications obscure the view of the lumen on MIP images.

CT angiography is noninvasive, is substantially less expensive than conventional digital subtraction angiography, and allows three-dimensional visualization of vessels from any angle from a single set of data acquisition (Catalano et al 2004). Another advantage of CTA over digital subtraction angiography is the ability to show the shape, size, and density of the vascular wall and the adjacent organs. Compared with CTA, the major disadvantages of conventional angiography are cost, failure to detect intramural hematoma (IMH), and excessive time required for the examination. CTA also has some disadvantages, which include lack of dynamic information and a somewhat poor visualization of small collaterals.

Because of the use of contrast media, the most common complications during general CT examinations are allergic reactions and contrast extra vasation, and quite a few cases of iatrogenic intravenous air embolism have been reported in the literature (Imai et al 2004).

2.1.6Abdominal Aortic Diameters by Computed Tomography

All participants underwent thoracic electrocardiographically gated, non-contrast-enhanced MDCT in a supine position using an 8-slice multidetector computed tomographic scanner (Light Speed Ultra; GE Healthcare, Milwaukee, Wisconsin). In the thorax, contiguous 2.5-mm slices (tube voltage 120 kVp, tube current 320 mA if body weight<220 lb and 400 mA if body weight >220 lb, gantry rotation time 500 ms, table feed 3:1) were acquired from the level of the carina to the level of the diaphragm. Two acquisitions were conducted during end-inspiratory breath holds (typical duration 18 seconds). Image acquisition was prospectively triggered in early diastole at 50% of the cardiac cycle. In the abdomen, 25 contiguous 5-mm slices (tube voltage 120 kVp, tube current 400 mA, gantry rotation time 500 ms, table feed 3:1) were acquired covering 125 mm above the level of the first sacral vertebral body.

At each FHS examination, information regarding risk factor levels was obtained from a history and physical examination obtained by a physician and by laboratory testing, as previously described. Cardiovascular disease outcomes were defined by the presence of coronary heart disease, stroke, peripheral arterial disease, or heart failure and were determined by a 3-physician end point committee, as previously described.8 A history of valve surgery or of surgery of the thoracic aorta or abdominal aorta was obtained by the physician examiner during the interview portion of the participant examination by a physician.

Quantitative measurements of thoracic and abdominal aortic diameters were acquired using the 2.5-mm axial slices acquired during the scan on an Aquarius 3D or kstation(Tera Recon Inc., San Mateo, California). As shown in Figure (2-5), measurements of the diameters of the ascending thoracic aorta (AA) and descending thoracic aorta (DTA) were acquired on axial slices at the level of the right pulmonary artery. Measurements of the abdominal aorta were acquired on axial slices at 1 slice level 5 cm above the aortoiliac bifurcation (infrarenal abdominal aorta [IRA]) andat 1 slice level above the bifurcation of the abdominal aortain to the common iliac arteries (lower abdominal aorta[LAA]). The measurements were traced manually from outside wall to outside wall of the aorta in the anteroposterior and transverse planes. At each of the 4 locations (i.e., AA, DTA, IRA, and LAA), the mean of anteroposterior and transverse measurements was calculated(mean AA diameter, mean DTA diameter, mean IRA diameter, and mean LAA diameter, respectively). Mean values were used to help control for obliquity of the vasculature on a small number of scans inherent in the use of axial images (Rogers et al, 2013).

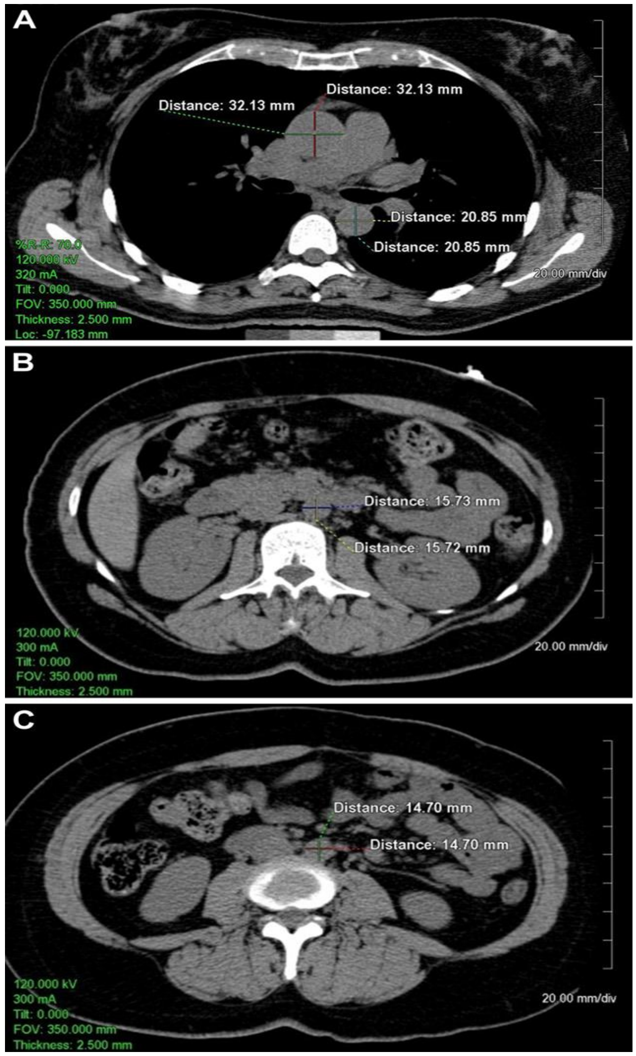


Figure (2-5). Axial non-contrast-enhanced computed tomographic imagesof the AA (measurements in upper part of figure) and DTA (measurementsin lower part of figure) at the level of the right pulmonary artery,(B)the IRA 5 cm above the aortoiliac bifurcation, and(C) the LAA just above the aortoiliac bifurcation. The images demonstrate sample measurements of the aorta from outside wall to outside wall in the anteroposterior andtransverse planes. (Rogers et al 2013)

2.1.7 The Inferior Vena Cava (IVC)

The inferior vena cava (IVC) is the main conduit of venous return to the right atrium from the lower extremities and abdominal viscera. It can be a source of critical information for referring clinicians, and recognition of IVC variants and pathologic characteristics can help guide patient treatment.

Because CT is used to evaluate a wide variety of abdominal symptoms, it is likely to be the most common imaging modality for initial detection of IVC variants and pathologic findings. Routine abdominal imaging at 60–70 seconds after intravenous administration of contrast material (portal venous phase) shows enhancement in the renal and suprarenal IVC but may also show admixture artifact in the infrarenal IVC (Kandpal et al 2008,Sheth and Fishman 2007). Increasing the delay after contrast material injection to 70–90 seconds allows more uniform enhancement of the entire IVC at CT. (Kandpal et al 2008,Sheth and Fishman 2007).

The end points of resuscitation in trauma patients are difficult to define yet under-resuscitated patients continue to have a higher incidence of cardiovascular collapse and multi-organ failure (Meregalli et al 2004, Porter and Ivatury 1998). During periods of tissue hypoxia, ATP production occurs via the anabolic pathway resulting in the production of lactate and hydrogen ions. Thus, lactate is often used as a marker of ongoing shock (Huckabee et al, 1961).

The size of the inferior vena cava (IVC) on CT scan has the potential to be an indicator of volume status in trauma patients. A few case series suggest that the IVC can be a useful gauge of volume status in dialysis patients (Naruse et al 2007). One study found that six of seven patients who had a flat IVC on CT scan following abdominal trauma were hypovolemic (Jeffrey and Federle 1988). However, a retrospective review of 500 patients who underwent abdominal CT scans for a wide variety of reasons found that 70 of them had a flat IVC. Analysis of these 70 patients' vital signs showed that 70% of them were hemodynamically normal with no clinical evidence of shock, suggesting that a ''flat'' IVC can be seen in patients who are not in shock. These authors suggested that a flat IVC might be an anatomical finding that is not relevant to the overall volume status of the patient (Eisenstat 2002).

To date, studies of IVC on CT scan are inconclusive with regards to the relationship between IVC and volume status. Currently, there is no evidence in the literature to support the use of measuring the IVC diameter on CT Scans to determine fluid resuscitation status. The inferior vena cava (IVC) is an essential but often overlooked structure at abdominal imaging. It is associated with a wide variety of congenital and pathologic processes and can be a source of vital information for referring clinicians. (Naruse et al 2007).

2.2: Previous studies

Luca Maria Sconfienza (2013), studied: titled when the diameter of the abdominal aorta should be considered as abnormal? A new ultrasonographic index using the wrist circumference as a body build reference, to use US to evaluate the normal values of aortic diameter (AD), stratifying the population by age, gender and body build, as measured using wrist circumference (WC), show that The definition of normal AD should consider body build. An AD2/WC ratio of 15% may be regarded as a threshold to differentiate AAA- from non-AAA patients. Patients with AD2/WC values comprised between 12% and 15% may be at risk for AAA.

Barbara L. Mc Comb (2016), in their polished article, Normative reference values of thoracic aortic diameter in American College of Radiology Imaging Network (ACRIN 6654) arm of National Lung Screening Trial, their study purpose aims to establish normative reference values for thoracic aortic diameter (AD) in participants in the National Lung Screening Trial and the results show mean AD (cm) and upper limits of normal for men and women were recorded for at each location. Smoking did not correlate with AD. Age, gender, and body surface area (BSA) were the most significant factors. Thoracic AD reference values are reported. They do not correlate with smoking, but they did for age, gender, and BSA(Comb al 2016).

AndriyNykonenko (2017), in their published paper titled, Abdominal aortic size and volume by computed tomography angiography in population of Ukraine: Normal values by age, gender, and body surface area, discovered a significant strong correlation between age, body surface area with the diameter and volume of the aorta. In all cases, there was no relationship between the length of the aorta, and anthropometric data. There was a significant difference in infrarenal aorta diameter and volume between men and women. The significant positive correlation between the body surface area, BMI and the diameter/volume of the IA was detected only in women .

Olga Vriz, MD (2013), in our review report Aortic Root Dimensions and Stiffness in Healthy Subjects, investigate the full range of aortic root diameters and stiffness in a group of subjects without known cardiovascular risk factors and/or overt cardiovascular disease. Four hundred and twenty-two healthy subjects (mean age 44.35 – 16.91 years, range 16 to 90, 284 men [67%]) underwent comprehensive transthoracic echocardiography. The leading edge method was used for the end-diastolic aortic root diameters measured at 4 locations (1) the aortic annulus, (2) the sinuses of Valsalva, (3) the sinotubular junction, and (4) the maximum diameter of the proximal ascending aorta .

Aortic wall stiffness was assessed using 2-dimensional guided M-mode evaluation of systolic and diastolic aortic diameter, 3 cm above the aortic valve. The absolute aortic root diameters increased with age in both genders. Aortic measurements were significantly greater in men than in women at all levels, whereas body surface are aeindexed values were similar in men and women, except for the ascending aorta for which women tended to have greater values. Multivariable regression analysis using age and body size (weight, height, and body surface area) predicted all aortic diameters, whereas blood pressure indexes predicted only the distal part of the aorta. Aortic stiffness increased with age in men and women with no differences between genders; only age predicted aortic stiffness. The increment in aortic diameter with age was lesser when adjusted for aortic stiffness. In conclusion, we define the physiologic range of aortic root diameters and related stiffness in healthy subjects stratified by age and gender. Moreover, aortic stiffness should also be taken into account when the increase of aortic diameter is considered [Vriz, et al 2013].

Ian S. Rogers (2013) in his study, Distribution, Determinants, and Normal Reference Values of Thoracic and Abdominal Aortic Diameters by Computed Tomography, Current screening and detection of asymptomatic aortic aneurysms is based largely on uniform cut-point diameters. The aims of this study were to define normal aortic diameters in asymptomatic men and women in a community-based cohort and to determine the association between aortic diameters and traditional risk factors for cardiovascular disease. Measurements of the diameters of the ascending thoracic aorta (AA), descending thoracic aorta (DTA), infrarenal abdominal aorta (IRA), and lower abdominal aorta (LAA) were acquired from 3,431 Framingham Heart Study (FHS) participants. Mean diameters were stratified by gender, age, and body surface area. Univariate associations with risk factor levels were examined, and multivariate linear regression analysis was used to assess the significance of covariate-adjusted relations with aortic diameters. For men, the average diameters were 34.1 mm for the AA, 25.8 mm for the DTA, 19.3 mm for the IRA, and 18.7 mm for the LAA. For women, the average diameters were 31.9 mm for the AA, 23.1 mm for the DTA, 16.7 mm for the IRA, and 16.0 mm for the LAA. The mean aortic diameters were strongly correlated ($p < 0.0001$) with age and body surface area in age adjusted analyses, and these relations remained significant in multivariate regression analyses. Positive associations of diastolic blood pressure with AA and DTA diameters in both genders and pack-years of cigarette smoking with DTA diameter in women and IRA diameter in men and women were observed. In conclusion, average diameters of the thoracic and abdominal aorta by computed tomography are larger in men compared with women, vary significantly with age and body surface area, and are associated with modifiable cardiovascular disease risk factors, including diastolic blood pressure and cigarette smoking [Rogers et al 2013].

Fay Y. Lin (2008), in their Original Research Article, Assessment of the thoracic aorta by multidetector computed tomography: Age- and sex-specific reference values in adults without evident cardiovascular disease, Dilatation of the aortic root and other segments of the thoracic aorta is important in the pathogenesis of aortic regurgitation and of aortic dissection. Although echocardiographic criteria exist to detect aortic root dilation, comparably standardized methods have not been developed to detect enlargement of the remainder of the thoracic aorta. Nongated axial chest computed tomography (CT), traditionally used to evaluate aortic size, does not account for the obliquity, systolic expansion, and nonaxial motion of the aorta during the cardiac cycle. Reference values for aortic diameters in anatomically correct double-oblique short axis images have not been established with the use of electrocardiogram (ECG)-gated 64-detector row multidetector CT (MDCT). To establish reference values for thoracic aortic diameters MDCT in healthy no rmotensive non obese adults without evident cardiovascular disease.

This study establishes age- and sex-specific ECG-gated MDCT reference values for thoracic aortic diameters in healthy, normotensive, non obese adults to identify aortic pathology by MDCT. MDCT measurements of the thoracic aorta should use ECG-gated double-oblique short-axis images for accurate quantification.

Hagen Kälsch(2011), in their published paper, ody-surface adjusted aortic reference diameters for improved identification of patients with thoracic aortic aneurysms: Results from the population-based Heinz Nixdorf Recall study, early identification of patients at risk for thoracic aortic aneurysm (TAA) has the potential of improving prognosis. So far, however, “normal” aortic dimensions are not well defined, rendering identification of patients with enlarged aortas difficult. In the present study we aimed to (1) establish age- and gender-specific distribution of thoracic aortic diameters and (2) to determine the prevalence of asymptomatic TAA in apopulation-based European cohort. Since BSA was independently associated with increasing aortic diameters, correction of aortic diameters for BSA may be more helpful in order to reliably identify patients at risk for aneurysm formation. Based on the normal distribution of body-surface adjusted thoracic aortic diameters displayed in age- and gender-specific percentiles we suggest a cut-off point for aneurismal aortic diameter at the 95th percentile[Kälsch, et al 2011].

Chapter Three

Chapter Three

Materials and Methods

This study was done at Department of Diagnostic Radiology, and Royal Care International Hospital, Sudan during the period from August 2015 to May2018.

3.1Materials:

3.1.1: The Sample

This Study was carried out in the Department of Diagnostic Radiology, Royal Care International Hospital, Sudan. It was a cross sectional comparative study. The target population for this study was the patients attend for abdominal CT scanning in the radiology department of Royal Care Hospital in Sudan during the period from August 2015 to May2018, included 200 patients (108 males and 92 females) with a mean age of 48.6 years .

Consecutive adult patients, above 20 years of age undergoing helical contrast-enhanced CT scans of the abdomen for non-cardiovascular reasons were included.

Those with large abdominal masses distorting the aorta and preventing accurate measurement of aortic diameters, those with known cardiovascular risk factors like Marfan's syndrome, Ehler-Dahnlos syndrome, vasculitis, those with significant cardiac disease, and other congenital aortic anomalies were excluded. The maximum transverse diameter (internal diameters) of the abdominal aorta was measured at T12, L1, L2and L3 vertebral levels [Figure 1] using the software available in the CT console and the mean values were obtained.

Figure (3.1): Sagittal reconstruction of the abdominal aorta on a contrast enhanced computed tomography (CT) abdomen with the corresponding axial CT sections at T12 and L3 vertebral levels

3.1.2Machines used:

The machine used in this study was Siemens CT scan machine Hi Speed CT/E Dual CT Scanner model SOMATOM definition flash with 256 detector manufacture date 2011).Three options of slice thickness: 2mm, 5mm and 10mm.Similar scan interspaces. figure (3-2)

Figure (3.2) shows Toshiba Aquilion 64 Slice CT scanner

3.2 Methods

3.2.1: Study protocols (Techniques)

Scan was done started from lower chest to symphisis pubis in the most cases contrast media (Omnipaque) to delivered into the body through the venous system the dose (70-100) according to patient weight and hospital polices with delay 30se-40 se ,the rate of injection 2 -3- ml/s.

The methodology section of this thesis described the design of the study, the setting where it took place, the sampling design that was used, and the instruments that were involved in data collection, and also the procedures that were followed for data collection. The statistics that were used for data analysis and a description of the way in which data were analyzed are also discussed. The technical exposures factors that were used in this study were 120 Kv, 100 mA, 10 mm increments, 5 - 10 mm slice thickness with identical reconstruction index and a rotation time 1.5 sec.

3.2.2 Image acquisition and interpretation:

Statistical analysis was performed using computer software package (Statistical Package for Social Sciences (SPSS) 16.0) and Excel program for significances of tests was used. Frequency tables mean and standard deviations were presented. The correlation between height, weight, BMI, and body surface area (BSA) and aortic diameter was analyzed. All analyses were done at 5% significance.

3.2.3: Measurements

3.2.3. 1Abdominal Aortic Measurements

All the measurements done for abdominal aorta diameters were obtained from the distant between the aorta lumens of 200 patients (108 males and 92 females) with a mean age of 48.6 years .All images of study are measurement to transverse abdominal aorta diameters in axial CT abdominal with contrast between two borders of aorta at levels T12, L1, L2and L3 the method show in figure (3.3)

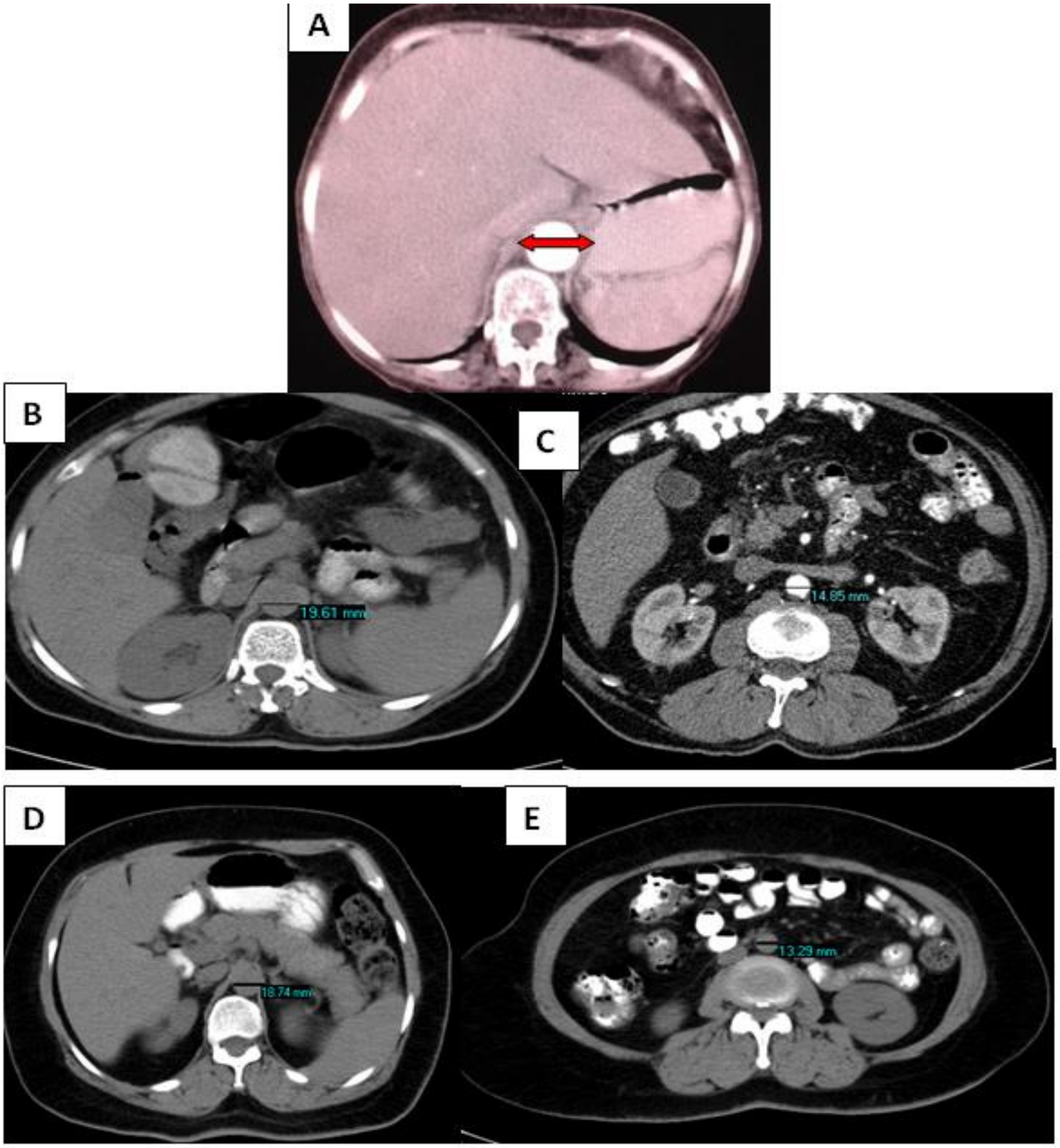


Figure (3.3) Axial images showing the levels of aortic diameter measurements. (A) Transverse Abdominal Aorta Measurement (B) aortic diameters measurements of 71 years old male at T12 level (C) aortic diameters measurements of 43 years old female at L3 level (D) aortic diameters measurements of 71 years old male at L 3 level(E) aortic diameters measurements of 43 years old female at T12 level

3.2.3.2 Inferior Vena Cava Measurements (IVC)

We measured the maximal anteroposterior and transverse diameters of the IVC at the level of the renal vein of 72 patients (41 males and 31 females) with a mean age of 47.2 years.

The caliber of the vessels was measured via a length measuring tool. The transverse diameter (T) and the anteroposterior diameter (AP) of the IVC were measured at four predetermined abdominal levels: just above the liver edge, just below the intrahepatic IVC, just above the renal veins, and just above the fork of the IVC**(Figure 1)**.

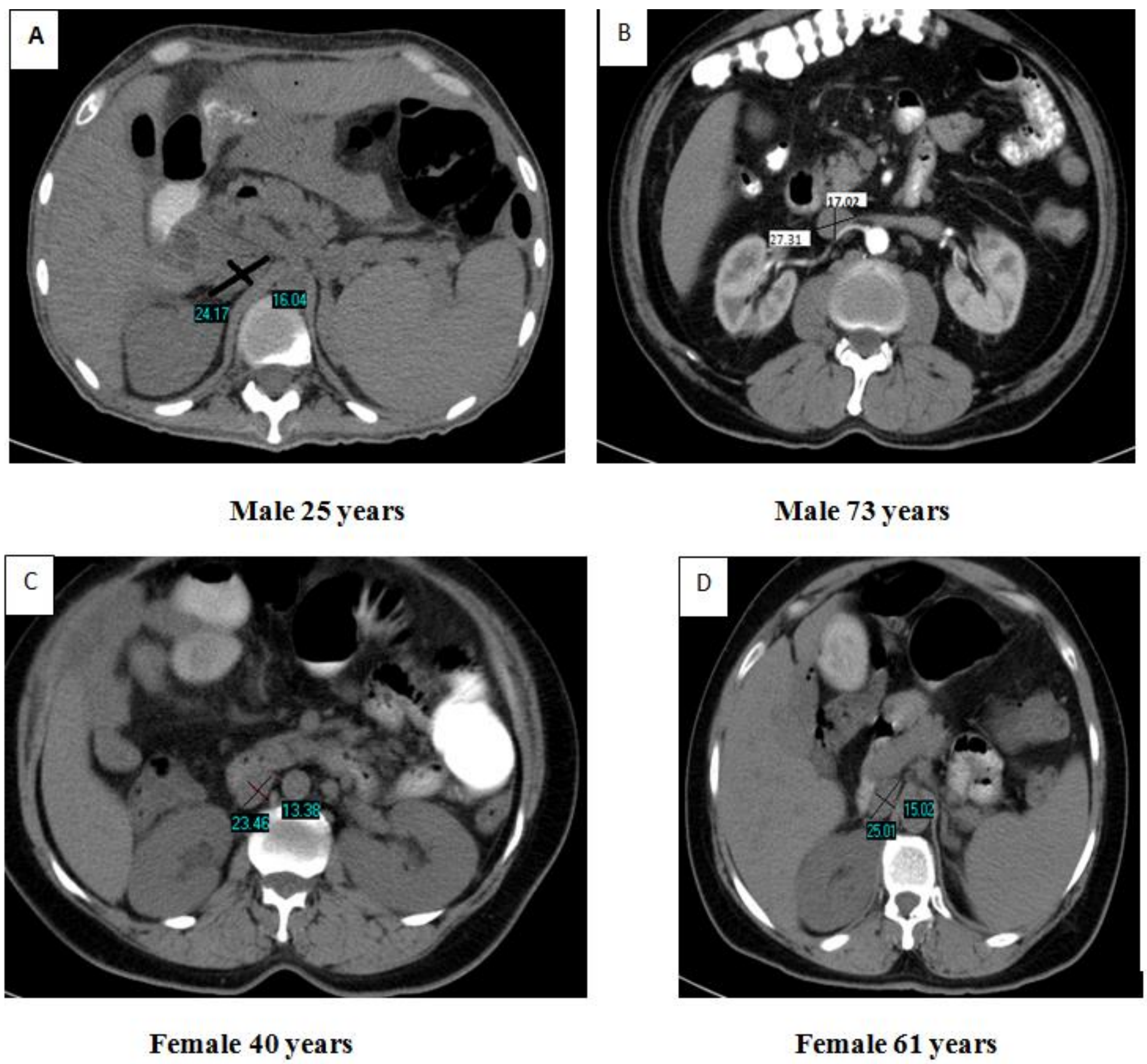


Figure 1(A-D). Method for measuring inferior vena cava (IVC) The maximal transverse and anteroposterior diameters of the IVC were measured using a length-measuring tool.

3.2.4: Statistical analysis

Continuous data are presented as mean ± standard deviation (SD) and compared using the t test. Categorical data were expressed as percent frequencies, and differences between proportions were compared using the chi square test. Statistical correlation between continuous variables was tested using the Pearson's product-moment coefficient of correlation (r). All tests of significance were two tailed and a p-value < 0.05 was considered statistically significant. All analyses were performed using SPSS version22. statistical software (SPSS Inc., Chicago, Illinois).

3.2.5 Ethical Consideration:

There is no patient identification or individual patient details will be published. Also confidentiality will be ensured by making the collected data accessible only to the researcher and consultant radiologist and the head of radiology department. And also keep all data collected during the study will be stored on computer protected by password. All paper format data will be stored in locked cabinet.

Chapter Four

Chapter four

Results

The following tables and figures presented the results of the study

Table 4.1 the patients classification according to gender

.

Gender	N	Percentages%
Female	92	46%
Male	108	64%
Total	200	100%

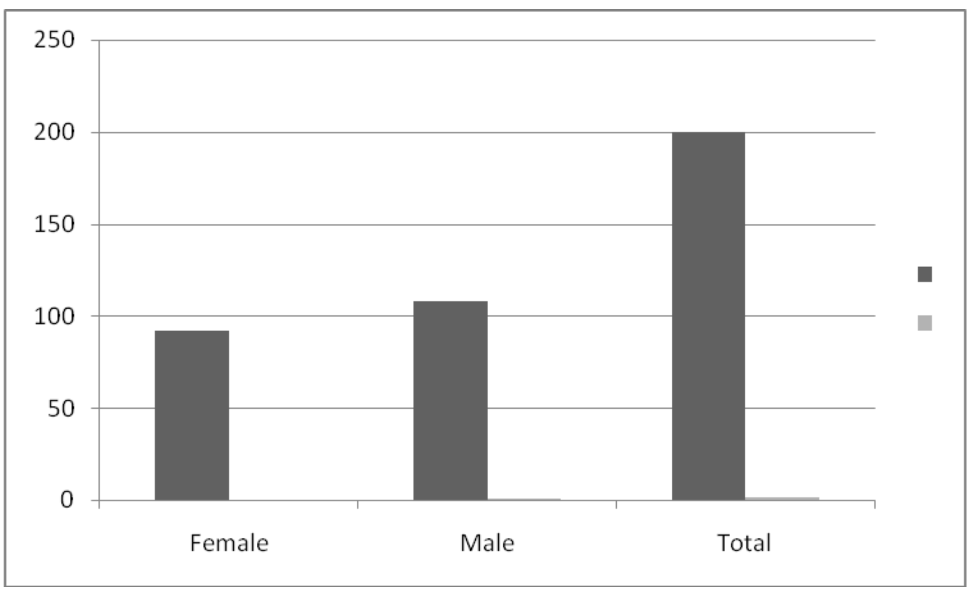


Figure4.1 the patients classification according to gender

Table 4.2 the patients' classification according to age

Gender	≥30	31-40	41-50	51-60	61-70	71-80	81-90
Female	13	11	25	31	6	4	2
Male	18	12	29	34	8	4	3
Total	31	23	54	65	14	8	5

Table 4.3 the patients' classification according to Weight

Gender	41-50	51-60	61-70	71-80	81-90	91-100	100<
Female	6	17	21	19	18	7	4
Male	6	20	26	28	15	8	5
Total	12	37	47	47	33	15	9

Table 4.4 the patients' classification according to height

Gender	150 >	151-160	161-170	171-180	181-190	190<
Female	3	21	32	27	9	-
Male	2	9	17	24	52	4
Total	5	30	59	51	61	4

Table 4.5 The Sample Demographic Data (Males and Females)

Gender	Variables	Age	Weight	Height	BMI	BSA
All Female and Male	Mean	48.6	70.43	169.25	26.31	1.85
	STDV	16.2	13.30	10.04	3.56	0.16

Table 4.6: The relationship between the mean diameters of suprarenal and infrarenal abdominal aorta and age male and female

	Age groups	Male (n=108)mm	Female (n=92) mm
Suprarenal abdominal aortas (T12)	21-30	18.64 ±1.64	**16.00±1.86**
	31-40	19.19±1.88	**17.81±1.83**
	41-50	20.85±1.7	**19.35 ±1.86**
	51-60	21.71±2.05	**20.92±1.71**
	61-70	21.98± 1.93	**21.33±2.06**
Infrarenal abdominal aortas (L3)	21-30	14.74±2.00	**12.55±1.63**
	31-40	15.18±1.60	**13.78±1.79**
	41-50	15.88±1.91	**14.40±1.66**
	51-60	16.45±1.69	**14,62±1.69**
	61-70	16.82±1.73	**14.94±1.85**
p<0.01			

Table 4.7: Mean abdominal aortic diameters in males and females in Suprarenal and Infrarenal levels

	Male **Mean diameter mm**	**Female** **Mean diameter mm**
Suprarenal abdominal aortas (T12)	20.97±1.74	19.44±1.51
Infrarenal abdominal aortas (L3)	15.81±1.67	14.14±1.72

Table 4.8: The mean aortic diameter with age and gender

Age	**Male** **Mean diameter mm**	**Female** **Mean diameter mm**
21-30	14.74	**12.55**
31-40	15.18	**13.78**
41-50	15.88	**14.40**
51-60	16.45	**14.62**
61-70	**16.82**	**14.94**

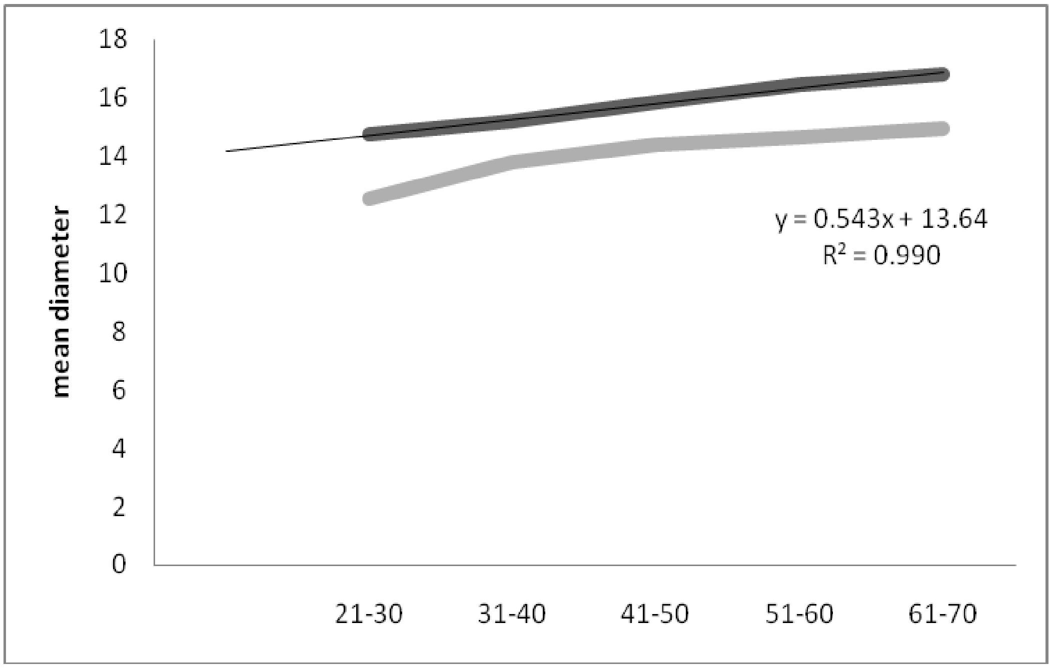


Figure 4.2Line presentations of mean aortic diameter and age.

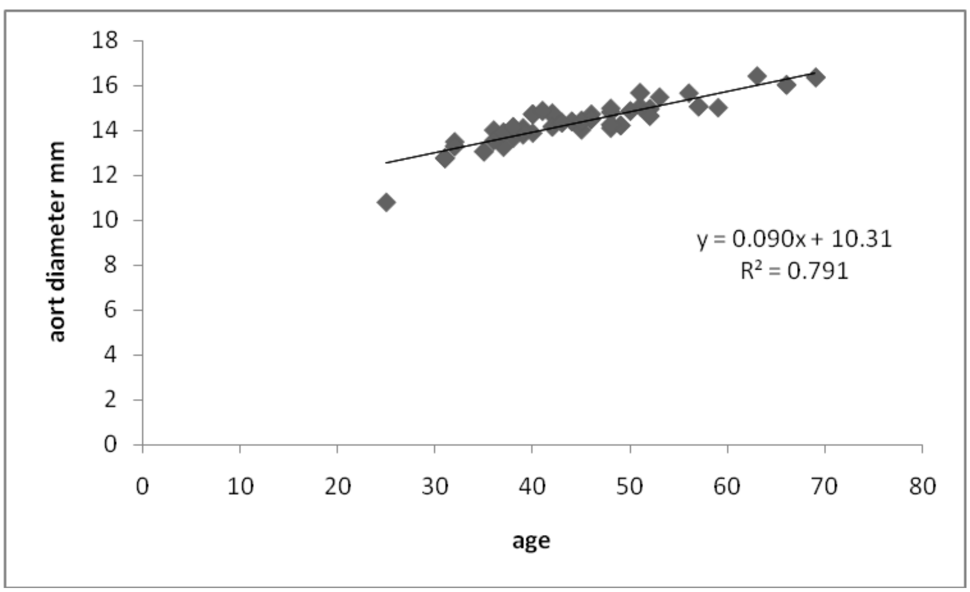


Figure 4.3: Scatter plot of the suprarenal aortic diameter measured at T12 levels and age in male

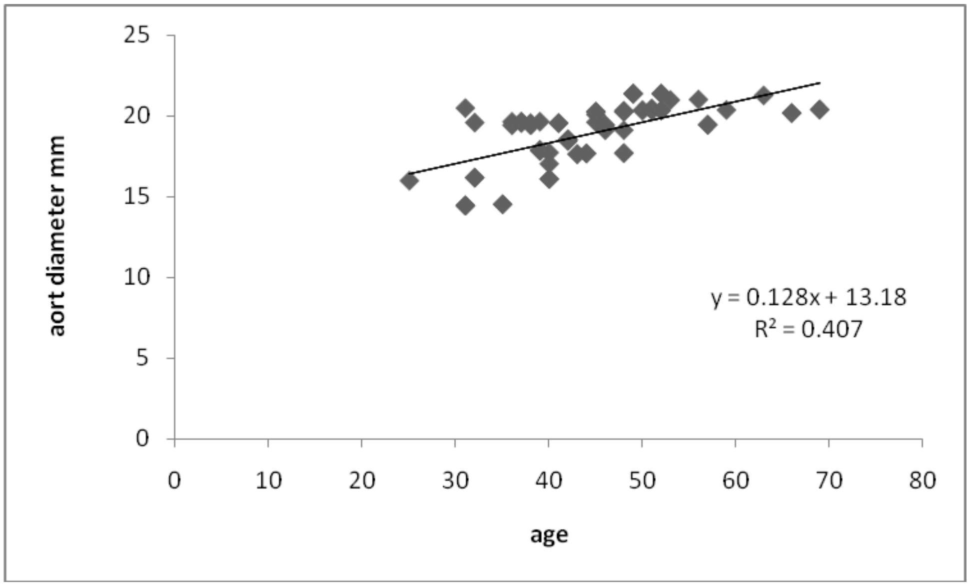


Figure 4.4: Scatter plot of the suprarenal aortic diameter measured at L3 levels

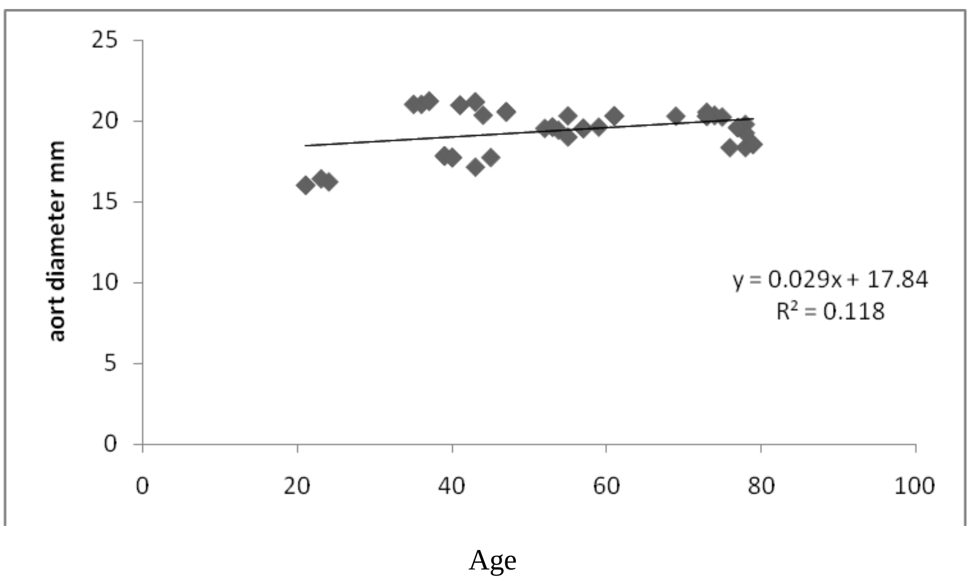
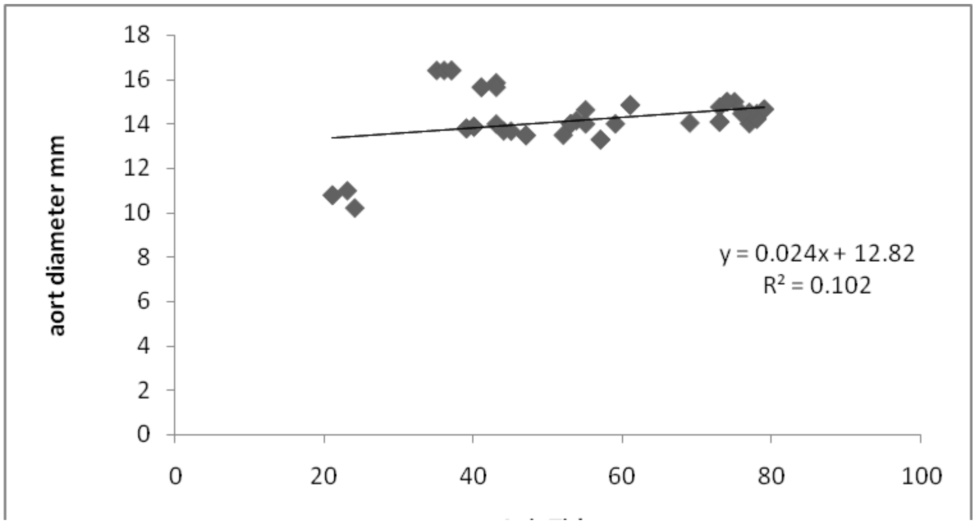


Figure 4.5: Scatter plot of the suprarenal aortic diameter measured at T12 levels



Age

Figure 4.6 : Scatter plot of the suprarenal aortic diameter measured at L3 levels

Table 4-9: Correlations between age , Weight, Body mass index and aorta diameters									
		age	T12	L1	L2	L3	Weight	Height	Body mass index
Age	Pearson Correlation	1	.186**	.110	.178*	-.023	.490**	-.127	.703**
	Sig. (2-tailed)		.008	.121	.012	.752	.000	.072	.000
	N	200	200	200	200	200	200	200	200
T12	Pearson Correlation	.186**	1	.866**	.850**	.034	.301**	.469**	-.029
	Sig. (2-tailed)	.008		.000	.000	.632	.000	.000	.681
	N	200	200	200	200	200	200	200	200
L1	Pearson Correlation	.110	.866**	1	.798**	.035	.361**	.615**	-.043
	Sig. (2-tailed)	.121	.000		.000	.625	.000	.000	.544
	N	200	200	200	200	200	200	200	200
L2	Pearson Correlation	.178*	.850**	.798**	1	.092	.446**	.564**	.072
	Sig. (2-tailed)	.012	.000	.000		.195	.000	.000	.312
	N	200	200	200	200	200	200	200	200
L3	Pearson Correlation	-.023	.034	.035	.092	1	.060	.067	.018
	Sig. (2-tailed)	.752	.632	.625	.195		.401	.345	.799
	N	200	200	200	200	200	200	200	200
Weight	Pearson Correlation	.490**	.301**	.361**	.446**	.060	1	.592**	.684**
	Sig. (2-tailed)	.000	.000	.000	.000	.401		.000	.000
	N	200	200	200	200	200	200	200	200
Height	Pearson Correlation	-.127	.469**	.615**	.564**	.067	.592**	1	-.161*
	Sig. (2-tailed)	.072	.000	.000	.000	.345	.000		.023
	N	200	200	200	200	200	200	200	200
Body massindex	Pearson Correlation	.703**	-.029	-.043	.072	.018	.684**	-.161*	1
	Sig. (2-tailed)	.000	.681	.544	.312	.799	.000	.023	
	N	200	200	200	200	200	200	200	200
**. Correlation is significant at the 0.01 level (2-tailed).									
*. Correlation is significant at the 0.05 level (2-tailed).									

Table 4-10: Correlations between age , Weight, Body mass index and vertebral diameters								
		age	Weight	Height	Body mass index	L1	L2	L3
Age	Pearson Correlation	1	.490**	-.127	.703**	.099	.032	-.218**
	Sig. (2-tailed)		.000	.072	.000	.165	.650	.002
	N	200	200	200	200	200	200	200
Weight	Pearson Correlation	.490**	1	.592**	.684**	.462**	.525**	.354**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000
	N	200	200	200	200	200	200	200
Height	Pearson Correlation	-.127	.592**	1	-.161*	.337**	.626**	.613**
	Sig. (2-tailed)	.072	.000		.023	.000	.000	.000
	N	200	200	200	200	200	200	200
Body mass index	Pearson Correlation	.703**	.684**	-.161*	1	.268**	.098	-.082
	Sig. (2-tailed)	.000	.000	.023		.000	.169	.246
	N	200	200	200	200	200	200	200
VL1	Pearson Correlation	.099	.462**	.337**	.268**	1	.819**	.688**
	Sig. (2-tailed)	.165	.000	.000	.000		.000	.000
	N	200	200	200	200	200	200	200
VL2	Pearson Correlation	.032	.525**	.626**	.098	.819**	1	.777**
	Sig. (2-tailed)	.650	.000	.000	.169	.000		.000
	N	200	200	200	200	200	200	200
VL3	Pearson Correlation	-.218**	.354**	.613**	-.082	.688**	.777**	1
	Sig. (2-tailed)	.002	.000	.000	.246	.000	.000	
	N	200	200	200	200	200	200	200
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

Table 4-11: Minimum, Maximum, Mean Std. Deviation aorta dimensions					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	200	21.0	79.0	48.055	15.4351
T12	200	16.00	23.45	20.0787	1.74419
L1	200	12.21	22.67	18.3677	1.80422
L2	200	11.43	19.50	16.5150	1.59967
L3	200	10.77	143.78	15.5876	9.22520
Weight	200	46.0	109.0	81.410	13.0554
Height	200	148.0	192.0	171.460	10.2177
Body mass index	200	20.90	36.96	27.6202	3.86318
Valid N (listwise)	200				

Table 4-12: Correlations between aorta and vertebral dimensions					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	200	21.0	79.0	48.055	15.4351
Weight	200	46.0	109.0	81.410	13.0554
Height	200	148.0	192.0	171.460	10.2177
Bodymassindex	200	20.90	36.96	27.6202	3.86318
VL1	200	32.24	48.44	40.0423	3.95291
VL2	200	33.79	50.73	41.9333	3.47383
VL3	200	35.80	52.40	44.7211	3.55411
Valid N (listwise)	200				

Table 4-13: Correlations between aorta and vertebral dimensions								
		T12	L1	L2	L3	VL1	VL2	VL3
T12	Pearson Correlation	1	.866**	.850**	.034	.358**	.330**	.505**
	Sig. (2-tailed)		.000	.000	.632	.000	.000	.000
	N	200	200	200	200	200	200	200
L1	Pearson Correlation	.866**	1	.798**	.035	.388**	.480**	.593**
	Sig. (2-tailed)	.000		.000	.625	.000	.000	.000
	N	200	200	200	200	200	200	200
L2	Pearson Correlation	.850**	.798**	1	.092	.380**	.391**	.564**
	Sig. (2-tailed)	.000	.000		.195	.000	.000	.000
	N	200	200	200	200	200	200	200
L3	Pearson Correlation	.034	.035	.092	1	.124	.066	.078
	Sig. (2-tailed)	.632	.625	.195		.080	.351	.271
	N	200	200	200	200	200	200	200
VL1	Pearson Correlation	.358**	.388**	.380**	.124	1	.819**	.688**
	Sig. (2-tailed)	.000	.000	.000	.080		.000	.000
	N	200	200	200	200	200	200	200
VL2	Pearson Correlation	.330**	.480**	.391**	.066	.819**	1	.777**
	Sig. (2-tailed)	.000	.000	.000	.351	.000		.000
	N	200	200	200	200	200	200	200
VL3	Pearson Correlation	.505**	.593**	.564**	.078	.688**	.777**	1
	Sig. (2-tailed)	.000	.000	.000	.271	.000	.000	
	N	200	200	200	200	200	200	200
**. Correlation is significant at the 0.01 level (2-tailed).								

Table 4-14 showed Minimum, Maximum, Mean, Std. Deviation of Demographics, and Inferior Vena Cava Index					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	72	21.0	79.0	47.167	15.5943
Weight	72	46.0	109.0	81.083	12.7994
Height	72	148.0	192.0	172.139	9.9835
Body Mass Index	72	20.90	36.96	27.3150	3.84181
Transverse	72	20.82	28.12	24.9036	1.76065
AP	72	11.38	17.72	14.7939	1.58759

Table 4-15 Showed Correlations of Demographics and Inferior Vena Cava Index							
		Age	Weight	Height	Body Mass Index	Transverse	AP
Age	Pearson Correlation	1	.477**	-.178	.710**	-.023	-.189
	Sig. (2-tailed)		.000	.134	.000	.848	.111
	N	72	72	72	72	72	72
Weight	Pearson Correlation	.477**	1	.564**	.689**	.228	.109
	Sig. (2-tailed)	.000		.000	.000	.054	.362
	N	72	72	72	72	72	72
Height	Pearson Correlation	-.178	.564**	1	-.189	.418**	.379**
	Sig. (2-tailed)	.134	.000		.112	.000	.001
	N	72	72	72	72	72	72
Body Mass Index	Pearson Correlation	.710**	.689**	-.189	1	-.060	-.194
	Sig. (2-tailed)	.000	.000	.112		.614	.103
	N	72	72	72	72	72	72
Transverse	Pearson Correlation	-.023	.228	.418**	-.060	1	.694**
	Sig. (2-tailed)	.848	.054	.000	.614		.000
	N	72	72	72	72	72	72
AP	Pearson Correlation	-.189	.109	.379**	-.194	.694**	1
	Sig. (2-tailed)	.111	.362	.001	.103	.000	
	N	72	72	72	72	72	72
**. Correlation is significant at the 0.01 level (2-tailed).							

Table 4-16 showed Minimum, Maximum, Mean, Std. Deviation of Demographics, and Inferior Vena Cava Index					
	N	Minimum	Maximum	Mean	Std. Deviation
age	41	25.0	68.0	42.439	12.0147
Weight	41	61.0	109.0	82.951	12.6372
Height	41	167.0	192.0	178.585	7.0142
Body Mass Index	41	20.90	29.80	25.8256	2.84733
Transverse	41	22.16	28.12	25.4724	1.69105
AP	41	12.23	17.72	15.3112	1.49919

Table 4-17 showed Correlations of Demographics and Inferior Vena Cava Index							
		Age	Weight	Height	Body Mass Index	Transverse	Ap
Age	Pearson Correlation	1	.569**	.132	.642**	-.145	-.344*
	Sig. (2-tailed)		.000	.412	.000	.365	.028
	N	41	41	41	41	41	41
Weight	Pearson Correlation	.569**	1	.729**	.844**	.023	.000
	Sig. (2-tailed)	.000		.000	.000	.885	.999
	N	41	41	41	41	41	41
Height	Pearson Correlation	.132	.729**	1	.291	.169	.195
	Sig. (2-tailed)	.412	.000		.065	.292	.223
	N	41	41	41	41	41	41
Body Mass Index	Pearson Correlation	.642**	.844**	.291	1	-.080	-.165
	Sig. (2-tailed)	.000	.000	.065		.619	.304
	N	41	41	41	41	41	41
Transverse	Pearson Correlation	-.145	.023	.169	-.080	1	.628**
	Sig. (2-tailed)	.365	.885	.292	.619		.000
	N	41	41	41	41	41	41
AP	Pearson Correlation	-.344*	.000	.195	-.165	.628**	1
	Sig. (2-tailed)	.028	.999	.223	.304	.000	
	N	41	41	41	41	41	41
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

Table 4-18 showed Minimum, Maximum, Mean, Std. Deviation of Demographics, and Inferior Vena Cava Index					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	31	21.0	79.0	53.419	17.6669
Weight	31	46.0	102.0	78.613	12.7950
Height	31	148.0	174.0	163.613	6.1950
Body Mass Index	31	21.00	36.96	29.2848	4.13278
Body Surface Area	31	1.37	2.09	1.8458	.16641
Transverse	31	20.82	27.31	24.1513	1.58001
AP	31	11.38	17.02	14.1097	1.45560

Table 4-19 showed Correlations of Demographics and Inferior Vena Cava Index								
		Age	Weight	Height	Body mass index	Body surface area	Transverse	AP
Age	Pearson Correlation	1	.611**	.149	.671**	.529**	.393*	.192
	Sig. (2-tailed)		.000	.423	.000	.002	.029	.301
	N	31	31	31	31	31	31	31
Weight	Pearson Correlation	.611**	1	.582**	.917**	.965**	.403*	.117
	Sig. (2-tailed)	.000		.001	.000	.000	.025	.532
	N	31	31	31	31	31	31	31
Height	Pearson Correlation	.149	.582**	1	.218	.773**	.314	.098
	Sig. (2-tailed)	.423	.001		.239	.000	.086	.599
	N	31	31	31	31	31	31	31
Body mass index	Pearson Correlation	.671**	.917**	.218	1	.785**	.342	.097
	Sig. (2-tailed)	.000	.000	.239		.000	.059	.603
	N	31	31	31	31	31	31	31
Body surface area	Pearson Correlation	.529**	.965**	.773**	.785**	1	.407*	.122
	Sig. (2-tailed)	.002	.000	.000	.000		.023	.515
	N	31	31	31	31	31	31	31
Transverse	Pearson Correlation	.393*	.403*	.314	.342	.407*	1	.669**
	Sig. (2-tailed)	.029	.025	.086	.059	.023		.000
	N	31	31	31	31	31	31	31
AP	Pearson Correlation	.192	.117	.098	.097	.122	.669**	1
	Sig. (2-tailed)	.301	.532	.599	.603	.515	.000	
	N	31	31	31	31	31	31	31
**. Correlation is significant at the 0.01 level (2-tailed).								

Chapter Five

Chapter five

Discussion, Conclusion and Recommendations

5.1 Discussion

This study was done using CT scan to establish normal diameters for abdominal aorta in the Sudanese population and to study the variation in aortic diameter according to age, gender, and different vertebral levels. In order to reduce confusion in terminology, aortic diameters greater than the upper limits of normal, but not meeting criteria for aneurysm, should be described as dilated.

200 patients were enrolled in the study of 92 female patients and 108 male patients between 21-90years old. The results showed that the normal transverse abdominal aorta diameter was correlated with patient age, gender, and vertebral levels.

In this study, the mean diameter of suprarenal abdominal aortas, measured at the T12 vertebral level was 19.44±1.51mm. in Female and was 20.97±1.74mm. in Male. The mean diameters of infrarenal abdominal aortas, measured at L3 vertebral level was14.14±1.72mm. in Female and 15.81±1.67mm. in Male.

This study agree with Jasper et al study in 2014, using computed tomography to evaluate normal abdominal aortic diameters in the Indian population, who found that the mean diameter of the suprarenal abdominal aorta in men was 19.0±2.3 mm. and in women was 17.1±2.3 mm. The mean diameter of the infrarenal abdominal aorta was 13.8±1.9 mm. in men and was 12.0±1.6 mm. in women. The mean aortic diameter of the Sudanese people was slightly larger than that of the Indian population at all levels in both genders. The mean aortic diameters had progressively increased values with increasing age in both the suprarenal and infrarenal aorta in both genders. The means aortic diameter of male patients is larger than that of female patients, at all levels which is similar to the previous studies.

Dilatation of the aortic root and thoracic aorta predispose patients to aortic regurgitation and aortic dissection. to the limits for aortic root diameter in relation to age and body size have been developed and widely adopted, but only limited data exist concerning reference values for diameters of more distal aortic segments .this agree with Olga Vriz, MD (2013), in our review report Aortic Root Dimensions and Stiffness in Healthy Subjects, investigate the full range of aortic root diameters and stiffness in a group of subjects without known cardiovascular risk factors and/or overt cardiovascular disease. Four hundred and twenty-two healthy subjects (mean age 44.35 – 16.91 years, range 16 to 90, 284 men [67%]) underwent comprehensive transthoracic echocardiography. The leading edge method was used for the end-diastolic aortic root diameters measured at 4 locations (1) the aortic annulus, (2) the sinuses of Valsalva, (3) the sinotubular junction, and (4) the maximum diameter of the proximal ascending aorta . Another study done by JOH JH,2013,in Korean population by ultrasound found was(1.90) / (2.04) In female / male at renal which was higher than Ours study and was (1.79) / (1.90) In female / male at infrarenal which was higher than Ours study this different may be due to smaller sample size in our study and different method of measurement . In another study done by Sariosmanoglu N, 2002 in Turkish population by ultrasound found (1.8± 3)/ (1.9 ± 4) cm In female / male which lower than Ours study. and the infrarenal level (1.5± 3) / (1.6 ± 4) In female / male which was higher than Ours study the different may be due to different height, size of body and methods of measurement.

Advances of multi detector computed tomographic (MDCT) scanners provide high spatial, temporal, and contrast resolution which, when coupled with electrocardiographic (ECG)-gating, permitted 3-dimensional (3D) assessment of cardiovascular (CV) structure and function.

Some limitations should be noted this was a single-center study in which only possibly limiting the applicability of our data to other patient populations.

In the future, if more attention is paid to the wealth of information that MSCT provides, earlier diagnosis of hypovolemic shock will be possible and will allow additional time for physicians to apply the necessary treatments to prevent further deterioration of patients with hypovolemic shock.

The inferior vena cava (IVC) is the main conduit of venous return to the right atrium from the lower extremities and abdominal viscera. It can be a source of critical information for referring clinicians, and recognition of IVC variants and pathologic characteristics can help guide patient treatment. The purpose of this article is to evaluate, through computerized tomography, the diameters of the Inferior Vena Cava, as well as they, are connected to gender, age and body surface area.

This study was done using CT scan to establish normal diameters for IVC in the Sudanese population and to study the variation in aortic diameter according to age, gender, and different vertebral levels. In order to reduce confusion in terminology, IVC diameters greater than the upper limits of normal, but not meeting criteria for an aneurysm, should be described as dilated.

72 patients were enrolled in the study (41 males and 31 females) with a mean age of 47.2 years .Table (14). The results showed that the normal IVC diameter was correlated with patient age, gender, and vertebral levels. Table (15).

We present a pilot study of the Multidetector Computed Tomography measurements of the IVC diameter in normovolemic subjects. A non-significant correlation was found between IVC and patients age. These data suggest that as the age increases, the transverse IVC measurements decrease, AP of IVC diameters also decrease.

In this study, The mean± standard deviation (SD) of the anteroposterior (AP) diameter of the IVC in men measured was 25.47±1.69 mm Table (16), 24.15±1.58 in women Table (19) The mean± standard deviation (SD) of the transverse (TV) diameters, measured were 14.11±1.46 mm, in women and 15.3112±1.49919mm in men.

There are several limitations to this study. Our study was a retrospective chart review at a single site, and only 72 patients were evaluated in this study. Large-scale retrospective and prospective research studies are needed to verify the practical value of this new method.

The IVC is a highly compliant vessel that changes its diameter and cross-sectional area in parallel with changes in blood volume and central venous pressure. Respiratory, intra-thoracic and intra-abdominal pressures may also influence the volume and diameter of the IVC. Accuracy in IVC measurement has clinical implications in the diagnosis and management of cardiac disorders because it affects the estimation of right-sided cardiac pressure, which is estimated semi-quantitatively by non-invasive ultrasound imaging.

Our study was agree with Shivan and Patil, et al 2010 watch used echocardiography to assessment of inferior vena cava diameter in normal Indian population during inspiration as well as expiration, was categorized as per height, weight and BMI of individuals. A strong correlation was obtained between the IVC diameter and height, weight and BMI; such that an increased height, weight and BMI presented with increased IVC diameter, both during expiratory and inspiratory phases. The average expiratory and inspiratory diameters were 1.69 cm and 1.04 cm, respectively. Average height, weight and BMI of the individuals were 1.64 m, 62.58 kg, and 22.90 kg/m2, respectively. Maximum number of individuals (N = 1410) had expiratory IVC diameter between 1.51 and 2.00 cm; with average height of 1.66 m, weight of 65.66 kg and BMI of 23.17 kg/m2, simulating demographics of normal Indian population this measurement lower than Ours study different may be due to different height, size of body and methods of measurement.

5.2 Conclusion

- The current data establish reference values for abdominal aortic diameters and areas by CT. These data can be used as a reference for future studies attempting to identify abdominal aortic pathology by CT.
- The diameter of Suprarenal abdominal aortas ranged from16.00±1.86 to 21.33±2.06mm in normal Sudanese female and from18.64 ±1.64 to 21.98± 1.93 mm in normal Sudanese male.
- The diameter of the Infrarenal omemal aortaabd ranged from12.55±1.63 to 14.94±1.85 mm in normal female and 14.74±2.00 to 16.82±1.73 mm in normal male .
- Male abdominal aortas bigger than the female abdominal aortas at Suprarenal and Infrarenal levels.
- This study is subject to limitations of retrospective analysis, small sample size relative to the overall normal abdominal aorta population.
- CTA has become a standard noninvasive imaging method for depicting vascular anatomy. It is the most frequently used technique when multiple imaging is needed.
- The quality and speed of CTA is superior to that of other imaging modalities, and it is cheaper and less invasive.
- CTA of the aorta has proven to be superior to conventional arteriography in diagnostic accuracy in several applications. It allows three-dimensional visualization from any angle and in any direction.
- Normal dimensions IVC by CT scan was established and correlated with age and gender, The information provided in this study will allow radiologists to detect and accurately characterize IVC abnormalities to guide clinical decision making and improve patient care. Recognition of IVC processes is essential to patient treatment

5.3 Recommendations:

- Proper imaging is of vital importance in diagnosing several cardiac anomalies
- Accurate differentiation between the true and false lumen is important
- Further Study to establish normative reference values for thoracic aortic diameter (TAD)
- This study is subject to limitations of retrospective analysis, small sample size relative to the overall Sudan population
- Further study of the anatomy of the aortic dimensions using CT and MR imaging examinations.
- Further study of the anatomy of the Inferior Vena Cava dimensions using ultrasound imaging examinations.

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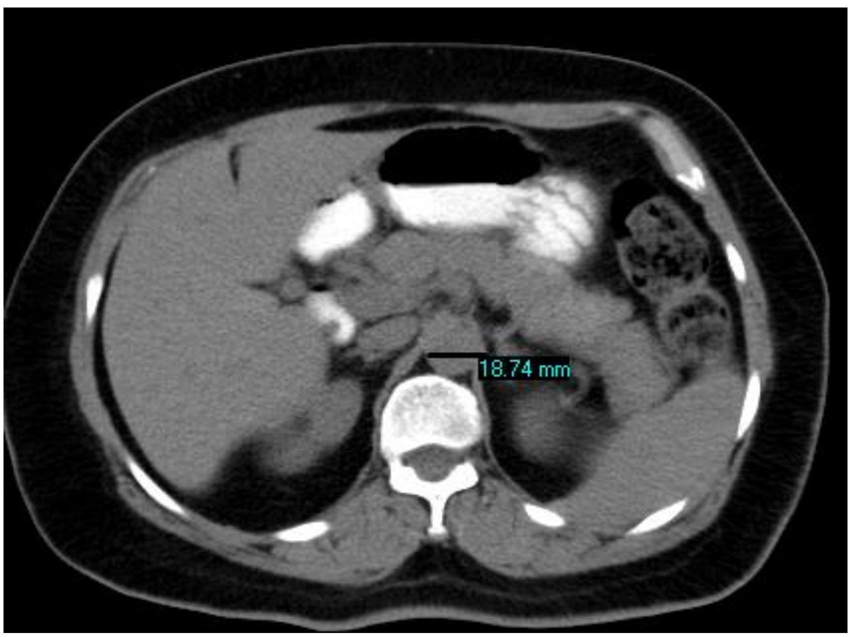
Appendices

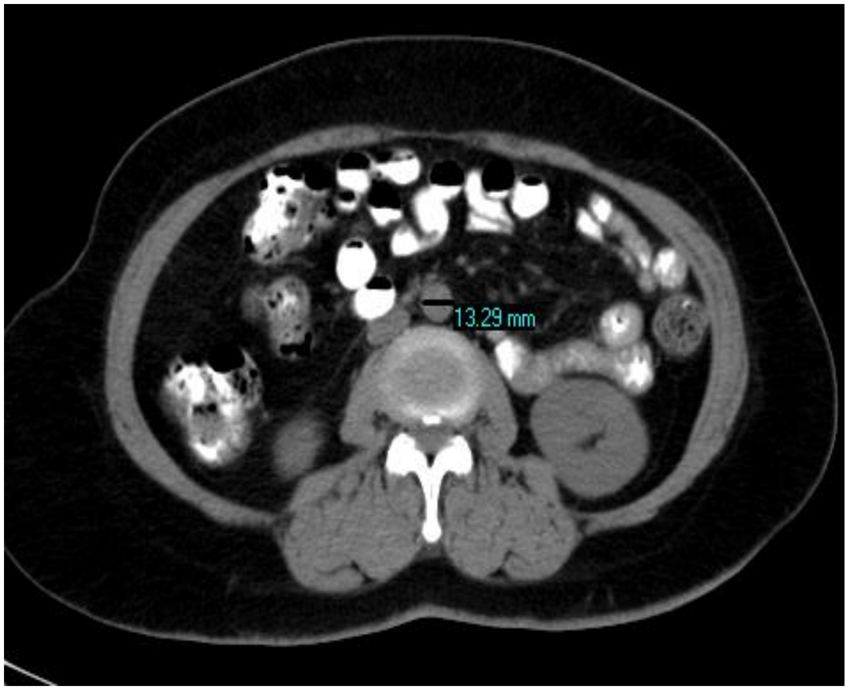
APPENDIX(A) DATA COLLECTION SHEET

No.	Age	Gender	Aorta mm				Vertebra mm				Inferior vena cava mm				Weight kg	Height cm	Body mass index
			T12	L1	L2	L3	T12	L1	L2	L3	T12	L1	L2	L3			

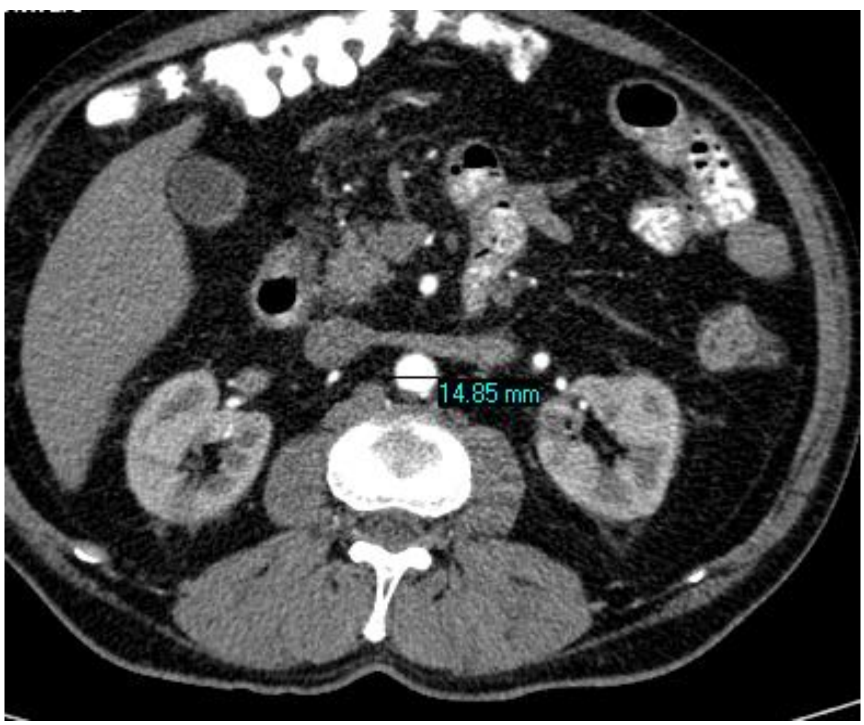
APPENDIX(B) IMAGES



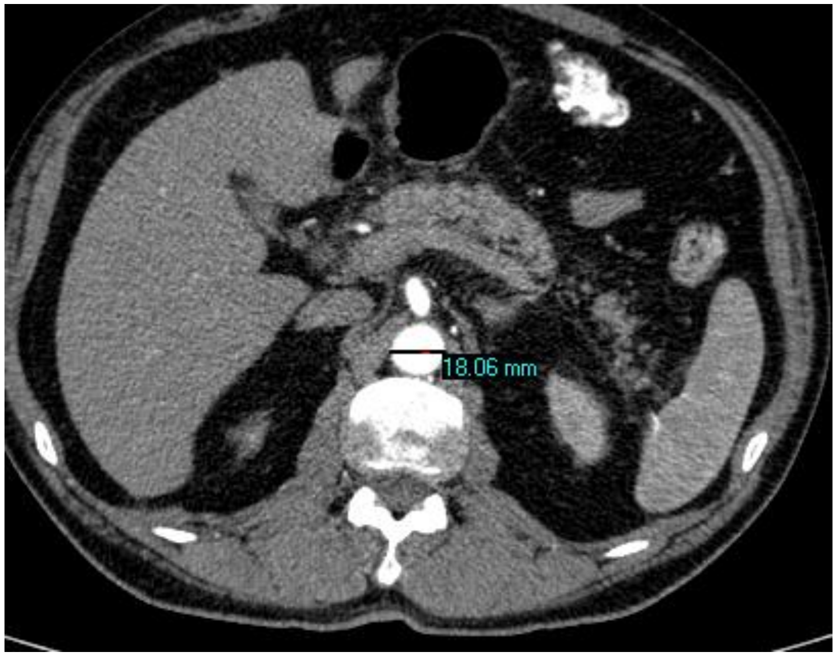
Image(1) Axial CT Scan image showing aortic diameters measurements of 71 years old male at L 3 level



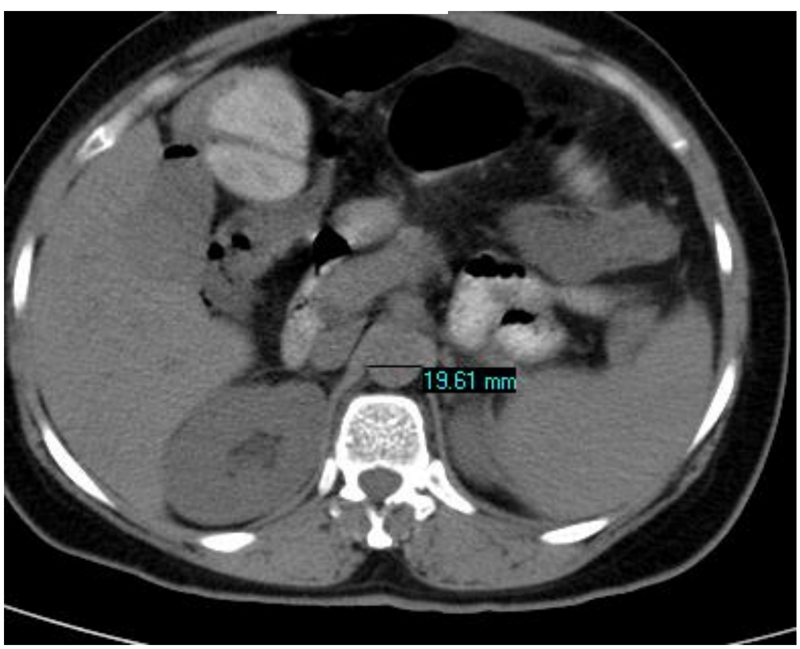
Image(2) Axial CT Scan image showing the aortic diameters measurements of 43 years old female at T12 level



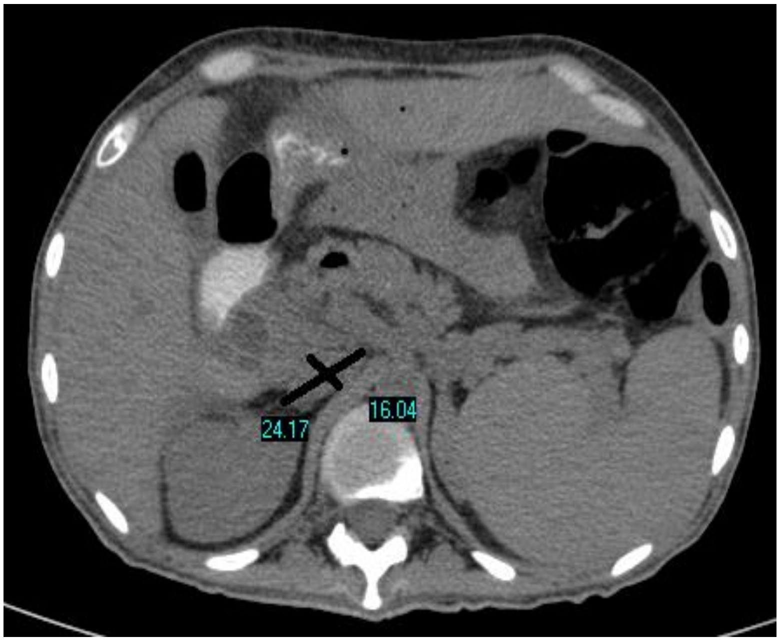
Image(3) Axial CT Scan image showing the aortic diameters measurements of 43 years old female at L3 level



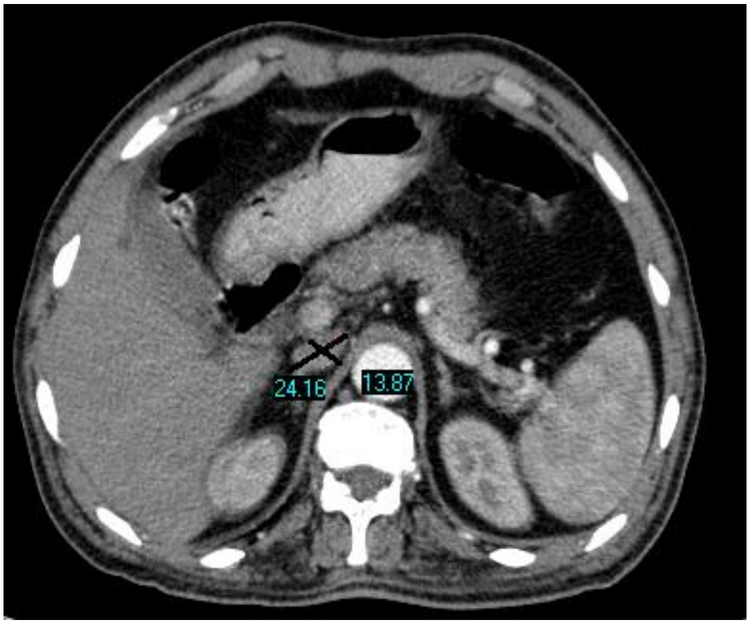
Image(4) Axial CT Scan image showing aortic diameters measurements of 71 years old male at T12 level



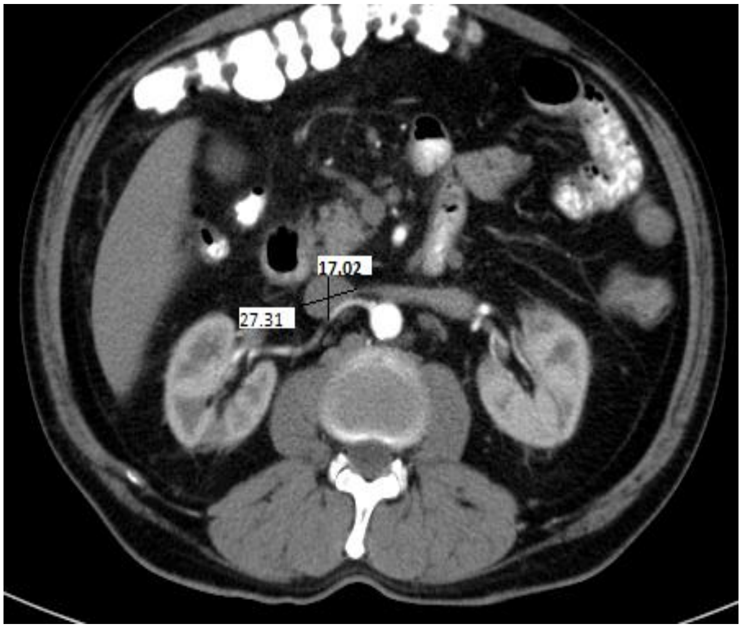
Image(5) Axial CT Scan image showing aortic diameters measurements of 47 years old male at T12 level



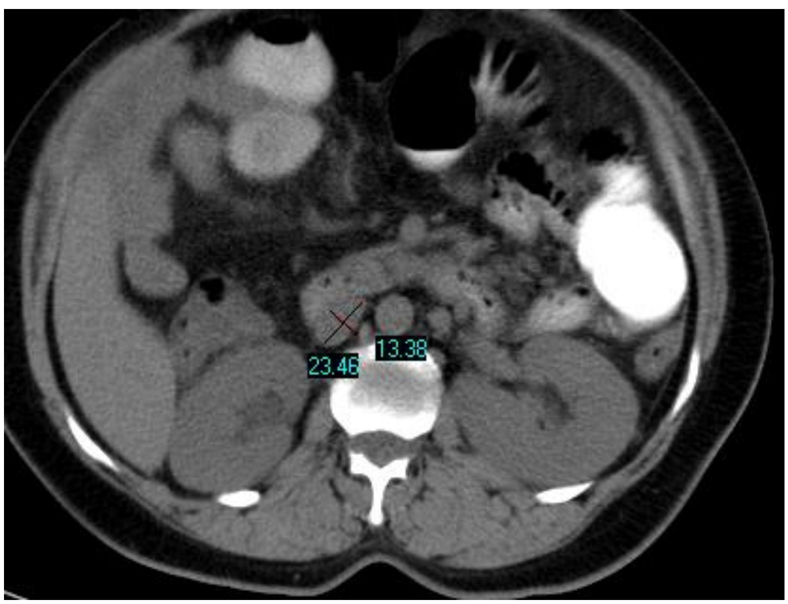
Image(6) Axial CT Scan image showing inferior vena cava diameters measurements of 25 years old male at T12 level



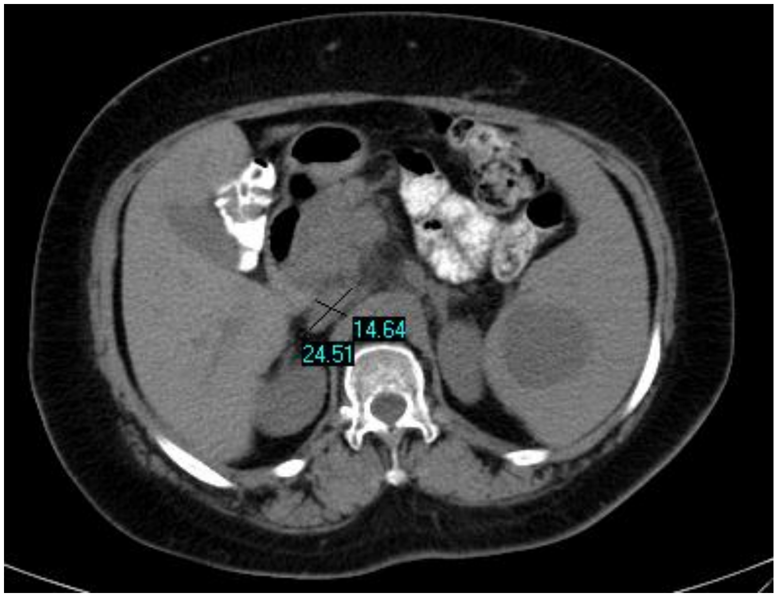
Image(7) Axial CT Scan image showing inferior vena cava diameters measurements of 52 years old male at T12 level



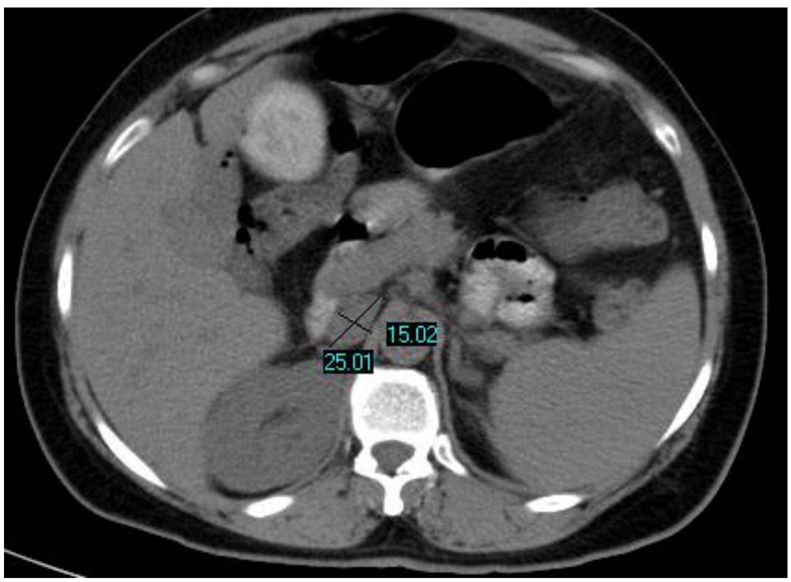
Image(8) Axial CT Scan image showing inferior vena cava diameters measurements of 73 years old male at T12 level



Image(9) Axial CT Scan image showing inferior vena cava diameters measurements of 40 years old female at L3 level



Image(10) Axial CT Scan image showing inferior vena cava diameters measurements of 57years old female at T12 level



Image(11) Axial CT Scan image showing inferior vena cava diameters measurements of 61 years old female at T12 level

APPENDIX(C) PUBLISHED PAPERS

- Albager S, Yousef M, Abdelaziz I, Salih M, Abdoh H. Normative Reference Values of Abdominal Aortic Diameters of Sudanese Using Computed Tomography. Nat Sci2018;16(10):37-43]. ISSN 1545-0740 (print);ISSN 2375-7167(online).http://www.sciencepub.net/nature.6.doi:10.7537/marsnsj161018.06.
- Albager S, Yousef M, Abdelaziz I, Salih M, Abdoh H, Evaluation of the Normal Inferior Vena Cava Diameters in Sudanese's By Multidetector Computed Tomography, IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS) e-ISSN:2278-3008, p-ISSN:2319-7676. Volume 13, Issue 4 Ver. V (Jul – Aug 2018), PP 29-34 www.iosrjournals.org