Sudan University of science and technology
College of graduate studies

Study of Pulmonary Embolism Using Computed Tomography Angiography

دراسة الجلطة الرئوية بإستخدام الأشعة المقطعية للشرايين والأوردة

A thesis Submitted for a partial fulfillment of award of Master Degree in Diagnostic Radiologic Technology

By

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الآية الكريمة

قال تعالى:

{فَتعالى اللّهُ الْمَلِكُ الْحَقُّ وَلا تَعْجَلْ بِالْقُرْآنِ مِنْ قبْلِ أَنْ يُقْضى إِلَيْكَ وَحْيُهُ وَقُلْ رَبِّ زِدْنِي عِلْمًا(114) }

صدق الله العظيم

سورة طه الآيه 114

Dedication

To my father **Hassan Hamad Ali**
Who always supported me in every endeavor

To my mother **Afaf Ser Alkhatem**
Who is the reason I am here at all, and made me who I am today

To my **brother and sisters**
If I donated to you everything in this world, is not enough
To give you your right

Acknowledgement

Grateful thanks and grace to **Allah** for guiding and helping me finishing this research.

I would like also to express sincere thanks and gratitude to my supervisor **Dr.Asmaa Ibrahim Ahmed** for her keen supervision, guidance and valuable comment and support from the idea of this research until finishing.

Special thanks to Dar Alelag specialized hospital and Modern Medical Center.

Finally I would like to thanks my friends, teachers and colleges.

Abstract

This was a descriptive study; the main objective of this study was to study of pulmonary embolism by using computed tomography angiography types, site and affected group of age.

The study was carried out at the Modern Medical Center and Dar Alelaj Specialized Hospital during the period from November 2017 to January 2018, and the data were collected from these two hospitals. for CT machine used 64-slice scanner (PHILIPS) and 64-slice scanner (GM-Optima, Health Care). This study included random fifty patients 9 males and 41 females with clinically diagnosed of pulmonary embolism.

The study has come out with many results including that the pulmonary embolism is higher in female (82%) than in male (18%). The most effected age group were the ages between (60-70) years and pulmonary embolism most commonly seen in the both side of pulmonary artery (78%) , right side (16%) and left side (6%) .

According to this result PE is rare in young patients and is more common in elder patients .

The results also showed that CT is the best modality to identifying and localizing pulmonary embolism .

It concluded that CTPA is a technical improvement of helical CT and a diagnostic tool with a high sensitivity and specificity for the detection of PE.

It recommended that Spiral CT technique should be the primary investigation performed for patient who suspected to have PE.

مستخلص البحث

تعتبر هذه الدراسة وصفية و كان الهدف الأساسي منها هو دراسة الجلطة الرئوية بواسطة الأشعة المقطعية للشرايين والأوردة من حيث النوع و الموقع و الفئة العمرية المتأثرة.

وتم تنفيذ هذه الدراسة و قد جمعت البيانات من المركز الطبي الحديث و مستشفى دار العلاج التخصصي في الفترة من نوفمبر 2017 إلى يناير 2018 وقد تم جمع البيانات في هذين المستشفيين بواسطة جهاز الأشعة المقطعية (أوبتيما جي- اي الرعاية الصحية) و نوع الشريحة 64 في المركز الطبي الحديث و جهاز (فيليبس) نوع الشريحة 64 في مستشفى دار العلاج التخصصي , و قد شملت هذه الدراسة عينة عشوائية بعدد خمسين مريضا , منهم 9 ذكور و 41 إناث ,تم تشخيصهم سريريا بالجلطة الرئوية.

خرجت الدراسة بنتائج مفادها أن حدوث الجلطة الرئوية شائع أكثر في الإناث (82%) منه في الذكور (18%) وكانت أكثر الأعمار إصابة هي في الفئة العمرية (70-60) سنة , و كانت أكثر منطقة للإصابة بالجلطة الرئوية هي الجهتين اليمنى و اليسرى معا (78%) تليها الجهة اليمنى (16%) ثم الجهة اليسرى (6%) .

وفقا لهذه النتائج اتضح أن الجلطة الرئوية أمر نادر الحدوث في المرضى الصغار و أكثر شيوعا في المرضى كبار السن .

و قد أظهرت هذه الدراسة أن الأشعة المقطعية هي أفضل طريقة لتشخيص الجلطة الرئوية لأن لها درجة عالية من الدقة والكفاءة في التشخيص الآمن.

و وصت هذه الدراسة أن الأشعة المقطعية للشرايين و الأوردة ضرورية لجميع المرضى الذين يشتبهون بأن لديهم جلطة رئوية.

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List of the Abbreviations

ABG	Arterial blood gas
BCE	Basel Cell Epithelium
CAT	Computed Axial Tomography
CBC	Complete Blood Count
CCF	Congestive Cardiac Failure
CHF	Chronic Heart Failure
CT	Computed Tomography
CTA	Computed Tomography Angiography
CTPA	CT Pulmonary Angiography
CUS	Common User System
DVT	Deep Vein thrombosis
ECG	Electrocardiography
EKG	Electrocardiogram
HF	Heart failure
HIV	Human Immunodeficiency
INR	International Normalized Ratio
MDCT	Multi Detector Computed Tomography
MRI	Magnetic Resonance Imaging
NSCLC	Non-Small Cell Lung Carcinoma
PE	Pulmonary Embolism
PIOED	Prospective Investigation of Pulmonary Embolism Diagnosis
SCLC	Small Cell Lung Carcinoma

SSA	Seronegative Spondylo Arthropahty
TB	Tuberculosis
TST	Tuberculin Skin Test
UPET	Urokinase-Pulmonary Embolism Trial
V-P	Ventilation-Perfusion
V/Q	Ventilation-Perfusion
VTE	Venous thromboembolism

Chapter One
Introduction

1-1-Introduction

Pulmonary artery is one of the two vessels which are formed as terminal branches of the pulmonary trunk and convey un-aerated blood to the lungs; the two pulmonary arteries differ in length and anatomy, and the right pulmonary artery is the longer of the two it passes transversely across the midline in the upper chest and passes below the aortic arch to enter the helium of the right lung as part of its root, the left pulmonary artery is the shorter of the two terminal branches of the pulmonary trunk, it pierces the pericardium (the sac around the heart) and enters the helium of the left lung (Dean and West, 1999).

Pulmonary embolism (PE) is a blockage of the main artery of the lung or one of its branches by a substance that has travelled from elsewhere in the body through the bloodstream (embolism) (Tardivon, 1999).

The diagnosis of pulmonary embolism (PE) remains a major clinical problem, Because of variable and non specific symptoms; imaging is required to establish the diagnosis.

CT pulmonary angiography (CTPA) is a medical diagnostic test that employs computed tomography to obtain an image of the pulmonary arteries it was introduced in the 1990s as an alternative to ventilation/perfusion scanning, which relies on radionuclide imaging of the blood vessels of the lung, because of its minimally invasive nature and high sensitivity and specificity, CTPA has evolved into the first line imaging study for the evaluation of suspected pulmonary embolism, images are acquired using a breath hold technique during the pulmonary arterial enhancement phase following intravenous contrast material injection, with pulmonary embolism appearing as a filling defect in the otherwise densely opacified pulmonary artery (Tardivon, 1999).

Furthermore, in 66% of patients, a definitive diagnosis could not be made by using V-P scanning and clinical data only (Kelly, 1991,). Recently, magnetic resonance imaging (Meaney, 1997), electron beam computed tomography (CT) (Teigen, 1993), and helical CT have demonstrated superiority over V-P scanning as screening tools for acute PE.

Investigators in recent studies have reported sensitivities and specificities of 53%–100% and 81%–100%, respectively, for helical CT in the detection of PE. In parallel, several investigators have pointed out the limitations of helical CT in the detection of PE in segmental and sub segmental vessels. (Garg, 1998)

The diagnostic value of helical CT in the detection of PE has been reported by several authors in experimental and clinical studies, with variable sensitivity and specificity values. However, to our knowledge, no large series of consecutive patients in which helical CT and selective pulmonary arteriography (the reference standard) were compared have been reported. (Drucker, 2000)

1-2 Problem of the study:

According to the risk of pulmonary embolism, CT pulmonary angiography is best and easiest method widely used to evaluation pulmonary embolism and helpful to confirm or exclude a diagnosis of PE after simpler first-line tests is used.

1-3 Objectives:

1-3-1 General objectives:

To Assessment of Pulmonary Embolism using CT angiography.

1-3-2 Specific objectives:

-To assess pulmonary embolism according to type, side, and affected age using CT angiography.

-To evaluate the accuracy of spiral computed tomography (CT) in the non-invasive diagnosis of pulmonary embolism (PE).

-To identify the key imaging features of pulmonary embolism at CT pulmonary angiography.

-To discuss the current role of CT angiography imaging in evaluation of patients with clinical signs of PE.

1-4 Overview of the study:

The research consists of five chapters:

Chapter one include introduction, statement of problem, objectives, significant of the study and overview.

Chapter two includes lung anatomy, physiology, pathology, diagnosis of pulmonary embolism and literature review.

Chapter three materials and methodology,

Chapter four includes results of the study and Chapter five includes discussion, conclusion and recommendation.

Finally there are references and appendix.

Chapter Two
Literature Review

2.1 Anatomy

2.1.1chest wall

The chest wall is made up of bones and muscles, the bones, primarily ribs, sternum and vertebrae, form a protective cage for the internal structures of the thorax. (Dean and West1991).

The main muscles of the chest wall, the external and internal intercostals, extend from one rib.

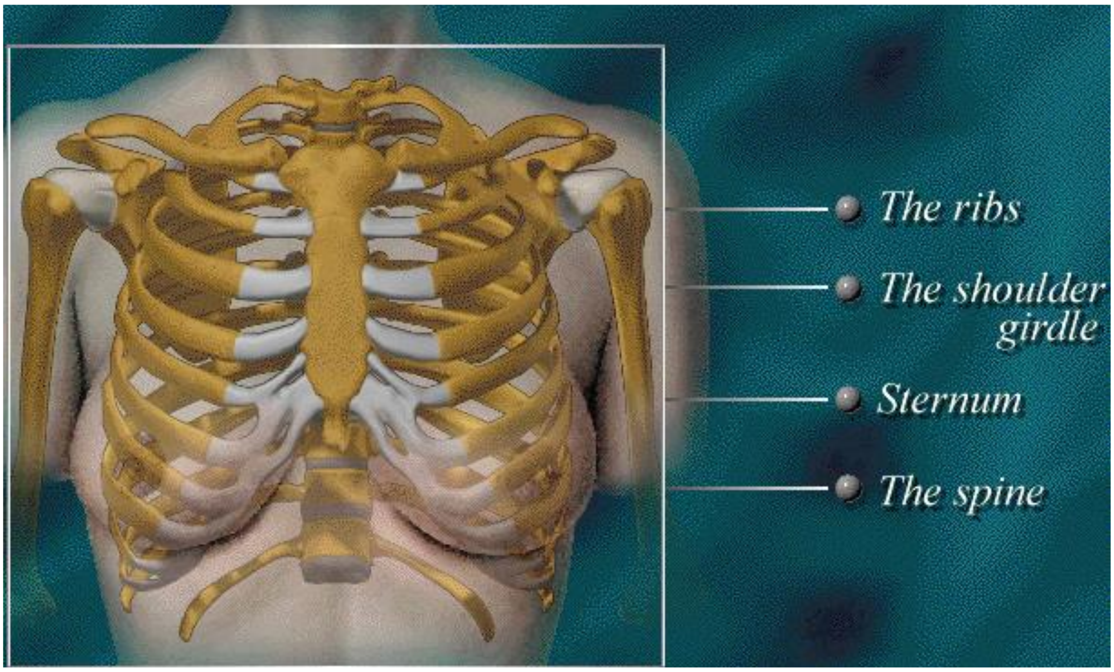

Figure (2-1) bones of the chest (overton 1988)

2.1.2 Mediastinum

The Mediastinum is located between the lungs. This contains the heart, the great vessels, parts of the trachea and esophagus, and other structures.(Dean and West 1991).

Pulmonary artery is one of the two vessels which are formed as terminal branches of the pulmonary trunk and convey un-aerated blood to the lungs; the two pulmonary arteries differ in length and anatomy, and the right pulmonary artery is the longer of the two it passes transversely across the midline in the upper chest and passes below the aortic arch to enter the helium of the right lung as part of its root, the left pulmonary artery is the shorter of the two terminal branches of the pulmonary trunk, it pierces the pericardium (the sac around the heart) and enters the helium of the left lung (Dean and West, 1999).

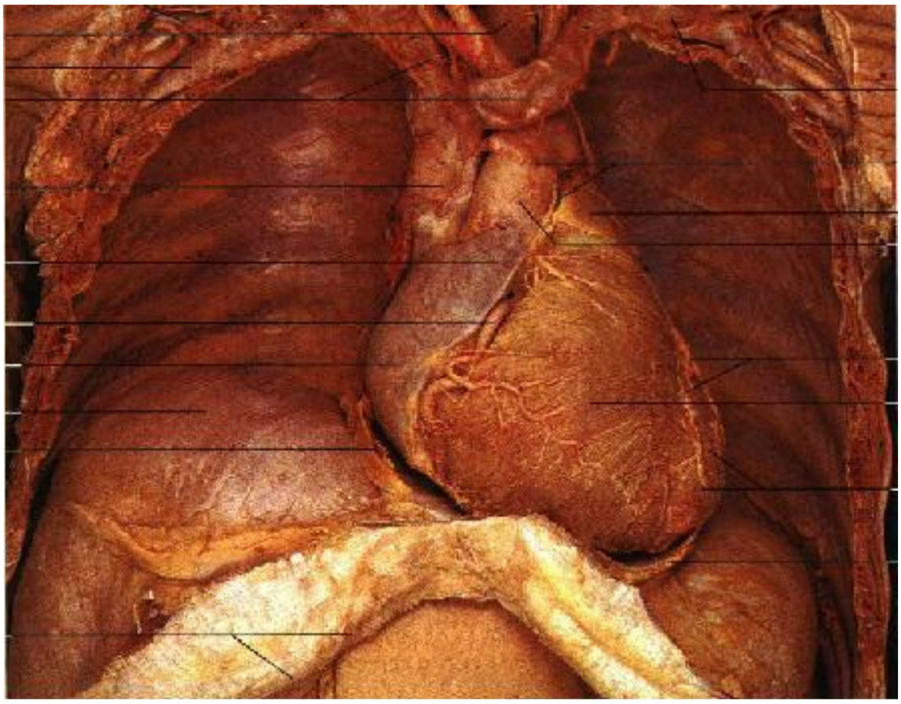

Figure 2-2 mediastinal (overton 1988)

2.1.3 Respiratory system:

The respiratory system is made up of nose, pharynx, larynx, trachea, bronchi and lungs.

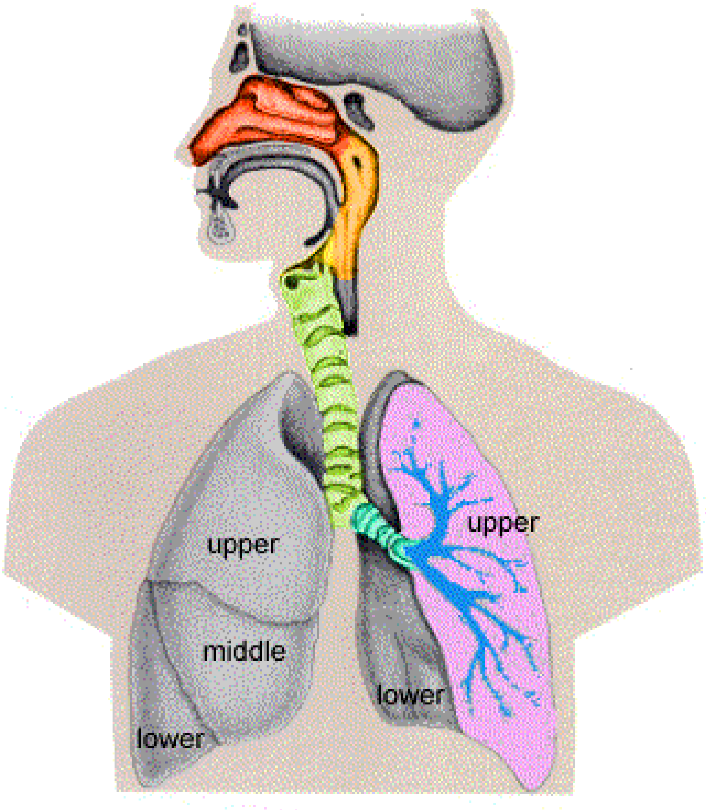

Figure 2-3 respiratory system (overton 1988)

2.1.4 Lungs

The lungs consist of airways (trachea and bronchi) that divide into smaller and smaller branches until they reach the air sacs, called alveoli. The airways conduct air down to the alveoli where gas exchange takes place. (Dean and West 1991).

Figure 2-4 out shape of lungs (overton 1988)

The lung itself is covered with a membrane called the visceral (or pulmonary) pleura. The visceral pleura are adjacent to the lining of the thoracic cavity which is called the parietal pleura.

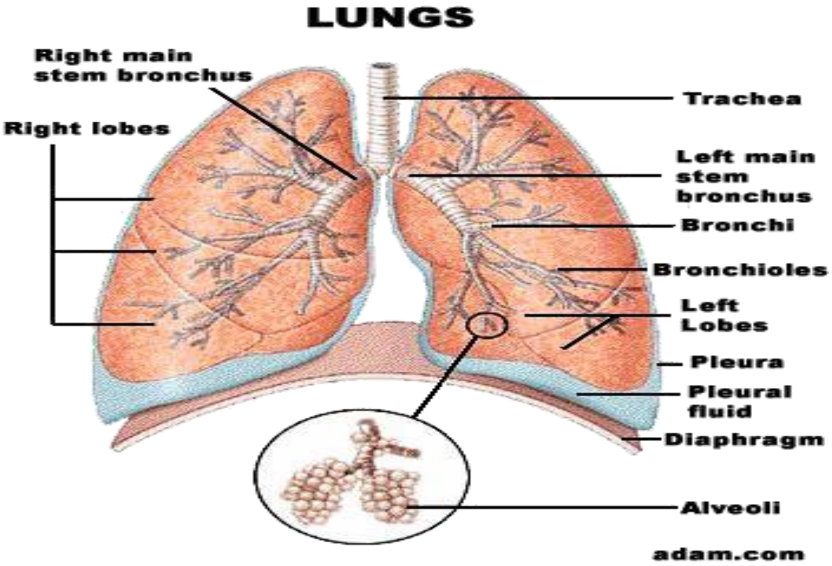

Figure 2-5 inner shape of lung (overton 1988)

2.1.5 Blood Supply of the Lungs

The bronchi, the connective tissue of the lung, and the visceral pleura receive their blood supply from the bronchial arteries, which are branches of the descending aorta. The bronchial veins (which communicate with the pulmonary veins) drain in to the azygos and hemiaziazygos veins (Overton 1988).

The alveoli receive deoxygenated blood from the terminal branches of the pulmonary arteries. The oxygenated blood leaving the alveolar capillaries drains into the tributaries of the pulmonary veins which follow the inter segmental connective tissue septa to the lung root Tow pulmonary veins leave each lung root to empty into the left atrium of the heart.(overton 1988).

2.2 Physiology of Gas Exchange

The pulmonary circulation carries the blood to and from the lungs. In the heart, the blood flows from the right atrium into the right ventricle; the tricuspid valve prevents backflow from ventricles to atria. The right ventricle contracts to force blood into the lungs through the pulmonary arteries. In the lungs oxygen is picked up and carbon dioxide eliminated, and the oxygenated blood returns to the heart via the pulmonary veins, thus completing the circuit. In pulmonary circulation, the arteries carry oxygenpoor blood, and the veins bear oxygen-rich blood (Dean and West 1991).

The exchange of the air between the lungs and blood are through the arterial and venous system. Arteries and veins both carry and move blood throughout the body, but the process for each is very different.

(Arteries carry blood from the heart to the body, Veins return blood from the body to the heat and the heart is a two-sided pump). (Dean and West 1991).

Oxygen-carrying blood travels from the left side of the heart to all the tissues of the body. The oxygen is extracted by the tissue, and carbon dioxide (a waste product) is delivered back into the blood.

The blood now deoxygenated and with higher levels of carbon dioxide, is returned via the veins to the right side of the heart.

The blood is then pumped out of the right side of the heart to the lungs, where the carbon dioxide is removed and oxygen is returned to the blood from the air we breathe in, which fills the lungs.

Now the blood, high in oxygen and low in carbon dioxide, is returned to the left side of the heart where the process starts all over again.

The blood travels in a circle and is therefore referred to as circulation (Dean and West 1991).

2.2.1 Blood clot formation

If a blood clot (thrombus) forms in the one of the body's veins deep vein Thrombosis (DVT), it has the potential to break off and enter the circulatory system and travel through the heart and become lodged in the one of the branches of the pulmonary artery of the lung.

A clot that travels through the circulatory system to another location is known as an embolus (plural emboli). A pulmonary embolus clogs the artery that provides blood supply to part of the lung. The embolus not only prevents the exchange of oxygen and carbon dioxide, but it also decreases blood supply to the lung tissue itself, potentially causing lung tissue to die (infarct). A pulmonary embolus is one of the life threatening causes of chest pain and should always be considered, when a patient presents to a healthcare provider with complaints of chest pain and shortness of breath.

Non-thrombus causes of pulmonary embolus are rare but include:

Fat emboli from a broken femur, an amniotic fluid embolus in pregnancy, and in some cases, tumor tissue from cancer.

The presentation is the same as that of a blood clot, caused by blockage of part of the arterial tree of the lung. (midicen.net.edu.org2009).

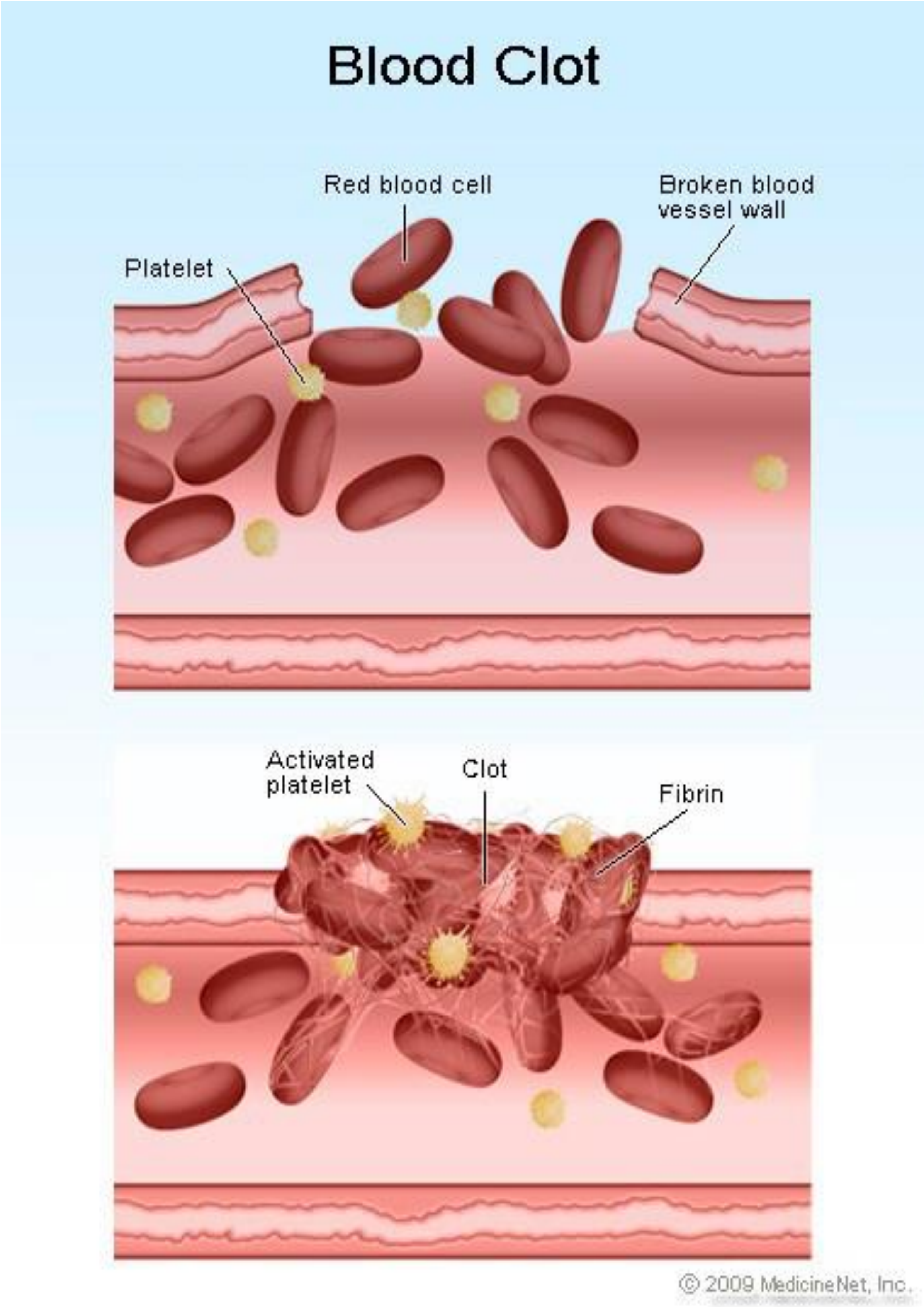

Figure (2.6) show blood clot formation(midicen.net.edu.org2009).

2.3 Pathology of the lung

2.3.1Congenital and hereditary disease

This includes Cystic fibrosis.

2.3.2 Inflammatory disease

Pneumonia is the most frequent type of lung infection, resulting in an inflammation of the lung and compromised pulmonary function. The main causes of pneumonia are bacteria, viruses and myoplasm (Roy, 2006).

2.3.3 Bronchiectasis

Bronchiectasis is permanent, abnormal dilatation of one or more large bronchi as result of destruction of the elastic and muscular component of the bronchial wall.

The basic pathogenesis is either congenital or an acquired weakness, typically following inflammation of the bronchial wall because of a viral or bacterial Infection (Roy, 2006).

2.3.4 Tuberculosis

Tuberculosis is an infection caused by inhalation of mycobacterium tuberculosis. Although it generally affects the lung, it may also affect the lung, it may also affect other organs of the body (Roy, 2006).

2.3.5 Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease refers to a group of disorders that causes chronic airway obstruction. The most common forms are chronic bronchitis and emphysema, with frequently and may be associated with varying degrees of asthma and bronchiectasis tow other causes of airway obstruction.

Pulmonary embolism (PE) is a relatively common cardiovascular emergency. By occluding the pulmonary arterial bed it may lead to acute life-threatening but potentially reversible right ventricular failure. PE is a difficult diagnosis that may be missed because of non-specific clinical presentation. However, early diagnosis is fundamental, since immediate treatment is highly effective. Depending on the clinical presentation, initial therapy is primarily aimed either at lifesaving restoration of flow through occluded pulmonary arteries (PA) or at the prevention of potentially fatal early recurrences.

Both initial treatment and the long-term anticoagulation that is required for secondary prevention must be justified in each patient by the results of an appropriately validated diagnostic strategy (Roy, 2006).

Epidemiology, predisposing factors, and the pathophysiology of PE have been described more extensively elsewhere.

This document focuses on currently available and validated methods of diagnosis, prognostic evaluation and therapy of PE. In contrast to previous guidelines, we decided to grade also the level of evidence of diagnostic procedures. The most robust data come from large-scale accuracy or outcome studies. Accuracy studies are designed to establish the characteristics of a diagnostic test (sensitivity and specificity) by comparing test results with a reference diagnostic criterion (the so-called gold standard).

Outcome studies evaluate patient outcomes when a given diagnostic test or strategy is used for clinical decision-making. In the field of PE, the outcome measurement is the rate of thromboembolic events [deep vein thrombosis (DVT) or PE] during a 3-month follow-up period in patients left untreated by anticoagulants.

The reference for comparison is the rate of DVT or PE in patients left untreated after a negative conventional pulmonary angiogram, which is around 1–2%, with an upper limit of the 95% confidence interval (CI) of 3% during a 3-month follow-up. The advantage of outcome studies is that they are easily carried out under normal clinical circumstances and their results are therefore generalizable. However, they do not yield any information on false positives and potential overtreatment (Roy, 2006).

2.3.5.1 Causes of pulmonary embolism

The most common causes of embolism are proximal leg deep venous thrombosis (DVT) pelvic vein thrombosis.

2.3.5.2 Risk factor of pulmonary embolism

Risk factor which are included for pulmonary embolism are prolonged bed rest, surgery, child birth, heart attack, stroke, congestive heart familiar, cancer, obesity, oral contraceptive, sickle cell anemia, congenital coagulation disorder, chest trauma, certain congenital heart defects and angina (Roy, 2006).

2.3.5.3 Complication of pulmonary embolism

Complication that can occur during or after of embolism are palpitation, heart failure or stroke, respiratory distress (severe breathing difficulties), sudden death, hemorrachge (usually are complication of thrombolytic or anti coagulant therapy), and pulmonary hypertension with recurrent pulmonary embolism (Dalen, 2002).

2.3.5.4 Epidemiology

PE and DVT are two clinical presentations of venous thromboembolism (VTE) and share the same predisposing factors. In most cases PE is a consequence of DVT. Among patients with proximal DVT, about 50% have an associated, usually clinically asymptomatic PE at lung scan.8 In about 70% of patients with PE, DVT can be found in the lower limbs if sensitive diagnostic methods are used.(Dalen, 2002).

2.3.5.5Predisposing factors

Although PE can occur in patients without any identifiable predisposing factors, one or more of these factors are usually identified (secondary PE).

The proportion of patients with idiopathic or unprovoked PE was about 20% in the International Cooperative Pulmonary Embolism Registry (ICOPER) (Goldhaber, 1999).

VTE is currently regarded as the result of the interaction between patient related and setting-related risk factors. Patient-related predisposing factors are usually permanent, whereas setting-related predisposing factors are more often temporary.

2.3.5.6 Types of PE

2.3.5.6.1 Acute massive pulmonary embolism

The pathophysiology is due to acute obstruction of more than 50% of either the main or the proximal pulmonary artery leading to an acute reduction of cardiac output and right ventricular dilatation. (Overton 1988)

To compare multi-detector row computed tomography (CT) and ventilation-perfusion (V-P) scintigraphy in the diagnosis of acute pulmonary embolism (PE) in outpatients who were cared for in the emergency department. (Overton 1988)

2.3.5.6.2 Acute minor pulmonary embolism

The majority of patient will present with so called pulmonary infarction syndrome with shortness of breath and haemoptysis, clinically there may be pleural effusion the chest radiography may show wedge-shaped opacity due to hemorrhage, pleural effusion or an elevated diaphragm.(Overton 1988)

2.4 Diagnosis

2.4.1 Pulmonary Embolism by Helical CT

Pulmonary embolism (PE) was clinically described in the early 1800s, and von Virchow first described the connection between venous thrombosis and PE. In 1922, Wharton and Pierson reported the first radiographic description of PE. Images depicting clots in the pulmonary arterial system are provided below (Wharton, 1922).

Imaging has played an important role in the diagnosis of PE. For many years, ventilation-perfusion (V/Q) scintigraphy has been the main imaging modality for the evaluation of patients with suspected PE. However, with the advent of and the widespread availability of faster computed tomography (CT) scanners, CT scanning has emerged as another important diagnostic test for the evaluation of not only PE, but also of deep venous thrombosis (DVT) in select patients (Jardin, 2007).

Three primary influences predispose a patient to thrombus formation; these form the so-called Virchow triad: (1) endothelial injury, (2) stasis or turbulence of blood flow, and (3) blood hypercoagulability (Jardin, 2007).

More than 90% of all PEs arise from thrombi within the large deep veins of the legs, typically the popliteal vein and the larger veins above it. The pathophysiologic consequences of thromboembolism in the lung largely depend on the cardiopulmonary status of the patient and on the size of the embolus, which, in turn, dictates the size of the occluded pulmonary artery (Jardin, 2007).

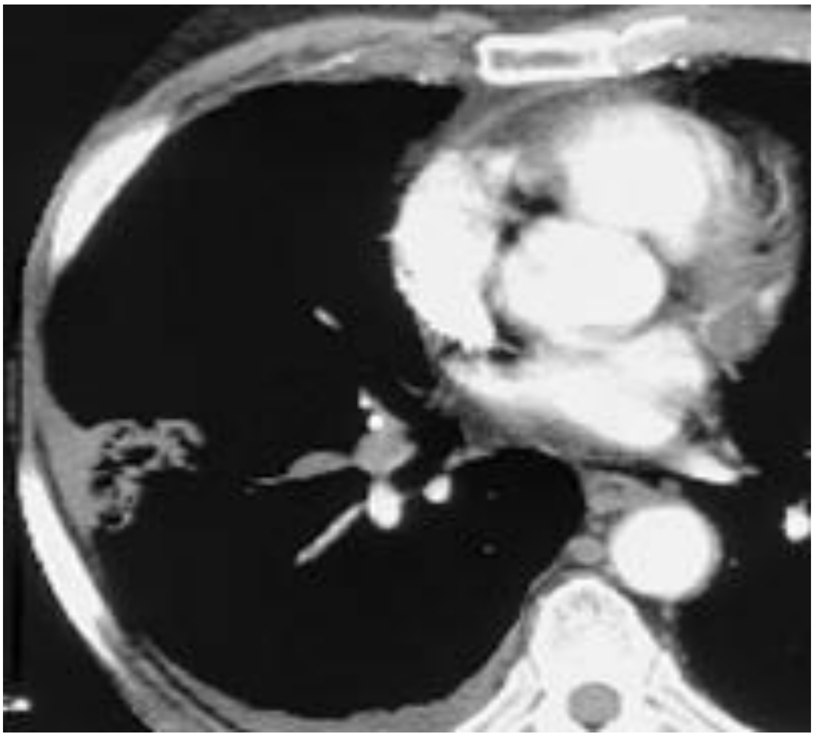

Figure (2-7) shows Computed tomography angiogram in a 53-year-old man with acute Pulmonary embolism. This image shows an intraluminal filling defect that occludes the anterior basal segmental artery of the right lower lobe. Also present is an infraction of the corresponding lung, which is indicated by a triangular, pleura-based consolidation (Hampton hump).

2.4.2 Preferred examination

In patients with possible PE, chest radiographic findings may indicate if lung scanning (V/Q) or helical CT scanning should be the next method of evaluation. If the chest radiograph is normal, V/Q findings may be diagnostic; if the chest radiograph is abnormal, helical CT should be performed (Stein, 2007).

A quantitative D-dimmer assay is reported to have high negative predictive value and may be effective for excluding the need for pulmonary CT angiography (CTA) in selected cases. Another study shows that using a clinical decision rule with D-dimmer level improved pulmonary CTA and better identified positives for pulmonary embolisms (Hoo, 2011).

Conventional pulmonary angiography is invasive, time consuming, and more expensive than other tests. The role of conventional angiography is limited to patients in whom other results are nondiagnostic or the clinical suspicion is high. In patients with suspected DVT, the workup should start with leg ultrasonography (Stein, 2007).

2.4.3 Limitations of techniques

Iodinated contrast agents are needed for helical CT pulmonary angiography, and their use may not be possible in patients with impaired renal function or a severe allergy to the contrast material. (Oser, 1996).

Small (sub segmental) emboli may be missed with CT angiography.

Compared with CT scanning, conventional pulmonary angiography requires more expertise and support staff. Conventional angiography is also invasive, time consuming, more expensive, and less available. In addition, a chronic central mural thrombus that is easily seen with CT scanning may be missed at pulmonary angiography (Oser, 1996).

Technical advances in CT scanning, including the development of multidetector-array scanners have led to the emergence of CT scanning as an important diagnostic technique in suspected PE. Contrast-enhanced CT scanning is increasingly used as the initial radiologic study in the diagnosis of PE, especially in patients with abnormal chest radiographs in whom scintigraphic results are more likely to be nondiagnostic.

CT scanning shows emboli directly, as does pulmonary angiography, and it is also noninvasive, cheaper, and widely available. CT scanning is the only test that can provide significant additional information related to alternate diagnoses; this is a clear advantage of CT scanning compared with either pulmonary angiography or scintigraphy. (Oser, 1996).

Because DVT and PE are part of the same disease process, CT venography can easily be performed after CT pulmonary angiography, without the administration of additional contrast material (Loud, 2000).

This study requires only a few extra minutes and allows "one-stop imaging" for PE and DVT.

The technique for CT pulmonary angiography with single-section helical CT involves the following parameters: 3-mm collimation, 2-mm reconstruction interval, pitch of 2, and an average acquisition time of 24 seconds. Iodinated contrast medium is administered as a bolus with an automated injector.

Generally, a large volume (100-150 ml) of contrast material is administered at a high flow rate (4 ml/s) for good-quality diagnostic opacification of vessels. (Schoepf, 2004).

CT venograms can be acquired 3-4 minutes after the start of the administration of contrast material. The new multidetectorrow CT (MDCT) scanners are considerably faster, allowing the performance of thin-section (1.25-mm) helical CT pulmonary angiography during a shorter breath hold (15-17 seconds). With introduction of dual-source CT technology, ECG-gated

CTA of the chest may become practical and help provide clinicians with cardiac functional information. Efforts should be made to minimize the radiation dose by using all available equipmentspecific dose reduction techniques. (Schoepf, 2004).

When a PE is identified, it is characterized as acute or chronic. An embolus is acute if it is situated centrally within the vascular lumen or if it occludes a vessel. Acute PE commonly causes distention of the involved vessel.

PE is further characterized as central or peripheral, depending on the location or the arterial branch involved. Central vascular zones include the following:

Main pulmonary artery, the left and right main pulmonary arteries, the anterior trunk, the right and left interlobar arteries, the left upper lobe trunk,the right middle lobe artery the right and left lower lobe arteries Peripheral vascular zones include the following:

The segmental and subsegmental arteries of the right upper lobe, the right middle lobe, the right lower lobe, the left upper lobe, the lingula, the left lower lobe.

There is ongoing research in the field of post processing of CT scan data for acute PE, one dealing with the detection of perfusion defects as an adjunct to transverse CT scans for detection of small peripheral PE and another focusing on the automatic computer-aided detection of end luminal clots.

2.4.4 Computer tomography

The basic equipment configurations for CT are three major systems: the imaging system, computer system and image display, recording, storage and communication system. Moss- (Gamsu-Genant2015)

2.4.4.1The three major systems are located in separate rooms as follows

The imaging system is located in the scanner room.

The computer system is located in the computer room.

The display, recording and storage system is located in the operator's room.

2.4.4.1.1 Imaging system

2.4.4.1.1.1 Gantry

Is amounted frame work that surrounds the patient in vertical plane. It contains a rotating scan frame on to which the x- ray generator, ray tube and other component are mounted.

2.4.41.1.2 Patient couch

The patient couch or table provides a plate from on which the patient lies during examination. The couch should be strong and rigid to support the weight of the patient, additionally it should provide for safety and comfort of the patient during examination (Moss-Gamsu-Genant 2015).

2.4.4.1.2 The computer system

The computer system in CT belongs to class of minicomputers. The two most important characteristics of the CT computer system are a large strong capacity and fast and efficient processing of various kinds of data (Moss-Gamsu-Genant 2015).

2.4.4.1.3 Imaging display, storage, recording and communication

2.4.4.1.3.1 Image display

a display device for CT generally a black and white or color monitor, where as images are usually displayed in gray scale. The features of the image display are display matrix, pixel, size, bit depth, CT value scale image monitor and number of lines, and selectable window width and window center (Moss-Gamsu-Genant 2015).

2.4.4.1.3.2 Image storage

Data are stored in digital form to preserve the wide dynamic range of image processing and intensity transformation and to decrease the possibility of lost records and reduce the space needed for archiving (Moss-Gamsu-Genant 2015).

2.4.4.1.3.3 Laser recording system

The requirements for hard copy recording of CT images are stringent because these images are used for diagnostic interpretation. (Moss-Gamsu-Genant 2015)

The steps in the laser printing film are:

-When the appropriate command from the operator is received;anun exposed film is transported to the exposure area of the printer.

-In the exposure area, the film is scanned systematically line by line. The laser received its signal from computer to produce a latent image.

-Depending on the printer, the laser. Scanned film is sent to the receiver or a chemical processor attached to the printer for development.

-The result is a laser printed film ready for viewing.

Figure 2-8 CT machine (64-slice) (Moss-Gamsu-Genant 2015)

2.4.5 Technique and strategies of computed tomography examination

The diagnostic methodology is part of diagnostic strategy and includes patient preparation, examination parameters and administration of contrast media.

2.4.5.1 Patient preparation

When patient presents for abdominal computed tomography the radiologist should assess the clinical problem and review previous imaging studies. Assess medical history, including the current indication for study, contrast allergies, renal impairment, past abdominal surgeries, radiation therapy...etc. (Moss-Gamsu-Genant 2015)

-Decision to be made to individualize the examination includes:

Contrast, intra venous, oral or rectal.

Area scanned, anatomic land marks.

Scan parameter, thickness, spacing, field of view, filters, dose and angulations.

Technique, dynamic sequence, as (axial - spiral - helical - time -matrix).

The radiologist should review the scan before patient leave.

2.4.5.2 Technical parameter

Slice thickness (2-3) mm is sufficient for most application of thoracic computed tomography.

Most scan are performed using contiguous slice (10mm-thick at 10mm interval) surgery examination may be performed at the longer interval 10mm thickness at 15-20mm.interval to sac radiation dose and time with minimal loss of information.

Sac time of 1-2 second used to diminish motion artifact from peristalsis and pulsating blood vessels.

Contiguous section must be scanned when second image reconstruction (reformatting) to be performed.

A reduction in slice thickness will lead to increase noise if the reduction dose per slice is not increase correspondingly.

Good patient preparation (anti peristallic agent) is also an important factor in reducing motion artifact.

The number of slices to be scanned deiarumie the total scans time; these should be considered when intra venous contrast administrated.

Depending on the slice thickness and size of the computer matrix, the selected dose per slice determines the degree of spatial and contrast resolution (Moss-Gamsu-Genant 2015).

Image reconstruction time during biopsy procedure 925*256 matrixes will usually suffice.

2.4.6 CT imaging technique

If using a single-detector-row scanner, thin collimation of 2 to 3 mm with pitch 1.7 to 2 generally provides adequate resolution for detection of segmental and larger emboli. Dysnic patients may be scanned using slightly thicker collimation to permit shorter breath-hold duration, but this will decrease detection of small emboli. Typical parameters for MDCT include a collimation of 1 to 2.5 mm and pitch 6. The volume of interest extends from the dome of the diaphragm (inferior pulmonary veins) up to the aortic arch, or approximately 10 to 12 cm along the z-axis. Patients are coached to hyperventilate two or three times before holding their breath in inspiration as the x-rays begin.(Moss-Gamsu-Genant 2015)

As most emboli go to the lower lobes, patients are scanned in a caudal-to-cranial direction, which helps ensure that dyspnoeic patients can hold their breath for at least the initial, lower lobe images. An injection rate of at least 3 cc/second should be used with 100 to 140 cc of full-strength nonionic contrast; many centers use higher flow rates.16 At higher injection rates, more dilute contrast may be used to avoid streak artifacts in the central veins. Contrast should be injected through an antecubital or more proximal vein.(Moss-Gamsu-Genant 2015)

The use of a standard injection delay is feasible in most cases; the value depends on flow rate but is usually between 15 and 20 seconds. A timing bolus may be of value if there is known severe pulmonary hypertension or circulatory delay. Images are reconstructed using overlapping intervals of 1 to 2 mm, unless 1-mm collimation is used. If cases are being filmed, those that are not clearly positive on film review must be viewed on a workstation to maximize accuracy (Moss-Gamsu-Genant 2015).

2.5 Previous studies

- Teigen CL (1993) In one of the early investigations, 42 patients were prospectively studied with spiral CT and selective pulmonary angiography for the detection of pulmonary embolism. One hundred and twelve emboli in the main, lobar, and segmental pulmonary arteries were detected at spiral CT and correlated exactly with the emboli detected on subsequent angiograms.
  All 23 patients with normal spiral CT had normal pulmonary angiograms, whereas of 19 patients with evidence of pulmonary embolism by spiral CT, 18 had pulmonary embolism by pulmonary angiography.
  The sensitivity of spiral CT for pulmonary embolism was 100% and the specificity was 96%.

- Kim et al (2010)Detection of Pulmonary Embolism in the Postoperative Orthopedic Patient Using Spiral CT Scans, to compare the clinical presentations of a suspected versus a documented PE/DVT and to determine the actual incidence of PE/DVT in the post-operative orthopedic patient in whom CT was ordered. All 695 patients at our institution who had a postoperative spiral CT to rule out PE/DVT from March 2004 to February 2006 were evaluated and information regarding their surgical procedure, risk factors, presenting symptoms, location of PE/DVT, and anticoagulation were assessed. Statistical analysis was performed using an independent samples *t* test with a two-tailed *p* value to examine significant associations between the patient variables and CT scans positive for PE. Logistic regression models were used to determine which variables appeared to be significant.
- Another study byRemy-Jardin M (2007) CTPA studies using the multislice technique showed a high sensitivity (96 to 100%) and specificity (97 to 98%), and they have replaced invasive pulmonary angiography as the reference test for acute PE. Sensitivity and specificity, depending on the location of the emboli, vary from 20 to 30% for small subsegmental emboli

using single row CT up to 95% for segmental, lobar, and central emboli using multislice CTPA.

- By Anderson DR (2007) a study from 2007 compared diagnostic test results of CTPA with V/Q scintigraphy and revealed comparable results with a prevalence of PE of 14 to 19% and a 0.6 to incidence of recurrent VTE after normal V/Q scan during 3-month follow-up The most important advantage of CTPA over V/Q scintigraphy is the low number of inconclusive test results (0.9 to 3.0 vs 28 to 46%) and the possibility to achieve an alternative diagnosis that can explain the complaints of the patients, including pneumonia, malignancy, or aortic dissection.

With the development of the CTPA technique, more and smaller, subsegmental emboli may become visualized. The clinical relevance of these emboli is yet uncertain.Although observational research suggests that treated as well as untreated patients have a good prognosis, the clinical relevance is not clear at this moment given the lack of good randomized outcome studies. Disadvantages of CTPA are the relative contraindications in patients with allergy to iodinated contrast material, occurring in 0.7% of patients, and in patients with impaired renal function. Contrast-induced nephropathy after CTPA is estimated to occur in 8.9 to 12% of patients. Overuse of CTPA, without assessment of the pretest probability, may lead to a high rate of more than 90% of negative results.

- Robert et al,(2010) studied the differences in clinical presentation of pulmonary embolism in women and men, the analyzed data concluding that from a total of 3414 outpatients with suspected PE. The study population comprised 1940 women (57%; mean age 60 ± 17) and 1474 men (43%; mean age 60 ± 20). The diagnosis of PE was confirmed in 773 patients (22.6%): 432 out of 1940 women and 341 out of 1474 men (22.3% vs. 23.1%; P = 0.55). Thromboembolic risk factors, symptoms and clinical signs according to gender are presented personal or family history of venous thromboembolism, or varicose veins was more commonly found in women. Among PE diagnosed by CT, the most proximal level was troncular in 29%, lobar in 37%, segmental in 30% and multiple sub segmental in 4%, without any significant difference between genders. However, the proportion of PEassociated proximal DVT was higher in men than in women: 43% of men compared with 33% of women had an associated proximal DVT (P = 0.009).

Chapter Three

Material and Methods

3.1 Place & time of the study

The study was performed in CT centers in Khartoum (The Modern Medical Center and Dar Alelaj Specialized Hospital).

Data were collected in the period from (15.11.2017) to (2.1.2018).

3.2 sample of the study

The entire populations of this study were 50 patients (9 males and 41 females) with ages range between (30-80), 5 patients aged between (30-40) years, 13 patients aged between (40-50) years, 10 patients aged between (50-60) years, 21 patients aged between (60-70) years, 1 patient age between (70-80). They referred to CT center for CT examination of chest. All patients suspected to have pulmonary embolism according to the clinical signs and symptoms.

3.3 Interpretation and getting results

A radiologist, a physician specifically trained to supervise and interpret radiology examinations, will analyze the images and send assigned report to primary care or referring physician

Data is collected from image reports that demonstrate size, site, texture and enhanced tumors

3.4 Machine used

For CT was used 64 slice scanner (PHILIPS), and 64 slice scanner (GM - optima-Health Care).

3.5 Technique used

Light speed 64-section CT scanners (PHILIPS) are used to acquire images of the thorax in a caudocranial direction. For intravenous access, introduction of an 18- or 20-gauge catheter into an antecubital vein is preferred. The chest field of view is the widest rib-to-rib distance acquired during breath hold after inspiration. Images are acquired with a standard algorithm and viewed with IMPAX version 4.1 software (AGFA, Teterboro, NJ). Images are displayed with three different gray scales for interpretation of lung window (window width/level [HU] = 1500/600), mediastinal window (400/40), and pulmonary embolism–specific (700/100) settings. Multiplanar reformatted images through the longitudinal axis of a vessel are sometimes used to overcome various difficulties encountered with axial sections of obliquely or axially oriented arteries. Reformatted images can help differentiate between true pulmonary embolism and a variety of patient-related, technical, anatomic, and pathologic factors that can mimic pulmonary embolism.

Multisection CT venography is simple and accurate, and when combined with lung imaging it allows fast and comprehensive evaluation for thromboembolic disease.

Bolus tracking using soft ware supplied with most multi detector scanner. A ROI (region of interest) is positioned over the pulmonary artery at the level of the carina. After commencing the injection a (trecker scan) monitors the Hounsfield level at the ROI and the scan is the triggered when the density at the ROI reaches a preset value.

3.6 Data processing

Data were first summarized into master data sheet, then analyzed by using statistical package and then using Microsoft Excel for data presentation (Appendex1).

Chapter Four

Results

The CT images of 50 patients were evaluated. For pathological finding, the site, size texture and enhancement of lesion with contrast were identified. All this information was shown in the following tables and graphs.

Table 4.1 shows division of Subject group according to the age

Patient age group	**Frequency**	**Percentage**
30-40	5	10%
40-50	13	26%
50-60	10	20%
60-70	21	42%
70-80	1	2%
Total	**50**	**100%**

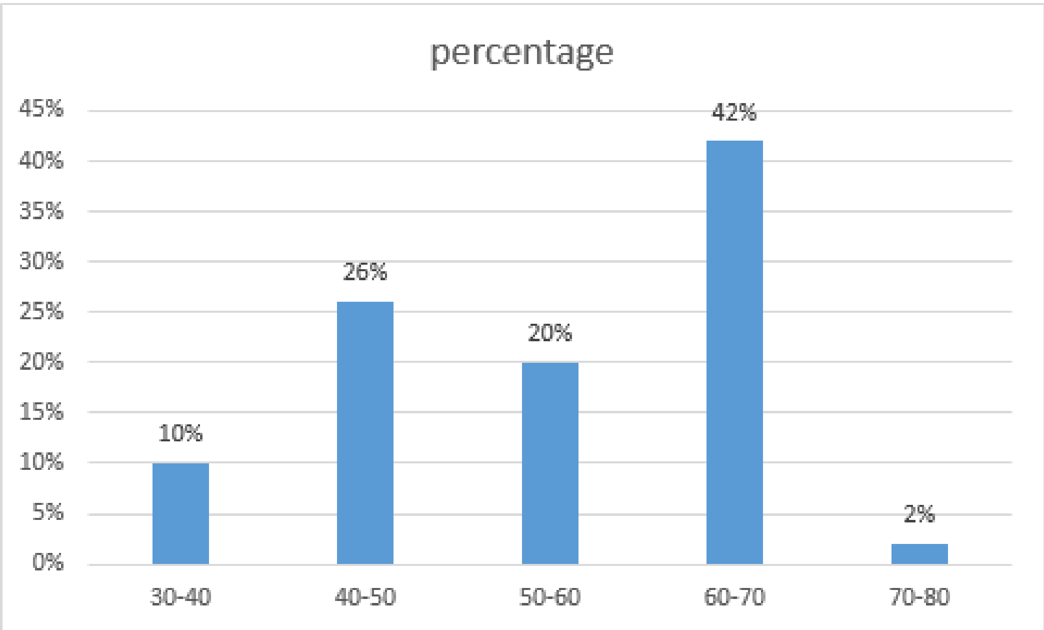

Fig 4.1 illustrate the percentage of population ages

Table 4.2 shows study group according to gender

Patient sex group	Frequency	Percentage
Male	9	18%
Female	41	82%
Total	**50**	**100%**

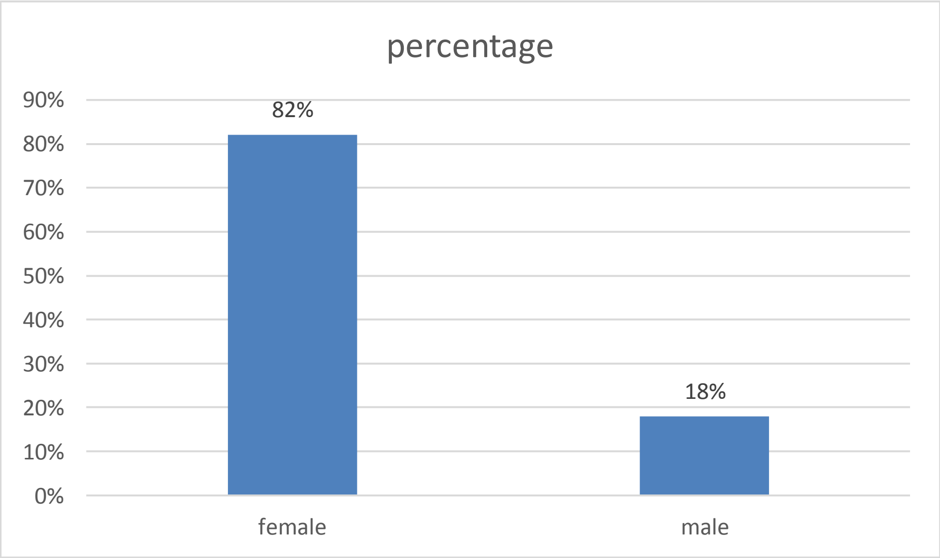

Fig 4.2 illustrated study groups according to gender

Table 4.3 shows study group according to location of PE

Location	Frequency	Percentage
Both pulmonary arteries	39	78%
Right pulmonary artery	8	16%
Left pulmonary artery	3	6%
Total	**50**	**100%**

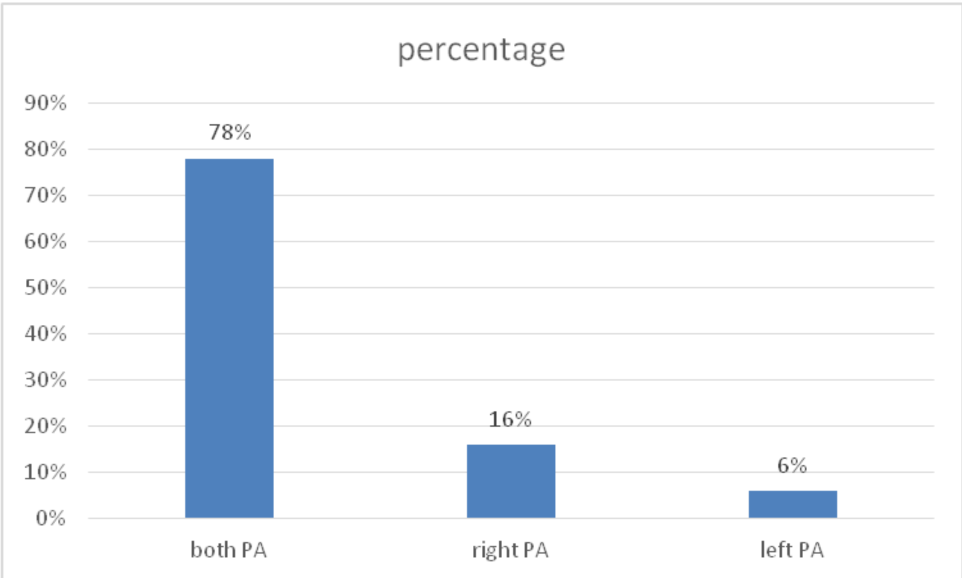

Fig 4.3 illustrated study group according to location of PE

Table 4.4 shows study group according to type

Type	Frequency	Percentage
Acute massive	46	92%
Acute minor	4	8%
Total	**50**	**100%**

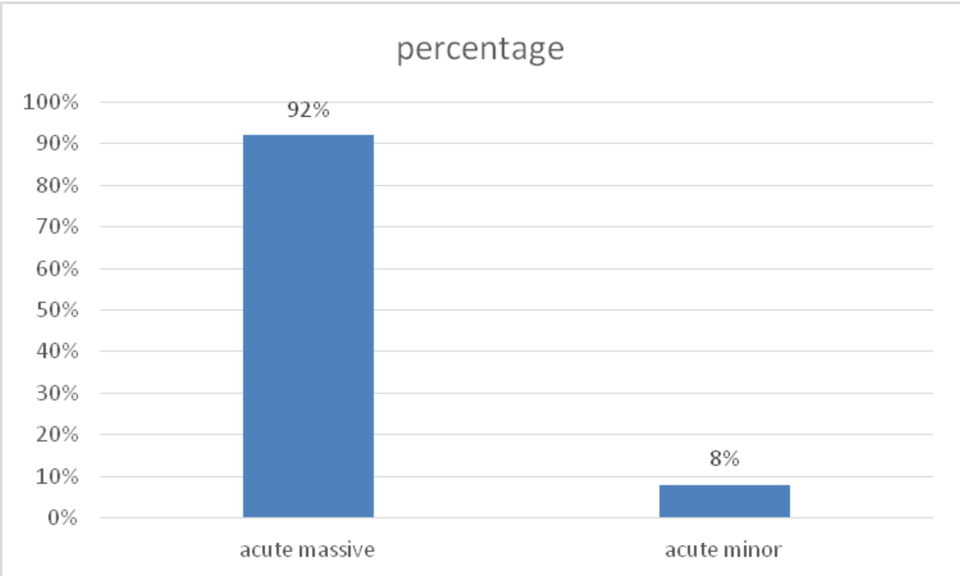

Fig 4.4 illustrated study group according to type of PE

Chapter Five

Discussion, Conclusion and Recommendation

5.1 Discussion

This study was performed in 50 patients 41 patients were females while 9 were males and their aged are ranged from 30 to 80 years old they referred for CT chest.

Frequency of Pulmonary Embolism was higher within females (41) than males (9). This result indicates that CT has a high technical success rate. The characteristic of the all variables in the sample studied were described as frequencies and percentages. CT for chest was used in this study axial and coronal to demonstrate PE found the following results:

The main CT pulmonary embolism finding were PE in 21 patients (42%) with age range (60-70) years,13 patients (26%) with age range (40-50) years,10 patients (20%) with range (50-60) years, 5 patients (10%) with range (30-40) years and 1 patient (2%) with range (70-80), according to this result PE is rare in young patients and is more common in elder patients.

The study showed common side for PE in both side .There were 39 patients form study group PE were found in both side (78%), the second common side was right side 8 patients (16%) and the rare side in left side 3 patients (6%) .

The study showed common type of PE is the acute massive type.

CT scanning of chest was providing great clarity and reveal high details in diagnosing of PE.

With regard to gender this study found good agreement with a previous study (Robert et al, 2010).

5.2 Conclusion

In conclusion, helical CT is a technical improvement of helical CT and a diagnostic tool with a high sensitivity and specificity for the detection of PE. These findings of study indicate that helical CT could replace pulmonary arteriography for the direct demonstration of endoluminal thrombi in the pulmonary arteries in a majority of patients.

Selective pulmonary arteriography should be reserved for select patients with an unresolved diagnosis. The evaluation of small vessels, which is improved by thin sections, remains a limitation of current helical CT. However, the developments of faster imaging systems with submillimeter isotropic imaging are expected to improve the evaluation of sub-segmental pulmonary vessels, with optimal spatial and temporal resolution, in the near future.

This modern equipment CT has diagnosing function and resulting in good high technical properties and this powerful procedure must be one important interests of our planning to progress and develop our medical services in the Sudan.

CT is the image modality of choice evaluate PE, as the provides a road map and excellent detail is available regarding to the anatomy, pathology and early diagnosis of PE very import factor in the disease management.

CT was used ideally for full evaluation of the PE and today CT scanners allow post processing reformats for further views in different planes if required.

With multi–detector row CT technology, past limitations of CT for the diagnosis of PE should be effectively overcome; for all practical purposes, CT has become the first-line modality for imaging in patients suspected of having PE. However, prospectively acquired patient outcome studies are still needed. Once this type of investigation has confirmed that a negative CT study can be used to safely rule out PE, we believe use of CT to aid in diagnosis of PE will be unanimously accepted.

5.3 Recommendation

CT chest should be performed for any patients complain of chest pain or breathing problem.

Spiral CT technique should be the primary investigation performed for patient suspected to have PE

The radiologist and technologist should be well trained.

There should be effective co operation between technologist, radiologist & Physicians to make full use of available spiral CT facilities.

The medication for the contrast media reaction should be available before Injection.

Detection of Pulmonary Embolism with Combined Ventilation–Perfusion SPECT and Low-Dose CT

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Appendix

Sudan University of Science & Technology
College of Graduate studies

DATA SHEET

NO	GENDER	AGE	SITE OF PE	TYPE OF PE
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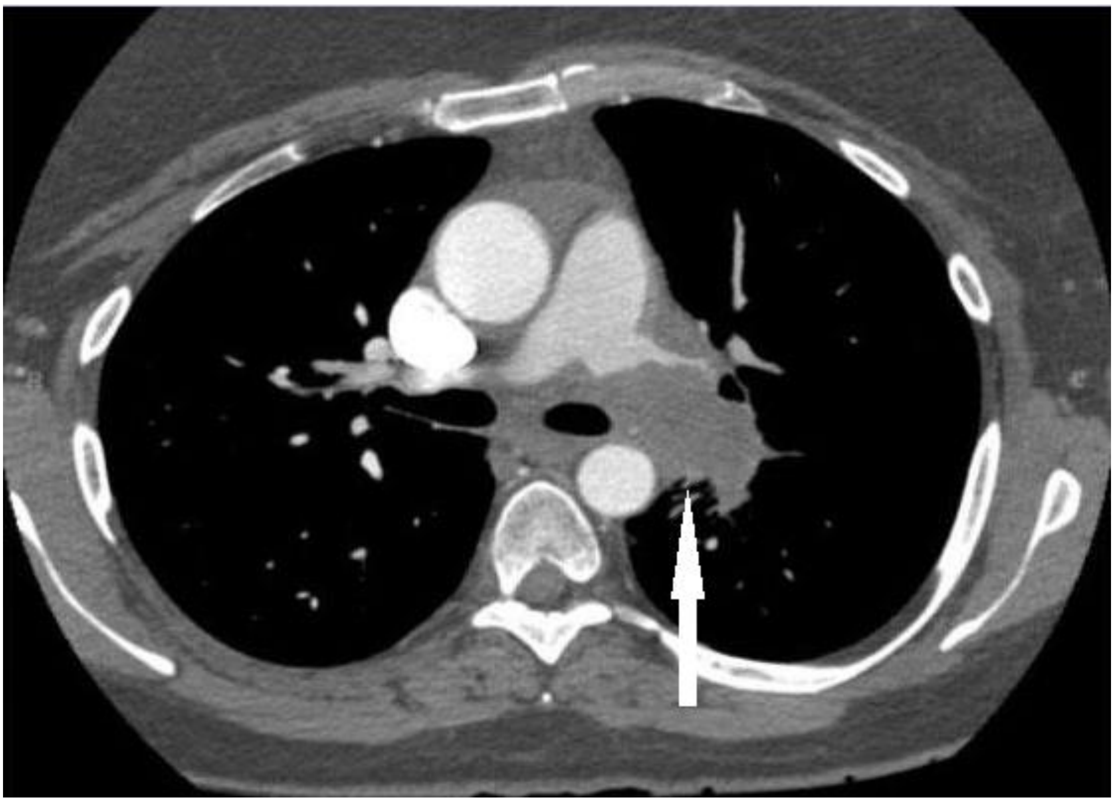

Image (1) A42 year's male axial CT image of the chest demonstrating acute massive pulmonary embolism in the left main pulmonary artery and extending into all subbranche

Image (2) A58 year's female axial CT image of the chest demonstrating acute massive pulmonary embolism in the right main pulmonary artery.

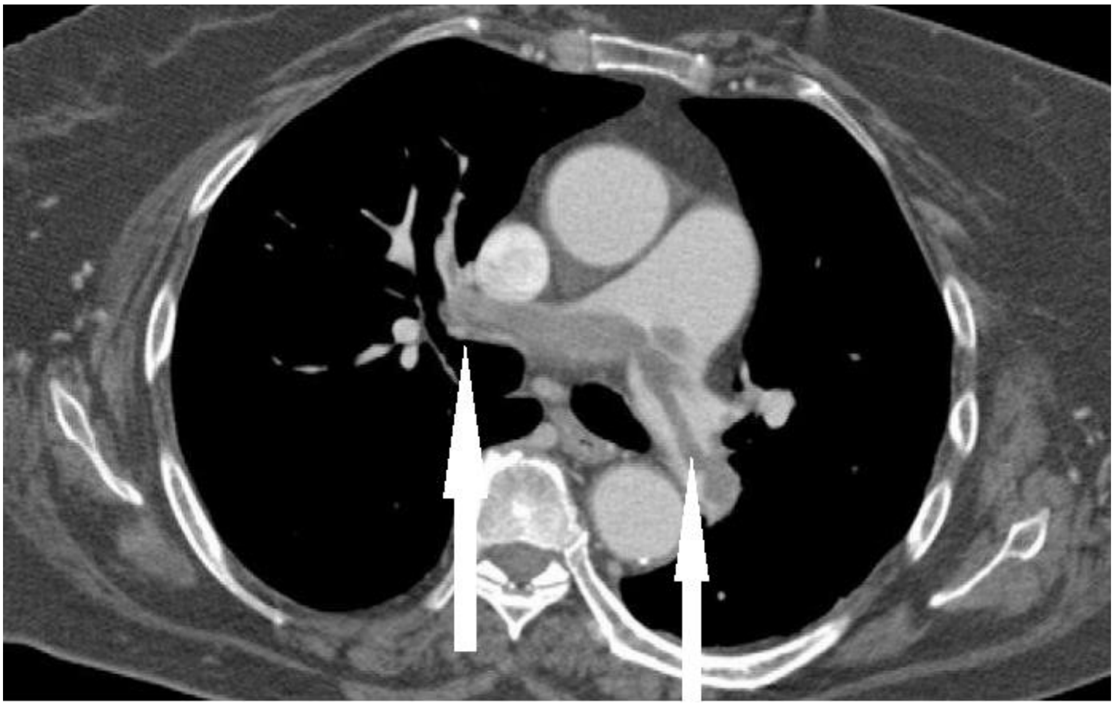

Image (3) A63 year's female axial CT image of the chest demonstrating acute minor pulmonary embolism in the both side of main pulmonary artery.

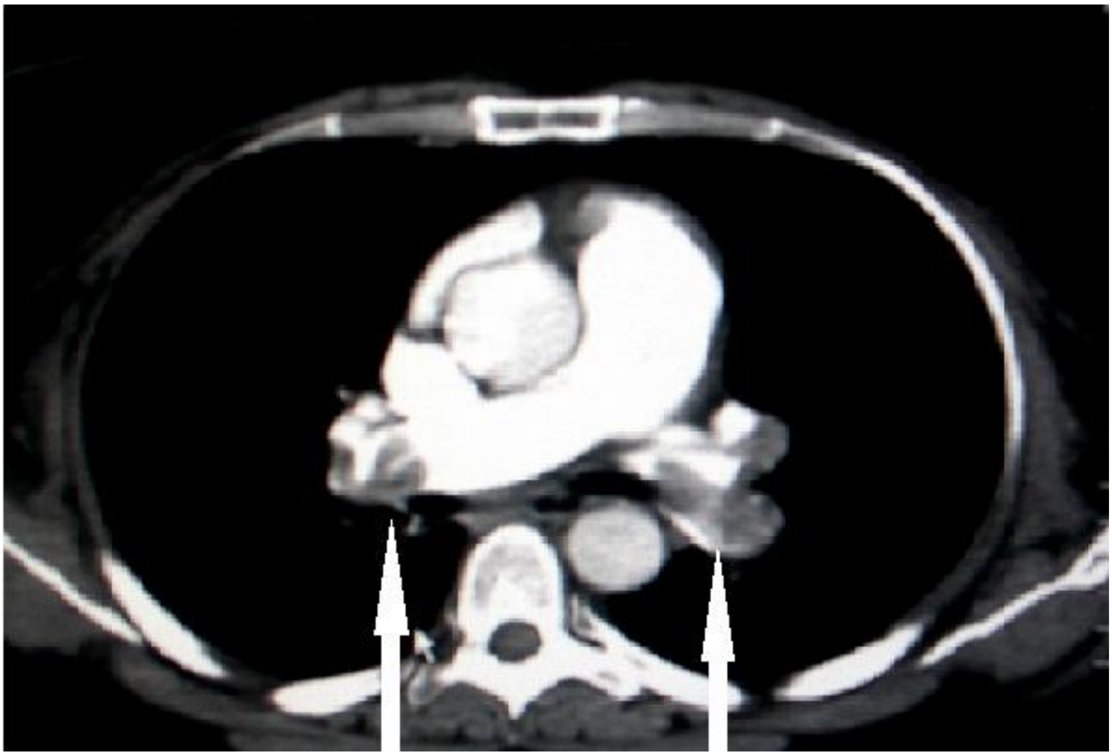

Image (4) A67 year's male axial CT image of the chest demonstrating acute massive pulmonary embolism in the both side of main pulmonary artery.

Image (5) A73 year's female coronal CT image of the chest demonstrating acute massive pulmonary embolism in the both side of main pulmonary artery.