International Journal of Medical Science in Clinical Research and Review
Online ISSN: 2581-8945
Available Online at http://www.ijmscrr.in Volume 1|Issue 01 (November-December)|2018 Page: 42-52

Original Research Paper

A Study of Ultrasound and Magnetic Resonance Imaging in Thoracic Tuberculosis in the Pediatric Population: Moving Beyond Conventional Radiology

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Article Received: 15-November-2018 Revised: 05-December-2018 Accepted: 25-December-2018

ABSTRACT:

Background: Early diagnosis of tuberculosis (TB) is necessary for effective treatment. In primary pulmonary TB, chest radiography remains the mainstay for the diagnosis of parenchymal disease, while computed tomography (CT) is more sensitive for detecting lymphadenopathy. **Aim and Objective:** Ultrasound and magnetic resonance imaging in thoracic tuberculosis in the pediatric population: **Method and material:** This observational study was conducted in the Department of Radio-Diagnosis and medicine, Mayo Institute of Medical Sciences, Gadia, Barabanki, UP, India. The data was collected from 40 patients with from the OPD of the hospital. In post-primary pulmonary TB, CT is the method of choice toreveal early bronchogenic spread. **Result:** Chest CT has a reported detection rate of 80% in patients with active tuberculosis and 89% in patients with inactive tuberculosis. The combined use of chest CT and the interferon gamma release assay is considered more effective than the conventional approach of chest radiography and the tuberculin skin test in differentiating between active infection, latent infection, and non-infection. **Conclusion:** CT and MRI are often performed for clinically diagnosed tuberculosis and the detection of various complications. MRI and US should be used for mediastinal lymph node detection where infrastructure and expertise are available because these modalities do not involve radiation risks. In low-resource settings where CT and MRI are not available, chest radiography and US hold the fort for radiology. For the future, advances in imaging technology hold promise to perform faster and more accurate cross-sectional imaging with no more radiation risks than a conventional radiograph.

Keywords: Ultrasound, CT, MRI, Tuberculosis

INTRODUCTION:

Tuberculosis continues to be an important cause of morbidity and mortality worldwide. It is the leading cause of infection-related deaths worldwide. Children are among the high-risk groups for developing tuberculosis and often pose a challenge to clinicians in making a definitive diagnosis. The newly released global tuberculosis report from the World Health Organization reveals a 50% increase in fatalities from tuberculosis in children.

Tuberculosis ranks among the top 10 causes of death worldwide, as per the recently released 2016 World Health Organization global report on tuberculosis. Although the number of deaths and the incidence rate of tuberculosis continue to fall, in 2015 there were an estimated 10.4 million new (incident) cases of tuberculosis worldwide, of which 1.0 million (10%) were children [1]. The World Health Organization also estimates that two-thirds of the world's population has no access to basic radiology services and that, when available, the quality and safety of the procedures are sometimes questionable or even dangerous to the patient, the health care worker, and the public. Such conditions are most prominent in low-resource countries with insufficient infrastructure, an unstable political environment, and a considerable burden of the disease. In such areas, diagnostic imaging services are rarely seen as a global health priority and are not integrated into national health plans [2–5]. Significantly, diagnostic and treatment algorithms for tuberculosis in children differ from those of adults. Bacteriologic confirmation of the disease is often difficult in children; hence, radiologists have an important role to play in the early diagnosis of this disease. Despite advancing technology, the key diagnostic imaging modalities for primary care and emergency services, especially in rural and low-resource areas, are chest radiography and ultrasonography.

The diagnosis of pulmonary TB in children is often challenging [6–8] and is made using a combination of history, clinical, radiological, and microbiological findings. [9-10] Children present with non-specific clinical symptoms, have difficulties providing

specimens, and have a low bacillary load [11], which compounds the diagnostic challenge. TB is confirmed microbiologically in only about 20–50% of children treated for TB.[8,12] In many children who are culture-negative, the diagnosis is made clinically or radiologically, including improvement with TB treatment. Radiological imaging supports a clinical diagnosis of pulmonary TB in children. [9] It can assess the response to treatment and evaluate the complications of TB.[8] However, radiological signs are often non-specific, and inter-observer variability in the interpretation of chest radiographs and computed tomography (CT) scans contributes to the difficulties in radiological interpretation and diagnosis. [6] Repeat imaging is only indicated if a child has persistent or worsening symptoms or signs. In this review, we discuss various diagnostic imaging modalities used in the evaluation of primarily intrathoracic tuberculosis and their indications.

MATERIALS AND METHOD:

This observational study was conducted in the Department of Radio-Diagnosis, Mayo Institute of Medical Sciences, Gadia, Barabanki, UP, India. The data was collected from 40 patients with hemorrhagia from the OPD of the hospital. Clinical history, physical examinations, laboratory examinations, and various medical imaging tools are combined to establish the diagnosis. The patient underwent a CT examination after obtaining a detailed clinical history. Ethical clearance was obtained from the Institutional Ethical Committee, and written informed consent was obtained before carrying out the study.

Computed Tomography:

CT is more sensitive than chest radiographs in the detection of mediastinal and hilar lymphadenopathy, pleural and parenchymal disease, and in the assessment of complications. CT can be used to identify enlarged lymph nodes in up to 60% of tuberculosis patients with normal chest radiographs. CT is very useful in evaluating the complications of lymphobronchial tuberculosis in children, including the presence and degree of tracheal and bronchial compression, lobar collapse, bronchiectasis, and pleural disease. CT can also be used to differentiate tuberculous pleural infections from non-tuberculous pleural infections, with interlobular septal thickening and sub-pleural nodules being characteristic features of pleural tuberculosis. High-resolution CT is recommended to detect centrilobular or miliary nodules, ground-glass opacities, and mosaic perfusion, while a contrast-enhanced CT scan is helpful in assessing pleural components and diagnosing empyema.

RESULTS:

It is important to differentiate latent infection from active or confirmed tuberculous disease because this determines the course of treatment. Tuberculous disease can be missed if only chest radiography is used. Chest CT has a reported detection rate of 80% in patients with active tuberculosis and 89% in patients with inactive tuberculosis. The combined use of chest CT and the interferon gamma release assay is considered more effective than the conventional approach of chest radiography and the tuberculin skin test in differentiating between active infection, latent infection, and non-infection. Characteristic findings on a CT scan that are suggestive of active tuberculosis include the following:

1. Lymphadenopathy: enlarged lymph nodes in the mediastinum or hilum with central necrosis (low attenuation central part) and a rim of peripheral enhancement.
2. Consolidation: The lobular pattern of consolidation favors tuberculosis but is nonspecific. The presence of an ipsilateral paratracheal or hilar lymphadenopathy favors tuberculosis.
3. Thick-walled pulmonary cavities.
4. Centrilobular nodules: These can be seen in a typical tree-in-bud appearance, which consists of multiple branching linear opacities.
5. Clustered and miliary nodules.

Magnetic Resonance Imaging:

MRI has recently emerged as a radiation-free alternative to CT for imaging children with pulmonary infections and compromised immune systems. MRI seems useful in particular for follow-up and primary diagnosis in children, pregnant women, and patients allergic to iodinated contrast media. However, MRI is expensive and often requires anesthesia or monitored sedation. With technological advances in MRI and faster acquisition times, high-quality MRI of the lung is being developed and used in various clinical applications. In pediatric tuberculosis, lymphadenopathy is the key imaging finding for making a correct and early diagnosis. In this context, thoracic MRI offers a great opportunity because it is comparable to multi-detector CT for detecting mediastinal lymph nodes. MRI yields sensitivity, specificity, and positive and negative predictive values of 100% for the detection of mediastinal lymph nodes >7 mm in size. MRI has also demonstrated perfect correlation with multi-detector CT in the detection of pulmonary consolidation, nodules (>3 mm), cysts and cavities, and pleural effusions. MRI has higher sensitivity for nodal involvement and pleural abnormalities in pulmonary tuberculosis than a non-contrastenhanced CT scan.

Ultrasound:

Mediastinal US has been proposed as an alternative to chest radiography in the detection of mediastinal lymph nodes, specifically in resource-limited settings where US might be the only imaging modality. A study investigating children with pulmonary tuberculosis who had normal chest radiographs found mediastinal lymphadenopathy in 67% of children using US of the mediastinum. On US, lymph nodes are well-defined hypoechoic structures, oval in shape, and can be easily identified as distinct from adjacent mediastinal vessels, which are echo-free and are elongated in at least one plane and show branches. The US has also been found useful as an imaging modality in monitoring the response to anti-tubercular treatment in children. Pericardial or pleural effusions, ascites, and focal lesions in the liver or spleen are likely to be features of extrapulmon.

DISCUSSION:

Available Techniques for Chest Imaging in PTB:

Chest radiography is often the first step in investigating a child with suspected PTB. [13] However, plain radiographs are inadequate for making the diagnosis of PTB. Plain chest radiographs are known to have poor sensitivity for detecting mediastinal and hilar lymphadenopathy, which are the defining features of primary PTB in children. Tuberculous lymphadenopathy is more common in children and decreases with increasing age. Chest ultrasound is a radiation-free, cost-effective, non-invasive imaging study that can be made available at the patient's bedside. [8] Ultrasound can be useful for assessing the presence and characteristics of pleural effusions, allowing for the differentiation of simple and complex effusions, detecting complications such as empyema, and guiding drainage. [12] A novel use of ultrasound is for the detection of mediastinal lymphadenopathy. The technique is not widely taught, and, as always, ultrasound is operator-dependent. The limited scope of ultrasound through an aerated lung leaves users mainly with the suprasternal window for accessing mediastinal lymphadenopathy. [6] A longitudinal study by Bosch-Marcet et al. found mediastinal ultrasound was useful in not only diagnosis but also monitoring of treatment and showed resolution of mediastinal lymphadenopathy over time with TB treatment. [10]

CT has been described as the "gold standard" for demonstrating the presence of lymphadenopathy in children with primary PTB and can define early features of TB (lymphadenopathy, nodules, small pleural effusion) before these become apparent on a chest radiograph. [13] CT allows for a more accurate evaluation of the disease process and complications. There is a reluctance to use CT in children due to the perceived risks from ionizing radiation because CT has a higher radiation dose than chest radiographs. Children are also considered to be at greater radiation risk than adults because their developing tissues are more radiosensitive, and they have a longer life expectancy to develop a radiation-induced malignancy. [14-15] This perception persists despite the development of low-dose techniques that are comparable to the doses of a few combination AP and lateral chest radiographs. In 2013, a CT chest dose was estimated at 8.8 mSv. With advances in technology, this has been reduced significantly.

A recent study by Ward et al. showed that the radiation dose for a child between the ages of 5 and 15 years was 0.01 mSv for a chest radiograph and between 0.91 and 1.96 mSv for a CT chest. [15] MRI is a radiation-free alternative to CT. However, this comes at a high cost, and as a result, the availability of MRI equipment is often limited. MRI is sensitive for detecting lymphadenopathy. A pilot study by Sodhi et al. showed that MRI is comparable to CT in the detection of pleural effusions, mediastinal and hilar lymphadenopathy, and cavitation in children with TB. MRI is more sensitive than non-contrast CT for small lymph nodes and pleural abnormalities and therefore has the advantage of avoiding intravenous access and the administration of contrast agents. Diffusion-weighted and post-contrast MRI may be better able to characterize disease activity. [8]

A major disadvantage of MRI is that it usually requires sedation or anesthesia for successful execution in children under about 6 years of age because of the long image acquisition time. However, fast MRI protocols, fast sequences for chest imaging, and motion-robust sequences are likely to make it possible to image without sedation or anesthesia in the near future.

Radio-pathologic Correlations in Primary TB:

TB is an infectious disease that spreads via inhalation of a droplet infected with Mycobacterium tuberculosis. The droplet travels through the airways to the terminal alveoli and causes an inflammatory process in the parenchyma termed the Ghon focus. [16] The bacilli spread via lymphatic vessels to regional lymph nodes, which enlarge. The combination of the Ghon focus and the enlarged lymph nodes is called the Ghon complex.

Uncomplicated/non-progressive Primary TB:

During the incubation period, in which tuberculin skin tests (TSTs) are negative, the chest radiograph is often normal and then may progress to demonstrate hilar and mediastinal lymphadenopathy. The thymus and heart are relatively larger in children than in adults and may obscure lymphadenopathy on chest radiographs. [6] Hilar lymphadenopathy may be visualized as convex lobulated opacities obliterating the hilar points on frontal view (Figure 1).

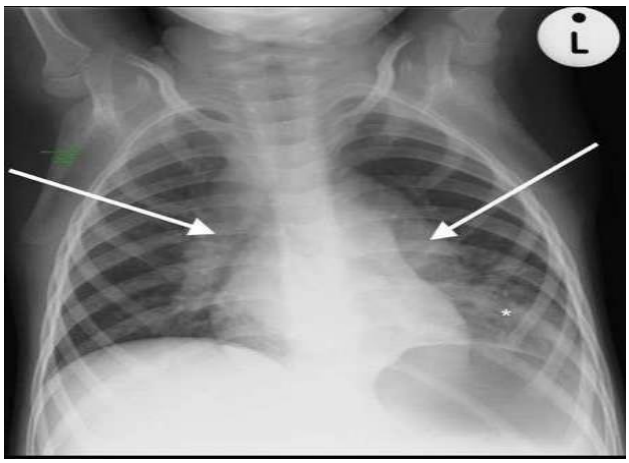

Figure 1. A chest radiograph of a child with TB demonstrates bilateral hilar lymphadenopathy (arrows) and left lower lobe consolidation

Right hilar adenopathy is more commonly visualized on a chest radiograph than left hilar adenopathy, as this is the more dominant pathway of lymphatic flow and also because left hilar adenopathy is often only seen when it projects beyond the prominent left cardiac margin. The trachea may be compressed or deviated to the left by right paratracheal lymphadenopathy, which is a useful sign because the trachea is typically right-sided in children due to the left position of the aortic arch. A lateral radiograph may show lymphadenopathy as a lobulated opacity inferior and posterior to the bronchus intermedius, also known as the "doughnut sign[17] (Figure 2).

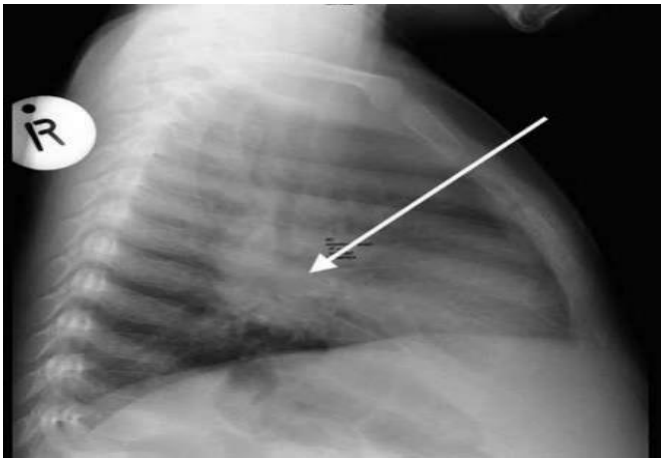

Figure 2. A lateral chest radiograph in a child with TB demonstrates the "doughnut sign"—a lobulated opacity in the hilar region (arrow).

The full ring of the "doughnut" is formed by normal anatomical vascular structures (right and left main pulmonary arteries and the aortic arch) making up the upper half and lymphadenopathy making up the inferior and posterior parts, with the trachea and upper lobe bronchi forming the central lucency of the "doughnut." Routine use of lateral radiographs is controversial. A study by Swingler et al. did not find improved accuracy of lymph node detection with a lateral radiograph, but the inclusion criteria may have favored patients with smaller lymphadenopathy in that study. [17]

As an alternative imaging method, ultrasound can be performed through the suprasternal notch window and can demonstrate anterior mediastinal lymphadenopathy in children. Ultrasound cannot, however, demonstrate lymphadenopathy at the hila through aerated intervening lungs. [10] On ultrasound, mediastinal lymph nodes are well defined; round or oval hypoechoic structures are seen between the mediastinal blood vessels (Figure 3).

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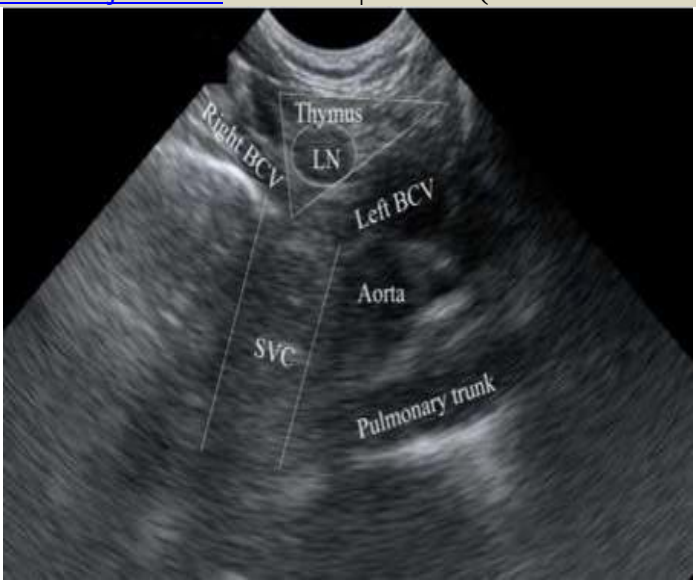

Figure 3. Annotated ultrasound demonstrates an anterior mediastinal lymph node.

Bosch-Marcet et al. confirmed that ultrasound was comparable to CT and had a higher sensitivity than chest radiographs in the detection of mediastinal lymph nodes. [18] Heuvelings et al. found that chest ultrasound had a higher inter-reader agreement and detected abnormalities more commonly than chest radiographs; they found mediastinal lymph nodes in children with confirmed TB were detected in 29% of children on ultrasound compared with only 11% of children with TB by chest radiograph. An additional advantage of ultrasound is that it can diagnose disseminated disease in children with suspected PTB by performing abdominal ultrasound to confirm lymphadenopathy and abdominal organ lesions.

CT is considered a superior technique for demonstrating lymphadenopathy in children. Lymphadenopathy can be detected on CT in children who have a normal or equivocal chest radiograph. Delacourt et al. showed that CT detected lymphadenopathy in up to 60% of patients with TB and normal chest radiographs. [19] On CT, TB lymph nodes have central low attenuation with peripheral rim enhancement or ghost-like enhancement, which represents a step beyond detection in that these are characteristics of necrosis within tuberculous lymphadenopathy that help in differentiating it from untreated lymphoma. Commonly involved lymph node groups are located in the right paratracheal region and hilum.

Sodhi et al. showed that MRI is comparable to CT in the detection of mediastinal and hilar lymphadenopathy in children with TB. Short tau inversion recovery (STIR) MRI has demonstrated the presence of low-signal-intensity mediastinal and hilar adenopathy in patients with TB (Figure 4). The authors have observed that texture analysis of lymph nodes on MRI may be able to further differentiate TB nodes from nodes from other causes. The Ghon focus (Figure 5) and Ghon complex have also been well demonstrated on MRI.

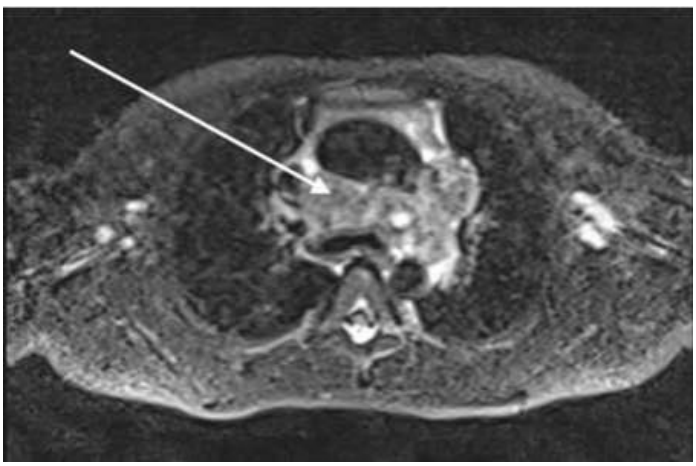

Figure 4. Axial STIR MRI in a child with TB demonstrates predominantly low signal mediastinal lymphadenopathy (arrow).

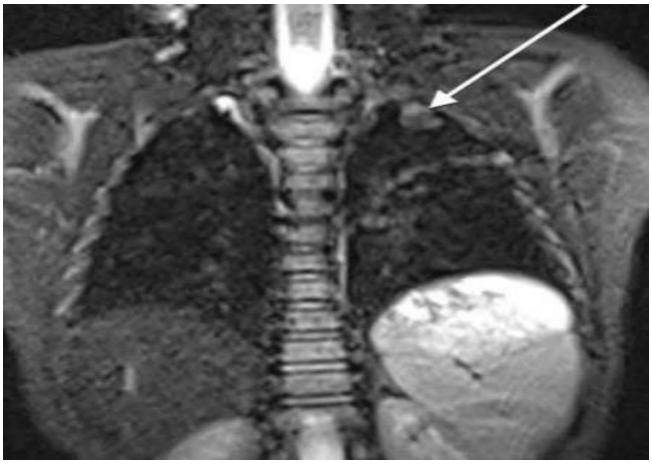

Figure 5. Coronal MRI in a child with TB demonstrates a left upper lobe Ghon focus (arrow), which is often missed on a chest radiograph.

Progressive Primary Tuberculosis and Complications of Primary PTB:

In the majority of children, both parenchymal lesions and lymphadenopathy may resolve spontaneously without destruction or scarring. However, primary infection may progress, and this may be referred to as progressive primary tuberculosis. This phenomenon is more commonly seen in younger children, those with immunosuppression (e.g., HIV or malnutrition), and adolescents. The bacilli may spread via the airways, blood, or lymphatics. Lymph nodes may enlarge and caseate [16], leading to endobronchial spread, lymphobronchial TB, or miliary dissemination.

Lymphotracheobronchial TB is a complication of primary pulmonary TB in children secondary to enlarged lymphadenopathy compressing the airway(s). Infants in particular have small, pliable airways that are vulnerable to compression (Figure 6).

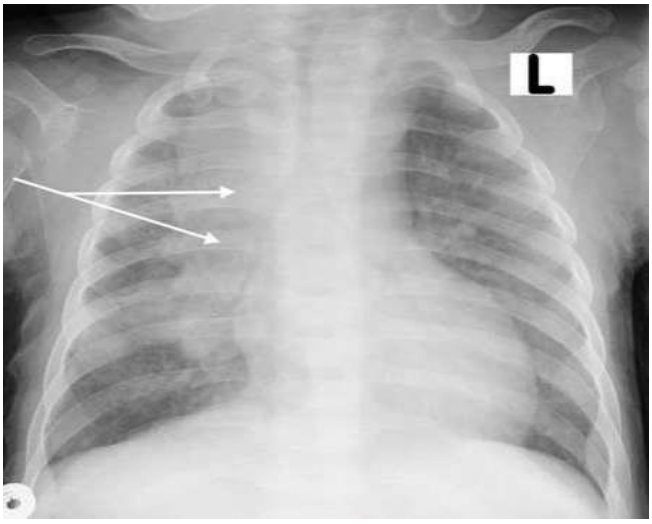

Figure 6. A chest radiograph in a child with TB demonstrates right paratracheal and hilar lymphadenopathy (white arrow) with attenuation of the bronchus intermedius.

Enlarged nodes may therefore compress the airway, causing bronchial stenosis, atelectasis, air trapping, or airspace consolidation. Enlarged nodes may also erode through the airway. Patients with lymphotracheobronchial tuberculosis may have a normal chest radiograph, and in some cases, enlarged nodes and airway narrowing might only be suggested on a high-kV film. Enlarged paratracheal nodes may also cause tracheal deviation. Unilateral hyperinflation in the chest may be the result of an incompletely obstructed bronchus with enlarged nodes. [20] Multifocal areas of air trapping and lobar or segmental collapse may also be seen on radiographs but are often more easily visualized with CT. In addition, CT has the advantage of being able to identify the cause of tracheobronchial stenosis (including tuberculous lymphadenopathy), which is often not visualized on chest radiographs. CT may show smooth bronchial narrowing secondary to nodal compression or irregular

wall thickening and mucosal irregularity secondary to eroding caseating granulomas.
Three-dimensional volume-rendered CT has advantages over multiplanar CT reconstructions and chest radiographs because it can allow accurate measurement of the length of stenosis, predict whether a lesion is endobronchial, submucosal, or peri-bronchial, and be more useful for planning bronchoscopy and surgery. A study by Du Plessis et al. for detecting airway compression in TB found that three-dimensional volume-rendered CT reconstructions had a sensitivity of 92% and a specificity of 85% against the gold standard bronchoscopy. [19]

Caseous necrosis within consolidation may develop as the disease progresses, resulting from post-obstructive atelectasis and cavitation, with bulging fissures becoming a feature on plain radiographs. Low attenuation areas within TB consolidation are a common finding on CT. Necrotic lung has a lower density than the surrounding consolidation on CT and does not enhance (on CT or MRI) as compared to consolidated non-necrotic viable lung tissue. MRI is comparable to CT in the detection of consolidation, but MRI has an advantage over CT as the MRI signal varies with the type and stage of necrosis and the presence of TB organisms within areas of caseation (Figure 7). Caseous necrosis, which is visible as a low signal on T2-weighted MRI (as opposed to a high signal from pyogenic abscesses), indicates active TB3 and is a potential biomarker for active PTB.

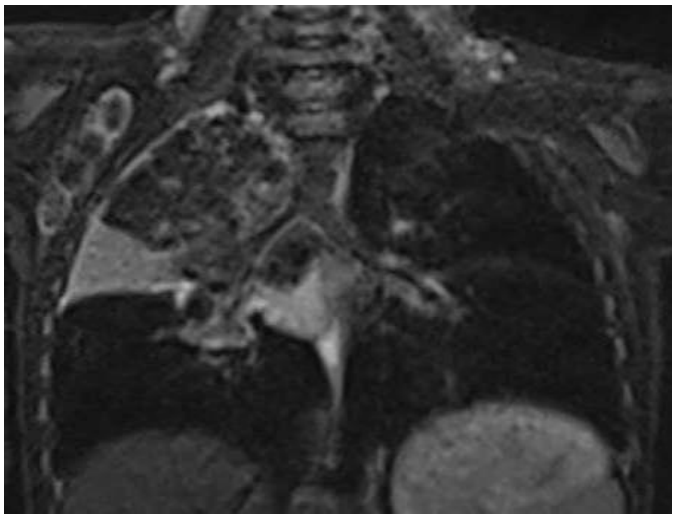

Figure 7. Coronal STIR MRI in a child with TB demonstrates inhomogeneous right upper lobe consolidation with areas of low signal, which indicate necrosis.

Miliary TB is secondary to the hematogenous dissemination of Mycobacterium tuberculosis bacilli [16], which usually occurs in young children and immune-compromised patients. Even though the classic description for these is on chest radiographs, which show randomly scattered millet-size nodules (<3mm) diffusely throughout both lungs [21] (Figure 8), chest radiographs may be normal initially. CT, on the other hand, may demonstrate the nodules some time before they are visualized on a chest radiograph. Nodules may be either sharply or poorly defined, are randomly scattered diffusely through both lungs, and are often associated with intra- and interlobular septal thickening. 4,11 Current MRI technology fails to demonstrate lung nodules <3 mm in size but is useful for demonstrating lesions in solid organs such as the liver and spleen in cases of bloodborne dissemination of TB.

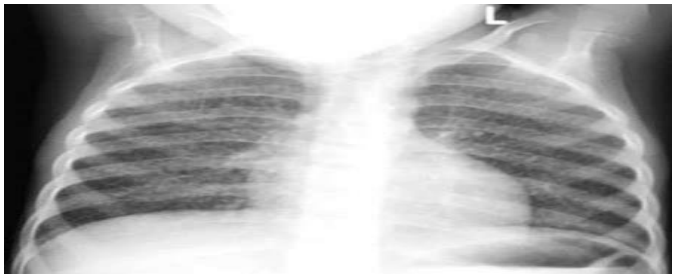

Figure 8. A chest radiograph in a child with miliary TB demonstrates multiple small, randomly scattered nodules diffusely throughout both lungs.

Pleural tuberculous disease is uncommon in infants and occurs more often in older children and adolescents. TB pleural effusions are usually unilateral and often occur associated with TB air-space

consolidation or nodal disease. Chest radiographs more commonly demonstrate lamellar effusions in children (Figure 9) (compared with a blunted costophrenic angle or a homogeneously opacified fluid level seen in adults). However, a significant amount of fluid must accumulate before it can be visualized on a chest radiograph. A supine chest radiograph may show "veiling" or an increased density of the hemithorax as the dependent fluid collects posteriorly and this may be missed by inexperienced interpreters. Ultrasound is particularly useful for detecting pleural effusions, as it can demonstrate even small amounts of fluid before these are visible on chest radiographs. Studies have shown that chest ultrasound can detect effusions [12] and consolidation [7] missed on a chest radiograph. Ultrasound is also an excellent tool to characterize the nature of the effusion and can differentiate a simple effusion from a complex pleural effusion or an empyema. A simple effusion is seen as an anechoic collection between the visceral and parietal pleura. Complex effusions are more echogenic and may contain septations. A color doppler can differentiate a pleural effusion from a pleural thickening by detecting color flow (related to respiration) between the visceral and parietal pleura. Ultrasound, therefore, remains the ideal bedside tool for diagnosing pleural effusions.

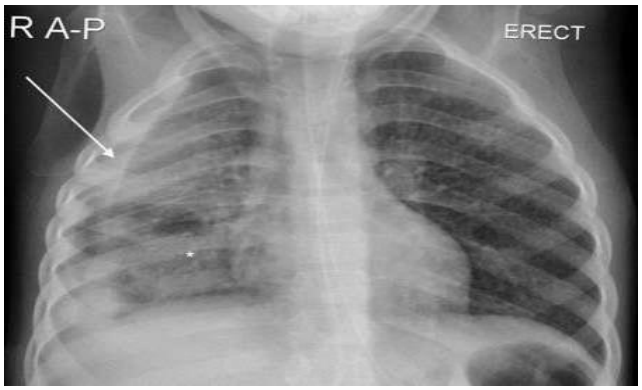

Figure 9. A chest radiograph in a child with TB demonstrates a right lamellar effusion (arrow) and right lower zone consolidation.

Although CT and MRI are useful in not only detecting effusions but also determining the size and nature of these, they are considered second-line imaging modalities for this purpose, with ultrasound being the first line. Both of these modalities have the ability to differentiate pleural thickening from a pleural effusion, but MRI is better than CT in demonstrating septations and internal debris in pleural effusions. [14] CT may demonstrate the "split-pleura" sign of an empyema (Figure 10), which is smooth enhancement of visceral and parietal pleura with loculated fluid between the two layers of pleura. An empyema may further complicate into an empyema necessitans [13] or a bronchopleural fistula. Empyema necessitans occurs when there is a break from the parietal pleura to form a subcutaneous abscess. A bronchopleural fistula is a communication between the pleural space and the airway and is suspected on a chest radiograph when there is an air fluid level in the empyema. CT may be able to demonstrate the bronchopleural fistula directly, allowing a definitive diagnosis to be made. Tuberculomas are parenchymal granulomas up to 5cm in size that occur in both primary and post-primary TB. Tuberculomas can be solitary or multiple, and they can cavitate or calcify. Chest radiographs demonstrate tuberculomas as well-defined ovoid lesions in the lung parenchyma. CT has an advantage in defining calcification or necrosis in tuberculomas better than a chest radiograph. MRI can show tuberculomas as having a low signal intensity on T1, but the T2 signal varies with the degree of caseation; caseating lesions demonstrate a low T2 signal on MRI, which is diagnostic of TB. [6]

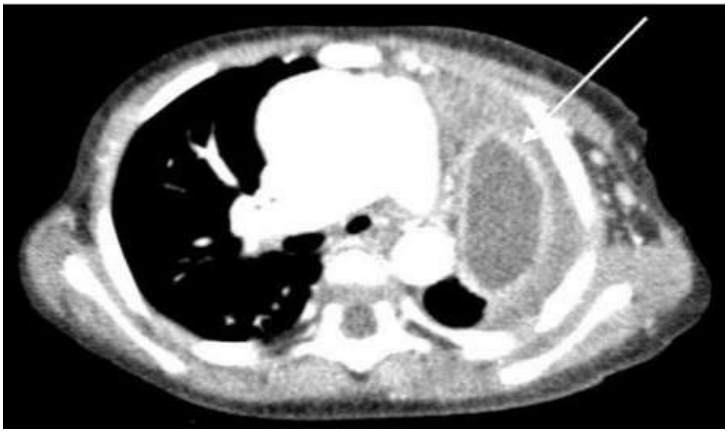

Figure 10. Axial CT in a child with TB demonstrates the "split pleura sign" (arrow) of an empyema.

Adult-type TB:

Adult-type TB occurs following a recent primary infection [3] and is not only the result of re-infection or reactivation of a dormant focus. This can occur rarely in children and more commonly in adolescents. [13] The apical and posterior segments of the upper lobes and the apical segment of the lower lobes are most commonly affected. The chest radiograph may show patchy airspace opacification, which progresses to coalesce, followed by parenchymal breakdown and cavity formation. [16] Cavitation is the radiographic hallmark of post-primary PTB. Cavities are formed by caseous necrosis and may have walls that are thin and smooth or thick and nodular.[13] Cavities are difficult to separate from the surrounding consolidated lung and may be missed on chest radiographs. CT can better define cavities than chest radiographs and may help to better differentiate thick-walled cavities (a sign of active infection) from thin-walled cavities (suggestive of healed infection) and from bullae and pneumatocoeles. MRI is equivalent to CT in the detection of cavities (Figure 11), and both CT and MRI are more sensitive than chest radiographs for detecting small cavities and the presence of and contents of intracavitary bodies. An air fluid level in a cavity is a sign of a super-added infection.

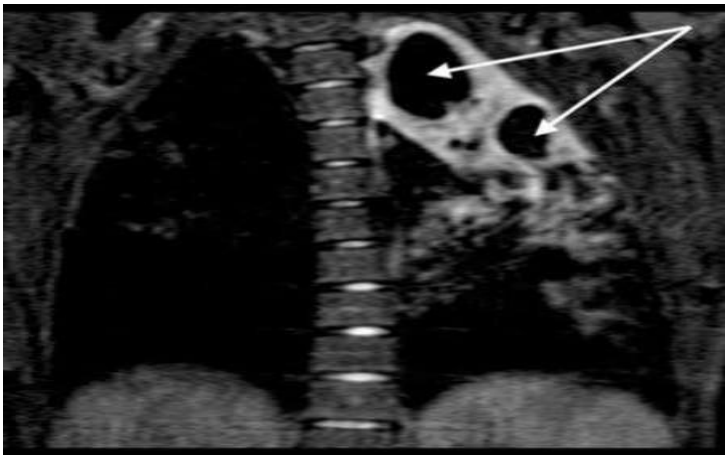

Figure 11. Coronal MRI in a child with pulmonary TB demonstrates thick-walled left upper lobe cavities with associated consolidation.

Other common findings in post-primary tuberculosis are bronchogenic spread and traction bronchiectasis. Chest radiographs can show bronchogenic spread, which presents as multiple, ill-defined micronodules, often in a segmental or lobar pattern. [16] CT better demonstrates bronchogenic spread much earlier than the "tree-in-bud" sign—small centrilobular nodules that appear as buds on the ends of linear branching opacities (Figure 12). Bronchogenic spread suggests an active disease. Destruction and fibrosis lead to bronchiectasis. [20] Chest radiographs may show multiple ring shadows, in keeping with cystic bronchiectasis. Bronchiectasis is more often demonstrated on CT (Figure 13) with the ''tram-track sign'' of thickened, nontapering dilated bronchi and the "signet-ring sign'' of an enlarged dilated bronchus compared to the adjacent artery in cross-section. Sodhi et al. showed that CT and MRI are both more sensitive than the chest radiograph in the detection of bronchiectasis. Continued inflammation leads to distortion of the lung parenchyma, scarring, and fibrosis, which are demonstrated by plain radiographs, CT, and MRIs alike. [7,16]

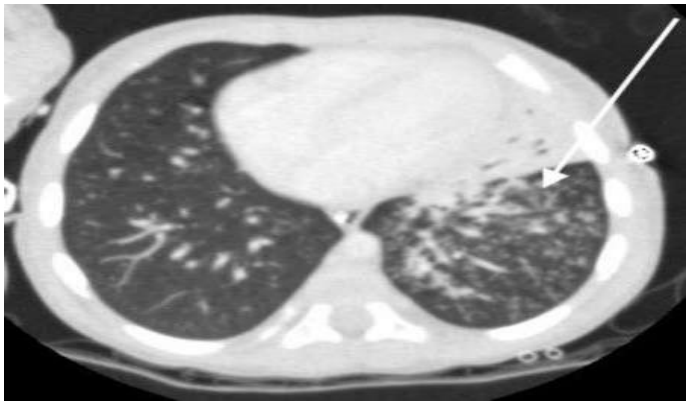

Figure 12. Axial CT lung window in a child with pulmonary TB demonstrates small centrilobular nodules that appear as buds on the ends of linear branching opacities (arrow), known as the "tree-in-bud" sign.

Role of the World Federation of Pediatric Imaging:

The World Federation of Pediatric Imaging seeks to create an impact in the global fight against childhood tuberculosis through the use of radiography in low-resource settings. The group emphasizes and delivers training and education on tuberculosis imaging through site visits, regional training exchanges, international training courses, and webinars. Through the World Federation of Pediatric Imaging

On their website, tuberculosis experts release instructional videos and lectures on the interpretation of chest radiographs in children suspected of having tuberculosis. Understanding the importance and magnitude of this disease, the federation has assembled experts from high-tuberculosis-burden countries in Africa, Asia, and Latin America in an attempt to impact childhood tuberculosis imaging diagnosis in lower-resource settings. The group makes open-access educational articles on tuberculosis freely available for wide dissemination [22–23].

CONCLUSION:

Despite some limitations and low specificity, chest radiography continues to be the key imaging modality used in the diagnosis of thoracic tuberculosis in children. CT and MRI are often performed for clinically diagnosed tuberculosis and the detection of various complications. MRI and US should be used for mediastinal lymph node detection where infrastructure and expertise are available because these modalities do not involve radiation risks. In low-resource settings where CT and MRI are not available, chest radiography and US hold the fort for radiology. For the future, advances in imaging technology hold promise to perform faster and more accurate cross-sectional imaging with no more radiation risks than a conventional radiograph. Judicious and optimum use of available imaging resources should be performed to obtain the best results in fighting the disease.

Conflict of Interest/Funding: None

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