

Chapter one

Introduction

Chapter one

1.1 Introduction

Examination of the carotid wall gives every clinician an opportunity to evaluate subclinical alterations in wall structure that precede and predict future cardiovascular clinical events. B-mode ultrasonography is a noninvasive, safe, easily performed, reproducible, sensitive, relatively inexpensive and widely available method for detection of early stages of atherosclerosis and is accepted as one of the best methods for evaluation of arterial wall structure (Escardio, 2015).

High resolution B-mode ultrasonography enables quantitative measurement of the thickness of the intima-media layer of superficial large arteries non-invasively. In this observational study we assess the normal measurement of carotid artery intima-media thickness in Sudanese people and correlate it with age, gender and body mass index (BMI). Intima-media thickness (IMT), also called intimal medial thickness, is a measurement of the thickness of tunica-intima and tunica-media, the innermost two layers of the wall of an artery. The measurement is usually made by external ultrasound and occasionally by internal, invasive ultrasound catheters. Measurement of normal carotid artery intima-media thickness measurement at various non-modifiable factors are necessary for the detection of abnormal measurement in CAIMT, most was based on western population. To our knowledge there is no data on the CAIMT measurement in Sudanese people (Salonen, 1991).

In a previous study the range of intima media thickness is from 0.04cm-0.07cm in healthy Sudanese people (Mohammed, 2012).

Also another studies intima media thickness of carotid artery was measured by sonographic method in healthy India and Bangladesh. They found that the mean CAIMT for healthy subject including all age group was $(754.94 \pm 11.96 \text{ micron})$ (Jayanta et al, 2012).

1.2 Problem:

The normal intima media thickness generally stated in a book or journal that carried out their study in different nation with different body characteristic therefore adoption of their normal might not give a true result, therefore measurement depend on Sudanese and attributed to body characteristic will give a better dynamic value and help us in atherosclerosis prediction and how to management it early.

1.3 Objectives:

1.3.1 General objectives:

To Measurement of carotid artery intima-media thickness measurement in healthy Sudanese people in order to account for the variation in respect to international index.

1.3.2 Specific objectives:

- To measure the carotid artery intima-media thickness in various area of carotid artery.
- To correlate CAIMT measurement with gender ,age and body mass index.
- To compare between right and left CAIMT.
- To compare between the CAIMT measurement and the international index.

1.4 Overview of the study:

this study contain five chapters ,chapter one deal with the introduction ,chapter two include the theoretical background and the previous study ,chapter three detail the material and methods then chapter four presents the result and chapter five presents the discussion ,conclusion and recommendation.

Chapter
Two
Literature review

Chapter two

Literature review

2.1 Theoretical background

2.1.1 Anatomy

2.1.1.1 The carotid arteries

The common carotid artery is present on the left and right sides of the body. The left common carotid artery arises from the aortic arch in front of the trachea and passes across this to lie on its leftside in the root of the neck. The right common carotid arises from the brachiocephalic trunk behind the right sternoclavicular joint. From this point the vessels have a similar course (Stephanie et al, 2004).

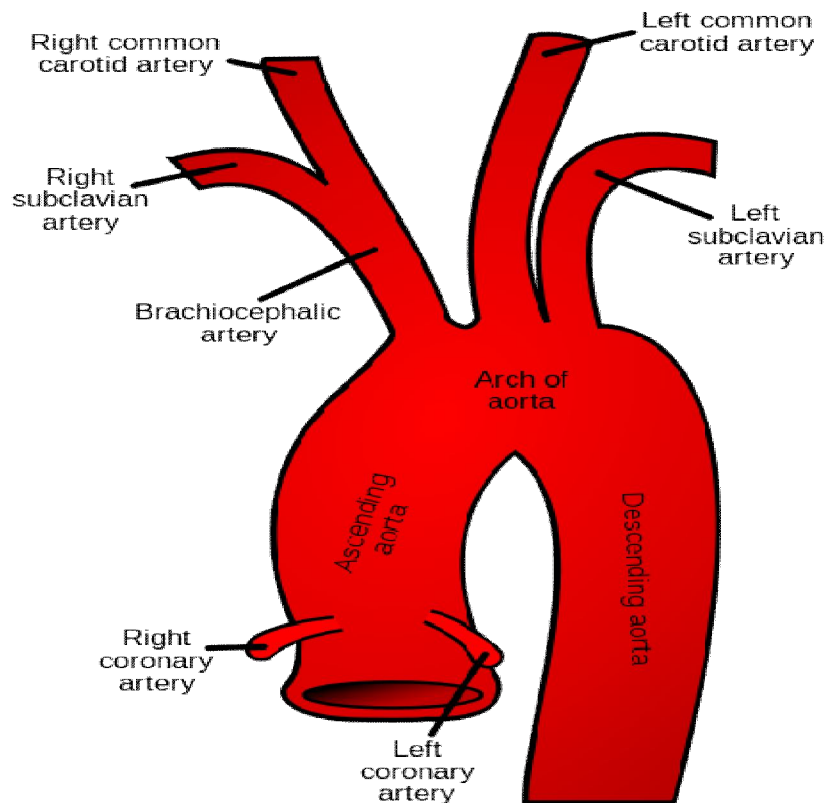


Figure (2.1): The common carotid artery arises directly from the aorta on the left, and as a branch of the brachiocephalic trunk on the right(Wikipedia ,2016)

The common carotid artery passes upwards and slightly laterally. It is accompanied by the internal jugular vein on its lateral aspect, with the vagus nerve lying posteriorly between the two. All three structures are invested in the carotid sheath. The common carotid artery bifurcates into internal and external branches at the level of C4. The external carotid artery passes anteriorly and curves slightly posteriorly as it ascends to enter the substance of the parotid gland, where it terminates by dividing into maxillary and superficial temporal arteries. The internal carotid artery continues superiorly from its origin to the base of the skull, maintaining the relationship of the common carotid artery with the internal jugular vein and vagus nerve in the carotid sheath. It has a localized dilatation at its origin called the carotid sinus. It has no branches in the neck (Stephanie et al, 2004).

2.1.1.2 Anatomical relations of the common carotid artery within the carotid sheath

The anatomical relations are as follows: Posteriorly is the sympathetic trunk. It is separated from the transverse processes of C4 to C6 by the prevertebral muscles. Medially are the trachea and esophagus, with the recurrent laryngeal nerve between them at first. At a higher level the larynx, pharynx and recurrent laryngeal nerve are medial, with the thyroid gland lying anteromedially. Anterolaterally the artery is covered by sternomastoid and the strap muscles at first. Above the level of the cricoid cartilage it is covered only by skin and fascia (Stephanie et al, 2004).

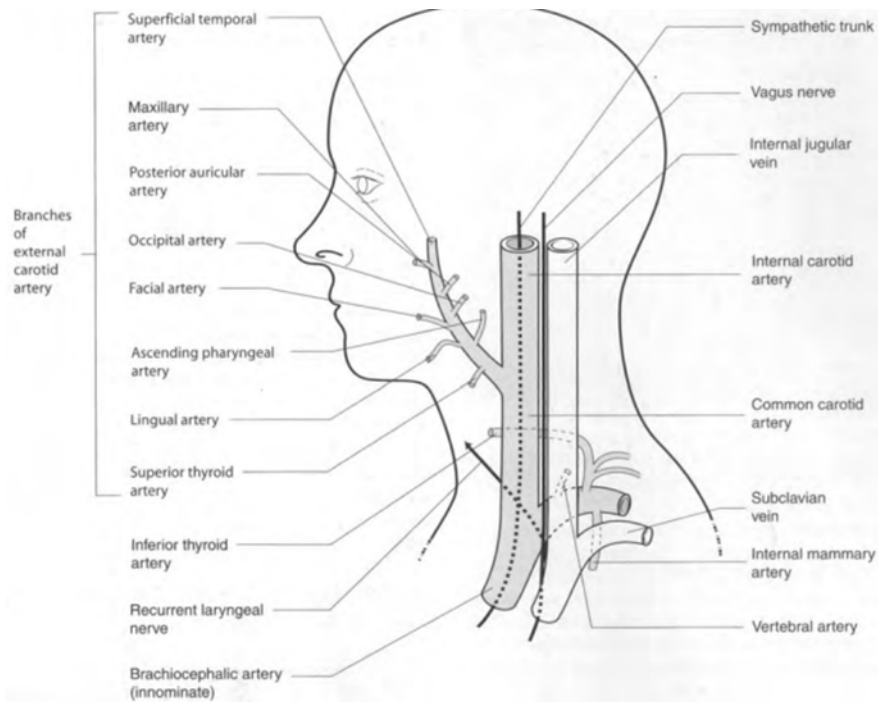


Figure (2.2): carotid artery in the neck (Stephanie et al, 2004).

2.1.1.3 Anatomical relations of the internal carotid artery within the carotid sheath

These are as follows: Posteriorly is the sympathetic trunk, prevertebral muscles and transverse processes of C1-C3. Medially is the lateral wall of the pharynx. Anterolaterally it is covered throughout its length by sternomastoid muscle. The styloid process and muscles separate it from the external carotid artery in its upper part. The artery becomes anterior to the internal jugular vein at the base of the skull and enters the carotid canal. The internal jugular vein and vagus nerve pass through the jugular foramen (Stephanie et al, 2004).

2.1.1.4 Anatomical relations of the external carotid artery

At its origin the internal carotid artery is lateral. As the external carotid artery ascends in the neck, it comes to lie in a more lateral plane than the internal carotid artery. Medially is the lateral wall of the pharynx at first. At a higher level it is separated from the internal carotid artery by the styloid process and its muscles. Anterolaterally is the anterior part of sternomastoid at first. It then

passes deep to the posterior belly of digastric and the stylohyoid muscles before entering the substance of the parotid gland (Stephanie et al, 2004).

2.1.1.1.5 Branches of the external carotid artery

The branches of the external carotid artery anastomose freely with each other and with their partners on the opposite side. There are also several points of anastomosis with the internal carotid circulation and with branches of the subclavian artery (Stephanie et al, 2004).

2.1.1.5.1 Superior thyroid artery

This branch arises anteriorly close to the origin and passes inferiorly to supply the thyroid gland, anastomosing with the inferior thyroid artery (Stephanie et al, 2004).

2.1.1.5.2 Ascending pharyngeal artery

This is a small branch that ascends deep to the external carotid on the lateral wall of the pharynx. It supplies the larynx and also gives rise to meningeal vessels, which pass through the foramen lacerum (Stephanie et al, 2004).

2.1.1.5.3 Lingual artery

This branch arises anteriorly and runs upwards and medially before curving downward and forward towards the hyoid bone in a characteristic loop. It then runs under muscles arising from that bone to supply the tongue and floor of the mouth. The lingual artery may arise with the facial artery as a common trunk, the lingulofacial trunk (Stephanie et al, 2004).

2.1.1.5.4 Facial artery

This vessel arises from the anterior surface of the external carotid artery above the level of the hyoid bone. It passes upward deep to the ramus of the mandible, grooving the posterior part of the submandibular gland. It then curves downward under the ramus of the mandible and hooks around it to supply the muscles and tissues of the face with a tortuous course. Its terminal branch

anastomoses with a branch of the ophthalmic artery. It also supplies the submandibular gland, soft palate and tonsil (Stephanie et al,2004).

2.1.1.5.5 Occipital artery

This arises posteriorly opposite the origin of the facial artery. It runs to the posterior part of the scalp, crossing the internal carotid and jugular vessels, and terminates in tortuous occipital branches supplying the scalp. It gives off muscular branches in the neck. The stylomastoid artery arises from the vessel in two-thirds of people, passing superiorly through the stylomastoid foramen to supply the middle and inner ear. Meningeal branches enter the skull through the jugular foramen and condylar canal and supply the dura of the posterior cranial fossa (Stephanie et al,2004).

2.1.1.5.6 Posterior auricular artery

This vessel arises posteriorly and ascends between the styloid process and parotid gland. It has muscular branches in the neck and supplies the parotid, pinna and scalp, anastomosing with branches of the occipital artery. In one-third of people it gives rise to the stylomastoid artery (Stephanie et al,2004).

2.1.1.5.7 Superficial temporal artery

This is the smaller of the two terminal branches. It arises within the parotid gland behind the neck of the mandible. It ascends over the posterior root of the zygomatic arch, dividing into tortuous anterior and posterior branches 5 cm above that point, and supplies the scalp and pericranium. It also gives branches to the parotid, temporomandibular joint, facial structures and outer ear. One of its branches anastomoses with the lacrimal and palpebral branches of the ophthalmic artery in yet another communication between internal and external systems (Stephanie et al,2004).

2.1.1.5.8 Maxillary artery

This is the larger of the two terminal branches. It arises within the parotid gland behind the neck of the mandible. It supplies the upper and lower jaws, muscles of mastication, palate, nose and cranial dura mater. It is divided into three parts by the lateral pterygoid muscle. Its first (mandibular) part passes deep to the neck of

the mandible. Its second (pterygoid) part runs forward and upward between the temporalis and the lower head of lateral pterygoid. Its third (pterygopalatine) part passes between the upper and lower heads of lateral pterygoid through the pterygomaxillary fissure to enter the pterygopalatine fossa. The maxillary artery has several important branches. Those of the first part are:

The middle meningeal artery enters the skull through the foramen spinosum and supplies the dura mater and bone of the cranium. This is a relatively straight artery compared with the tortuous overlying superficial temporal artery.

The accessory meningeal artery may arise from this part or from the middle meningeal artery. It passes through the foramen oval to supply the dura mater and bone. The inferior dental artery descends to supply the structures of the lower jaw. The branches of the second part are the branches to the temporalis, pterygoid and masseter muscles (Stephanie et al, 2004).

The branches of the third part are:

The superior dental artery arises just as the artery enters the pterygopalatine fossa and supplies the structures of the upper jaw.

The infraorbital artery enters the orbital cavity through the infraorbital fissure, running along the infraorbital groove to supply the contents of the orbit (Stephanie et al, 2004).

The greater palatine artery descends from the pterygopalatine fossa through the palatine canal and through the greater palatine foramen of the hard palate. It supplies the tonsil, palate, gums and mucous membrane of the roof of the mouth (Stephanie et al, 2004).

The sphenopalatine artery is the terminal part of the maxillary artery. It passes from the fossa through the sphenopalatine foramen into the cavity of the nose, branching to supply the nasal structures and the sinuses (Stephanie et al, 2004).

2.1.1.

2.1.1.7 Variation

2.1.1.7.1 Origin

The right common carotid may arise above the level of the upper border of the sternoclavicular joint this variation occurs in about 12 percent of cases. In other cases the artery on the right side may arise as a separate branch from the arch of the aorta, or in conjunction with the left carotid. The left common carotid varies in its origin more than the right. In the majority of abnormal cases it arises with the brachiocephalic trunk; if that artery is absent, the two carotids arise usually by a single trunk. It is rarely joined with the left subclavian artery, except in cases of transposition of the aortic arch (Wikipedia, 2016).

2.1.1.7.2 Point of division

In the majority of abnormal cases, the bifurcation occurs higher than usual, the artery dividing opposite or even above the hyoid bone; more rarely, it occurs below, opposite the middle of the larynx, or the lower border of the cricoid cartilage. In at least one reported case, the artery was only 4 cm in length and divided at the root of the neck. Very rarely, the common carotid artery ascends in the neck without any subdivision, either the external or the internal carotid being absent; and in a few cases the common carotid has itself been found to be absent, the external and internal carotids arising directly from the arch of the aorta. This peculiarity existed on both sides in some instances, on one side in others (Wikipedia, 2016).

2.1.1.7.3 Occasional branches

The common carotid usually gives off no branch previous to its bifurcation, but it occasionally gives origin to the superior thyroid artery or its laryngeal branch, the ascending pharyngeal artery, the inferior thyroid artery, or, more rarely, the vertebral artery (Wikipedia, 2016).

2.1.2 Physiology

The arterial and venous systems are often thought of as a series of tubes that transport blood to and from organs and tissues. In reality, blood vessels are highly complex structures that respond to nervous stimulation and interact with chemicals in the blood stream to regulate the flow of blood throughout the body. Changes in cardiac output and the tone of the smooth muscle cells in the arterial walls are crucial factors that affect blood flow. The structure of a blood vessel wall varies considerably depending on its position within the vascular system. Arteries and veins are composed of three layers of tissue, with veins having thinner walls than arteries. The outer layer is called the adventitia and is predominantly composed of connective tissue with collagen and elastin. The middle layer, the media, is the thickest layer and is composed of smooth muscle fibers and elastic tissue. The intima is the inner layer and consists of a thin layer of epithelium overlying an elastic membrane. The capillaries, by contrast, consist of a single layer of endothelium, which allows for the exchange of molecules through the capillary wall. It is possible to image the structure of larger vessel walls using ultrasound and to identify the early stages of arterial disease, such as intimal thickening (Mitchil,2004).

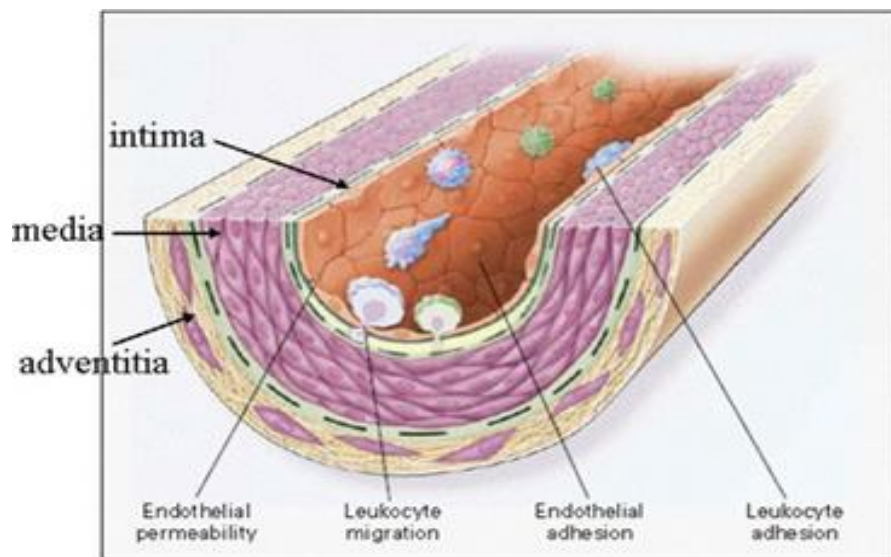


Figure (2.4) structure of arterial wall (nanobme ,2016)

The arterial tree consists of elastic arteries, muscular arteries and arterioles. The aorta and subclavian arteries are examples of elastic or conducting arteries and

contain elastic fibers and a large amount of collagen fibers to limit the degree of stretch. Elastic arteries function as a pressure reservoir, as the elastic tissue in the vessel wall is able to absorb a proportion of the large amount of energy generated by the heart during systole. This maintains the end diastolic pressure and decreases the load on the left side of the heart. Muscular or distributing arteries, such as the radial artery, contain a large proportion of smooth muscle cells in the media. These arteries are innervated by nerves and can dilate or constrict. The muscular arteries are responsible for regional distribution of blood flow. Arterioles are the smallest arteries, and their media is composed almost entirely of smooth muscle cells. Arterioles have an important role in controlling blood pressure and flow, and they can constrict or dilate after sympathetic nerve or chemical stimulation. The arterioles distribute blood to specific capillary beds and can dilate or constrict selectively around the body depending on the requirements of organs or tissues (Mitchil,2004).

2.1.3.Pathology:

2.1.3.1 The atherosclerosis

Carotid atherosclerosis is a chronic disease of the carotid arteries, with potentially-life threatening acute complications, particularly stroke. Atheroma can become clinically-evident either by the growth of the lesion within the vascular wall, until blood flow through the lumen is obstructed, and/or by provoking thrombo-emboli, with or without blood flow obstruction, by exposing the bloodstream to thrombogenic substances within the lesion (Schaller,2005).

In response to injury, inflammation may moderate the healing of the vessel wall, as in other tissues (Schaller, 2005).

In atherogenesis, the vascular healing process goes awry. Atheromata are made by insudates of inflammatory cells and inflammants, particularly lipids, and, in advanced lesions, by the hyperplasia of vascular tissue. Inflammatory cells and molecules are drawn into atherosclerotic lesions both through the intima and outer layers of the vessel wall. The internal microenvironment of the atheroma is a haywire network of cell signaling and a poisoned atmosphere, with oxidants which derange inflammatory and endothelial cells. Vascular inflammation can perpetuate itself, by stimulating the malformation of new, incompetent vasa vasorum which spill inflammatory cells and substances into the lesion. If the vessel wall fails to heal, after decades, then the endothelium loses its capacity for further self-repair; such endothelial senescence opens the intimal door to tissue inflammants. Yet all carotid atheromata become clot-provoking lesions. Some resolve into silent fibrotic or calcific scars. The incidence and fate of nascent atheromata are determined at all levels, even beyond the plaque itself, reflecting a profile of the whole patient, from genetics, cellular events, and blood biochemistry to patient diet and behavior. For example, the ‘vulnerable patient’ and the patient who is less or not vulnerable to a stroke may, theoretically, have identical plaques, but one patient is ‘vulnerable’ because his or her blood has a composition with a greater predisposition to clotting, when exposed thrombogenic factors within the plaque. As such, other non-imaging clinical tests, particularly serum analyses, will play a great role, in risk-stratifying patients with carotid atherosclerosis. The character of the plaque is a key to distinguishing the vulnerable patient, as carotid symptoms and events are associated with specific plaque characteristics. The concentration of inflammation in the cap and rupture of malformed vessels frequently mark the ‘vulnerable plaque’. Noninvasive imaging has begun to provide physicians with the ability to

detect and measure the plaque features which precipitate carotid stroke, on anatomical and biochemical levels, as subsequent chapters will discuss (Schaller,2005).

2.1.3.2 Carotid plaque pathology:

2.1.3.2.1 Early lesions

The normal carotid artery consists of three layers, the intima, media, and adventitia. The intima is the layer adjacent to the lumen and in humans consists of smooth muscle cells, proteoglycan-rich extracellular matrix, and a layer of endothelial cells lining the lumen surface. The next layer, the media, is separated from the intima by the internal elastic lamina and is composed of multiple bands of elastin interspersed with smooth muscle cells. Between the media and adventitia is another thick band of elastic called the external elastic lamina. The adventitia covers the outer surface of the vessel and provides thin strands of connective tissue to anchor the artery to surrounding structures. Under normal conditions the adventitia contains the vasovasorum, the small blood vessels that supply blood to the artery wall, smooth muscle cells and macrophages. Initiation of the carotid atherosclerotic plaque begins with adaptive intimal thickening and development of fatty streaks in the intima. These nascent lesions consist of lipid-containing macrophages called foam cells, smooth muscle cells, and lymphocytes. Lipid, in early lesions is distributed in the extracellular matrix with foci of fat-filled macrophages and smooth muscle cells. Such lesions correspond to the type I and II lesions in coronary arteries (Schaller,2005).

In general, the first lesions that are clearly identifiable by non-invasive imaging are the type III lesions lesions that have extracellular lipid pools below layers of foam cells. From an imaging perspective, these lesions are of most interest for investigating the natural history of the disease, or the therapeutic response of early lesions. Imaging may also serve as a screening tool to identify appropriate subjects for aggressive, early therapy (Schaller,2005).

2.1.3.2.2 Advanced lesions:

Type IV, V, and VI lesions are characterized by the appearance of a fibrous cap separating the lipid/necrotic core of the plaque from the lumen. Type IV and V lesions are distinguished by the transition of the fibrous cap from one consisting primarily of proteoglycan and smooth muscle cells into a thicker collagen-rich cap in the latter type. Type VI lesions are characterized by disruption of the plaque leading to fibrous cap rupture, intraplaque hemorrhage, and/or luminal thrombi. Type VII lesions are predominately calcified, and Type VIII lesions consist of thickened, reparative fibrous connective tissue with an absence of necrotic cores or calcifications. Lesions Type IV thru VI are of considerable importance in imaging with the goal of identifying them prior to clinical events (Schaller, 2005).

2.1.3.3 Non atheromatous carotid artery diseases:

Non atheromatous extracranial carotid diseases include aneurysms, carotid body tumors and dissection, but all are relatively rare. Patients may have a pulsatile swelling in the neck, which can be investigated with ultrasound to rule out an aneurysm. The carotid arteries should be scanned along their length, especially in the area of the suspected swelling, and the cross-sectional diameter measured. Any unusual appearances relating to the arteries should be reported. In many cases, the 'pulsatile swelling' is due to a superficial brachiocephalic bifurcation or carotid bifurcation, often associated with tortuous vessels, leading to the vessel being easily palpated. Another possible cause of a pulsatile swelling is the presence of a carotid body tumor. The carotid body is a small structure within the vessel wall, situated at the carotid bifurcation, and is responsible for detecting blood gases and pH. As a carotid body tumor grows, it causes the ICA and ECA to be splayed apart, and small tortuous vessels can often be seen within the tumor with color flow imaging. However, further investigation is required to confirm any ultrasound findings. Carotid artery wall dissection, which can be due to trauma, can create a false lumen within the carotid arteries. This may remain patent and be seen as a second flow lumen on color flow imaging. Alternatively, the false lumen may occlude, causing a reduction in the residual vessel lumen or possibly a complete occlusion of the vessel. An intimal flap may be seen on the image as a fine line within the lumen that may move due to the pulsatile blood flow; however, it may be difficult to image (Schaller, 2005).

2.1.4 Ultrasound physics, types and instrumentation

2.1.4.1 ultrasound physics

2.1.4.1.1 Definition

Ultrasound is a high frequency sound, exceeding the upper limit of human hearing – 20.000 cycles per second (20 KHz). Knowledge of basic ultrasound physics is essential for understanding image formation, echo machine settings optimization, advantages and limitations of the technique (scardio 2010).

2.1.4.1.2 General principles

Sound is a longitudinal mechanical wave transmitted through the medium by local displacement of particles within the medium. The displacement of the particle from their equilibrium position produces changes in the medium density (areas of compression/rarefaction). Ultrasound is defined as sound with frequencies above the human audible range between 20 Hz and 20.000 Hz. Diagnostic medical ultrasound uses frequencies from 1.000.000 to 40.000.000 Hz = 1 to 40 megahertz (MHz). The ultrasound wave is often graphically displayed as a sine wave in which the peaks and nadirs represent the areas of compression and rarefaction, respectively (scardio 2010).

2.1.4.1.3 Properties of sound waves

Sound waves are characterized by the following parameters:

Frequency - The frequency of the sound wave is the number of oscillations per unit of time

Amplitude - The magnitude of the pressure changes, i.e. the difference between the pressure peaks and pressure nadirs (The strength of the wave, loudness of the sound). Amplitude is measured in decibels, a logarithmic unit that relates acoustic pressure to some reference value. The primary advantage of using a logarithmic scale to display amplitude is that a very wide range of values can be accommodated and weak signals can be displayed along side much stronger signals. There are some other logarithmic variables used in clinical practice (scardio 2010).

Since sound waves are mechanical waves, they are further characterized by the following additional parameters which depend on the medium in which the wave propagates:

Wavelength - The length of one period of the wave; e.g. from one pressure peak to the next. The wavelength depends on the frequency and the medium in which the sound wave propagates.

Velocity - The speed at which sound propagates through a given medium. Velocity through a given medium is inversely related to the density and directly related to stiffness of that medium. Ultrasound waves travel faster through a stiff medium, such as bone. In echocardiography, the velocity of sound is assumed to be approximately 1,540 m/sec (or 1.54 m/msec). Sound waves travel through the air with speed of 330 m/s (scardio 2010).

The wave equation: product of wavelength (λ) and frequency (f) represents the velocity (c) of the sound wave.

$$c = \lambda f$$

Velocity through soft tissue is assumed to be constant (1540 m/s) hence there is an inverse relationship between frequency and wavelength(scario 2010).

2.1.4.1.4 Interaction between ultrasound and tissue

2.1.4.1.4.1 Attenuation

Attenuation is a measure of the rate at which the intensity of the ultrasound beam diminishes as it penetrates the tissue. Attenuation always increases with depth and the higher the frequency of ultrasound is, the more rapidly it will attenuate.

2.1.4.1.4.2 Reflection, refraction and scattering

When the ultrasound beam crosses a boundary between two media some of the ultrasound energy is reflected at the interface and some is transmitted through the interface. The transmitted portion of the energy is refracted, depending on the angle of incidence and differences in acoustic impedance (resistance at the interface) between the tissues. The acoustic impedance of a medium is the product of speed of sound in the medium and the density of the medium. Ultrasound images are created by reflection of the ultrasound beam. The amount of ultrasound reflected

depends upon the relative changes in the acoustic impedance between the two media or tissues. Depending on size targets can reflect directly back to the transmitter in an angle dependent fashion (specular echoes) or scatter the ultrasound in more directions (scattered echoes). Targets that are small relative to the wavelength of the transmitted ultrasound produce scattering and such objects that reflect energy concentrically are called Rayleigh scatters (for example scatters from moving red blood cells forms the basis for Doppler echocardiography). Scattered echoes contribute to the visualization of surfaces that are parallel to the ultrasonic beam and also provide the substrate for visualizing the texture of gray-scale images (basis for speck tracking imaging (scardio 2010).)

2.1.4.2 Types of Ultrasound Imaging

The choice of which type of image to use depends on the goals for a particular test, the phenomena being investigated and what equipment is available (scardio 2010).

2.1.4.2.1 Two Dimension Ultrasound

The most common and type of ultrasound picture is a series of flat, two-dimensional cross section images of the scanned tissue. Referred to simply as 2d ultrasound, this mode of scanning is still standard for many diagnostic and obstetric situations after a half-century of use (scardio 2010).

2.1.4.2.2 Three Dimension Ultrasound

In recent years, 2d ultrasound images have also been projected into three-dimensional representations. This is achieved by scanning tissue cross sections at many different angles and reconstructing the data received into a three-dimensional image. A common use for 3d ultrasound pictures is to provide a more complete and realistic image of a developing fetus (scardio 2010).

2.1.4.2.3 Four Dimension Ultrasound Imaging

By updating 3d ultrasound images in rapid succession, sonographers can also create 4d ultrasound pictures. In the 4d ultrasound, the fourth dimension, time, adds movement and creates the most realistic representation of all. In some cases, 3d and 4d ultrasound pictures may reveal abnormalities not readily seen using 2d ultrasound. For expectant mothers and family members, the ability to see realistic

images of an unborn baby in the uterus can be rewarding and heartwarming although the medical community in general cautions against performing ultrasound tests solely for this purpose (scardio 2010).

2.1.4.2.4 Doppler Ultrasound

Evaluating blood flow as it moves through blood vessels is a common component of many of the types of ultrasound. While traditional 2d ultrasound and its three-dimensional offshoot show internal tissues and structures, a different kind of ultrasound is required to evaluate blood flow and pressure within a blood vessel. A Doppler ultrasound analysis bounces high-frequency sound waves off blood cells in motion and records changes in frequency of the sound waves as they echo back to the transducer probe. It then converts this data into a visual representation of how fast and in what direction blood is flowing. Doppler ultrasound is an indispensable diagnostic tool in all areas of ultrasound testing and is preferable in many cases to X-ray angiography because it does not require injecting the patient with contrasting dye (scardio 2010).

Three types of Doppler ultrasound are currently in use in addition to routine gray scale imaging. Of these, color Doppler uses a wide choice of colors to visualize blood flow measurements and embed them within a conventional 2d ultrasound of tissues and structures. This provides a more pronounced representation of blood flow speed and direction than is the case with traditional gray scale images. Power Doppler provides color imaging of more sensitive and detailed blood flow measurements than regular color Doppler does. It can sometimes even achieve images in situations not accessible with color Doppler. However, power Doppler is limited in another way because it cannot indicate the direction in which blood is flowing. Like conventional and color Doppler, spectral Doppler can scan to determine both blood flow and direction but displays this data in graphic form rather than with gray scale or color images (scardio 2010).

2.1.3 Ultrasound imaging of carotid artery

2.1.3.1 Objectives and preparation

The purpose of the carotid scan is to identify the extent of any atheroma within the CCA and extracranial ICA and ECA and to determine the degree of narrowing of the vessels. The examination should also demonstrate the presence and direction of flow in the vertebral arteries. No specific preparation is required, but the patient must be capable of lying or sitting still during the examination. The optimal position for scanning the carotid arteries is with the sonographer sitting behind the patient's head. This allows easy access to the neck and enables the operator to rest the arm on the examination table while performing the scan (Fig. 2.5). Alternatively the sonographer can sit by the side of the patient while resting the arm on the patient's upper chest. The patient should lie supine on the couch with the head resting on a pillow. The neck should be extended and the head turned in the opposite direction to the side being examined. If the patient has difficulty in breathing or has back problems it may be necessary to sit the patient in a more upright position. If the patient is in a wheelchair (e.g., following a disabling stroke), it may be easier to do the scan in the wheelchair with the head resting on a pillow for support, preventing unnecessary movement of the patient (Hartshorne et al,2005).

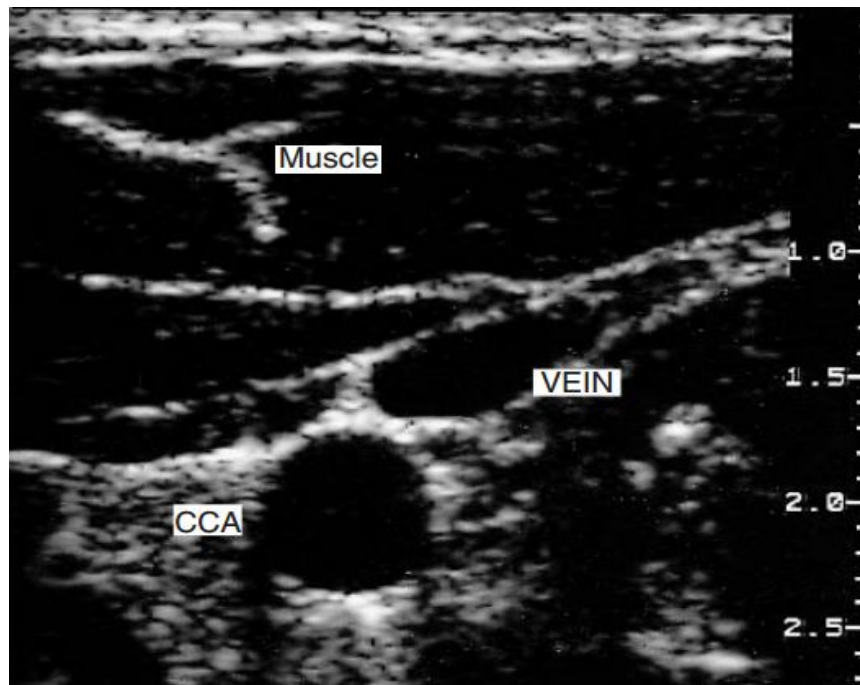
The examination can be performed with a medium- to high-frequency (e.g., broadband 4–7 or 5–12 MHz) flat linear array transducer. The higher the frequency, the better the resolution of the vessel wall structure; however, in some cases the carotid bifurcation lies deep in the neck, requiring a lower frequency transducer for visualization. Bloodflow velocities detected in the majority of normal and diseased carotid arteries are reasonably high, so the scanner should be configured to visualize high-velocity pulsatile flow. Most ultrasound systems have examination presets available that are suitable for the majority of carotid examinations, but it may be necessary to alter these to enable the detection of low-velocity flow when differentiating carotid artery occlusion from a subtotal occlusion. A small spectral Doppler sample volume is usually used to interrogate the carotid arteries, as it allows for more selective investigation of areas of velocity increase or flow disturbance (Hartshorne et al,2005).

2.1.3.2 Technique

The carotid arteries are best visualized through the sternocleidomastoid muscle, which provides a good ultrasonic window, and this is done using a lateral rather than an anterior approach. The procedure is as follows:

1. Using B-mode imaging only, the CCA should be visualized in transverse section (Fig. 2.6A), starting at the base of the neck. On the right side, it is usually possible to visualize the distal brachiocephalic artery and the origin of the CCA and subclavian arteries. On the left side, the origin of the CCA cannot be visualized as it lies too deep in the chest. The CCA should be scanned along its length, in transverse section, up to the bifurcation, and along the ICA and ECA (Fig. 2.6B) as high up the neck as can be seen. This allows the sonographer to ascertain the level and orientation of the carotid bifurcation and also gives the first indications of the presence and location of any arterial disease. The jugular vein lies over the CCA (Fig. 2.6A) and is usually easily compressed. However, it is important not to apply too much transducer pressure when scanning the carotid arteries as there is a possibility of dislodging an embolus from the vessel wall (Hartshorne et al, 2005).

(A)



(B)

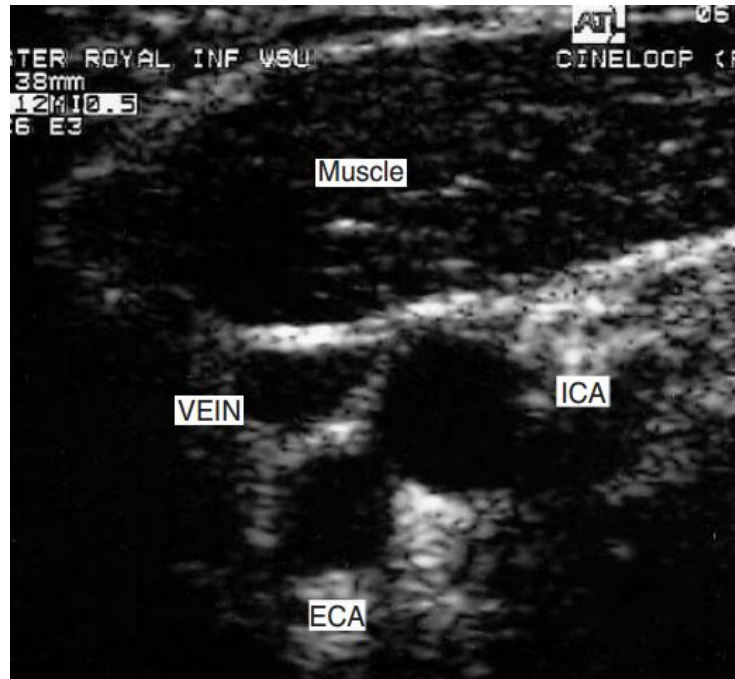


Figure (2.6): Transverse B-mode images. A: CCA and jugular vein. B: The ICA and ECA just above the carotid bifurcation (Hartshorne et al,2005).

2.The CCA is now visualized in longitudinal section using B-mode imaging, starting at the base of the neck. A longitudinal image of the CCA can be easily obtained by imaging the CCA in transverse section and then, keeping the CCA in the center of the image, rotating the probe so the CCA first appears as an ellipse and finally can be seen in longitudinal section. Prior knowledge of the orientation of the ICA and ECA (Figure 2.5). The optimal position for scanning the carotid arteries (Hartshorne et al, 2005).

Gained from transverse imaging is helpful for locating the correct longitudinal imaging plane to view the bifurcation. It is necessary to use a range of longitudinal scan planes to visualize the carotid arteries, especially at the bifurcation (Fig. 2.7). Typically, the ICA lies posterolateral or lateral to the ECA and is usually the larger of the two vessels. In a small percentage of cases, the bifurcation will appear as a tuning fork arrangement, but in the majority of cases the ECA and ICA will not be

seen in the same plane and will have to be imaged individually. This is achieved by keeping the lower portion of the probe face over the CCA and slowly rotating the upper portion through a small angle to image first the ICA and then the ECA, or vice versa. Only small probe movements are required when imaging the ICA and ECA, as the vessels usually lie close together (Hartshorne et al,2005).



Figure (2.7): Longitudinal scan planes used to visualize the carotid arteries. A: Posterior. B: Lateral. C: Anterior (Hartshorne et al,2005).

3. Having located the three vessels and observed any evidence of disease in the B-mode image, color flow imaging can be used to investigate the flow from the proximal CCA up into the ICA and ECA. Identification of ECA branches (either on B-mode or color imaging) serves as a further indication as to which vessel is the ECA, as the ICA has no branches below the jaw (Fig.2.8). Color flow imaging can provide evidence of disease, such as velocity changes due to stenosis, areas of filling defects due to the presence of atheroma and the absence of flow due to occlusion. Diagnosis should not be made based on the color flow imaging alone, but it greatly aids the sonographer in selecting areas that require close investigation with the spectral Doppler (Hartshorne et al,2005).

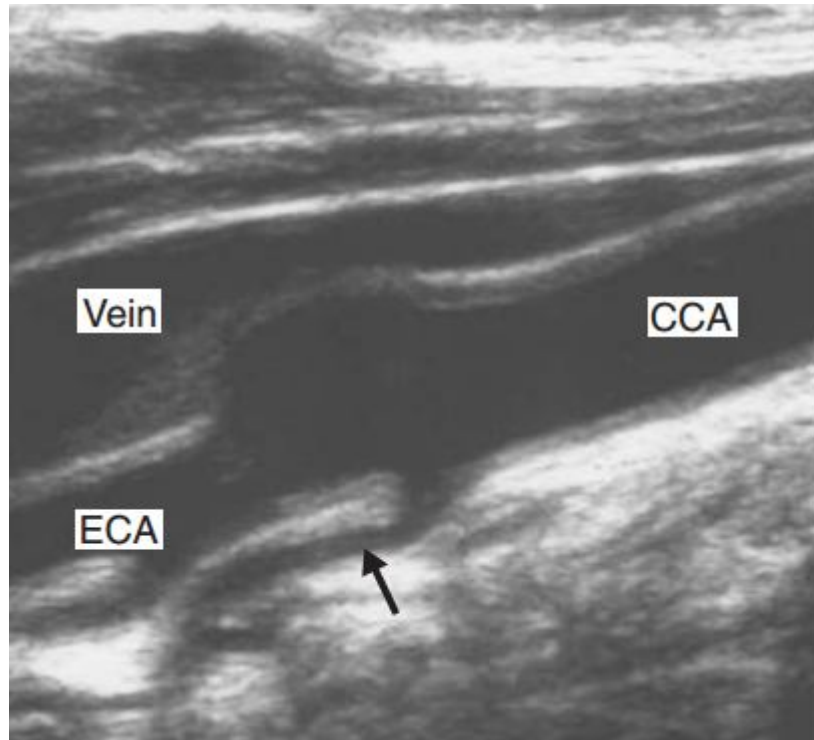


Figure (2.8):B-mode image of the ECA showing the superior thyroid branch (arrow)(Hartshorne et al,2005).

2.1.3.3 Normal appearance

The normal vessel walls will often appear as a double-layer structure when imaged in longitudinal section (Fig. 2.9), especially if a high frequency transducer is used. This represents the intima-media layer and adventitia and is most clearly seen on the posterior wall in the CCA, when the vessel lies at right angles to the ultrasound beam. The normal thickness of the intima-media layer is of the order of 0.5 mm (Pignoli et al 1986). A normal vessel lumen should appear anechoic, but it is possible for the sonographer to remove echoes from within the lumen by reducing the time gain compensation so careful use of the imaging controls is important. Reverberation artifacts can also give the appearance of structures within the lumen. Occasionally, it is difficult to obtain adequate B-mode images of the bifurcation. In this case, color flow imaging may help locate the vessels and enable spectral Doppler measurements to be made (Hartshorne et al,2005).

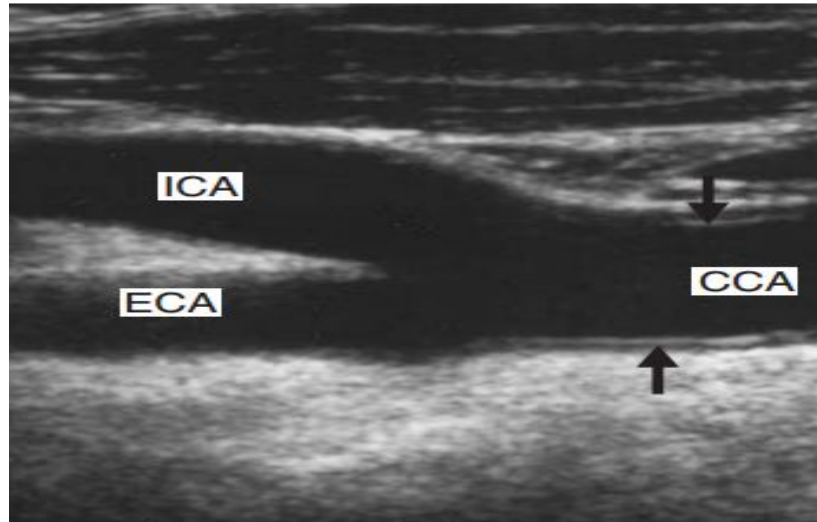


Figure (2.9): Longitudinal B-mode image of the carotid bifurcation with the ICA and ECA seen in the same plane. The arrows mark where the intima-media layer can be seen (Hartshorne et al, 2005).

2.1.4 Intima-media thickness measurement (IMT)

2.1.4.1 Definition

IMT is defined as a double-line pattern visualised by echo 2D on both walls of the common carotid artery (CCA) in a longitudinal view. Two parallel lines (leading edges of two anatomical boundaries) form it: lumen-intima and media-adventitia interfaces (Escardio,2015).

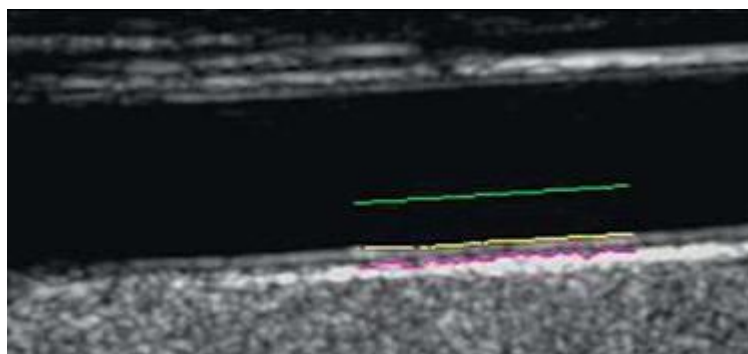


Figure (2.10): Intima-media thickness (IMT) definition – IMT is measured as the distance between lumen-intima (yellow line) and media-adventitia (pink line) interfaces (Escardio,2015).

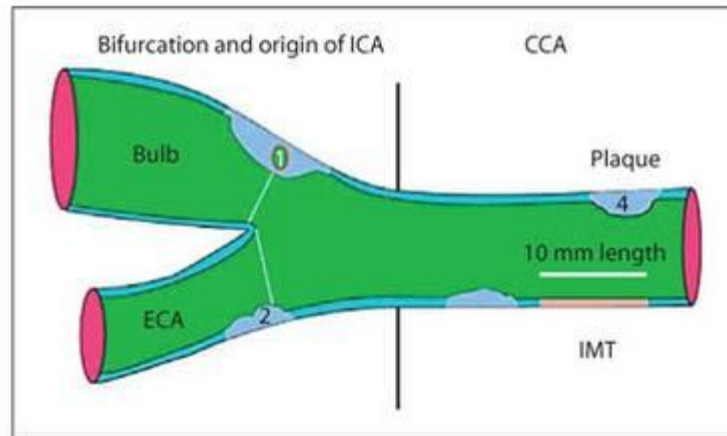


Figure (2.11): Proper location for IMT measurement(Escardio,2015).

2.1.4.2 Challenges and current recommendations for IMT measurement

One of the main problems in interpreting IMT results from clinical trials is the differences in measurement methodology. These discrepancies can refer to either one or more of these parameters: the precise definition of the investigated carotid segment, the use of mean or maximal IMT, the measurement of near and far wall or only far wall IMT, the insonation at a single or different angles, employing manual tracking or an automated software, including carotid plaques or not and uni- or bilateral measurements(10-12).To avoid this problem standards for IMT measurement have been developed (Escardio,2015).

2.1.4.3 What to include in observation

Inclusion of carotid bifurcation in the image plane serving as a landmark to provide accurate serial measurements.IMT measurement along a segment of the artery free of atherosclerotic plaque with clearly defined lumen-intima and media-adventitia interfaces (Figure 2.10) 10-mm-in-length straight arterial segment is required. IMT measured in triplicate The far wall of the common carotid artery is preferred (13) (Escardio, 2015).

2.1.4.4 How to conduct observation

Arterial wall segments assessed longitudinally and perpendicular to the

ultrasound beam. Lateral probe position (best resolution for image acquisition for IMT measurement) is preferred. Insonation from multiple angles is not recommended. Horizontal position of the artery in the image sector to optimise the visualization of lumen-intima interface. IMT measurement at a distance of at least 5 mm below the distal end of CCA (IMT could also be measured at the carotid bifurcation and internal carotid artery bulb, but the values should be given separately) (Escardio,2015).

2.1.4.5 Data treatment

IMT values averaged. Mean IMT values are preferred (more reproducible than maximal values; maximal IMT may reflect more advanced stages with focal thickening or plaque or represent a sampling error). Increased reproducibility of IMT measurement when values from right and left CCA are combined (14); most of the data points for higher values on the left side (15) (Escardio,2015).

2.1.4.7 Normal versus abnormal values

Normal IMT values and reference ranges are age- and sex-dependent there is a significant steady increase in IMT with advancing age in all carotid segments (16-18) and significantly higher IMT values in men than in women (Table 2.1)(Escardio,2015).

Which IMT values should be considered as abnormal, however, is a controversial topic. The relationship of IMT with cardiovascular risk is continuous and dichotomising this parameter (i.e. determining a threshold IMT value) would be incorrect. Nevertheless it should be noted that in the latest ESH/ESC hypertension guidelines (2013) carotid IMT > 0.9 mm has been re-confirmed as a marker of asymptomatic organ damage, although it has been proven that in middle-aged and elderly patients the threshold values indicating high cardiovascular risk are higher (19,20). The American Society of Echography (ASE) Task force recommends that IMT \geq 75th percentile is considered high and indicative of increased cardiovascular risk. Values from the 25th to the 75th percentile are considered average and indicative of unchanged cardiovascular risk. Values \leq 25th percentile are considered low and indicate lower than the expected cardiovascular risk. There are also more conservative cut-off suggestions: IMT values \geq age-adjusted

97.5th percentile to be defined as abnormal (and predictive of increased vascular risk). The reason for that is that in a large cross-sectional study the association of CCA-IMT with vascular risk has been found to be present only for values falling in the highest quintile of the population values (Escardio,2015).

Intima-media thickness is accepted as a marker of subclinical atherosclerosis and IMT screening can help the clinician to reclassify a substantial proportion of intermediate cardiovascular risk patients into a lower or higher risk category. In order to implement IMT screening in our daily practice, however, we should be aware of the standards of measurement, as they are described here (Escardio,2015).

2.2 Previous studies:

The study about Sonography of common carotid arteries' intima media thickness in the normal adult population in Sudan) the study was to determine the common carotid artery (CCA) intima-media thickness (IMT) in the normal adult Sudanese, 440 participants, the intima-media thickness was obtained sonographically in the supine position at the point of 1 cm section distal to the carotid bulb. due to ethnic variations, participants were divided into a five ethnic groups according to their geographic distribution in Sudan, mean carotids' IMT was slightly higher in females compared to males, he mention that the ranges of IMT found in the study were from 0.04 cm to 0.07 cm, mean carotids' IMT was slightly higher in females compared to males. no significant differences were found between IMT and different ethnics but significance was noted among participants' age and IMT of both sexes (Mahmoud, 2012) .

The other study about measurement of carotid artery intima media thickness by B mode ultrasound in healthy people of India and Bangladesh and relation of age and sex with carotid intima media thickness made on 93 healthy people were examined by B mode ultrasonography the study showed that the mean CAIMT for healthy subject including all age group was (754.94±11.96micron). mean CAIMT was higher in age group of 61-80 years (908.75±39.02 micron) , the age group 20-40year (713.62±16.59 micron) and 41-60 years 745.55±13.05micron). CAIMT was positively correlated with age and sex (Jayanta&et.al,2012).

A comparison of ultrasound intima media thickness measurement of the left and right common carotid artery , the study was perform on 1104longitudinal section ultrasound images acquired from 568male and 536femal out of whom 125 had cardiovascular symptoms, the corresponding (normal vs CVD) IMT mean ± stander deviation value for the left and right sides were 0.74±0.24vs0.87±0.24mm and 0.70±0.17vs0.80±0.18mm . The finding of this study was perform there was no significantdifference between CAIMT right and left side, there was increasing in linear relationship of left and right CAIMT measurement with age for the normal group(Christos p& et.al,2015).

Chapter three

Materials and methods

Chapter three

Material and method

3.1 Materials

3.1.1 Patient

Study includes 50 healthy Sudanese males and females in Khartoum state who were examined for right and left main common carotid arteries.

3.1.2 Instrumentation:

Ultrasound machine Minderay model DP-20 portable B\W system serial number QM-26000258 with probe F 7,5MHZ.

3.2 Method

3.2.1 Study design

An observation study.

3.2.2 Study area:

The study was conducted in department of ultrasound in Bashair hospital.

3.2.3 Study duration:

The study was conducted between May 2016 to September 2016.

3.2.4 Study variables:

The variables of this study include gender, age and BMI.

3.2.5 Inclusion criteria:

Inclusion criteria for this study include Adult patients of age ranged between 20 to 50 Year.

3.2.6 Exclusion criteria:

Cigarettes smokers, hypertensive heart disease, thyroid or other known endocrine diseases, cardiovascular diseases (coronary heart disease, arrhythmia, heart failure), vascular brain diseases (stroke or a transient ischemic attack), peripheral obstructive artery disease and diabetes mellitus .

3.2.7 Tools of data collection:

Primary data was collected from data collection sheets and carotid artery ultrasound examinations.

Secondary data was collected from books and internet.

3.2.8 Data analysis:

For the statistical analysis, Microsoft Excel Software and Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 15 were used. Participants' results were described as means, standard deviations (SD); mean \pm SD and percentages in a form of comparison tables, graphs and correlations.

3.2.9 Data presentation:

The data was presented in table and figures.

3.2.10 Image interpretation :

Scanning protocol followed, was the protocol of the American Institute of Ultrasound in Medicine (AIUM). Selected samples from subjects in supine position with knee support, and the examiner seated towards the patient's head.

The neck scanning was enhanced by tilting and rotating the head away from the side being examined, with possible adjustment for the position of the head and neck during the examination to facilitate visualization of the common carotid arteries. Several transducer positions were used in this research to examine the common carotid arteries in long-axis (longitudinal) planes.

All sonographic measurements of IMT were made in the longitudinal plane at the point of CCA along a 1-2 cm section of the artery proximal to the carotid bulb. This method of measuring IMT was proved to be a simple and reproducible method for assessing IMT of the common carotid artery for routine practice.

In high resolution B-mode of CCA of the sample, to recognize the intima media layer (IML), the hypoechoic arterial lumen acts as an acoustic window and allows the double echogenic lines of the far wall to be seen more clearly.

The first echo along the far wall is derived from the lumen-intimal interface, while the second echogenic line represents the media-adventitia interface. The combined intima-media is thus the hypoechoic region between these two echogenic lines, with the media making up the substantial portion of this complex .

Chapter Four

Results

Chapter Four

Results

The following table and figures presented the data obtained from 50 patients who were examined for. Patient's age, weight, height & body mass index (BMI) were also measured. The data were analyzed using Excel program and SPSS version 22 for significance of tests. Frequency table, means and standard deviations were presented.

Tale 4.1 showing the mean, standerdiviation, minimum and maximum values according to age, body mass index (BMI), right main intima media thickness and left main intima media thickness .

	Mean	STD	Min	Max
<i>Age</i>	34.92	10.03	20	50
<i>BMI</i>	25.67	4.29	16.8	40.2
<i>R.mainCCAimt</i>	0.59	0.007	0.04	0.073
<i>L.mainCCAimt</i>	0.055	0.008	0.04	0.07

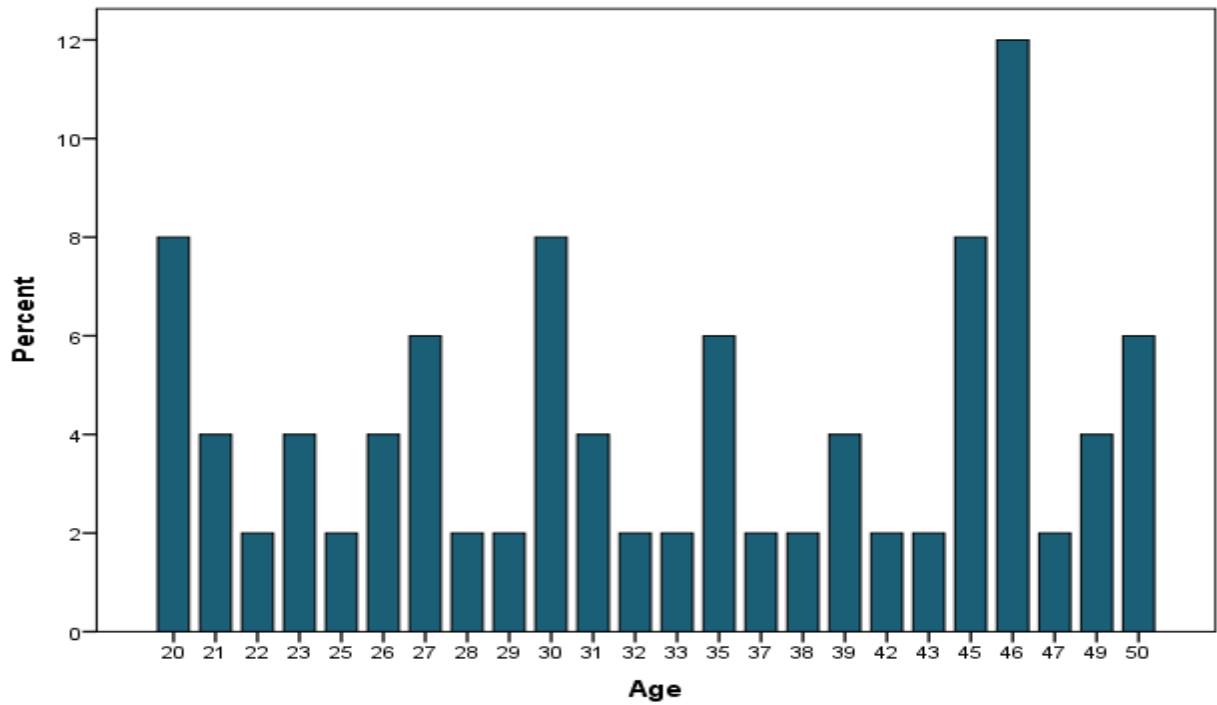


Figure 4.1 show age frequencies.

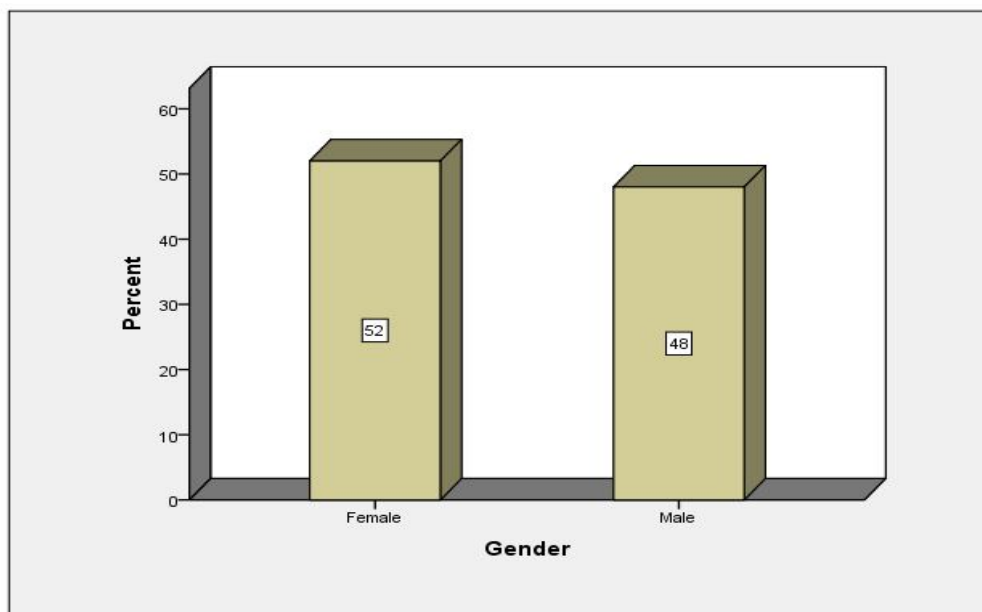


Figure 4.2 show accountof Gender.

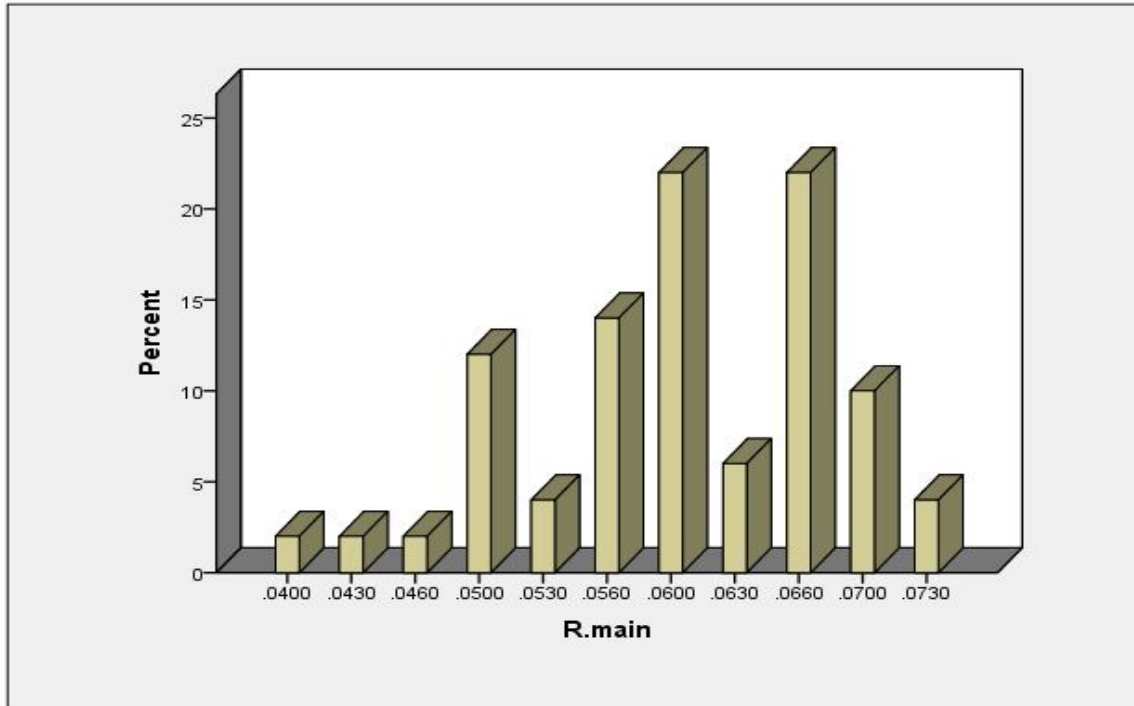


Figure 4.3 show distribution of Right main common carotid IMT measurement by cm for all patient.

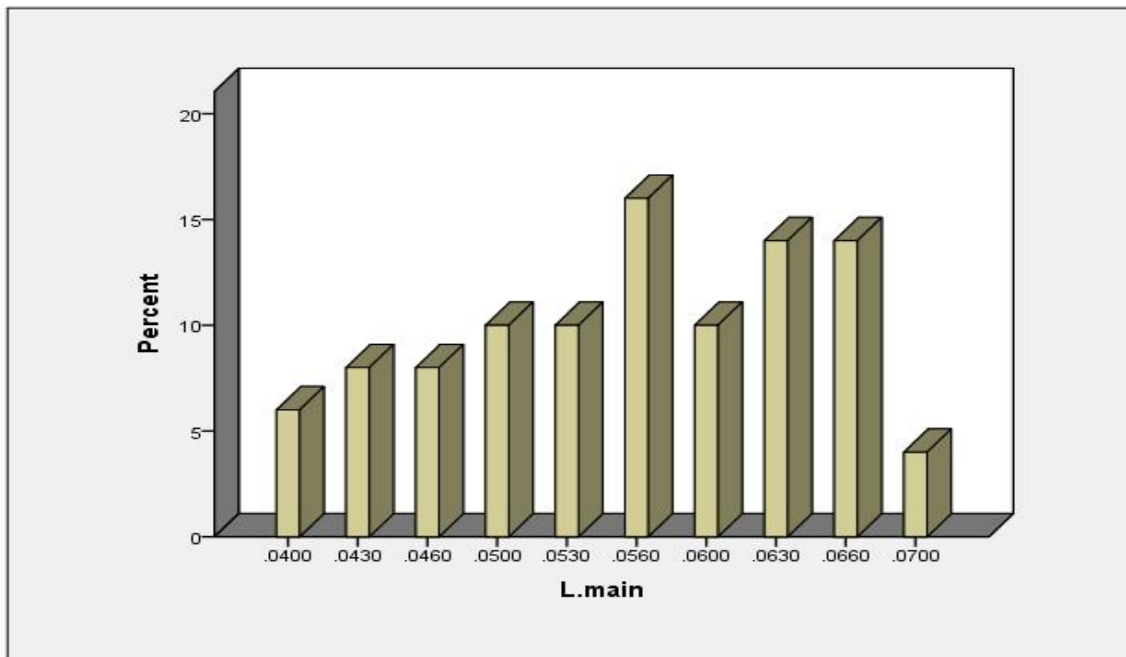


Figure 4.4 show distribution of left main common carotid IMT measurement by cm for all subject.

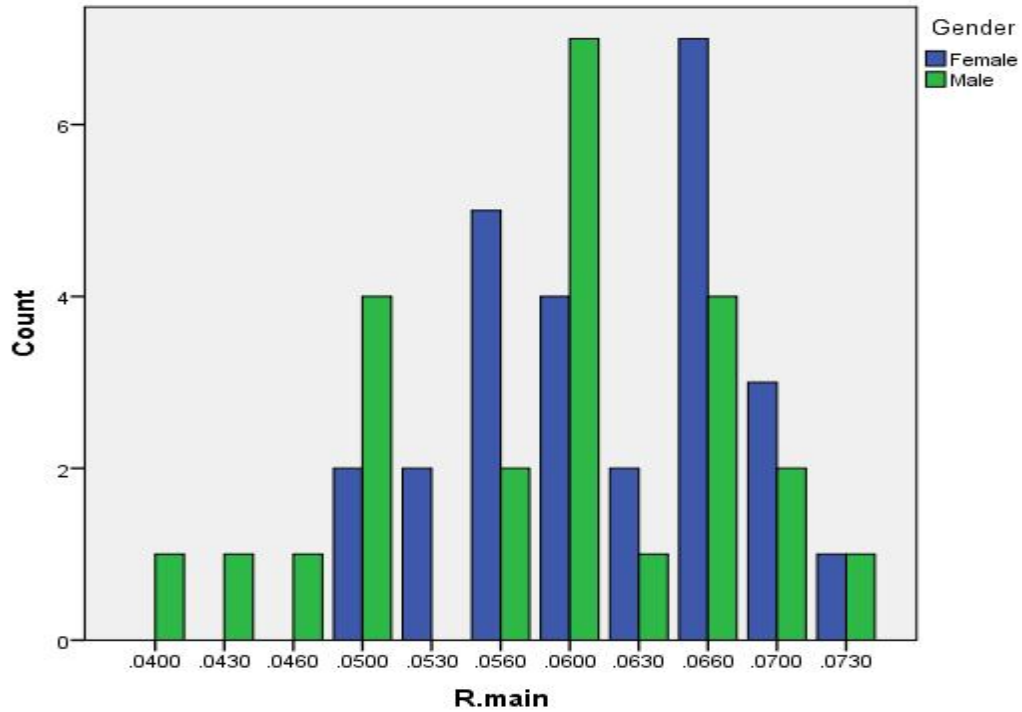


Figure 4.5 show correlation between values of right main IMT measurement by cm and gender.

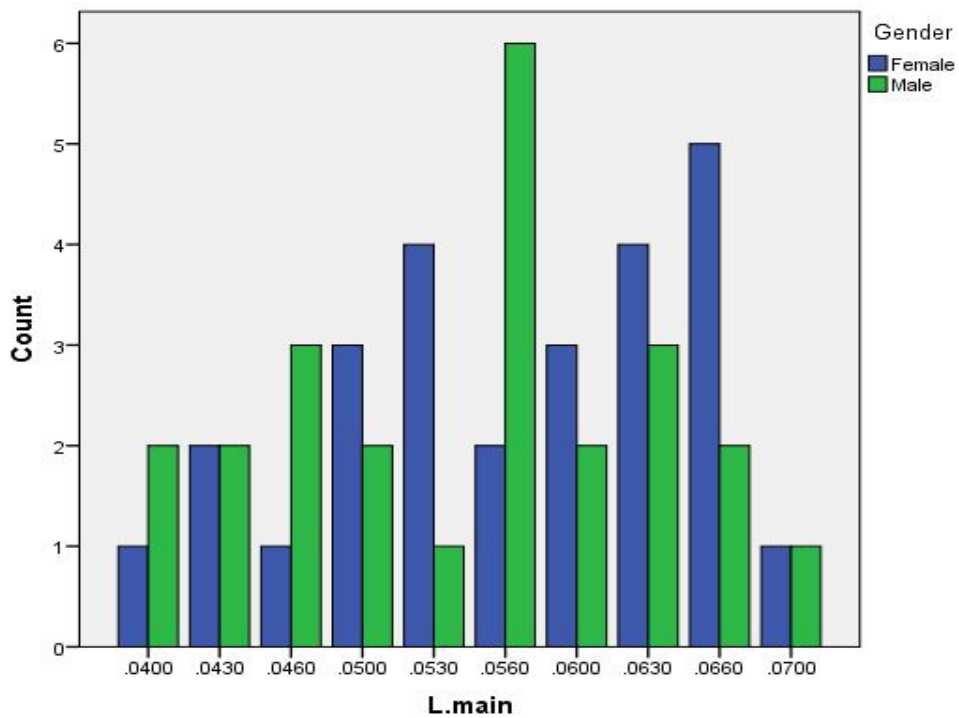


Figure 4.6 show correlation between values of left main IMT measurement by cm and gender.

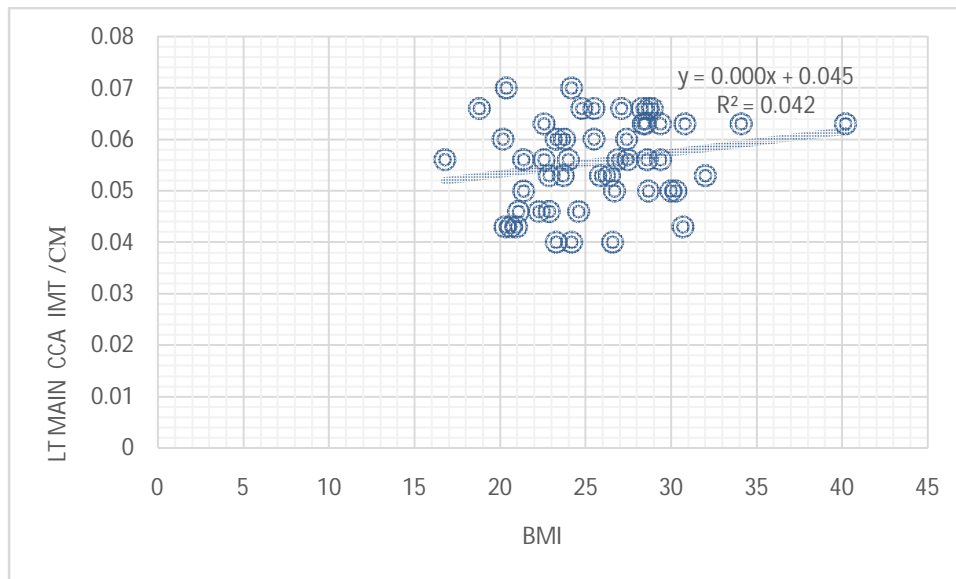


Figure 4.7: A scatter plot diagram shows relationship between the **LT main CCAIMT** by cm(vertical)and the **BMI** (horizontal)of the subjects, $R^2=0.0428$.

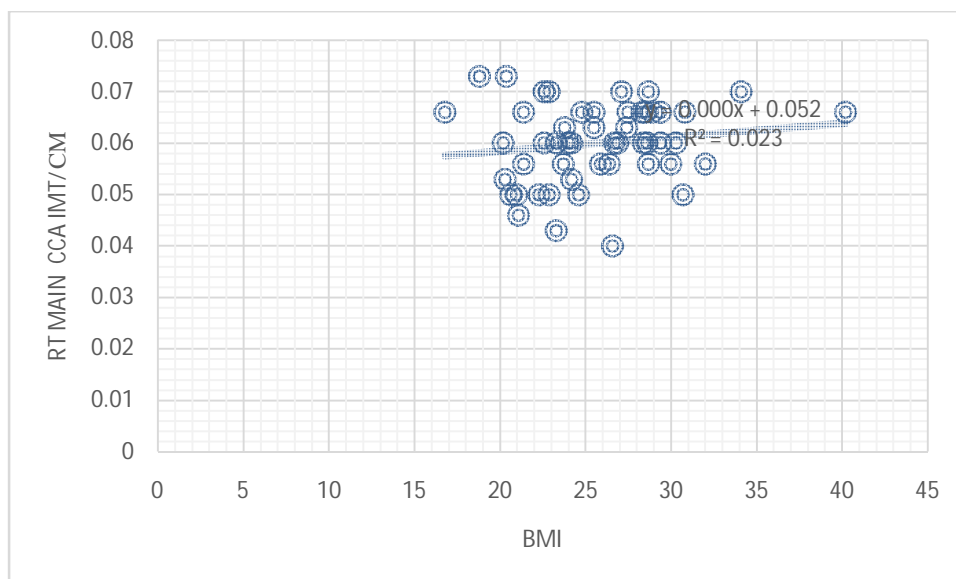


Figure 4.8: A scatter plot diagram shows relationship between the **RT main CCA IMT**by cm(vertical)and the **BMI**(horizontal)of the subjects, $R^2=0.0231$.

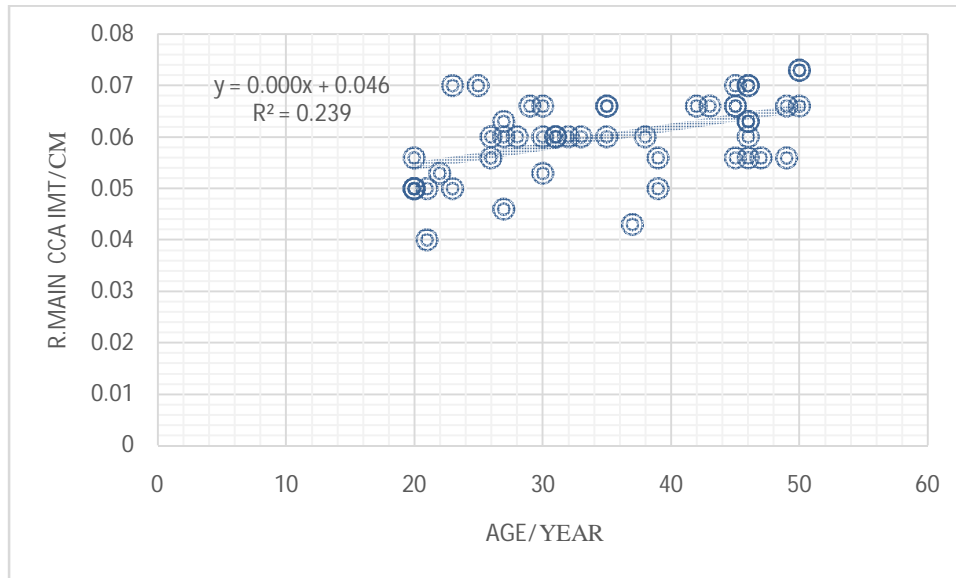


Figure 4.9: A scatter plot diagram shows relationship between the **RT main CCA IMT** by cm (vertical) and the **Age** by year (horizontal) of the subject, $R^2=0.239$.

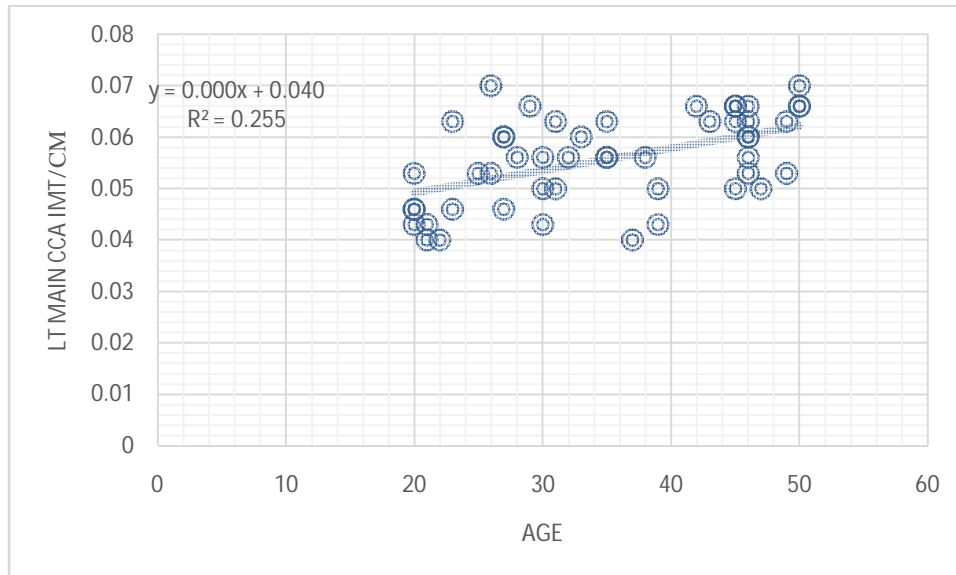


Figure 4.10: A scatter plot diagram shows relationship between the **LT main CCA IMT** by cm (vertical) and the **Age** by year (horizontal) of the subject, $R^2=0.2556$.

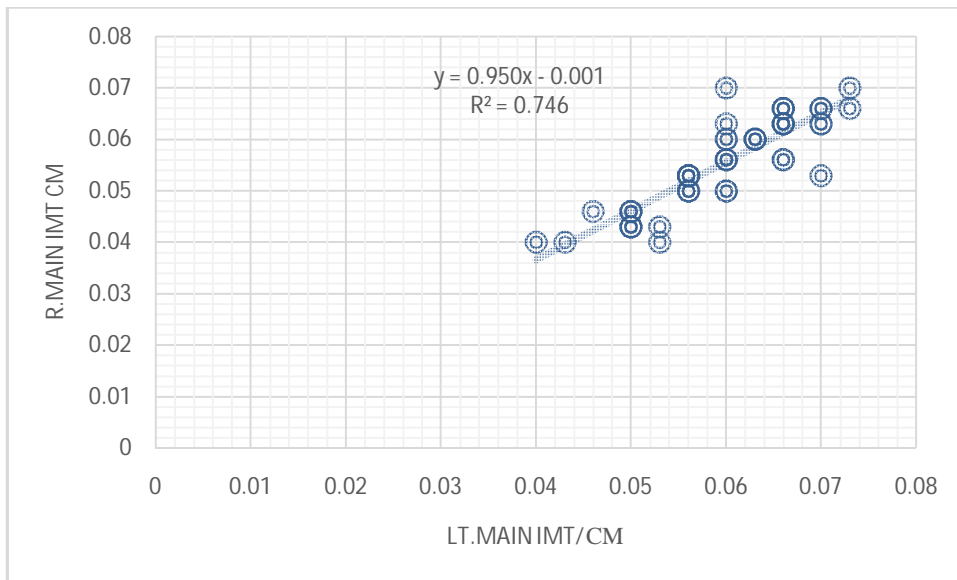


Figure 4.11: A scatter plot diagram shows relationship between the **RT main IMT** by cm(vertical)and the **LT main IMT** by cm(horizontal)of the subjects, $R^2=0.7468$.

Chapter five

Discussion, conclusion and recommendation

Chapter five

Discussion, conclusion and recommendation

5.1 Discussion

This study was performed on 50 healthy people. The data collected from people ages ranged between 20-50 years old (figure 4-1), 24 male represent (48%) and 26 female represent (52%) of data figure (figure 4-2), with (mean +_stander deviation), for age (34.92+_10.03), BMI (25.67+_4.29), RT main (0.59+_0.007), LT main (0.055+_0.008) (Table 4-1).

In this study we found that the right main of common carotid artery IMT range between 0.04cm to 0.073 The mean value of main RT carotid artery IMT measurement was 0.059cm (figure 4-3), while the left main common carotid artery IMT range between 0.04 cm to 0.07cm, the mean value of main common carotid artery IMT measurement was 0.055cm, 0.073cm this result was the same result as Mahmoud 2012, (figure 4-4).

The study showed that the main right common carotid IMT measurement for female range between 0.05cm to 0.073cm , which the value 0.066cm more frequencies in female, while in male range between 0.04cm to 0.073cm which the value of 0.06cm more frequencies in male, and for main left common carotid artery IMT measurement for female and male range between 0.04cm to 0.07cm which the value of 0.066cm more frequencies in female and 0.056cm in male that was means the female had higher values in both right and left of CCA IMT measurement than male (figure 4-5) and (figure 4-6).

We observe that the relationship between body mass index (BMI) and common carotid artery IMT measurement on right and left were represented by $R^2=0.042$ and $R^2=0.023$ respectively, that was mean there was a weak degree of correlation between right and left main common carotid artery IMT measurement and body mass index (figher4-7), (figure4-8).

On this study according to age and main common carotid artery IMT measurement right and left $R^2=0.239$ for right and $R^2=0.255$ for the left had a weak correlation, this result mismatch with the study (Jayanta et al, 2012) (figure 4-9), (figure 4-10).

The study reveals that there were very strong degree of correlation between right main common carotid artery IMT and left main common carotid artery IMT while square sample equal $R^2=0.7468$ (figher4-11) this was mismatch the study of A comparison of ultrasound intima media thickness measurement of the left and right common carotid artery study did by Christos p&et.al,2015.

5.2 Conclusion

The study concluded that the mean normal right and left CCAIMT in Sudanese peoples according to the findings of ultrasound images was found to be (0.04cm to 0.073cm) and (0.04 cm to 0.07cm) respectively.

The CCAIMT values were higher in female than in male, possibly because Sudanese females tend to weigh more than males.

There were a weak degree of correlation between CCAIMT and the subject age and BMI.

The normal reference ranges for CCAIMT given in this study can serve as a standard to judge whether the atherosclerosis is present in patients and the size of abnormality.

The right CCAIMT measurement is higher than left.

5.3 Recommendation

Ultrasound examination need special operator training to confirm the result.

Use Doppler to find out if there is difference in carotid artery (IMT) with using wave parameters.

Used advance modalities (threedimensional)to find more accurate result.

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

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Appendix

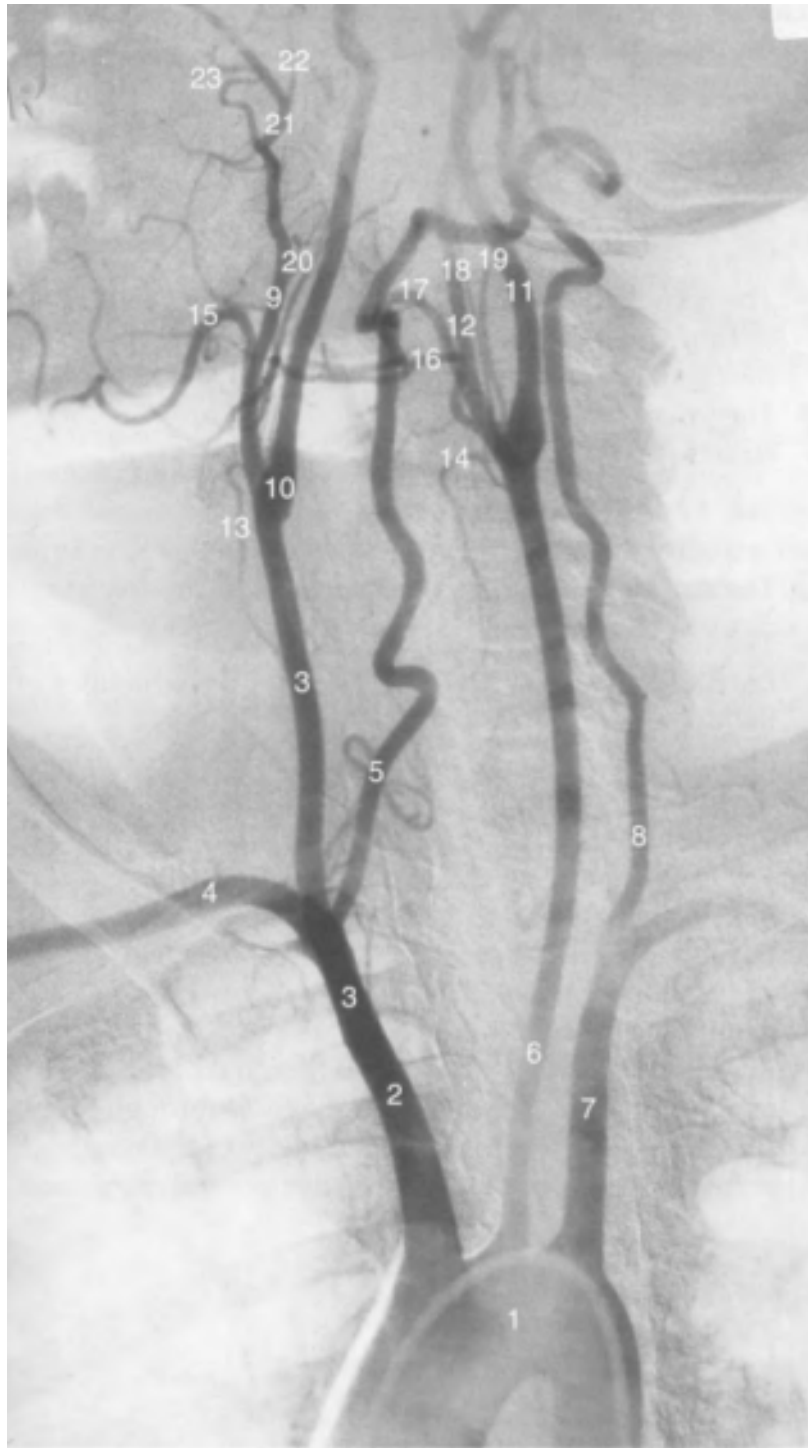


Figure (2.3): Arch aortogram : subtraction film . The catheter is in the aortic arch . All branches of the external carotid are shown except the occipital artery. The facial artery is not filling on the right (Stephanie et al,2004).

- 1 . Arch of aorta.
2. Brachiocephalic trunk.
3. Right common carotid artery (superimposed upon the subclavian artery).
4. Right subclavian artery.
5. Right vertebral artery.
6. Left common carotid artery.
7. Left subclavian artery.
8. Left vertebral artery.
9. Right external carotid artery.
10. Sinus of right internal carotid artery.
11. Left internal carotid artery.
12. Left external carotid artery.
13. Right superior thyroid artery (arising from the external carotid artery).
14. Left superior thyroid artery (arising from common carotid artery).
15. Right lingual artery.
16. Left lingual artery.
17. Left facial artery.
18. Left ascending pharyngeal artery.
19. Left posterior auricular artery.
20. Right posterior auricular artery.
21. Right maxillary artery.
22. Middle meningeal artery (branch of right maxillary artery).
23. Right superficial temporal artery.



Figure (2.5): The optimal position for scanning the carotid arteries (Hartshorne et al,2005).

Table (2.1): Normal IMT values–median (P50), 25th and 75th percentile (P) IMT values for men and women at different age categories, separately for right (A) and left (B) CCA (1)

A right

Age	P25	P50	P75
Men <30	0.39	0.43	0.48
Men 31-40	0.42	0.46	0.50
Men 41-50	0.46	0.50	0.57
Men >50	0.46	0.52	0.62
Women <30	0.39	0.40	0.43
Women 31-40	0.42	0.45	0.49
Women 41-50	0.44	0.48	0.53
Women >50	0.50	0.54	0.59

B left

Age	P25	P50	P75
Men <30	0.39	0.43	0.48
Men 31-40	0.42	0.46	0.50
Men 41-50	0.46	0.50	0.57
Men >50	0.46	0.52	0.62
Women <30	0.39	0.40	0.43
Women 31-40	0.42	0.45	0.49
Women 41-50	0.44	0.48	0.53
Women >50	0.50	0.54	0.59

Appendix two

Measurement

2.1 Image of Literature review

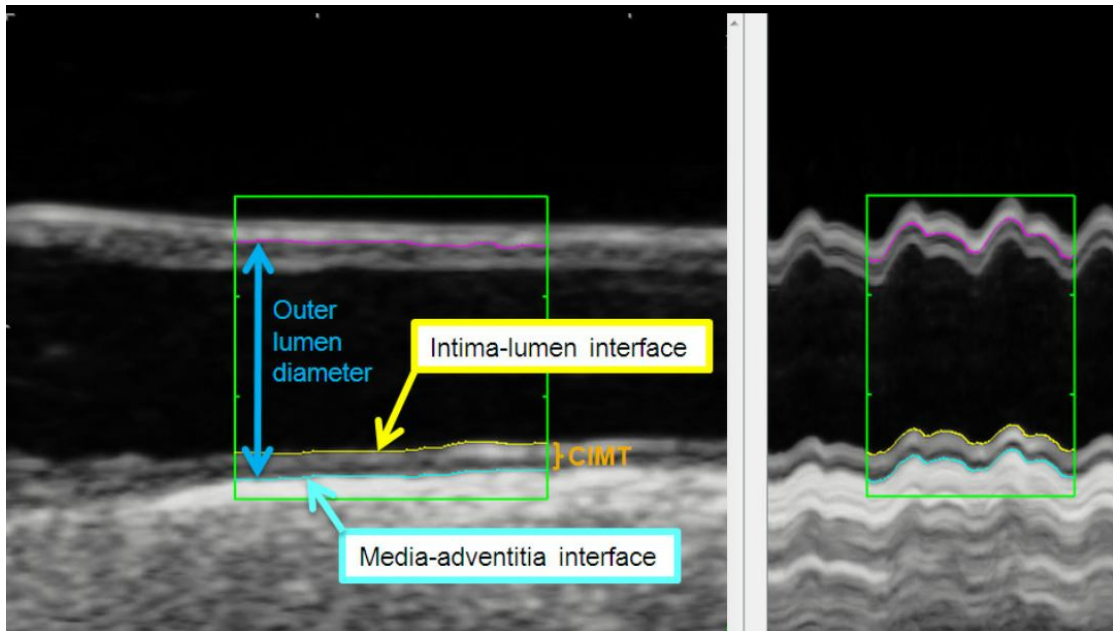


Image No 1 longitudinal ultrasound image show measurement of carotid artery IMT.

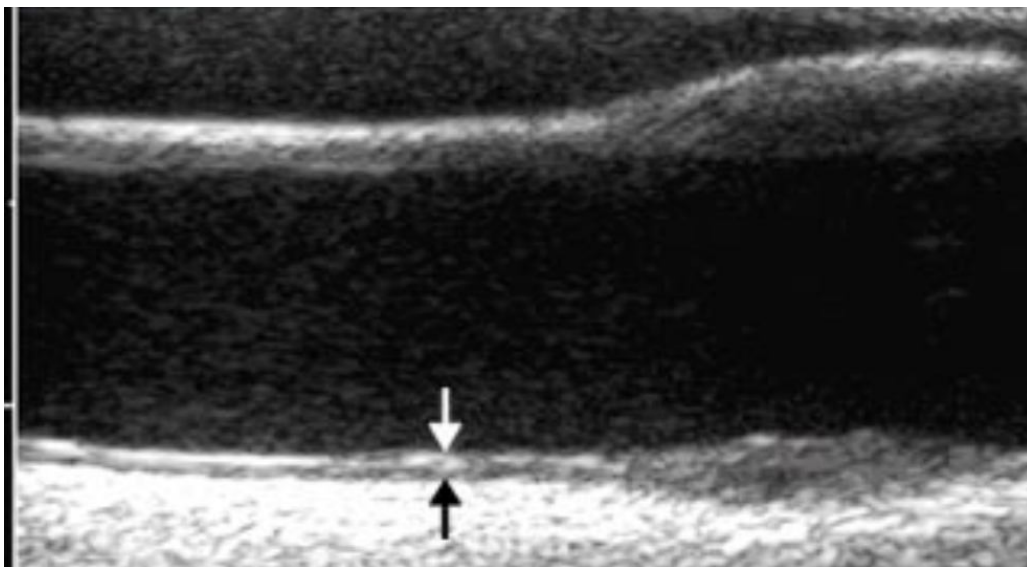


Image No 2 longitudinal ultrasound image show measurement of carotid artery IMT.

2.2 Image of research

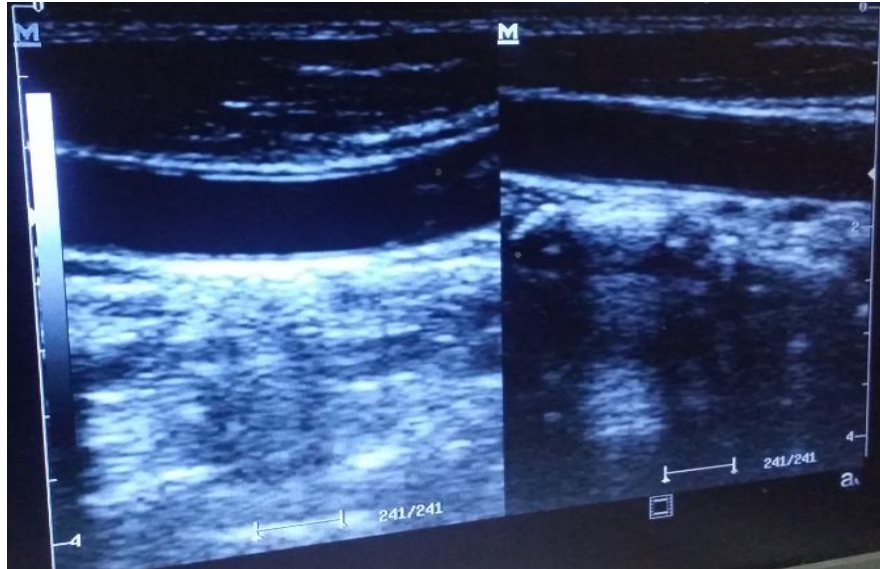
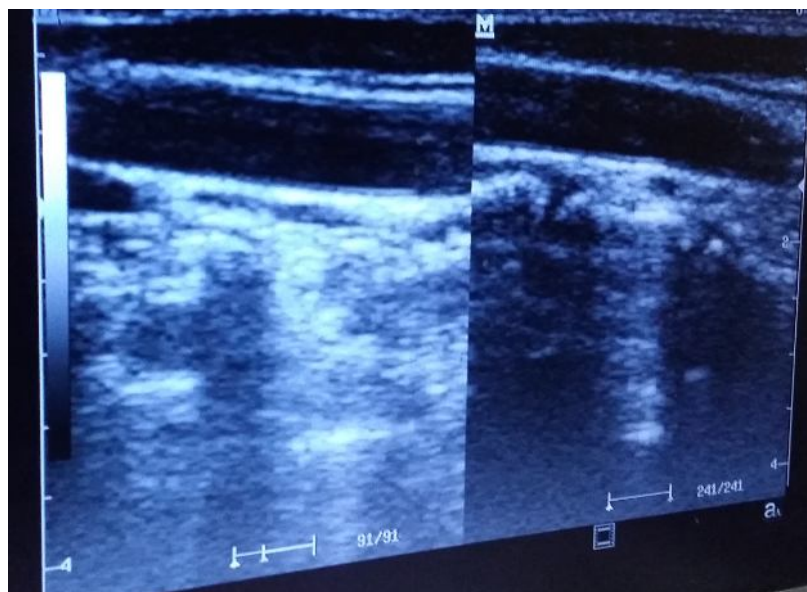
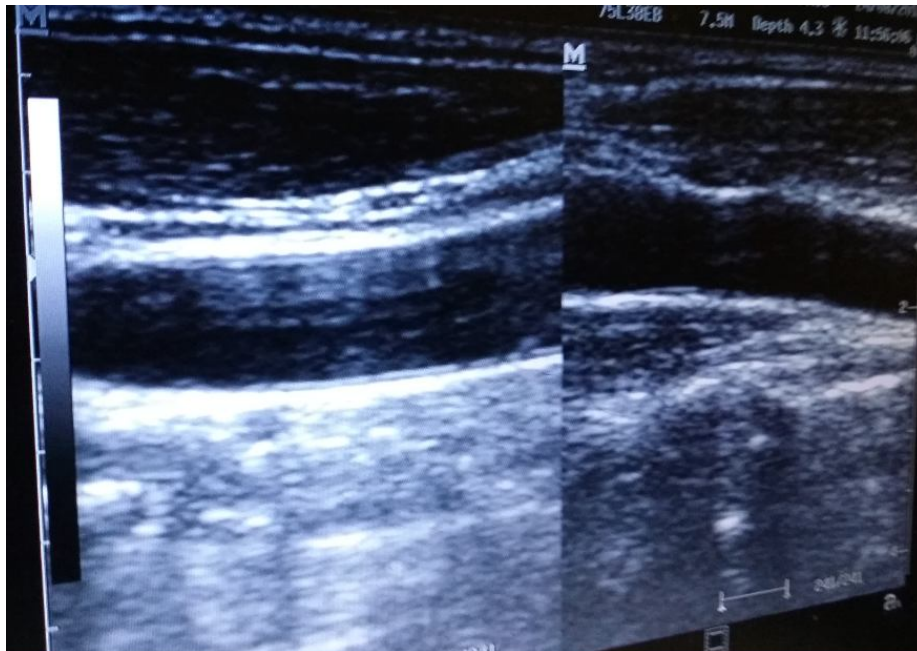


Image NO 1 longitudinal ultrasound image show measurement of carotid artery IMT for 31 years female with subject in supine, the neck extended and the head turned in the opposite direction.



Img NO 2 longitudinal ultrasound image show measurement of carotid artery IMT for 20 years male with subject in supine, the neck extended and the head turned in the opposite direction.



Imge NO 3 longitudinal ultrasound image show measurement of carotid artery IMT for 25 years male with subject in supine, the neck extended and the head turned in the opposite direction.