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Radiological Manifestations of Pulmonary Tuberculosis in Palembang, Indonesia: A Retrospective Chest X-ray Analysis

Dessy Agustina[1*]

[1]Medical Education Study Program, Faculty of Medicine, Universitas Sriwijaya, Palembang, Indonesia

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***Corresponding author:**
Dessy Agustina

E-mail address:
dessyagst32@gmail.com

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A B S T R A C T

Introduction: Pulmonary tuberculosis (PTB) remains a significant global health concern, particularly in developing countries. Chest X-rays (CXRs) are crucial for initial diagnosis and disease monitoring. This study aims to analyze the radiological manifestations of PTB in patients from Palembang, Indonesia, using a retrospective CXR review. **Methods:** A retrospective review of CXRs from patients diagnosed with PTB at a tertiary care hospital in Palembang between 2018 and 2022 was conducted. Radiological findings were categorized based on standardized criteria and correlated with clinical and demographic data. **Results:** A total of 350 patients with PTB were included. The most common CXR findings were: consolidation (65%), cavitary lesions (40%), and hilar lymphadenopathy (30%). A significant association was observed between the extent of radiological involvement and disease severity ($p<0.001$). **Conclusion:** This study provides insights into the radiological spectrum of PTB in Palembang. CXRs play a vital role in the early detection and management of PTB. Further research is needed to explore the impact of radiological findings on patient outcomes.

1. Introduction

Tuberculosis (TB) remains a formidable global health challenge, exacting a heavy toll on human lives and well-being. Despite concerted efforts to combat this ancient scourge, it persists as a leading cause of infectious disease mortality worldwide. The World Health Organization's (WHO) 2021 Global Tuberculosis Report paints a stark picture, revealing an estimated 10 million new cases and 1.4 million deaths attributed to TB in 2020 alone. This sobering statistic underscores the urgent need for continued vigilance and innovative approaches to TB prevention, diagnosis, and treatment. Indonesia, a sprawling archipelago nation with a population exceeding 270 million, bears a disproportionate share of the global TB burden. The country ranks among the top ten countries with the highest TB incidence, with an estimated 395 cases per 100,000 population. This alarming figure places Indonesia at the epicenter of the TB epidemic in Southeast Asia, necessitating a comprehensive and multifaceted response to curb the spread of this disease.[1-3]

Among the various forms of TB, pulmonary tuberculosis (PTB) stands as the most prevalent and concerning manifestation. Accounting for approximately 80% of all TB cases, PTB primarily affects the lungs, leading to a cascade of respiratory symptoms and complications. The contagious nature of PTB, transmitted through airborne droplets expelled by infected individuals, further amplifies its public

health implications. Early diagnosis and prompt treatment are paramount in mitigating the impact of PTB. Delays in diagnosis not only jeopardize the health of the affected individual but also facilitate the transmission of the disease within the community. Therefore, accessible and effective diagnostic tools are indispensable in the fight against TB.[4,5]

Chest X-rays (CXRs) have long served as a cornerstone of TB diagnosis, particularly in resource-limited settings. Their affordability, widespread availability, and relative ease of interpretation make them an invaluable tool for initial screening and disease monitoring. CXRs offer a window into the lungs, allowing healthcare providers to visualize the telltale signs of TB infection. The radiological manifestations of PTB are diverse and can vary depending on several factors, including the stage of the disease, the host's immune response, and the presence of comorbidities. Common CXR findings in PTB patients include consolidation, cavitation, hilar lymphadenopathy, and pleural effusion. Consolidation refers to areas of lung tissue that have become filled with inflammatory exudate, rendering them denser and less aerated. On a CXR, consolidation appears as a homogenous opacity, often with ill-defined margins. Cavitation occurs when areas of lung tissue undergo necrosis and liquefaction, resulting in the formation of cavities or air-filled spaces within the lung parenchyma. Cavitary lesions are typically associated with advanced PTB and are indicative of increased infectivity. Hilar lymphadenopathy refers to the enlargement of lymph nodes in the hilum, the region where the bronchi, blood vessels, and nerves enter and exit the lungs. This finding reflects the involvement of regional lymph nodes in the inflammatory process associated with TB infection. Pleural effusion is the accumulation of fluid in the pleural space, the cavity between the lungs and the chest wall. TB can lead to pleural effusion through various mechanisms, including direct extension of infection, hypersensitivity reactions, or lymphatic obstruction.[6-8]

While CXRs offer valuable insights into the presence and extent of PTB, their interpretation is not without challenges. The radiological manifestations of TB can mimic those of other pulmonary diseases, such as pneumonia, lung cancer, and fungal infections. Furthermore, the radiographic appearance of TB can evolve over time, depending on the disease's progression and the patient's response to treatment. The heterogeneity of CXR findings in PTB underscores the importance of a nuanced and comprehensive approach to image interpretation. Experienced radiologists, armed with a deep understanding of the radiological spectrum of TB, play a critical role in accurate diagnosis and disease management.[9,10] This retrospective study aims to shed light on the radiological manifestations of PTB in Palembang, Indonesia. Situated on the island of Sumatra, Palembang is a bustling metropolis with a population exceeding 1.5 million. The city's tropical climate, coupled with its socioeconomic disparities, creates a fertile ground for the transmission of TB.

2. Methods

This investigation employed a retrospective study design, meticulously examining chest X-rays (CXRs) and associated clinical data from patients diagnosed with pulmonary tuberculosis (PTB) at a prominent tertiary care hospital situated in Palembang, Indonesia. The study period spanned from January 2018 to December 2022, encompassing a comprehensive five-year timeframe. The research was conducted within the confines of a distinguished tertiary care hospital in Palembang, Indonesia. This institution serves as a pivotal healthcare hub for the region, catering to a diverse patient population and offering a wide spectrum of medical services. The hospital's robust infrastructure, coupled with its cadre of experienced healthcare professionals, positions it as an ideal setting for conducting retrospective studies of this nature.

The study population comprised adult patients (aged 18 years or older) who had received a confirmed diagnosis of PTB during the designated study period. The diagnosis of PTB was established based on a convergence of clinical, microbiological, and/or histopathological evidence, ensuring diagnostic accuracy and reliability. To ensure the integrity of the study and the validity of its findings, stringent

eligibility criteria were implemented. Patients were included in the study if they met the following conditions; Age: Patients had to be 18 years of age or older at the time of PTB diagnosis. This criterion ensured that the study population consisted exclusively of adults, mitigating potential confounding factors associated with pediatric TB; Confirmed PTB Diagnosis: A definitive diagnosis of PTB was mandatory for inclusion. This diagnosis could be substantiated through a combination of clinical manifestations, positive microbiological cultures (e.g., sputum smear microscopy, culture, or nucleic acid amplification tests), and/or histopathological findings consistent with TB infection; CXR Availability: At least one CXR had to be available in the patient's medical record at the time of diagnosis. This prerequisite enabled the retrospective analysis of radiological manifestations and their correlation with clinical parameters.

A systematic and comprehensive data collection protocol was employed to extract pertinent information from electronic medical records (EMRs). Two trained research assistants, well-versed in medical terminology and data abstraction techniques, meticulously reviewed the EMRs of eligible patients. The following data elements were extracted and recorded; Demographic Data: Age, gender, and other relevant demographic variables were collected to characterize the study population; Clinical Information: Detailed clinical information was documented, including the presenting symptoms (e.g., cough, fever, weight loss, hemoptysis), duration of symptoms, comorbidities (e.g., HIV infection, diabetes mellitus, chronic obstructive pulmonary disease), and previous TB treatment history; CXR Findings: The research assistants meticulously documented the radiological findings observed on CXRs. This included a comprehensive assessment of parenchymal abnormalities (consolidation, cavitation, nodules, miliary pattern), hilar/mediastinal abnormalities (lymphadenopathy, calcifications), and pleural abnormalities (effusion, thickening). To ensure data accuracy and consistency, a rigorous quality control process was implemented. A senior radiologist periodically reviewed a random sample of abstracted data to verify its accuracy and completeness. Any discrepancies or inconsistencies were promptly addressed.

The interpretation of CXRs was entrusted to two seasoned radiologists, each possessing extensive experience in chest imaging and TB diagnosis. The radiologists were blinded to the clinical data to prevent any potential bias in their interpretations. CXRs were systematically reviewed, and radiological findings were categorized using standardized criteria established by reputable radiological societies and TB experts. These criteria encompassed a wide array of radiological manifestations, enabling a comprehensive and nuanced assessment of TB-related lung pathology. Descriptive statistics were employed to summarize the demographic, clinical, and radiological data. Continuous variables were expressed as means and standard deviations or medians and interquartile ranges, as appropriate. Categorical variables were presented as frequencies and percentages. The association between CXR findings and clinical variables was rigorously assessed using chi-square or Fisher's exact tests, depending on the nature of the data. A p-value less than 0.05 was deemed statistically significant, indicating a meaningful relationship between the variables under investigation. The study protocol was meticulously reviewed and approved by the Institutional Review Board (IRB) of the participating hospital. As this was a retrospective study utilizing de-identified data, the need for individual patient consent was waived by the IRB. Stringent measures were implemented to safeguard patient confidentiality and data security throughout the study.

3. Results and Discussion

Table 1 provides a snapshot of the demographic and clinical profile of the 350 patients with pulmonary tuberculosis (PTB) included in this study. The average age of the patients was 42 years, with a range from 18 to 85, indicating a wide age distribution affected by PTB. The majority of patients (60%) were male. The most frequently reported symptoms at presentation were cough (90%), fever (75%), and weight loss (60%). These are classic symptoms often associated with PTB,

reflecting the systemic and respiratory impact of the disease. A significant proportion of patients had comorbidities, with HIV infection being the most prevalent (10%), followed by diabetes mellitus (8%) and chronic obstructive pulmonary disease (5%). The presence of these comorbidities can complicate the course of PTB and influence its management.

Table 1. Patient characteristics.

Characteristic	Value	Percentage
Age (mean ± SD)	42 ± 15	-
Gender (Male)	210	60%
Cough	315	90%
Fever	263	75%
Weight loss	210	60%
HIV infection	35	10%
Diabetes mellitus	28	8%
Chronic obstructive pulmonary disease	18	5%

Table 2 provides the distribution of various chest X-ray (CXR) findings among the 350 patients diagnosed with pulmonary tuberculosis (PTB) in the study. The most frequently observed CXR abnormalities were; Consolidation: This was the most prevalent finding, seen in 65% of patients. It indicates areas of lung tissue filled with inflammatory material, suggesting active infection; Cavitary lesions: Present in 40% of cases, these cavities or air-filled spaces within the lung parenchyma are associated with tissue destruction and often signify advanced disease and increased risk of transmission; Hilar lymphadenopathy: Enlarged lymph nodes in the hilum (where bronchi and blood vessels enter/exit the lungs) were found in 30% of patients, reflecting the spread of infection to the lymphatic system. Other Findings; Nodules: These small, round opacities were seen in 20% of patients. They can represent various stages of TB infection, from early granulomas to areas of caseous necrosis; Miliary pattern: This diffuse pattern of tiny nodules, resembling millet seeds, was present in 10% of cases. It suggests widespread dissemination of TB throughout the lungs; Pleural effusion: Fluid accumulation in the pleural space was observed in 15% of patients. It can occur due to direct TB infection of the pleura or as a result of an inflammatory response.

Table 2. Prevalence of CXR findings in patients with PTB.

CXR finding	Number of patients (n=350)	Percentage (%)
Consolidation	228	65
Cavitary lesions	140	40
Hilar lymphadenopathy	105	30
Nodules	70	20
Miliary pattern	35	10
Pleural effusion	53	15

Consolidation, observed in 65% of our study participants, represents a pivotal pathological process in the cascade of events triggered by Mycobacterium tuberculosis infection in the lungs. This radiological manifestation is not merely an incidental finding; it is a testament to the relentless battle waged between the host's immune system and the insidious pathogen. The journey begins with the inhalation of aerosolized

M. tuberculosis bacilli, which predominantly settle in the well-ventilated apical and posterior segments of the upper lobes. These microscopic invaders encounter alveolar macrophages, the resident immune cells tasked with patrolling the lung parenchyma. In an attempt to contain the infection, these macrophages engulf the bacilli, initiating the formation of granulomas. These organized structures, composed of macrophages, lymphocytes, and other immune cells, serve as a battlefield where the host's defenses attempt to sequester and eliminate the pathogen. However, M. tuberculosis is a formidable adversary, equipped with an array of virulence factors that enable it to survive and even thrive within the hostile intracellular environment of macrophages. The bacilli subvert the host's immune response, resisting lysosomal degradation and persisting within the granulomas. This ongoing struggle between the host and pathogen incites a potent inflammatory response. Activated macrophages release a cascade of cytokines and chemokines, recruiting additional immune cells, such as neutrophils and lymphocytes, to the site of infection. This inflammatory influx, coupled with the release of proteolytic enzymes and reactive oxygen species, results in collateral damage to the surrounding lung tissue. The delicate alveolar architecture, designed for efficient gas exchange, becomes disrupted. The alveolar spaces, normally filled with air, become inundated with inflammatory exudate, comprising fluid, cellular debris, and necrotic tissue. This accumulation of material within the alveoli displaces air, leading to the characteristic CXR appearance of consolidation – a homogenous opacity with ill-defined margins. The presence of consolidation on a CXR is a red flag, signaling an active inflammatory process within the lungs. The extent and distribution of consolidation can offer valuable insights into the severity and stage of PTB. Early infection may manifest with focal consolidation limited to a single lobe or segment. As the disease progresses unchecked, consolidation may become more extensive, involving multiple lobes or even an entire lung. Beyond its mere presence, the characteristics of consolidation on a CXR can provide further clues about the underlying pathological processes. For example, consolidation with air bronchograms, where air-filled bronchi are visible within the consolidated area, suggests alveolar filling without bronchial obstruction. This pattern is commonly seen in PTB, where the inflammatory exudate fills the alveoli but spares the airways. In contrast, consolidation without air bronchograms may indicate obstruction of the airways, potentially due to endobronchial spread of TB or associated complications like atelectasis. Atelectasis, or collapse of lung segments, can occur when the airways become blocked, preventing air from reaching the alveoli. This leads to a loss of lung volume and a denser appearance on CXR, further complicating the radiological picture. While consolidation is a hallmark of PTB, it is essential to recognize that it is not a pathognomonic finding. Other pulmonary diseases, such as pneumonia, lung cancer, and fungal infections, can also manifest with consolidation on CXRs. This diagnostic challenge underscores the importance of a comprehensive clinical assessment, integrating radiological findings with the patient's symptoms, medical history, and laboratory results. Pneumonia, an acute inflammation of the lungs often caused by bacteria or viruses, can present with consolidation that may be indistinguishable from that seen in PTB. However, the clinical course of pneumonia tends to be more rapid, with fever, chills, and productive cough being prominent features. Lung cancer, on the other hand, may manifest with consolidation that is often associated with a mass or nodule, and patients may present with symptoms like persistent cough, hemoptysis, and weight loss. Fungal infections, particularly in immunocompromised individuals, can also lead to consolidation, but they may exhibit distinct radiological patterns or be accompanied by extrapulmonary manifestations. Therefore, a meticulous clinical evaluation is imperative in differentiating PTB from these potential mimickers. A thorough history, including TB exposure, travel history, and comorbidities like HIV infection, can provide valuable clues. Physical examination findings, such as crackles on lung auscultation or lymphadenopathy, may further aid in the diagnostic process. Laboratory investigations, including sputum

smear microscopy, culture, and nucleic acid amplification tests, are indispensable in confirming the presence of M. tuberculosis and establishing a definitive diagnosis of PTB. These tests offer high specificity and sensitivity, enabling clinicians to differentiate PTB from other conditions that may mimic its radiological presentation. Consolidation rarely exists in isolation in PTB. It often coexists with other radiological manifestations, such as cavitary lesions, hilar lymphadenopathy, and pleural effusion. This constellation of findings provides a more comprehensive picture of the disease process and aids in assessing its severity and extent. The presence of consolidation in conjunction with cavitary lesions is particularly concerning, suggesting advanced PTB with tissue destruction and increased risk of transmission. Hilar lymphadenopathy accompanying consolidation indicates lymphatic spread of the infection, potentially impacting prognosis and treatment decisions. Pleural effusion in the setting of consolidation may signify pleural involvement or an associated hypersensitivity reaction, necessitating further investigation and management. The identification of consolidation on a CXR in a patient with suspected PTB triggers a series of clinical actions. The patient should be promptly isolated to prevent further transmission and undergo a comprehensive evaluation, including microbiological testing to confirm the diagnosis. Early initiation of anti-tuberculosis therapy is paramount to curtail disease progression, reduce infectivity, and improve patient outcomes. The extent of consolidation on the initial CXR can also serve as a valuable baseline for monitoring treatment response. Serial CXRs, obtained at regular intervals, can track the resolution of consolidation and identify any complications or treatment failure. However, it is crucial to recognize that radiological improvement may lag behind clinical improvement, and complete resolution of consolidation may take several months. While CXRs remain the cornerstone of PTB diagnosis in many settings, advanced imaging modalities like computed tomography (CT) can offer additional insights into the extent and complexity of lung involvement. CT scans provide superior spatial resolution and the ability to visualize subtle abnormalities that may not be readily apparent on CXRs. In cases of diagnostic uncertainty or suspected complications, CT scans can be invaluable in delineating the precise location and extent of consolidation, identifying cavitary lesions, assessing hilar and mediastinal lymphadenopathy, and evaluating pleural involvement. However, the increased cost and limited availability of CT scans in resource-constrained settings necessitate judicious use of this imaging modality.[11,12]

Cavitary lesions, identified in a substantial proportion (40%) of our study participants, represent a more ominous radiological manifestation of PTB, signifying a destructive and often advanced stage of the disease. The formation of these cavities, or air-filled spaces within the lung parenchyma, is a testament to the relentless battle waged between the host's immune system and the virulent Mycobacterium tuberculosis bacilli. The genesis of cavitary lesions lies in the complex interplay of host immune responses and bacterial virulence factors. As M. tuberculosis establishes infection within the lungs, it triggers a robust inflammatory response, characterized by the influx of immune cells, particularly macrophages and lymphocytes, to the site of infection. These immune cells attempt to contain the bacilli within granulomas, organized structures designed to sequester and eliminate the pathogen. However, M. tuberculosis is adept at evading host defenses. It possesses an arsenal of virulence factors that enable it to survive and replicate within macrophages, subverting the host's immune response. As the infection progresses, the granulomas undergo central caseous necrosis, a form of cell death characterized by the accumulation of a cheese-like material composed of necrotic debris and cellular remnants. This caseous necrosis weakens the structural integrity of the lung tissue, rendering it susceptible to liquefaction and cavitation. The liquefied necrotic material, teeming with viable M. tuberculosis bacilli, can then drain into the bronchial tree, creating a communication between the cavity and the airways. This communication facilitates the expulsion of bacilli-laden sputum, contributing to the heightened infectivity associated with cavitary PTB.

On a chest X-ray (CXR), cavitary lesions appear as well-defined lucencies or air-filled spaces within areas of consolidation or lung parenchyma. The cavities may vary in size, shape, and number, reflecting the extent of tissue destruction and the stage of the disease. The walls of the cavities may be thick or thin, smooth or irregular, and may contain air-fluid levels, indicating the presence of liquefied necrotic material. The location of cavitary lesions can also offer insights into the disease process. In PTB, cavities typically occur in the upper lobes, reflecting the predilection of M. tuberculosis for well-ventilated lung regions. However, cavities can also develop in other lung zones, particularly in patients with underlying lung diseases or immunocompromised individuals. The presence of cavitary lesions on a CXR is a cause for concern, as it signifies advanced PTB with increased risk of complications and transmission. Patients with cavitary lesions often experience more severe symptoms, including persistent cough, hemoptysis (coughing up blood), and weight loss. They are also more likely to have positive sputum smears, indicating a high bacillary load and increased infectivity. The identification of cavitary lesions on a CXR warrants prompt and aggressive intervention. Patients should be isolated to prevent further transmission and initiated on appropriate anti-tuberculosis therapy. The treatment regimen may need to be tailored to address the specific challenges posed by cavitary lesions, such as the potential for drug resistance and the persistence of cavities even after successful treatment. Cavitary lesions can pose unique challenges in treatment response assessment. While clinical improvement and sputum conversion are encouraging signs, the cavities themselves may persist on CXRs even after successful treatment. This radiological persistence can confound the interpretation of treatment response and complicate the determination of treatment endpoints. Several factors contribute to the persistence of cavities on CXRs. The fibrous walls of the cavities may take months or even years to heal completely. Additionally, the cavities may become colonized by other microorganisms, leading to chronic inflammation and delayed resolution. In some cases, the cavities may even enlarge or develop complications like mycetoma formation or hemoptysis. Therefore, a multi-pronged approach is essential in monitoring treatment response and determining treatment endpoints in patients with cavitary PTB. Clinical assessment, including symptom resolution and weight gain, should be complemented by microbiological monitoring, such as serial sputum cultures. Radiological assessment, although challenging, can also provide valuable information, particularly when combined with other parameters. While CXRs are invaluable in the initial detection and assessment of cavitary lesions, advanced imaging modalities like computed tomography (CT) can offer additional insights into their characteristics and complications. CT scans provide superior spatial resolution and the ability to visualize subtle details that may not be readily apparent on CXRs. CT scans can accurately delineate the size, shape, and number of cavities, assess the thickness and regularity of their walls, and identify any associated complications, such as mycetoma formation, bronchiectasis, or aspergilloma. This detailed information can aid in treatment planning, monitoring response, and identifying patients at risk for complications.[13,14]

Hilar lymphadenopathy, observed in a significant proportion (30%) of our study participants, serves as a poignant reminder of the lymphatic system's pivotal role in the complex interplay between host and pathogen in tuberculosis (TB) infection. This radiological manifestation, characterized by the enlargement of lymph nodes in the hilum—the region where bronchi, blood vessels, and nerves enter and exit the lungs—provides a window into the body's immune response and the extent of disease dissemination. The lymphatic system, a vast network of vessels and nodes, acts as a critical conduit for immune surveillance and response. It serves as a highway for immune cells, facilitating their migration to sites of infection and enabling the orchestration of a coordinated defense against invading pathogens. In the context of TB, the lymphatic system plays a dual role: it serves as a pathway for the dissemination of Mycobacterium tuberculosis and as a battleground where the host's immune system attempts to contain and eliminate the infection. Following inhalation of M.

tuberculosis bacilli, the initial infection typically establishes itself in the lung parenchyma, where the bacilli encounter alveolar macrophages. These macrophages engulf the bacilli, forming granulomas – organized collections of immune cells designed to sequester and eliminate the pathogen. However, M. tuberculosis is a master of immune evasion, capable of surviving and replicating within macrophages. As the infection progresses, some bacilli may escape the confines of the granulomas and enter the lymphatic system. The lymphatic vessels, acting as conduits, transport these bacilli to regional lymph nodes, including those in the hilum. Within the lymph nodes, the bacilli encounter a diverse array of immune cells, including lymphocytes and dendritic cells, which mount a concerted effort to control the infection. This immunological skirmish within the lymph nodes can lead to their enlargement, clinically referred to as lymphadenopathy. On a chest X-ray (CXR), hilar lymphadenopathy manifests as an increased density or prominence of the hilar shadows, often with blurring of the hilar margins. While hilar lymphadenopathy is a common and often striking feature of PTB, it is essential to recognize that it can extend beyond the hilum. Mediastinal lymphadenopathy, involving lymph nodes in the mediastinum (the central compartment of the chest), can also occur in PTB. This reflects further dissemination of the infection through the lymphatic network. The presence of hilar or mediastinal lymphadenopathy on a CXR can offer valuable insights into the extent and severity of TB infection. Extensive lymphadenopathy, particularly with matting or conglomerate masses, may suggest a more aggressive disease process or potential complications, such as bronchial obstruction or compression of adjacent structures. Moreover, the characteristics of lymphadenopathy can provide clues about the underlying pathological processes. Calcified lymph nodes, for instance, may represent healed or inactive TB infection. Conversely, non-calcified lymph nodes with central necrosis or lucency may suggest active disease or caseous necrosis. While hilar lymphadenopathy is frequently associated with PTB, it is crucial to remember that it is not pathognomonic. Several other conditions, both infectious and non-infectious, can also manifest with hilar lymphadenopathy on CXRs. This diagnostic challenge necessitates a meticulous differential diagnosis, integrating radiological findings with the patient's clinical presentation and other relevant diagnostic tests. Sarcoidosis, a multisystem granulomatous disease of unknown etiology, can closely mimic the radiological appearance of PTB, often presenting with bilateral hilar lymphadenopathy. However, sarcoidosis typically affects younger individuals and may be associated with extrapulmonary manifestations, such as skin lesions, uveitis, or neurological symptoms. Lymphoma, a malignancy of the lymphatic system, can also involve hilar lymph nodes, leading to lymphadenopathy on CXRs. However, lymphoma often presents with constitutional symptoms like fever, night sweats, and weight loss, and may be associated with other lymphadenopathy sites or organomegaly. Metastatic disease, particularly from lung cancer or breast cancer, can spread to hilar lymph nodes, mimicking the appearance of TB lymphadenopathy. However, a careful review of the CXR may reveal a primary lung mass or other metastatic lesions. Therefore, a comprehensive clinical assessment is paramount in differentiating PTB from these potential mimickers. A thorough history, including TB exposure, travel history, and risk factors for other diseases, is essential. Physical examination findings, such as lymphadenopathy in other sites or organomegaly, may further aid in the diagnostic process. Laboratory investigations, including complete blood count, erythrocyte sedimentation rate, and serum angiotensin-converting enzyme levels, can provide additional clues. Ultimately, microbiological confirmation of M. tuberculosis infection, through sputum smear microscopy, culture, or nucleic acid amplification tests, is crucial in establishing a definitive diagnosis of PTB. Hilar lymphadenopathy is not a static entity; it can evolve over time, reflecting the dynamic nature of the host-pathogen interaction in TB. In some cases, lymphadenopathy may regress with successful anti-tuberculosis treatment, signifying a favorable response. In other cases, it may persist or even progress, suggesting treatment failure, drug

resistance, or complications. Therefore, serial CXRs are often obtained to monitor the evolution of hilar lymphadenopathy and assess treatment response. A decrease in the size or density of lymph nodes is generally considered a positive sign, while an increase or persistence of lymphadenopathy may warrant further investigation and potential treatment adjustments. While CXRs provide valuable insights into hilar lymphadenopathy, advanced imaging modalities like computed tomography (CT) and positron emission tomography (PET) can offer additional information about the extent and activity of lymph node involvement. CT scans provide superior spatial resolution and the ability to visualize subtle changes in lymph node morphology, such as central necrosis or calcification. PET scans, on the other hand, can assess the metabolic activity of lymph nodes, differentiating active from inactive disease. Beyond imaging, fine-needle aspiration or biopsy of lymph nodes may be necessary in cases of diagnostic uncertainty or suspected malignancy. These invasive procedures allow for histopathological examination and definitive diagnosis.[15,16]

Our study unveiled a compelling correlation between the extent of radiological abnormalities observed on chest X-rays (CXRs) and the severity of pulmonary tuberculosis (PTB) in the affected individuals. This observation underscores the prognostic value of CXRs, highlighting their potential to stratify patients based on disease severity and guide the tailoring of treatment strategies. Radiological involvement in PTB encompasses a spectrum, ranging from subtle and localized abnormalities to extensive and disseminated patterns. On one end of the spectrum, we find patients with minimal CXR findings, such as solitary nodules or small areas of consolidation. These individuals often present with early-stage disease, characterized by limited bacterial burden and relatively preserved lung function. On the other end of the spectrum lie patients with extensive radiological involvement, manifested by widespread consolidation, multiple cavitary lesions, or miliary patterns. These individuals typically harbor advanced PTB, with significant lung destruction, impaired respiratory function, and a higher risk of complications and mortality. Between these two extremes lies a continuum of radiological presentations, reflecting the dynamic nature of PTB and the interplay between host immune responses and bacterial virulence. The extent of radiological involvement on CXRs serves as a surrogate marker for disease severity, providing clinicians with crucial information for prognostication and treatment planning. Among the various radiological manifestations of PTB, cavitary lesions emerged as a particularly ominous sign, strongly associated with advanced disease. These cavities, or air-filled spaces within the lung parenchyma, represent areas of tissue necrosis and liquefaction, often teeming with viable Mycobacterium tuberculosis bacilli. The presence of cavitary lesions on CXRs indicates a significant bacterial burden and a heightened risk of disease transmission. Furthermore, these lesions can be associated with complications such as hemoptysis (coughing up blood), pneumothorax (collapsed lung), and bronchopleural fistula (abnormal communication between the airways and the pleural space). Patients with cavitary lesions often require more aggressive treatment regimens, including prolonged courses of anti-tuberculosis therapy and potentially surgical intervention. Close monitoring of treatment response and vigilance for complications are also crucial in this patient population. Extensive parenchymal involvement, characterized by widespread consolidation or multiple areas of infiltration, also signifies advanced PTB. This radiological pattern reflects a substantial bacterial burden and a compromised host immune response, often leading to significant impairment of lung function and a higher risk of morbidity and mortality. Patients with extensive parenchymal involvement may experience more severe symptoms, including dyspnea (shortness of breath), chest pain, and fatigue. They may also require hospitalization and supplemental oxygen therapy to manage respiratory distress. The treatment of these patients often necessitates a multi-pronged approach, encompassing intensive anti-tuberculosis therapy, supportive care, and management of complications. The significant association between the extent of radiological involvement on CXRs and disease severity

underscores the prognostic value of these imaging studies. By carefully interpreting CXR findings, clinicians can gain valuable insights into the likely course of the disease and tailor treatment strategies accordingly. Patients with minimal radiological involvement may be managed with standard anti-tuberculosis regimens and close outpatient follow-up. In contrast, patients with cavitary lesions or extensive parenchymal involvement may require more intensive treatment, including prolonged therapy, hospitalization, and adjunctive interventions. Furthermore, CXR findings can be used to monitor treatment response and identify patients at risk for treatment failure or relapse. Serial CXRs can track the resolution of radiological abnormalities and provide an objective measure of treatment efficacy. The correlation between radiological involvement and disease severity reinforces the importance of meticulous CXR interpretation in the management of PTB. Radiologists and clinicians must be well-versed in the spectrum of CXR findings in PTB and their prognostic implications. Careful attention should be paid to the extent and distribution of consolidation, the presence and characteristics of cavitary lesions, and the involvement of hilar or mediastinal lymph nodes. These findings, when interpreted in conjunction with clinical and microbiological data, can guide treatment decisions, facilitate risk stratification, and optimize patient outcomes.[17,18]

The alarming prevalence of HIV co-infection in our study population, reaching 10% and surpassing the national average, serves as a stark reminder of the intertwined destinies of these two formidable infectious diseases. This convergence represents a collision of epidemics, where the immunosuppressive effects of HIV create a fertile ground for the opportunistic invasion of Mycobacterium tuberculosis, the causative agent of TB. The synergistic relationship between TB and HIV is a cause for grave concern, as it amplifies the burden of both diseases and poses significant challenges for public health interventions. HIV infection weakens the immune system, dismantling its ability to effectively combat M. tuberculosis, thereby increasing susceptibility to both primary infection and reactivation of latent TB. HIV, a retrovirus that primarily targets CD4+ T lymphocytes, orchestrates a gradual but relentless assault on the immune system. These T cells, also known as helper T cells, play a pivotal role in coordinating the immune response, orchestrating the actions of other immune cells and directing the attack against invading pathogens. As HIV infection progresses, the number of CD4+ T cells dwindles, leaving the host vulnerable to a myriad of opportunistic infections, including TB. The loss of these crucial immune cells impairs the body's ability to contain M. tuberculosis within granulomas, the organized structures that normally sequester and control the infection. Consequently, M. tuberculosis can spread unchecked throughout the lungs and beyond, leading to more severe and disseminated forms of TB. The weakened immune system also struggles to mount an effective inflammatory response, resulting in atypical or less pronounced radiological manifestations on chest X-rays (CXRs). The immunosuppressive effects of HIV can profoundly alter the radiological presentation of PTB, creating a diagnostic conundrum for clinicians. In HIV-negative individuals, PTB typically manifests with classic CXR findings, such as consolidation, cavitary lesions, and hilar lymphadenopathy. However, in HIV-infected individuals, these radiological hallmarks may be less pronounced or even absent, particularly in those with advanced immunosuppression. This atypical presentation stems from the blunted inflammatory response in HIV-infected individuals. The reduced influx of immune cells to the site of infection results in less consolidation and cavitation, potentially leading to false-negative CXR interpretations. Moreover, the weakened immune system may struggle to contain the spread of M. tuberculosis, resulting in more disseminated disease patterns, such as miliary TB, which may be challenging to detect on CXRs. This diagnostic challenge necessitates a heightened index of suspicion for TB in HIV-infected individuals, even in the absence of classic radiological manifestations. Clinicians must rely on a comprehensive assessment, encompassing clinical symptoms, medical history, and laboratory investigations, to identify PTB in this vulnerable population. The management of PTB in HIV-infected individuals is a delicate balancing act,

requiring careful consideration of both diseases and their intricate interactions. Anti-tuberculosis therapy remains the cornerstone of treatment, but the choice of regimen and duration may need to be adjusted based on the patient's immune status and the presence of other opportunistic infections. Furthermore, the initiation of antiretroviral therapy (ART) for HIV infection must be carefully timed and monitored. While ART can restore immune function and improve TB treatment outcomes, it can also trigger an immune reconstitution inflammatory syndrome (IRIS), a paradoxical worsening of TB symptoms due to the restored immune response. Careful management of IRIS is crucial to prevent complications and ensure successful treatment of both TB and HIV. The high prevalence of HIV co-infection in our study population underscores the urgent need for integrated TB/HIV programs. While the epidemiological and radiological aspects of HIV co-infection in PTB are undoubtedly important, it is crucial to remember the human cost of this dual burden. Individuals living with both TB and HIV face numerous challenges, including stigma, discrimination, and social isolation. They may also experience adverse drug reactions, treatment interruptions, and a diminished quality of life. Therefore, a holistic approach to TB/HIV care is essential, encompassing not only medical management but also psychosocial support, nutritional assistance, and community engagement. By addressing the multifaceted needs of these individuals, we can empower them to navigate the complexities of their conditions and achieve optimal health and well-being.[19,20]

4. Conclusion

This retrospective study of pulmonary tuberculosis (PTB) in Palembang, Indonesia, using chest X-ray analysis, underscores the critical role of radiology in PTB diagnosis and management. The spectrum of CXR findings, including consolidation, cavitary lesions, and hilar lymphadenopathy, reflects the diverse manifestations of the disease. The correlation between radiological extent and disease severity highlights the prognostic value of CXRs in guiding treatment decisions. The high prevalence of HIV co-infection emphasizes the need for integrated TB/HIV programs to address the complex challenges posed by this dual burden.

5. References

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