Chapter One

Introduction

1.1 Introduction:

Tuberculosis is one of the oldest ailments having an impact on humankind and is a noteworthy reason for mortality around the world. The causative agent of tuberculosis is Mycobacterium tuberculosis complex and mostly influences the lungs. Other organs are affected in up to 33% of cases. Drug susceptible tuberculosis is curable in essentially all cases. If it is left untreated, the malady may be deadly within 5 years in 50–65% of cases ˹Figueiredo, 1994).

The most common form of pulmonary tuberculosis in adults is post primary disease or reinjection. Although chest radiographs are extremely good for the diagnosis of active pulmonary tuberculosis, minimal exudative tuberculosis can be overlooked on standard chest radiography (Figueiredo, 1994). Computed tomography (CT) is superior to conventional radiography in detecting activity and CT features of pulmonary(Figueiredo, 1994).

Tuberculosis has been described. In recent years, because of high-resolution power and minimal partial volume effect, high resolution computed tomography (HRCT) is superior to conventional chest radiography and standard CT in the localization of disease in the pulmonary lobule and the evaluation of pulmonary parenchymal disease(Figueiredo, 1994)..

High-Resolution Computed Tomography (HRCT) has been discovered to be more sensitive than a chest x-ray in the identification of small exudative lesions, slight or occult parenchymal disease and in assessing disease activity in pulmonary TB (Figueiredo, 1994).

1.2. Statement of problem:

Although chest radiographs usually provide sufficient information for the diagnosis of pulmonary tuberculosis in the second stage, the early stages of the disease do not show high accuracy in the X-ray and also do not accurately determine the characterization of changes in the lung tissue, leading to the spread of disease Tuberculosis in the lungs

1.3- Objectives:

1.3.1-General objective:

To study CT findings of pulmonary tuberculosis in adult Sudanese patient

1.3.2-specific objectives:

To evaluate the findings of HRCT among TB patients

To evaluate the main clinical presentation among TB patients

To assess the association between the HRCT findings and the age of the patients

To assess the association between the HRCT findings and the gender of the patients

Chapter two

Literature review and previous study

2.1. Anatomy:

A major organ of the respiratory system, each lung houses structures of both the conducting and respiratory zones. The main function of the lungs is to perform the exchange of oxygen and carbon dioxide with air from the atmosphere.

The lungs are pyramid-shaped, paired organs that are connected to the trachea by the right and left bronchi; on the inferior surface, the lungs are bordered by the diaphragm, lungs are enclosed by the pleurae, which are attached to the mediastinum. The right lung is shorter and wider than the left lung, and the left lung occupies a smaller volume than the right. The cardiac notch is an indentation on the surface of the left lung, and it allows space for the heart .The apex of the lung is the superior region, whereas the base is the opposite region near the diaphragm. The costal surface of the lung borders the ribs. The mediastinal surface faces the midline. The diaphragm is the flat, dome-shaped muscle located at the base of the lungs and thoracic cavity (Joseph, F2008).

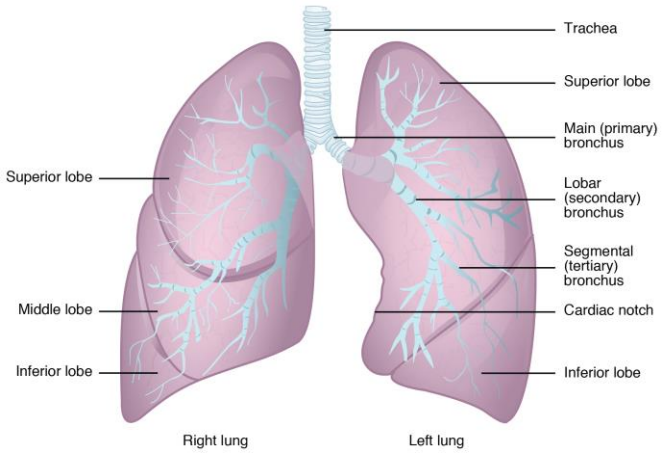

Figure (2.1) show Lung anatomy (http://pediaa.com/difference-between-right-and-left-lung/)

Each lung is composed of smaller units called lobes. Fissures separate these lobes from each other. The right lung consists of three lobes: the superior, middle, and inferior lobes. The left lung consists of two lobes the superior and inferior lobes. A bronchopulmonary segment is a division of a lobe, and each lobe houses multiple bronchopulmonary segments. Each segment receives air from its own tertiary bronchus and is supplied with blood by its own artery. Some diseases of the lungs typically affect one or more bronchopulmonary segments, and in some cases, the diseased segments can be surgically removed with little influence on neighboring segments. A pulmonary lobule is a subdivision formed as the bronchi branch into bronchioles. Each lobule receives its own large bronchiole that has multiple branches. An interlobular septum is a wall, composed of connective tissue, which separates lobules from one another(Joseph, F2008).

2.1.1 Blood Supply:

The major function of the lungs is to perform gas exchange, which requires blood from the pulmonary circulation. This blood supply contains deoxygenated blood and travels to the lungs where erythrocytes, also known as red blood cells, pick up oxygen to be transported to tissues throughout the body. The pulmonary artery is an artery that arises from the pulmonary trunk and carries deoxygenated, arterial blood to the alveoli. The pulmonary artery branch multiple times as it follows the bronchi, and each branch becomes progressively smaller in diameter. One arteriole and an accompanying veinule supply and drain one pulmonary lobule. As they near the alveoli, the pulmonary arteries become the pulmonary capillary network. The pulmonary capillary network consists of tiny vessels with very thin walls that lack smooth muscle fibers. The capillaries branch and follow the bronchioles and structure of the alveoli. It is at this point that the capillary wall meets the alveolar wall, creating the respiratory membrane. Once the blood

is oxygenated, it drains from the alveoli by way of multiple pulmonary veins, which exit the lungs through the hilum (Joseph, F2008).

2.1.2 Nervous Innervation:

Dilation and constriction of the airway are achieved through nervous control by the parasympathetic and sympathetic nervous systems. The parasympathetic system causes bronchoconstriction**,** whereas the sympathetic nervous system stimulates bronchodilation. Reflexes such as coughing, and the ability of the lungs to regulate oxygen and carbon dioxide levels, also result from this autonomic nervous system control. Sensory nerve fibers arise from the vagus nerve, and from the second to fifth thoracic ganglia. The pulmonary plexus is a region on the lung root formed by the entrance of the nerves at the hilum. The nerves then follow the bronchi in the lungs and branch to innervate muscle fibers, glands, and blood vessels (Joseph, F2008).

2.1.3 Pleura of the Lungs:

Each lung is enclosed within a cavity that is surrounded by the pleura. It is a serous membrane that surrounds the lung. The right and left pleurae, which enclose the right and left lungs, respectively, are separated by the mediastinum. The pleurae consist of two layers. The visceral pleura is the layer that is superficial to the lungs, and extends into and lines the lung fissures. In contrast, the parietal pleura is the outer layer that connects to the thoracic wall, the mediastinum, and the diaphragm. The visceral and parietal pleurae connect to each other at the hilum. The pleural cavity is the space between the visceral and parietal layers (Joseph, F2008).

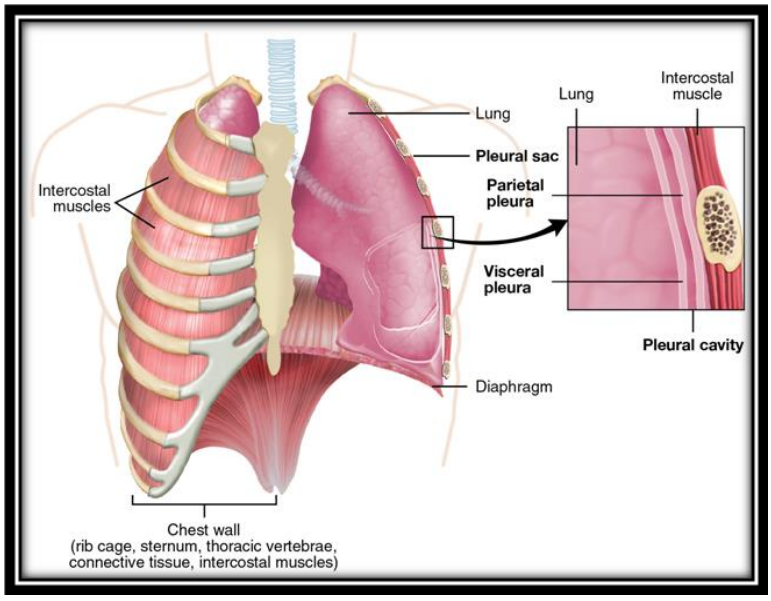

Figure (2.2) show pleural sac and pleural cavity (http://pediaa.com/difference-between-right-and-left-lung/)

The functions of pleurae produce pleural fluid and create cavities that separate the major organs**.** Pleural fluid is secreted by mesothelial cells from both pleural layers and acts to lubricate their surfaces. This lubrication reduces friction between the two layers to prevent trauma during breathing, and creates surface tension that helps maintain the position of the lungs against the thoracic wall. This adhesive characteristic of the pleural fluid causes the lungs to enlarge when the thoracic wall expands during ventilation, allowing the lungs to fill with air. The pleurae also create a division between major organs that prevents interference due to the movement of the organs, while preventing the spread of infection (Joseph, F2008).

2.2 Physiology :

2.2.1 Gas Exchange:

Gas exchange occurs at two sites in the body: in the lungs, where oxygen is picked up and carbon dioxide is released at the respiratory membrane, and at the tissues, where oxygen is released and carbon dioxide is picked up. External respiration is

the exchange of gases with the external environment, and occurs in the alveoli of the lungs. Internal respiration is the exchange of gases with the internal environment, and occurs in the tissues. The actual exchange of gases occurs due to simple diffusion. Energy is not required to move oxygen or carbon dioxide across membranes. Instead, these gases follow pressure gradients that allow them to diffuse. The anatomy of the lung maximizes the diffusion of gases: The respiratory membrane is highly permeable to gases; the respiratory and blood capillary membranes are very thin; and there is a large surface area throughout the lungs (John, 2009).

2.2.1.1 External respiration:

The pulmonary artery carries deoxygenated blood into the lungs from the heart, where it branches and eventually becomes the capillary network composed of pulmonary capillaries. These pulmonary capillaries create the respiratory membrane with the alveoli. As the blood is pumped through this capillary network, gas exchange occurs. Although a small amount of the oxygen is able to dissolve directly into plasma from the alveoli, most of the oxygen is picked up by erythrocytes and binds to a protein called hemoglobin, a process described later in this chapter. Oxygenated hemoglobin is red, causing the overall appearance of bright red oxygenated blood, which returns to the heart through the pulmonary veins. Carbon dioxide is released in the opposite direction of oxygen, from the blood to the alveoli. Some of the carbon dioxide is returned on hemoglobin. The External respiration occurs as a function of partial pressure differences in oxygen and carbon dioxide between the alveoli and the blood in the pulmonary capillaries (JOHN, 2009).

2.2.1.2 Internal respiration:

The gas exchange that occurs at the level of body tissues. Similar to external respiration, internal respiration also occurs as simple diffusion due to a partial

pressure gradient. However, the partial pressure gradients are opposite of those present at the respiratory membrane. The partial pressure of oxygen in tissues is low, about 40 mm Hg, because oxygen is continuously used for cellular respiration. In contrast, the partial pressure of oxygen in the blood is about 100 mm Hg. This creates a pressure gradient that causes oxygen to dissociate from hemoglobin, diffuse out of the blood, cross the interstitial space, and enter the tissue. Hemoglobin that has little oxygen bound to it loses much of its brightness, so that blood returning to the heart is more burgundy in color (JOHN, 2009).

Considering that cellular respiration continuously produces carbon dioxide, the partial pressure of carbon dioxide is lower in the blood than it is in the tissue, causing carbon dioxide to diffuse out of the tissue, cross the interstitial fluid, and enter the blood. It is then carried back to the lungs either bound to hemoglobin, dissolved in plasma, or in a converted form. By the time blood returns to the heart, the partial pressure of oxygen has returned to about 40 mm Hg, and the partial pressure of carbon dioxide has returned to about 45 mm Hg. The blood is then pumped back to the lungs to be oxygenated once again during external respiration (JOHN, 2009).

2.3 Pathology:

2.3.1 Tuberculosis (TB):

Tuberculosis (TB) is an infectious disease caused by the bacterium Mycobacterium tuberculosis (MTB) ˹Jean, 2013) .Tuberculosis generally affects the lungs, but can also affect other parts of the body. Most infections do not have symptoms, known as latent tuberculosis. About 10% of latent infections progress to active disease which, if left untreated, kills about half of those infected. The classic symptoms of active TB are chronic cough with or without blood-containing sputum, fever, night sweats, and weight loss. Tuberculosis spread through the air when people who have active TB in their lungs cough, spit, speak, or sneeze. People with latent TB

do not spread the disease. Active infection occurs more often in people with HIV/AIDS and in those who smoke. The diagnosis of active TB is based on chest X-rays, as well as microscopic examination and culture of body fluids. The diagnosis of latent TB relies on the tuberculin skin test (TST) or blood tests. Prevention of TB involves screening those at high risk, early detection, and treatment of cases, and vaccination with the bacillus Calmette-Guérin vaccine. Those at high risk include household, workplace, and social contacts of people with active TB. Treatment requires the use of multiple antibiotics over a long period (Jean, 2013).

General signs and symptoms include fever, chills, night sweats, loss of appetite, weight loss, and fatigue. Significant nail clubbing may also occur (Zaman, 2010)

2.3.1.1 Causative agent:

The bacteria from the Mycobacterium tuberculosis complex that are found primarily in humans and are known to cause TB to include M. tuberculosis, M. Bovis, M. africanum, M. microtia, and M. Canetti. The Mycobacterium species belong to the order of Actinomycetales, family mycobacteriaceae and genus Mycobacterium. There are more than 70 species of mycobacterium of which two are considered major human pathogens; Mycobacterium tuberculosis (Tuberculosis or Koch's disease, Koch, 1882) and Mycobacterium leprae+ (leprosy or Hansen's disease, Hansen, 1874). (Jean, 2013)

2.3.1.2 Risk factors for TB :

Host factors

Categories of host factors are outlined in the following sections. The relative risk for selected risk factors is outlined below. The relative importance of different risk factors varies with the prevalence of exposure across regions (Jean, 2013).

Drug use: The epidemiologic factors associated with injection and non-injection drug use (e.g., homelessness, incarceration) contribute to the high prevalence of TB among drug users (James, 2013)

Tobacco Cigarette smoking confers a relative risk of about 1.5 to 2.0 for the development of tuberculosis (TB). Smoking is associated with both risks of relapse of TB and TB mortality. Passive smoking also increases the risk of TB (Tejaswi,K 2013) The Alcohol risk of active TB is substantially elevated in individuals who consume more than 40 g alcohol per day. This may be due to the effect of alcohol and alcohol-related conditions on the immune system (Tejaswi,K 2013).

The Malnutrition is generally understood to be an important risk factor for TB, although the relation between impaired immunity due to malnutrition and the risk of acquiring TB has not been well characterized (Tejaswi, 2013) The Underweight of Persons who are underweight (body mass index of <18.5) have an increased risk for TB by a factor of 2.6 (1.2 to 4.8) (Tejaswi,K 2013)

The Vitamin D plays an important role in macrophage activation and restriction of mycobacterium growth, and diminished serum vitamin D levels appear to increase the risk for TB infection. Among African immigrants in Australia, for example, individuals with latent or active TB were observed to have substantially lower serum vitamin D levels than those without TB (Tejaswi,K 2013)

The Renal disease risk of TB among patients with chronic renal disease risk is 6.9 to 52.5 times that of individuals without renal disease. Uremia causes reduced cellular immunity. Other factors that may diminish immunity in the setting of renal failure include malnutrition, vitamin D deficiency, and hyperparathyroidism (Tejaswi,K 2013).

b. Immune compromising:

The HIV infection markedly increases the risk for primary and reactivation TB; the magnitude of risk is likely variable depending on the degree of HIV-

induced immunosuppression. Among HIV-seropositive individuals, the risk of acquiring TB is 9 to16 times that of HIV-seronegative individuals. The risk of TB decreases with the initiation of antiretroviral therapy (Tejaswi,K 2013).

Glucocorticoids: Patients receiving a daily dose of ≥15 mg of prednisone (or its equivalent) for ≥1 month are at increased risk for TB. A case-control study in the United Kingdom including more than 16 million person-years of TB risk demonstrated that patients with TB were 4.9 times more likely to have been using glucocorticoids than those without TB (Tejaswi,K 2013).

TNF inhibitors: Tumor necrosis factor (TNF)-alpha inhibitors (used in the treatment of rheumatic diseases and inflammatory bowel disease) impair host resistance to TB. This issue is discussed in detail separately (Tejaswi,K 2013).

Transplant: Renal, cardiac, liver, and allogeneic stem cell transplants are all associated with increased risk for TB. The risk in allogeneic stem cell transplants is less than in solid organ transplant patients; there does not appear to be an increased risk of TB in autologous stem cell transplant patients (Tejaswi,K 2013).

Age and gender:

The In the developing world TB rates are highest among young adults, reflecting primary transmission in this age group. In the United States and other developed countries, the rate of TB among the younger is higher than among elder adults and children, reflecting reactivation disease, possibly attributable to impaired immunity (Tejaswi,K 2013).

Gender: The rate of TB is higher among men than women, beginning in the young adult years and persisting throughout life. This is a longstanding observation thought to reflect more frequent TB exposure in the community among men than women (Tejaswi,K 2013).

d. Social and environmental factors:

Household contact: Close household contact with an individual with smear-positive pulmonary TB is the most important risk factor for TB. In a study of TB contact investigation including 1080 smear-positive patients and their 6225 close contacts, 36 percent of contacts had positive tuberculin skin tests; this compares to an expected skin-test positive rate of only 2.9 percent in the general population (Tejaswi,K 2013).

Overseas screening for TB among United States-bound immigrants and refugees is a high-yield intervention for identifying TB and could reduce the number of TB cases among foreign-born persons in the United States. Between 1999 and 2005, the prevalence of smear-negative and latent TB cases among immigrants was 961 and 837 cases per 100,000, respectively; the prevalence of these entities among refugees was 1036 and 2838 per 100,000 respectively. Active pulmonary TB and latent TB were diagnosed in the United States in 7 and 1.6 percent of those with overseas diagnoses, respectively (Tejaswi,K 2013).

Socioeconomic status: TB has traditionally been associated with low socioeconomic status, which also may be associated with crowding, poor nutrition, and poor access to medical care, public assistance, unemployment, and low education (Tejaswi,K 2013).

2.3.1.3. Transmission:

When people with active pulmonary TB cough, sneeze, speak, sing, or spit, they expel infectious aerosol droplets 0.5 to 5.0 μm in diameter. A single sneeze can release up to 40,000 droplets. Each one of these droplets may transmit the disease, since the infectious dose of tuberculosis is very small (the inhalation of fewer than 10 bacteria may cause an infection) (Cdonough,M 1993).

People with prolonged, frequent, or close contact with people with TB are at particularly high risk of becoming infected, with an estimated 22% infection rate.

A person with active but untreated tuberculosis may infect 10–15 (or more) other people per year. The transmission should occur from only people with active TB – those with latent infection are not thought to be contagious. The probability of transmission from one person to another depends upon several factors, including the number of infectious droplets expelled by the carrier, the effectiveness of ventilation, the duration of exposure, the virulence of the M. tuberculosis strain, the level of immunity in the uninfected person, and others. The cascade of person-to-person spread can be circumvented by segregating those with active ("overt") TB and putting them on anti-TB drug regimens. After about two weeks of effective treatment, subjects with nonresistant active infections generally do not remain contagious to others. If someone does become infected, it typically takes three to four weeks before the newly infected person becomes infectious enough to transmit the disease to others (Cdonough,M 1993).

2.3.1.4 Pathogenesis:

About 90% of those infected with M. tuberculosis have asymptomatic, latent TB infections with only a 10% lifetime chance that the latent infection will progress to overt, active tuberculous disease. In those with HIV, the risk of developing active TB increases to nearly 10% a year. If effective treatment is not given, the death rate for active TB cases is up to 66% (Yon, 2015).

TB infection begins when the mycobacteria reach the pulmonary alveoli, where they invade and replicate within endosomes of alveolar macrophages. Macrophages identify the bacterium as foreign and attempt to eliminate it by phagocytosis. During this process, the bacterium is enveloped by the macrophage and stored temporarily in a membrane-bound vesicle called a phagosome. The phagosome then combines with a lysosome to create a phagolysosome. In the phagolysosome, the cell attempts to use reactive oxygen species and acid to kill the

bacterium. However, M. tuberculosis has a thick, waxy mycolic acid capsule that protects it from these toxic substances. M. tuberculosis can reproduce inside the macrophage and will eventually kill the immune cell (Yon, 2015).

The primary site of infection in the lungs, known as the "Ghon focus", is generally located in either the upper part of the lower lobe or the lower part of the upper lobe. Tuberculosis of the lungs may also occur via infection from the bloodstream. This is known as Simon's focuses and is typically found at the top of the lung. This hematogenous transmission can also spread the infection to more distant sites, such as peripheral lymph nodes, the kidneys, the brain, and the bones. All parts of the body can be affected by the disease, though for unknown reasons it rarely affects the heart, skeletal muscles, pancreas, or thyroid (Ian,A 2015).

2.3.1.5 Pathology Location:

The location of infection within the lung varies with both the stage of infection and age of the patient:

Primary infection can be anywhere in the lung in children whereas there is a predilection for the upper or lower zone in adults

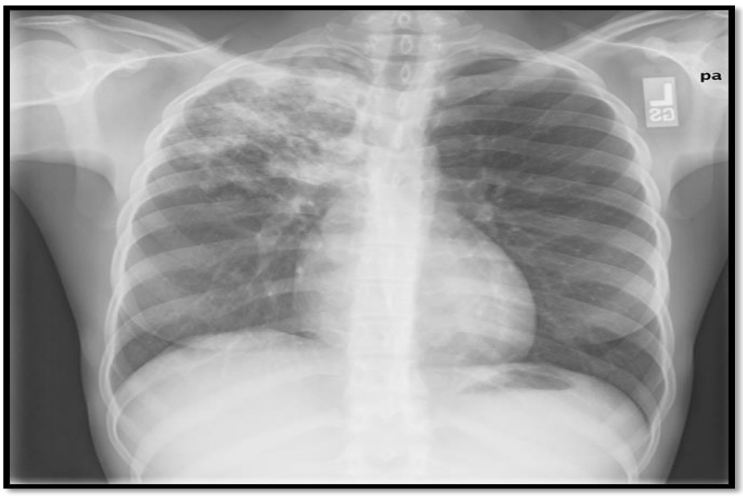

Figure 2.3: (show the primary infection of pulmonary tuberculosis)

(https://radiopaedia.org/articles/tuberculosis-pulmonary-manifestations-1)

Post-primary infections have a strong predilection for the upper zones

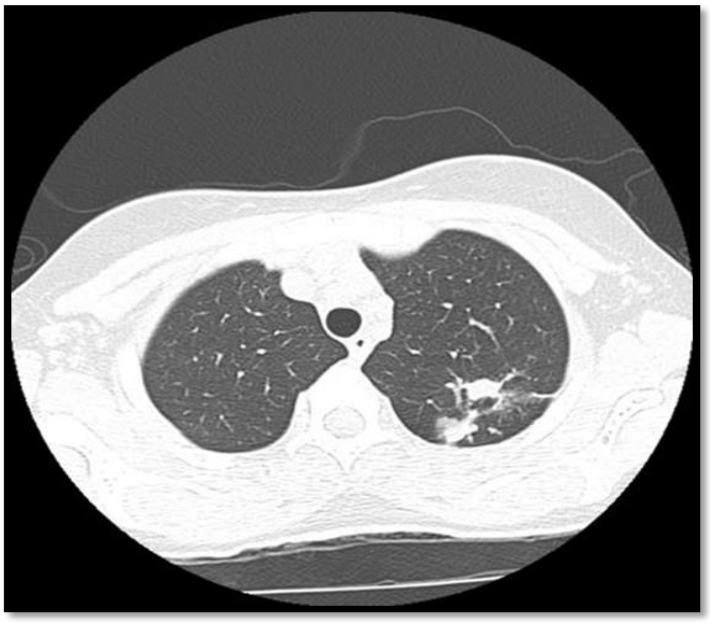

Figure 2.4: (show the post primary infection of pulmonary tuberculosis)

(https://radiopaedia.org/articles/tuberculosis-pulmonary-manifestations-1)

miliary tuberculosis is evenly distributed throughout both lungs

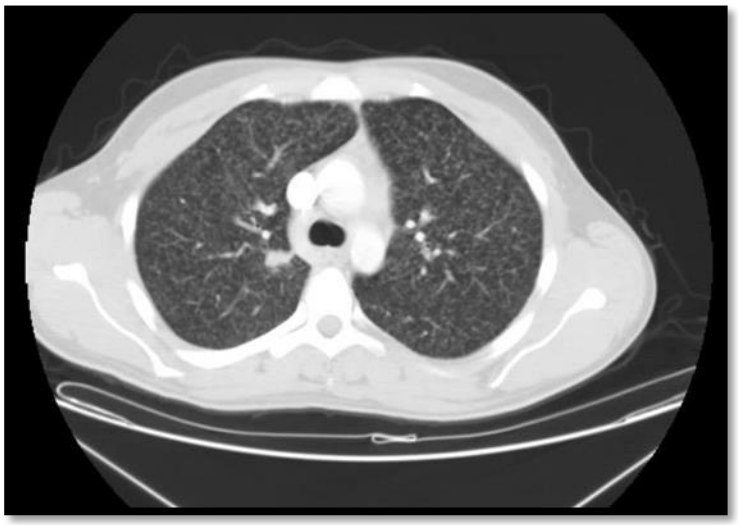

Figure 2.5: (show miliary tuberculosis throughout both lungs)

(https://radiopaedia.org/articles/tuberculosis-pulmonary-manifestations-1)

2.3.1.6 Diagnosis of tuberculosis:

A retrospective analysis of respiratory medicine in 2003 concluded that the clinical practice with scientific evidence-based medicine (EBM) test results was the major goal for early diagnosis and management to improve community health. Various diagnostic and disease monitoring tools are not supported by a high quality of evidence testing's e.g. subjective reading of TST positive reaction differs between different countries according to TB endemicity which necessitates improvements in the diagnostic accuracy of TB and PTB-related clinical-laboratory-radiography combinations (Yon, 2015)**.**

2.3.1.7. Clinical examination:

The WHO recommends TB investigations any individual having persistent cough more than 3 weeks until proven otherwise, similarly to any chest X-ray cavity as probable LTBI until proven otherwise. TB can be diagnosed through passive case detection i.e. detection via symptoms. History taking from the subject includes obtaining symptoms of TB and PTB disease such as prolonged cough more than three weeks associated with/without chest pain. Other generalized symptoms include low-grade remittent fever, chills, night sweats, appetite loss, weight loss, easy fatigability. Expectorations such as those producing mucoid sputum changing to purulent or hemoptysis (blood) can be considered as a clinical predictor in smear-negative TB patients (Yon, 2015)**.**

Medical/ clinical examination looking for physical signs performed to detect subject experienced symptoms. Any shared or common finding(s) to other health-related disorders ¸ like fever, chest pain or productive cough, will complicate TB diagnosis. Pulmonary presentations are common in adults, whereas, systemic complications (TB dissemination) are noticed in children or immunocompromised individuals. PTB thoracic sequelae involve all parts of the chest and respiratory tract system; acute respiratory distress syndrome (ARDS), multiple cystic lesions,

extensive consolidations, pleural effusions, pneumothorax or empyema (Yon, 2015).

Other symptom-based characteristics proposed for active TB diagnosis in children are the following predictors: 1) persistent, non-remittent coughing or wheezing; 2) failure to thrive despite food supplementation; and 3) fatigue or reduced playfulness. Comparative studies testing immune-competency in controls reveal that TB cases lose more than 10% of total body weight within a short period, night sweating, hypoxemia, abnormal sputum and sometimes auscultation abnormalities. Systemic or organ/tissue evaluation and lung examinations by auscultation and percussion help to limit TB differential diagnoses and reaching a final correct diagnosis. Case finding depends on the various clinical presentation(s) to the health service. The mean duration of symptoms (287 days) was longer in subjects reporting coughing with other chest symptoms compared to relatively short durations (146 days) from reporting a cough alone. The longer the period of symptomatic complaints (> 52 weeks) is associated with having high sputum positive grading (3+) and the presence of a sick contact within the same household. Smear positive grading was not associated with systemic symptom combination compared with significant findings in patients having only symptomatic chest complaints (Yon, 2015).

2.4. High-resolution computed tomography (HRCT):

High-resolution computed tomography imaging of the lungs is well-established for diagnosing and managing many pulmonary diseases the optimal methods of acquisition and interpretation of High-resolution computed tomography images require knowledge of anatomy and path physiology as well as familiarity with the basic physics and techniques of computed tomography (Prosch, H.2013)

is the use of thin-section CT images 0.625-mm to 1.5-mm slice thickness with a high spatial frequency reconstruction algorithm, to detect and characterize diseases that affect the pulmonary parenchyma and small airways Following the development and widespread availability of multidetector scanners capable of acquiring near-isotropic data throughout the entire thorax in a single breath-hold, two general approaches are available for acquiring HRCT images The first and more traditional method entails obtaining axial HRCT images spaced at 10-mm to 20-mm intervals throughout the lungs. The second method uses the ability of MDCT scanners to provide volumetric single breath-hold datasets allowing spaced, contiguous, and/or overlapping HRCT images to be reconstructed. With MDCT, the volumetric data enables multiplanar thin-section HRCT reconstruction, which facilitates evaluation of the distribution of diffuse lung disease and the application of post processing techniques such as maximum intensity projection and minimum intensity projection and software that uses volumetric data for quantification of features in the lungs and airways(Prosch, H.2013).

Optimal performance of HRCT studies requires familiarity with the advantages and disadvantages of each HRCT method, with the choice between these approaches reflecting available equipment, clinical indication(s), and radiation dose considerations. With both methods, image data are routinely acquired at suspended full inspiration with patients in the supine position. Additional options, useful in many cases, include obtaining aspiratory prone images to differentiate posterior lung disease from dependent atelectasis and end-expiratory images to evaluate for air trapping. The main objective of High-resolution computed tomography is to detect, characterize, and determine the extent of diseases that involve the lung parenchyma and airways (Beigelman, C 2005).

2.4.1 Indications of High-resolution computed tomography:

The indications for the use of HRCT of the lungs include, but are not limited to, the following:

Evaluation of known or clinically suspected diffuse lung disease that is incompletely evaluated on standard chest CT or chest x-ray or that which is chest x-ray occults

Evaluation of suspected small airway disease

Quantification of the extent of diffuse lung disease for evaluating effectiveness of treatment

Guidance in selection of the most appropriate site for biopsy of diffuse lung disease

2.4.2 Contraindications:

There are no absolute contraindications to HRCT of the lungs. As with any imaging procedure, the benefits and risks should be considered prior to thoracic CT performance.

2.4.3 Technical Parameters:

Although many of the operations of a CT scanner are automated, a number of technical parameters remain operator-dependent. As these factors can significantly affect the diagnostic value of the HRCT examination it is necessary for the supervising physician to be familiar with the following:

Radiation exposure factors (mAs, KvP)

Collimation

Display section thickness for multidetector systems

Table increment or pitch and gantry rotation time and table speed

Matrix size, scan field of view, and reconstruction field of view

Window settings (width and center)

Reconstruction algorithm, filter or kernel

Image reconstruction interval or increment

Detector configuration for multidetector systems

Automatic exposure control (angular and longitudinal tube current modulation) and image quality reference parameter

Radiation dose report

Reformatted images (multiplanar (MPR), curvilinear, MIP, and minIP) and 3-D surface or volume rendered (VR) and image plane (axial, coronal, sagittal)

Reconstruction techniques such as filtered back projection or iterative reconstruction.

Axial or helical mode of the CT scanner

2.4.4 Optimal HRCT Protocol:

Optimization of the CT examination requires the supervising physician to develop an appropriate HRCT protocol based on careful review of relevant patient history and clinical indications as well as all prior available imaging studies that are relevant(Beigelman,C et all 2005).

Protocols should be prepared according to the specific medical indication. Technique should be selected that provide image quality consistent with the diagnostic needs of the examination at acceptably low radiation dose levels to the patient. When volumetric HRCT data are acquired, utilization of the multiplanar capabilities is encouraged to facilitate assessment of disease distribution and morphology. For each indication, the protocol should include at least the following:

a. Tube potential and tube current appropriate to patient size. Typically this entails use of 120 (kVp) and approximately ≤240 mAs. Use of lower tube potentials (eg, 100 kVp) and tube-current settings is encouraged, especially for younger patients or those who may need serial imaging. In this case, using similar technical

parameters for each study facilitates direct comparison between studies and is of particular value if quantitative CT measurements are employed.

b. Utilization of techniques available to minimize dose (eg, tube current modulation) is encouraged

c. Proper supine and/or prone patient positioning with optimal breathing instructions

d. State of respiration (inspiration and/or expiration), with appropriate breathing instructions; Expiratory images are typically acquired at end-expiration.

e. Table speed for volumetric HRCT to enable single-breath-hold acquisition, when possible

f. Axial (incremental HRCT) or helical (volumetric HRCT) modes of data acquisition. Acquiring exploratory and/or prone sequence images in a helical fashion is discouraged. For those sequences, axial acquisition with nonirradiated increments of 10–20 mm or more is preferable.

g. Gantry rotation: ≤1 second

h. Reconstructed image thickness (≤ 1.5 mm for axial CT, ≤1.5 mm nominal slice thickness for helical CT)

i. Moderately high-spatial-frequency reconstruction algorithm, such as a bone algorithm for lung images

j. Proper patient positioning (positioning the patient at isocenter to minimize radiation dose and optimize image quality)

k. Superior and inferior extent of the region of interest to be imaged, typically from the lung apices to the costophrenic sulci. For additional series such as prone or expiratory HRCT imaging, shorter z-axis coverage and/or greater increment between imaging locations is encouraged to decrease patient radiation exposure.

l. When possible, scan field of view should be selected appropriate to patient size at time of image.

m. Reconstructed field of view limited to the lungs adjusted for small, medium, and large patients to optimize spatial resolution for each patient

n. Plane, thickness, and interval for reconstructions or reformats (eg, coronal, sagittal, oblique MPRs and MIPs) from volumetric HRCT data to be sent to the picture archiving and communications system (PACS) or reconstruction directly at the PACS workstation.

Attention should be directed toward the following:

a. Radiation dose to the degree indicated in the ACR-SCBT-MR-SPR Practice Parameter for the Performance of Thoracic Computed Tomography considering factors influencing radiation dose, particularly for small adults. Techniques such as increasing pitch, lowering tube current or kV, and limiting the z-axis coverage to the region of clinical question. Other factors that can decrease radiation dose are the use of sequential acquisition and larger interscan gap, which can be employed when expiratory and prone HRCT imaging is performed to supplement an aspiratory examination. The necessity of prone imaging should be considered in all patients, particularly on subsequent HRCT scans; omitting unnecessary sequences provides an opportunity to reduce dose (Christe A.2013)

b. Producing motion-free images at the appropriate inspiratory and expiratory level

3. Use of intravenous (IV) iodinated contrast should not be used when performing an HRCT to evaluate the lung parenchyma and small airways primarily, as subtle pulmonary findings may be obscured by intrapulmonary contrast. In addition, IV contrast adds little value to the interpretation of diffuse lung disease while exposing patients to the risks associated with the administration of iodinated contrast(Beigelman,C et all 2005)..

2.4.1. Technique:

HRCT is performed using a conventional CT scanner. However, imaging parameters are chosen to maximize spatial resolution. Narrow slice width is used usually 1–2 mm with high spatial resolution image reconstruction algorithm is used ,Field of view is minimized, to minimize the size of each pixel and Other scan factors (e.g. focal spot) may be optimized for resolution at the expense of scan speed. And also Depending on the suspected diagnosis, the scan may be performed in both inspiration and expiration. The patient may also lie prone (face down) rather than the more usual supine face up(Beigelman,C et all 2005)..

HRCT aims to assess a generalized lung disease; the test is conventionally performed by taking thin sections 10–40 mm apart. The result is a few images that should be representative of the lungs in general, but that covers only approximately one-tenth of the lungs(Beigelman,C et all 2005)..

Because HRCT does not image the whole lungs (by using widely spaced thin sections), it is unsuitable for the assessment of lung cancer or other localized lung diseases. Similarly, HRCT images have very high levels of noise (due to thin sections and high-resolution algorithms), which may make them non-diagnostic for the soft-tissues of the mediastinum (Beigelman,C et all 2005).

Intravenous contrast agents are not used for HRCT as the lung inherently has very high contrast (soft tissue against air), and the technique itself is unsuitable for assessment of the soft tissues and blood vessels, which are the major targets of contrast agents(Beigelman,C et all 2005)..

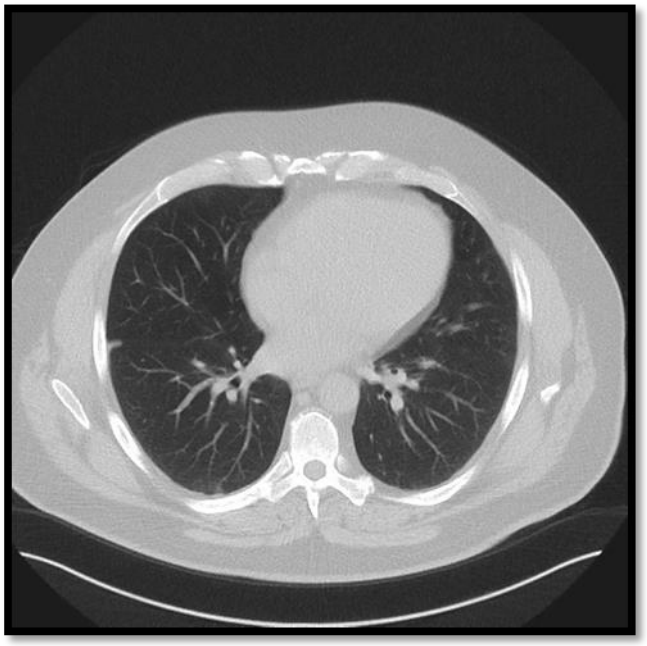

Figure 2.6: (show normal HRCT lungs)

(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5338576/)

2.5. Previous studies:

Hatipoglu O. et al was assessed the findings of active pulmonary tuberculosis on high resolution computed tomographic (HRCT) scans, and to evaluate their possible use in determining disease activity. Thirty two patients with newly diagnosed active pulmonary tuberculosis and 34 patients with inactive pulmonary tuberculosis were examined. The HRCT findings in patients with active pulmonary tuberculosis are; Centrilobular nodular or linear structures (n=29, 91%) (p<0 001), "tree-in-bud" appearance (n = 23, 71%) (p<0001), and macronodules (n=22, 69%) (p<0001) were the most common HRCT findings seen in active pulmonary tuberculosis (Hatipoglu O. 2012).

Soujanya B. et al was conducted a study to determine the pattern of HRCT findings in active & inactive Pulmonary Tuberculosis. 38 females and 62 males aged 1 to 87 years, with an average age of 44.15±22.6 were in the study. HRCT findings

showed; 71% had ill defined nodules, 67% had consolidation, 75% had tree in bud appearance and 41.6% had cavitations and 50% had per bronchial thickening (Soujanya B. 2014).

Tayfun C. et al was studied the High resolution computed tomography findings in pulmonary tuberculosis patients. The mean age was 22.48±3.18 years. Micronodules (87%), large nodules (63%) and centrilobular nodules (62%) were the most common HRCT findings. HRCT findings were observed in the right upper (72%), left upper (56%), right lower (32%), and left lower lobes (29%). Cough (37%) and chest pain (32%) were the most frequent symptoms at presentation. (Tayfun C. 2014).

Also, Sumit S. et al was performed a study to evaluate the role of high resolution computed tomography in the in pulmonary tuberculosis. The HRCT findings were; 'Tree in bud' appearance (71.4%), consolidation (42.8%) and scattered nodules (28.5%) are features of active disease while fibrosis (50%), honeycombing (50%), traction bronchiectasis (37.5%) and calcified granuloma (37.5%) are features of inactive disease (Tayfun C. 2014) .

Chapter Three

Material and method

3. Method:

31. Study Design:

A decretive cross-sectional hospital-based study conducted to evaluate the HRCT findings among pulmonary TB patients

3.2. Study Area and duration:

The study was conducted in ALSha'ab Teaching Hospital in Khartoum state from Feb. 2018 to Aug 2018.

3.3. Study Population:

All patients diagnosed with pulmonary tuberculosis.

3.3.1. Inclusion Criteria:

Patients with pulmonary tuberculosis only.

All adult patients (more than 18 and less than 50 years).

Both sex (males and females).

3.3.2. Exclusion criteria:

Young patient less than 18

Old patient more than 49

Extra-pulmonary tuberculosis

3.4. Sample Size and Sampling Technique:

Total converge during the period of the study, which is composed of 50 pulmonary tuberculosis patients.

3.5. Data Collection:

A structured questionnaire was used in the data collection, which is consisted of; demographic data (age and gender), clinical presentation and HRCT findings

3.6. Technique:

HRCT

Interpretation of findings

3.7. Study variables

Dependent variables

HRCT findings

Independent variables

Age

Gender

Clinical presentation

3.8. Data management:

The collected data was entered and encoded in Excel datasheet, and then the data was transcript in the SPSS datasheet.

3.9. Data analysis:

Entered data were analyzed by Statistical Package for Social Science program (SPSS; version 21.0). The analyzed data represented in tables and figures. The chi-square test was used as a test of significance, and the P. value was considered significant at level 0.05.

Chapter Four

4. Results

Table 4.1: Showed the distribution of the age among the pulmonary tuberculosis patients (N= 50)

Age (Years)	Number	%
<20	2	4
20-29	21	42
30-39	13	26
40-49	14	28
Total	50	100

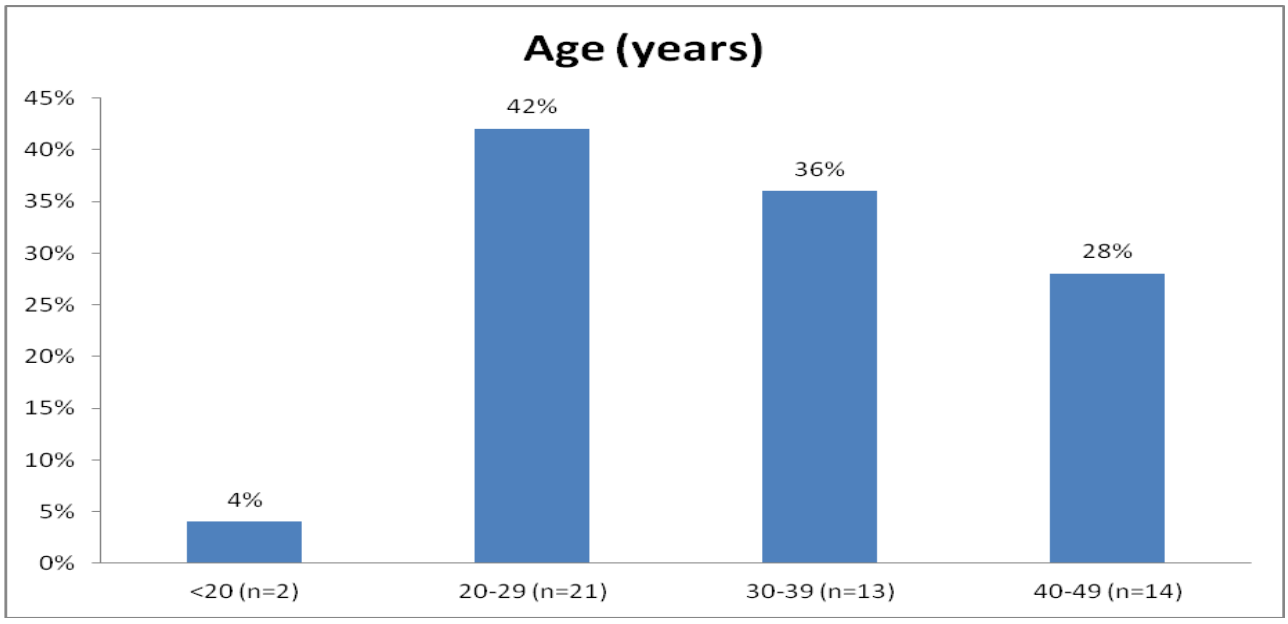

Figure 4.1: Showed the distribution of the age among the pulmonary tuberculosis patients (N= 50)

Table 4.2: Showed the distribution of the gender among the pulmonary tuberculosis patients (N= 50)

Gender	Number	%
Male	32	64
Female	18	36
Total	50	100

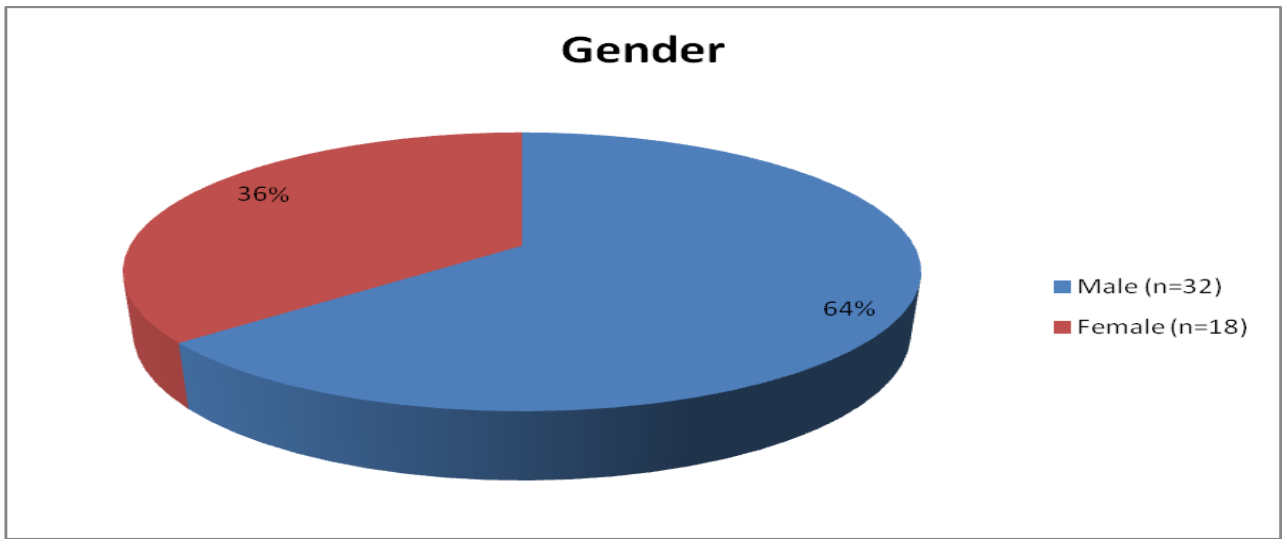

Figure 4.2: Showed the distribution of the gender among the pulmonary tuberculosis patients (N= 50)

Table 4.3: Showed the distribution of the clinical presentations among the pulmonary tuberculosis patients (N= 50)

Clinical presentation	Number	%
Cough	33	66
Fever	25	50
Chest pain	16	32
Weight loss	10	20

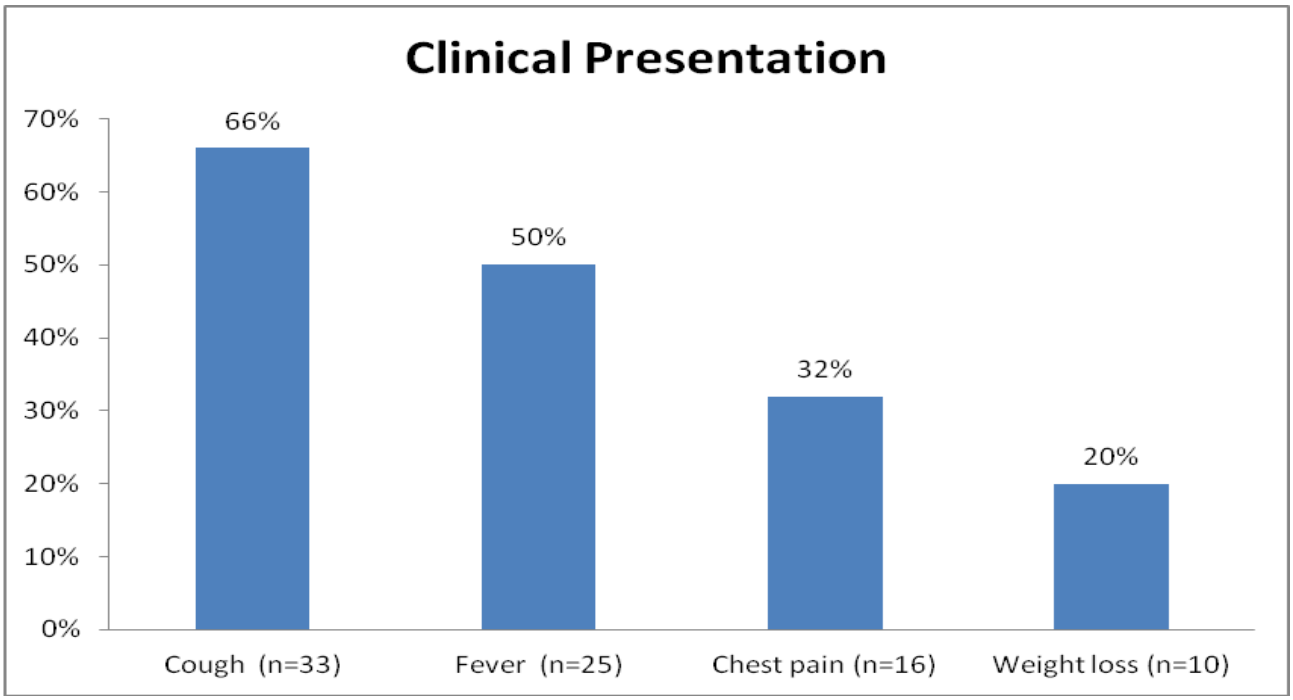

Figure 4.3: Showed the distribution of the clinical presentations among the pulmonary tuberculosis patients (N= 50)

Table 4.4: Showed the distribution of the HRCT findings among the pulmonary tuberculosis patients (N= 50)

HRCT findings	Number	%
Nodules	17	34
Cavity	13	26
Consolidation	10	20
Tree-in-Bud	7	14
LAP	3	6
Total	50	100

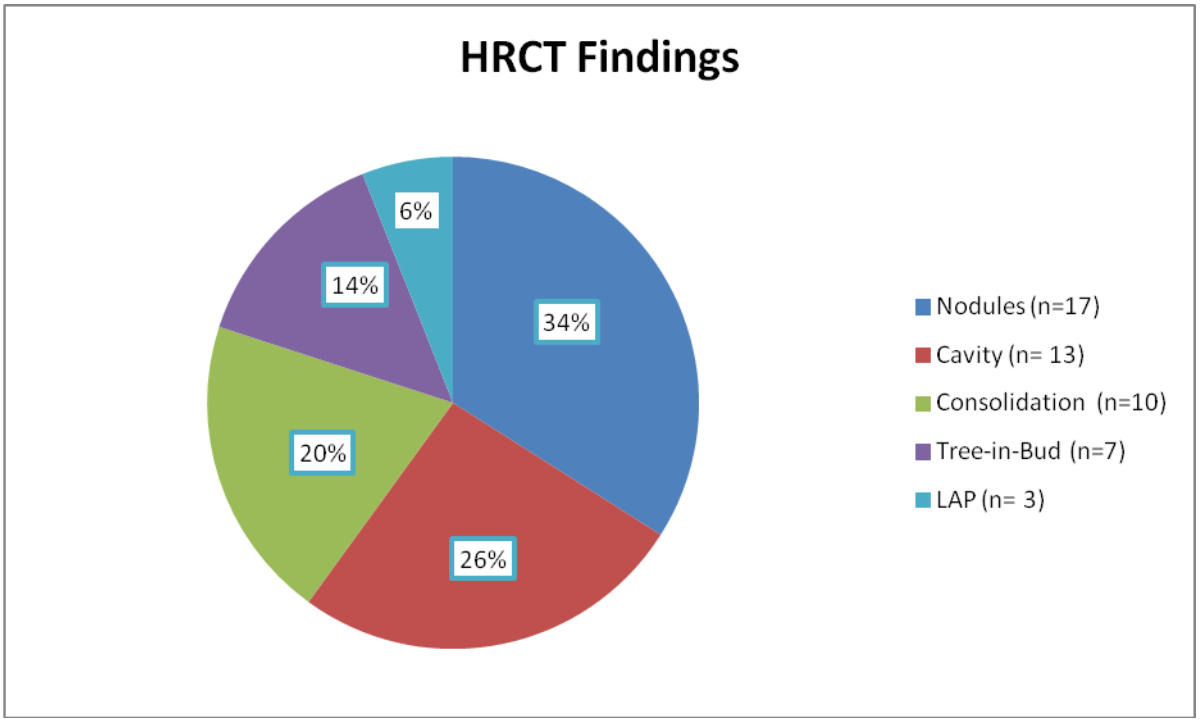

Figure 4.4: Showed the distribution of the HRCT findings among the pulmonary tuberculosis patients (N= 50)

Table 4.5: Showed the association between HRCT findings and age of pulmonary tuberculosis patients

	Nodules (n=17)	Cavity (n= 13)	Consolidation (n=10)	Tree-in-Bud (n=7)	LAP (n= 3)
<20 (n=2)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2(66.7%)
20-29 (n=21)	10 (58.8%)	6 (46.2%)	5 (50%)	0 (0%)	0 (0%)
30-39 (n=13)	3 (17.6%)	5 (38.5%)	2 (20%)	3(42.9%)	0 (0%)
40-49 (n=14)	4 (23.6%)	2 (15.3%)	3 (30%)	4(57.1%)	1(33.3%)
		P. value= **0.000***			

***P. value is significant at level 0.05**

Chi-square test was used

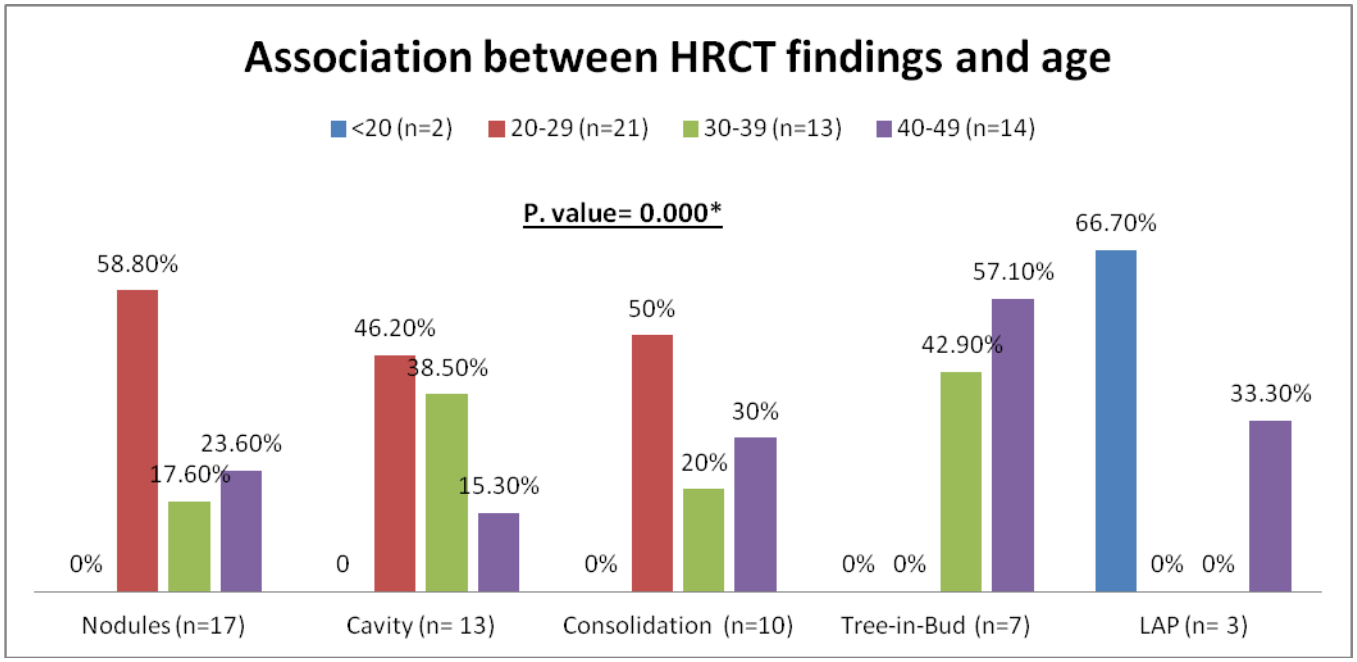

Figure 4.5: Showed the association between HRCT findings and age of pulmonary tuberculosis patients

Table 4.6: Showed the association between HRCT findings and gender of pulmonary tuberculosis patients

	Nodules (n=17)	Cavity (n= 13)	Consolidation (n=10)	Tree-in-Bud (n=7)	LAP (n= 3)
Male (n=32)	10 (58.8%)	7 (53.8%)	7(70%)	5 (71.4%)	3 (100%)
Female (n=18)	7 (41.2%)	6(46.2%)	3 (30%)	2 (28.6%)	0 (0%)
P. value= **0.000***					

***P. value is significant at level 0.05**

Chi-square test was used

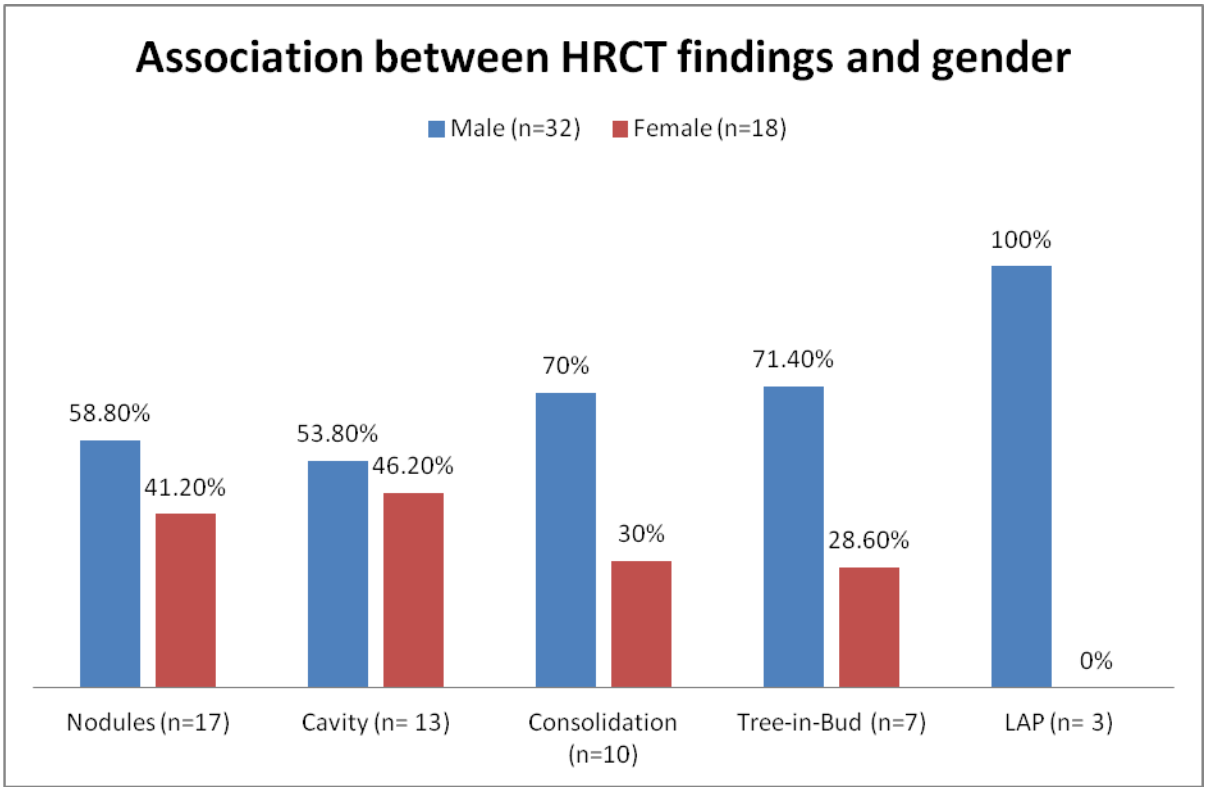

Figure 4.6: Showed the association between HRCT findings and gender of pulmonary tuberculosis patients

Chapter Five

Discussion, Conclusion & Recommendations

5. Discussion:

This study was conducted to evaluate the findings of HRTC in among 50 pulmonary tuberculosis patients in ALSha'ab Teaching hospital. Among the study population, TB was higher in younger adults (20-29 years) and male patients, and this agreed with what is mentioned in the literature (Tejaswi,K 2013). The present study also showed that cough was the main presenting symptoms among our study patient in (66%). Our findings agreed with Nakashi et al. who reported that cough was seen in 83% of patients (Nakanishi M 2009).

In HRCT findings the current study demonstrated that in, nodules (34%) were the main findings followed by; cavity (26%) and consolidation (20%), Tree-in-Bud (14%) and lymphadenopathy (6%). Hatipoglu O. et al found that Centrilobular nodular or linear structures (n=29, 91%) (p<0 001), "tree-in-bud" appearance (n = 23, 71%) (p<0001), and macro nodules (n=22, 69%) (p<0001) were the most common HRCT findings (Hatipoglu O. 2012). Also, Soujanya B. et al reported that 71% had ill-defined nodules, 67% had consolidation, 75% had a tree in bud appearance and 41.6% had cavitations and 50% had peribronchial thickening (Soujanya B. 2014). Additionally, Tayfun C. et al noticed (87%), large nodules (63%) and centrilobular nodules (62%) were the most common HRCT findings (Tayfun C. 2014). Furthermore, Sumit S. et al found 'Tree in bud' appearance (71.4%), consolidation (42.8%) and scattered nodules (28.5%) are features of active disease while fibrosis (50%), honeycombing (50%), traction bronchiectasis (37.5%) and calcified granuloma (37.5%) were the most the HRCT findings (Sumit. S 2017) .These variations in HRCT findings between our study and other

studies might be attributed to differences in origins, HRCT techniques procedures used, sampling and sample size.

The current study also revealed that the majority of HRCT findings belonged to the age group 20 – 29 years and in the male gender.

5.1. Conclusion:

The present study conducted the adults younger and males were more commonly predominantly affected by pulmonary tuberculosis. Nodules, cavity, consolidation, and Tree-in-Bud were the main HRCT findings among pulmonary tuberculosis patients, also male and namely age group 20 – 29 years were more related to the findings of HRCT.

5.2. Recommendations:

HRCT is a useful tool in the diagnosis and management as it can differentiate active from inactive disease with greater sensitivity

HRCT is recommended when the radiographic findings are normal or inconclusive and tuberculosis is suspected clinically for the confirmation of diagnosis and determination of activity.

HRCT can be used to select candidate patients for further laboratory tests or bronchoscopy.

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Tayfun C., Tuncer O., Serkan A., Hatice K., Mehmet I., Asim U. High resolution computed tomography findings in smear-negative pulmonary tuberculosis patients according to their culture status. J Thorac Dis. 2014 Jun

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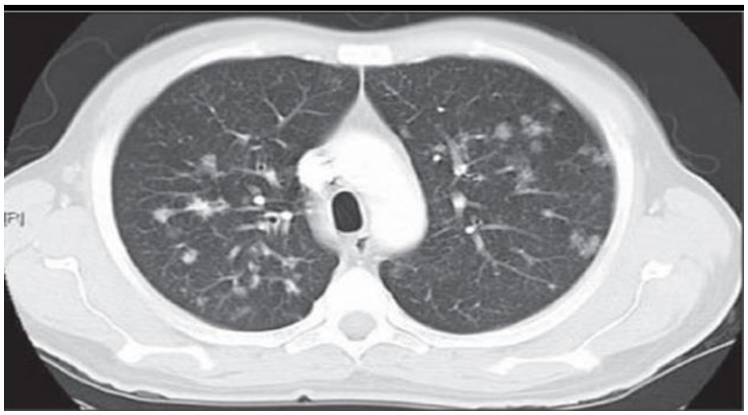
Yon J. Diagnosis of Pulmonary Tuberculosis: Recent Advances and Diagnostic Algorithms. Tuberc Respir Dis (Seoul). 2015 Apr; 78(2): 64–71.

Appendix

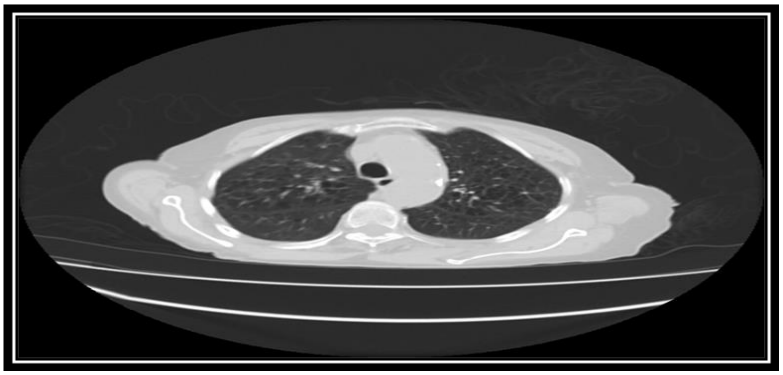
Cassese

Case 1



29 year old show tree in bud pattern and bilateral tubular images in tree with minute nodulation at the extremities, most noticeable in the right lung.

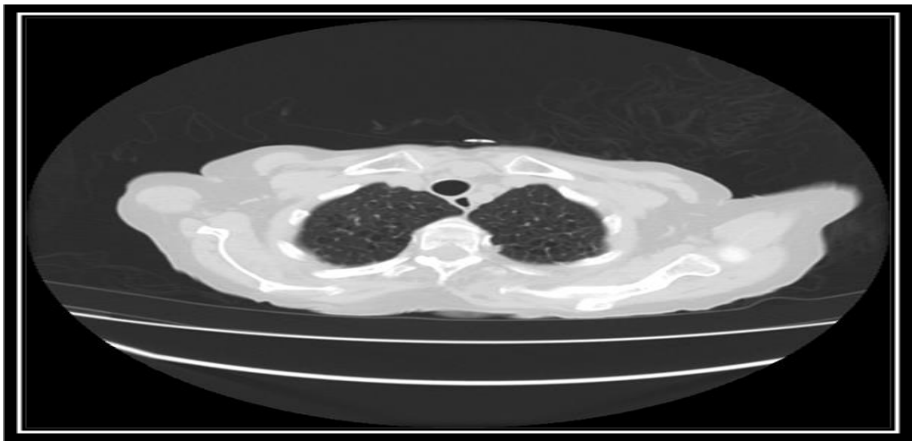
Case 2



— 35y old was showing a small, irregular thick-walled cavity in the lateral-basal segment of the left lower lobe and adjacent satellite nodules.

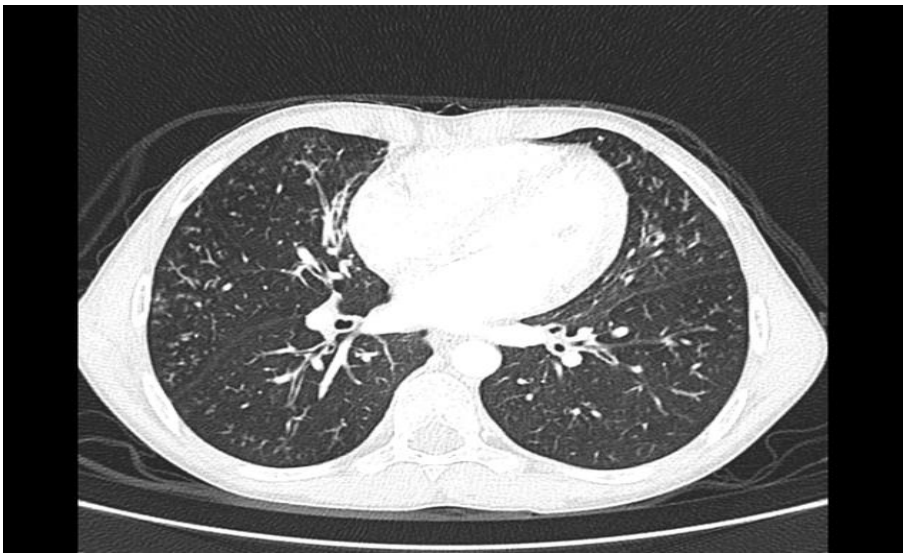
—

Case 3



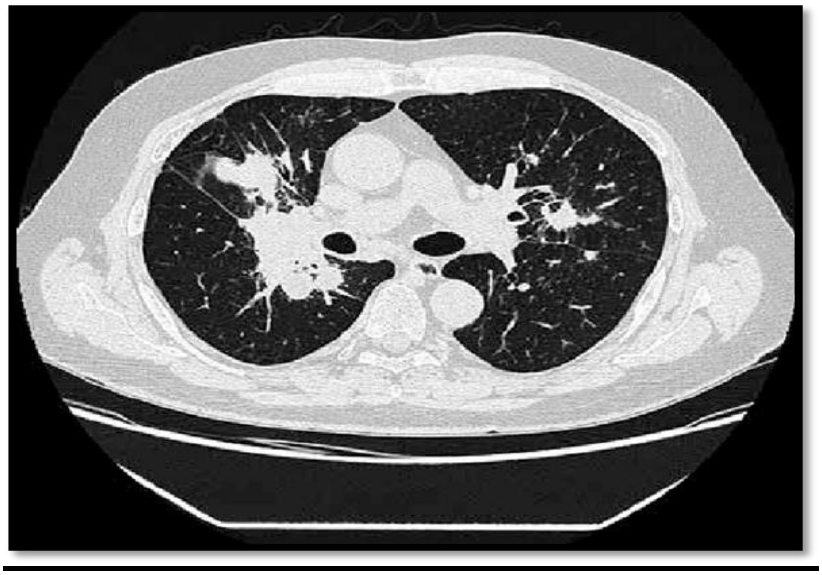
35Y was showing bilateral cavitations

Case 4



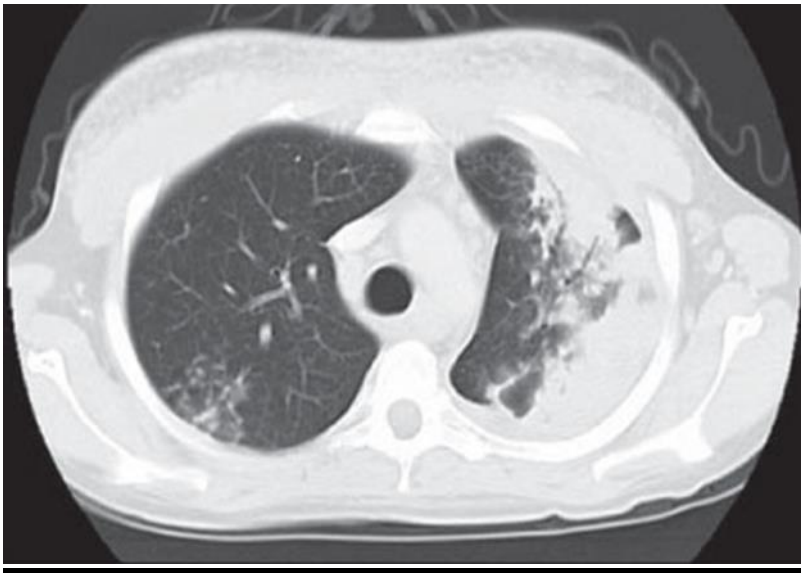
45y old show Tree in bud in right and left lung

Case 5



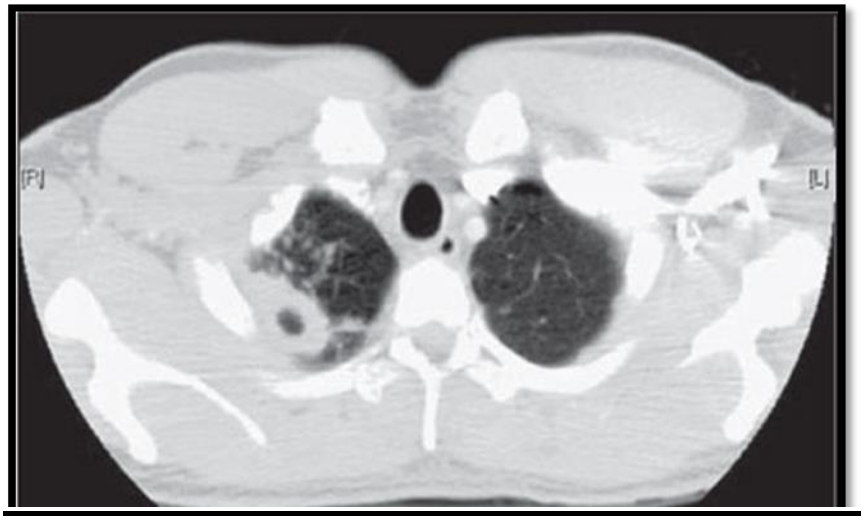
48 y old showing Fibrotic nodule

Case 6



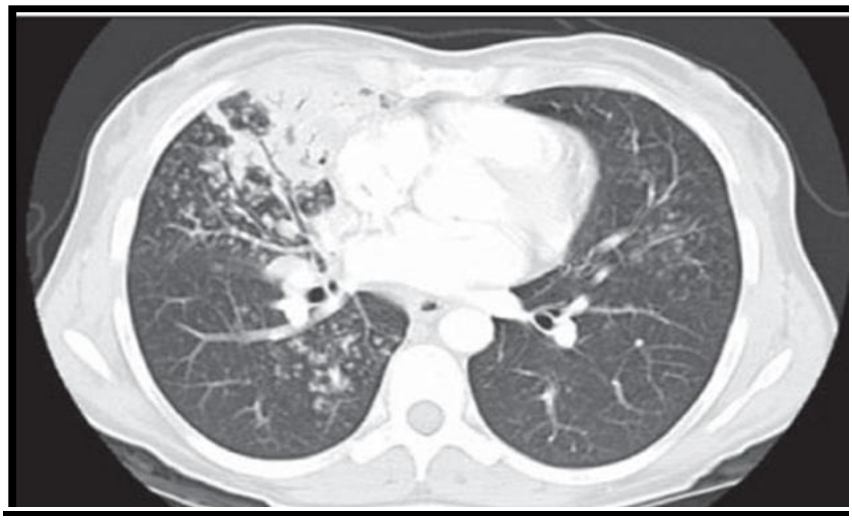
33y old show centrilobular nodules with segmental distribution and extensive consolidation in upper left lobe is observed

Case 7



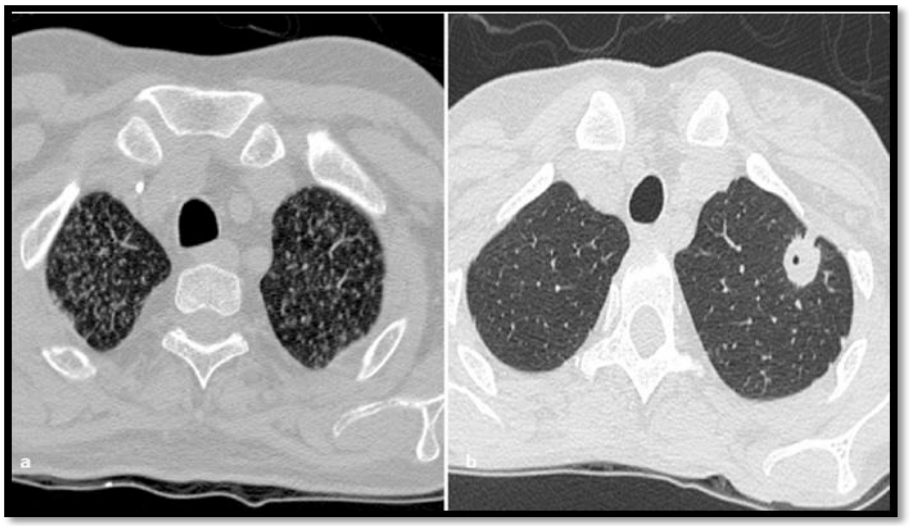
40y was showing bilateral cavitations

Case 8



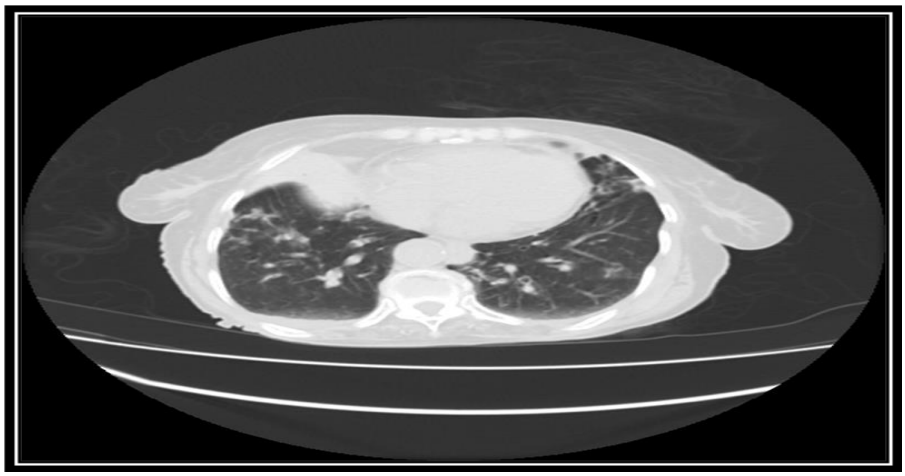
36y old show consloidation in right lung with multible nodules

Case 9



24 y old show Noduls and cavitiations

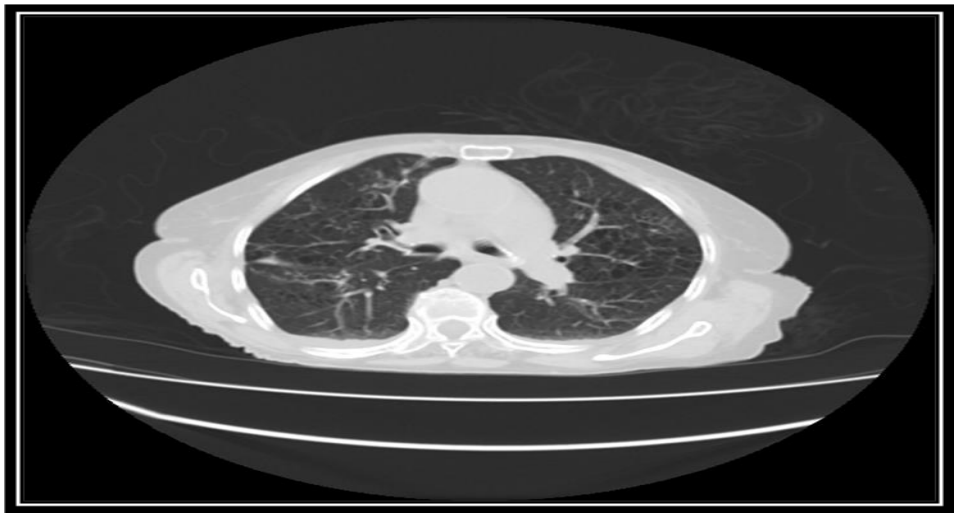
Case 10



— 37Y old. showing diffuse pleural thickening, and consolidation

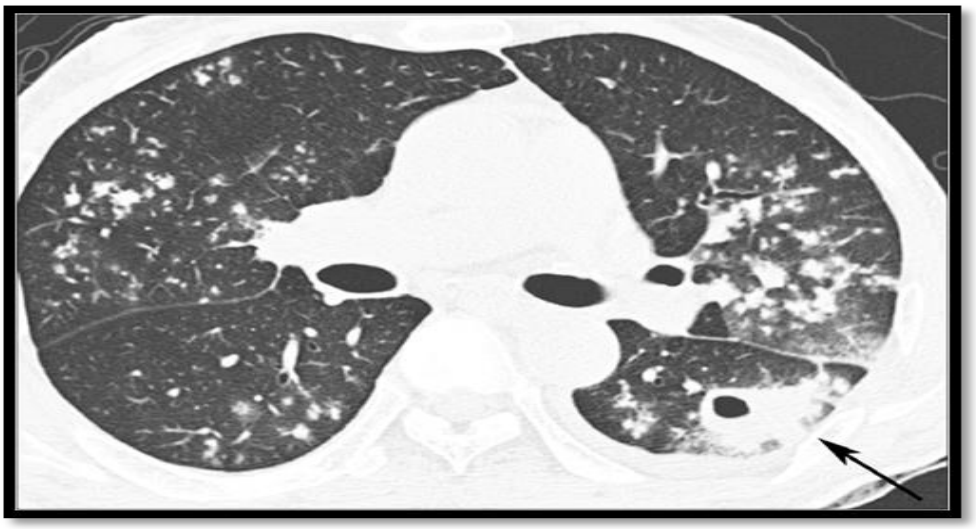
—

Case 11



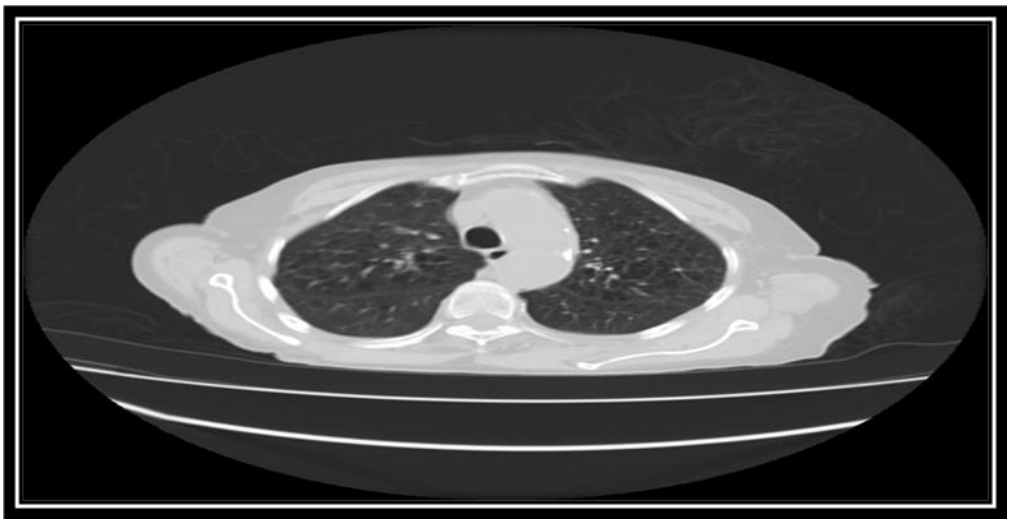
48y old showing tree in bud

Case 12



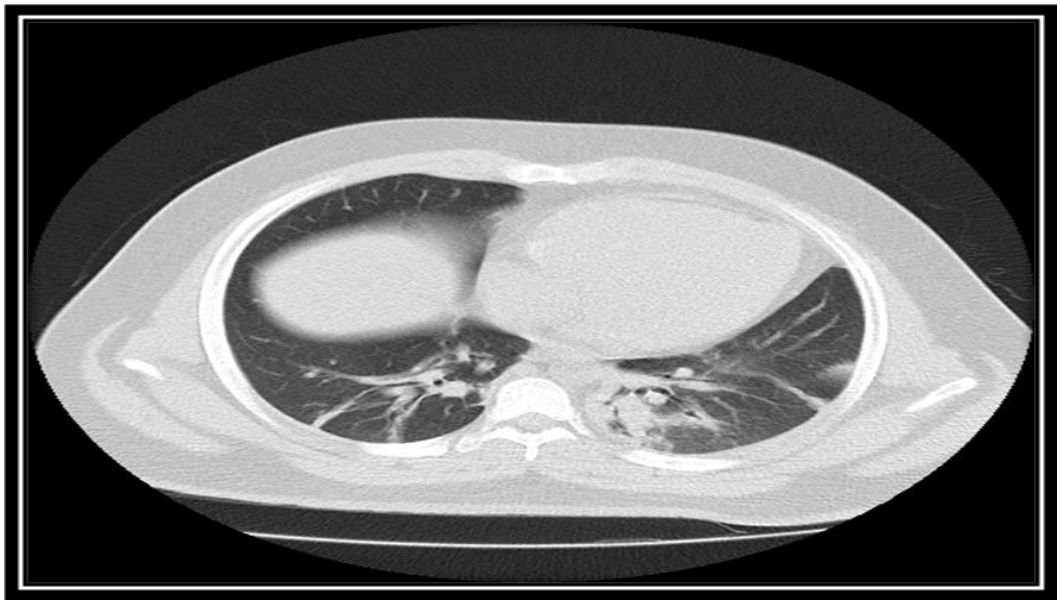
38y old showing cavitation

Case 13



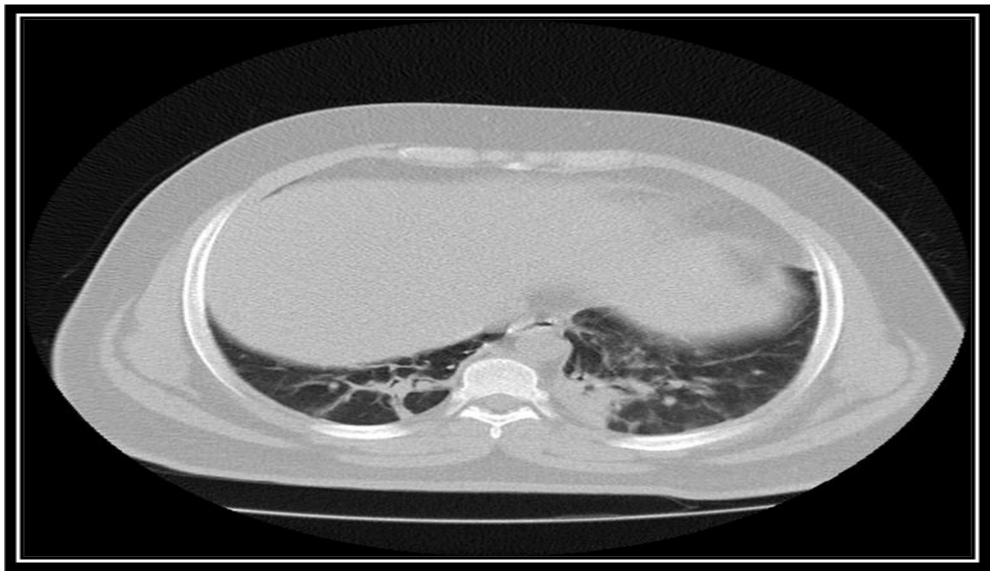
31y old show cavitation

Case 14



24y old show Conslditaion

Case 15



26 Y old show bi lateral cavitations in lower lobe

Sudan University of sciences and technology

College of graduate studies

Department of radiological sciences

Data collection sheet

Tuberculosis patients with CT scan

❖ **Age :**

<20	
20-29	
30-39	
40-49	

❖ Gender

M F

❖ Clinical presentation

Cough	
Fever	
Chest pain	
Weight loss	

HRCT findings

Nodules	
Cavity	
Consolidation	
Tree-in-Bud	
LAP	