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ORIGINAL ARTICLE

Reading chest radiographs in children suspected of having pulmonary tuberculosis

Robert P Gie[1]

INTRODUCTION

Although more than 1 million are globally suffer from tuberculosis every year the diagnostic tests are not child- friendly and lack both sensitivity or specificity resulting in under diagnosis is some situations and over diagnosis in others. This lack of child-friendly diagnostics has resulted in clinicians throughout the world relying on diagnostic tests, like the chest radiograph (CXR), Mantoux skin test, and *Mycobacterium tuberculosis* (MTB) culture that have been available for approximately a century.

Although the CXR is widely used it has it is limited by the fact that the radiographic images are not diagnostic of tuberculosis but rather suggestive that the child has pulmonary tuberculosis. In children exposed to an infective tuberculosis case of certain CXR images are certainly highly suggestive of tuberculosis making the CXR a useful clinical investigation. To be able to read the CXR with a certain degree of accuracy requires the clinician and radiologist to understand the challenges that one has to face when reporting a CXR of a child being investigated for tuberculosis. This chapter only focusses on the interpretation of the CXR and not on the other imaging modalities used in the diagnosis of pulmonary tuberculosis.

CHALLENGES IN READING A CXR IN A CHILD SUSPECTED OF HAVING PULMONARY TUBERCULOSIS

The following are some of the challenges one faces in reporting of a CXR in a child suspected of having pulmonary tuberculosis:

1. Quality of the CXR:

As tuberculosis is wide-spread throughout the world a CXR is often taken in a facility where the staff have not received adequate training in taking CXRs of infants and young children. This is further complicated by the behavior of the child when exposed to an unknown and unfriendly environment in the Radiology Department. These factors can result in a CXR of poor quality. A rotated CXR can create the image of enlarged mediastinal lymph nodes while a poorly inspired image will result in an image similar to that of airspace disease. The CXR needs to be assessed to ensure that rotation, poor inspiration and over/under-penetration are not present as these limit the correct interpretation of a CXR.

[1] Emeritus Professor - Department of Paediatrics and Child Health, Faculty of Medicine and Health Sciences, Stellenbosch University, South Africa.

Correspondence to:
Robert P Gie.
Department of Paediatrics and Child Health, Faculty of Medicine and Health Sciences, Stellenbosch University. PO Box 241, Cape Town 8000, South Africa. E-mail: rpg1@sun.ac.za

2. Anatomy of the chest:

Tuberculosis lymph gland enlargement occurs most often in the hilar and paratracheal regions of the chest. The anatomy of these 2 regions of the chest is challenging as there are pulmonary arteries, pulmonary veins, large airways, the aorta and superior vena cava all are present in this region of the chest. To distinguish enlarged lymph nodes from these structures can be challenging. A common error is to confuse the pulmonary arteries with enlarged lymph nodes. A good point of differentiation is that pulmonary vessels branch like a tree trunk as the vessels divide towards the periphery of the lung. Hilar and paratracheal lymph nodes glands are globular structures without branching structures. (Figure 1)



Figure 1. A pulmonary arteriogram illustrating the size, shape and position of the pulmonary arteries and importantly their branching structure.

3. Thymic enlargement:

The thymus is known to be enlarged in young children especially those younger than 2 years of age. A thymus should be excluded as a cause of an enlarged mediastinum in all young children. The typical radiological signs of an enlarged thymus should be sought: sail sign, wave sign. As the thymus occupies the anterior mediastinum a good indication that the mediastinum is enlarged, due to a thymus, is if the anterior mediastinum is opacified.

4. Overlap of causes of pathology:

As there are no radiological signs that are pathognomonic of pulmonary tuberculosis the radiological images considered to be highly suggestive of tuberculosis overlap with other diseases. Enlarged mediastinal lymph nodes can be caused by acute leukemia, lymphoma, HIV related lung disease and histoplasmosis amongst others. In countries with a high prevalence of HIV and tuberculosis overlap between these 2 diseases is very common and to make matters even more difficult dual infection is not unusual. The classic example of overlap being miliary tuberculosis and lymphocytic interstitial pneumonitis (LIP). Deciding on what is the most likely cause of the abnormal CXR needs to take the local context, patient's history as well of the clinical picture into account.

5. Pre-diagnosis likelihood of the cause of possible cause:

The likelihood that the changes seen on a CXR depend on the pre-diagnosis suspicion of what is the likely cause if an abnormality is reported. If a child has the clinical picture of a hematological malignancy and the clinician decides to take a CXR then enlarged mediastinal lymph nodes are most likely an hematological malignancy. In the same scenario if the child has been exposed to an adult TB source case and has symptoms suggestive of tuberculosis then the enlarged mediastinal lymph nodes on CXR are most likely caused by MTB. The pre-diagnosis likelihood is often not taken into consideration when compiling a differential diagnosis of the abnormalitie seen on the CXR.

6. Inter-and intra-variability amongst readers:

Although there are good descriptions of the various radiological pictures caused by MTB there is not many articles of how accurately these images can be correctly identified. In a vaccine preventative study the proportion of normal CXRs (n = 1400) read by 3 experienced readers varied from 71% to 5%[1]. This study gives an indication of the variability in reading CXRs. Similar to this study other studies have reported large inter-observer and intra-observer variability[2].

7. Does not differentiate between drug susceptible and drug resistant forms of pulmonary tuberculosis:

The radiological images caused by drug susceptible and drug resistant MTB are similar. The diagnosis of drug resistant MTB is suspected when a child is in contact with a drug resistant source case or when a child that is adherent to treatment fails to respond to treatment. An abnormal CXR suggest that the child under these circumstances has MTB but drug resistant tuberculosis is proven by culturing the organism and performing drug resistant testing. Drug resistant MTB is a laboratory and not a radiological diagnosis By reviewing a series of CXRs drug resistant tuberculosis is suspected if the CXR image has not improved or worsened over time.

IS THE CXR USEFUL IN THE DIAGNOSIS OF CHILDHOOD TUBERCULOSIS?

Although the CXR has many challenges the CXR remains a useful special investigation in the investigation of children with symptoms suggestive of childhood pulmonary tuberculosis.

1. To exclude diseases with similar symptom profiles:

A chronic cough, fever, a productive cough and loss of weight are common symptoms indicative of chronic lung disease. This symptom complex can be caused by cystic fibrosis, non-cystic bronchiectasis, foreign body aspiration, chronic bacterial bronchitis, cardiac failure as well as pulmonary tuberculosis. The CXR often aids the clinician in making the diagnosis.(Figure 2)

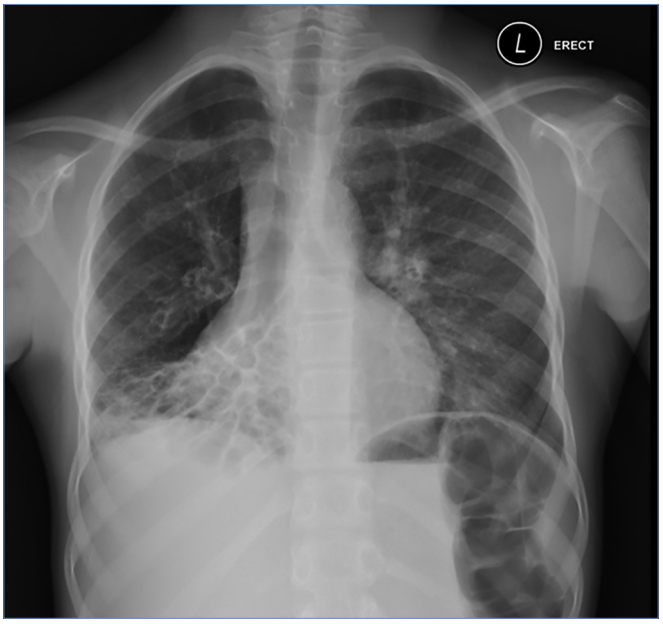


Figure 2. Right middle and lower lobe volume loss with typical signet rings visible in the affected lung region highly suggestive of bronchiectasis.

2. Investigating a child not responding to anti-tuberculosis therapy:

The common causes of non-response to treatment include non-adherence to the prescribed treatment, a disease caused by drug resistant MTB, having an underlying immune deficiency especially HIV disease, developing an exaggerated immune response to MTB while on treatment (TB-IRIS) and making the wrong diagnosis. The CXR is useful as it confirms that the presumed pulmonary tuberculosis is not responding to treatment and/or raises the suspicion that one is dealing with the wrong diagnosis. (Figure 3)

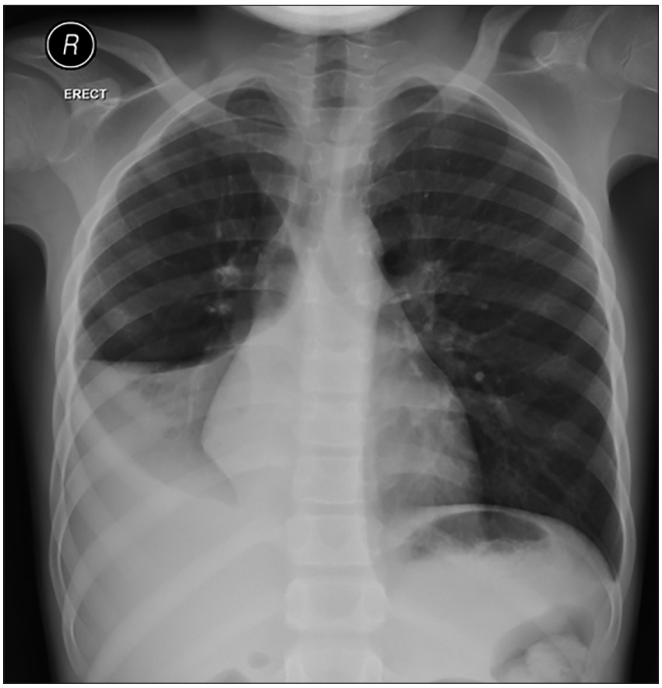


Figure 3. The CXR of a 10-year-old girl not responding to 5 months of TB treatment. The collapse of the right lower lobe and the absence of air-bronchograms is suggestive of wrong diagnosis. A foreign body removed from bronchus intermedius.

3. Defining the underlying pathology:

In certain cases, the CXR may be define the underlying pathology but the underlying cause might not be clear. In infants and young children enlarged mediastinal lymph nodes commonly compress the large airways especially left and right main bronchus and bronchus intermedius. The compressed airways clinically present with monotonic wheezing and on CXR, especially if the CXR is slightly over-penetrated, the compressed airways are visible. (Figure 4)

While airway compression might be suggestive of pulmonary tuberculosis it is not diagnostic and further investigations are needed to confirm the diagnosis of pulmonary tuberculosis. In cases with airway compression either flexible bronchoscopy or chest computer tomography are useful in eliciting the cause of the airway compression.

4. Add diagnostic certainty when pulmonary tuberculosis is suspected:

If a child after being in contact with an infectious source case of tuberculosis develops symptoms suggestive of pulmonary tuberculosis a CXR often adds to the diagnostic certainty especially if other special investigations are not positive. Visualizing an enlarged hilar lymph node on the CXR of the child described above will encourage the clinician to start treatment with greater certainty. (Figure 5).

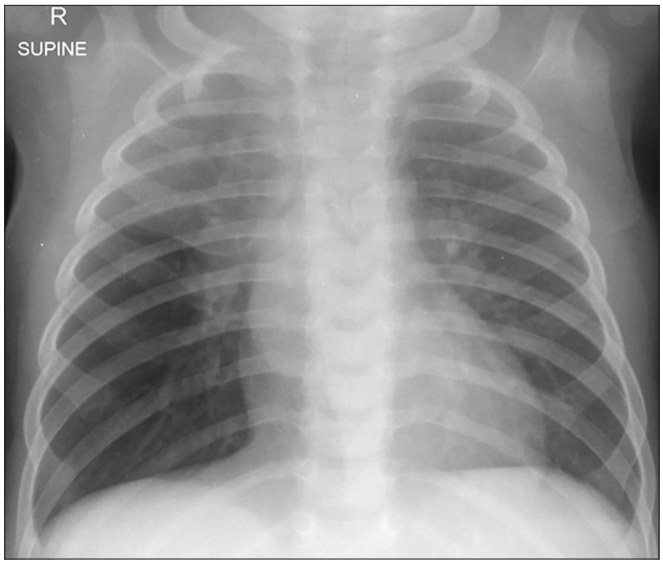


Figure 4. A hyperinflated CXR of a 3-month-old infant with persistent monotonic wheezing. Compression of left and right main bronchus are visible as well as an enlarged subcarinal lymph node mass. In addition there is hyperinflation of the right lower lobe.

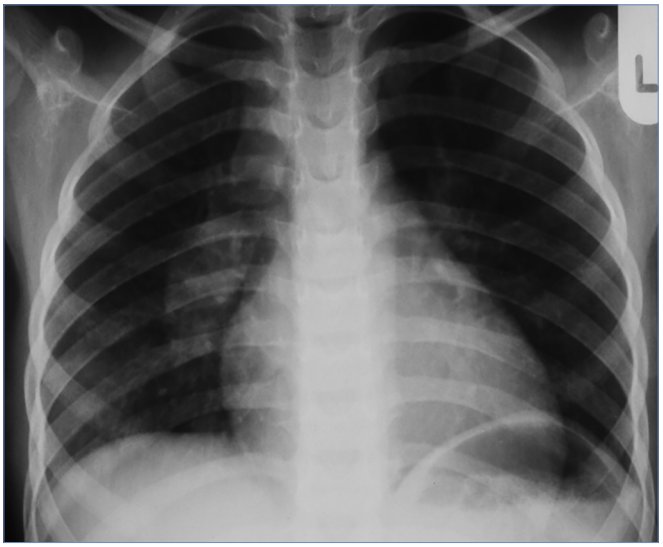


Figure 5. The CXR of the most common radiological sign suggestive of pulmonary tuberculosis: enlarged hilar lymph nodes.

Common radiological images caused by tuberculosis seen on a CXR:

The most common radiological images seen on a CXR are mediastinal and hilar lymph node involvement and the complications caused by these TB lymph nodes when they infiltrate mediastinal structures especially the airways. In most children, the most common CXR abnormality is mediastinal and/or lymph node enlargement (50%) (Figure 5), followed by alveolar opacification (air space disease) (20%), pleural effusion (8%) (Figure 6) and miliary TB (5%) (Figure 7).

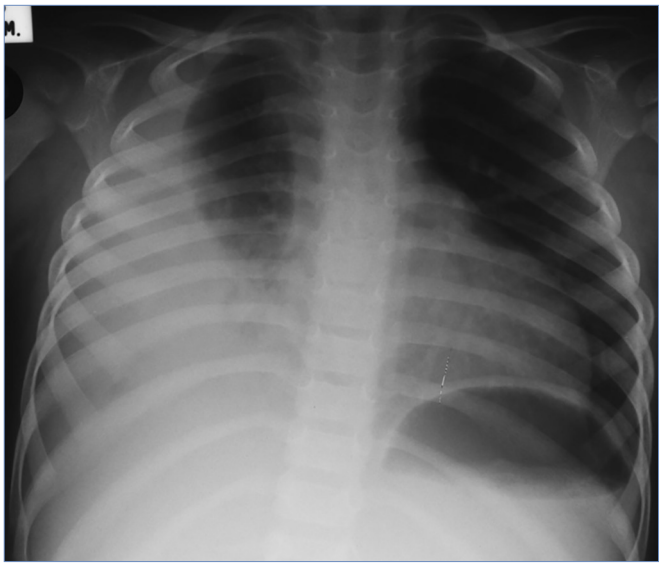


Figure 6. A large pleural effusion in an older child. Compression of the underlying lung is seen in the medial-lower zone. Lung compression does not represent underlying lung disease.



Figura 7. A classic miliary tuberculosis image involving all the lobes of the lung. Note that there are not enlarged lymph nodes visible. The example is of the classic "millet sized" nodules. Larger nodules can also occur in miliary tuberculosis.

Chest X-ray as related to age:

In infancy miliary tuberculosis(30%) (Figure 7) is more common than in older children (1-5%)[3].

In infancy and younger children, airway compression due to enlarged lymph nodes is more common and is a useful clue that there is enlarged mediastinal lymph node enlargement present (Figure 4). The airways that are commonly compressed are the left and right main bronchus and bronchus intermedius. In older children, especially those during adolescences the radiological picture is similar to adult-type TB with upper lobe air-space disease with

cavitation (Figure 8.) During adolescence, pleural effusion is also common.



Figura 8. Severe adult type tuberculosis in a 10-year-old child. The radiological picture is characterized by the upper lobe involvement with cavitation.

AIDS to identifying the most common radiological images:

The following are aids to help clinicians and other inexperienced readers to make the diagnosis of pulmonary tuberculosis:

1. Hilar lymph gland involvement:

Due to the overlay of the pulmonary vessels and hilar lymph glands to distinguish between the structures can be difficult. Firstly, the CXR must be of good quality. Poorly inspired and rotated CXRs often result in the faulty impression that enlarged lymph nodes are present. Secondly, it useful to remember that the pulmonary arteries branch, like a tree, as it transvers from the hilum into the parenchyma. Enlarged lymph nodes are round or oval in form, do not dived and form branches and have a different density to the pulmonary arteries.

The commonest lymph nodes to enlarge in pulmonary tuberculosis are in the subcarinal region. Enlargement of the subcarinal lymph nodes are difficult to visualize on a AP CXR in a child. There are 2 useful tips to remember. With subcarinal lymph node enlargement the large airways are often compressed. Seeing compressed large airways, especially the left and right main bronchi and bronchus intermedius, this is often indicative of subcarinal lymph node enlargement (Fig 4). The CXR has to be done in good inspiration as a CXR done in expiration will lead to a false impression of airway compression (narrowing). The second useful image to visualize enlarged subcarinal lymph nodes is the lateral CXR. Enlarged subcarinal lymph nodes are seen inferior to the left and right pulmonary artery and aortic arch on the lateral (Fig 9)



Figura 9. Enlarged hilar lymph nodes visible on the lateral CXR. The certainty of the structures being enlarged lymph nodes is if image of an enlarged lymph node is in the posterior inferior area of the hilum.

2. Enlarged paratracheal lymph nodes:

Enlarged paratracheal lymph nodes seen more commonly on the right had side of the mediastinum than the left-hand side. Isolated enlarged left sided paratracheal lymph nodes, only visible on the left side, are so rare that a diagnosis other than tuberculosis must be considered. In contrast, right sided enlarged paratracheal are commonly seen. Clues to the presence of paratracheal glands are displacement of the trachea to the left side and tracheal narrowing. Another useful radiological sign in distinguishing paratracheal from large blood vessels is their shape. Vessels give a convex impression while enlarged gland give a concave impression.

3. Cavities:

Cavities are thought to be rare in childhood pulmonary tuberculosis but can occur in approximately 5% of cases. Cavities can occur at all ages even during infancy; the result of necrotic breakdown of a Ghon focus. If one suspects a cavity try to confirm the cavity on the lateral chest radiograph. If the cavities are not seen on both projections cavities are highly unlikely to be present. Cavities are more common in adolescent patients with pulmonary tuberculosis; their image is similar to pulmonary tuberculosis seen in adult patients.

4. Miliary tuberculosis:

Miliary tuberculosis, especially small millets, can be quite difficult to see on a CXR (Figure 7) The one helpful sign is that the miliary images occurs throughout all lung fields. If one

is uncertain look if the miliary image is also visible on the lateral CXR especially in the retrosternal and prevertebral spaces.

5. Pleural effusion:

Unilateral large pleural effusions seldom occur in children younger than 6 years of age. If a large pleural effusion occurs in a young child think of an alternate diagnosis. In older child pleural effusion is a relatively common presentation especially amongst adolescent patients.

Other imaging modalities in the investigation of childhood pulmonary tuberculosis:

The following investigative imaging techniques can be useful in children suspected of having pulmonary tuberculosis:

1. Chest ultrasound:

Chest ultrasound is particularly useful in confirming the presence of a pleural effusion, describing the underlying character of the pleural effusion and underlying air space disease. If there are numerous adhesions present in the pleural effusion it is unlikely to be tuberculous effusion. The ultrasound also helps in marking the position on the chest wall where a pleural aspirate should be performed. Abdominal ultrasound is also useful to demonstrate enlarged abdominal lymph nodes and micro splenic abscess; raising the likelihood of pulmonary tuberculosis.

2. Chest computer tomography:

Chest computer tomography is not recommended in the routine diagnosis of uncomplicated pulmonary tuberculosis in children. The reason is that chest computer tomography results in high radiation exposure which might increase a child's risk of developing a malignancy. Chest computer tomography is only recommended in children with complicated pulmonary tuberculosis who would benefit from an intervention, such as thoracic surgery.

3. Chest magnetic resonance scanning:

At present the role of this investigation is still in the research stage of development and is not indicated for the diagnosis or management of pulmonary tuberculosis but holds much promise in the future due to its lack of radiation.

Follow up CXRs:

CXRs are of particular value in 2 situations: when the diagnosis of pulmonary is uncertain and the second situation being when a child fails to respond to anti-tuberculosis treatment.

1. Uncertain diagnosis:

If the diagnosis of pulmonary tuberculosis remains uncertain and the CXR is not suggestive of pulmonary tuberculosis it is often worthwhile to repeat the CXR after 14 days. If the CXR has improved without the child receiving anti-tuberculosis treatment the diagnosis of tuberculosis is highly unlikely. This approach is not recommended in children younger than 6 months and those who are HIV infected. The risk that the tuberculosis will disseminate in these high-risk groups is not worth taking.

2. Failure to respond to treatment:

The most likely causes of failure to respond to treatment are non-adherence, multidrug resistant tuberculosis or a wrong initial diagnosis. A follow-up CXR is often very useful in contributing to the diagnosis if the child is adherent to treatment. In contrast to the above 2 conditions routinely repeating a CXR in children responding to anti-tuberculosis treatment contributes little to the management as in approximately 30% the CXR is not normal but does not require further treatment. It is therefore recommended that a CXR not be routinely repeated.

The role of the CXR in the diagnosis of childhood tuberculosis:

The CXR plays an important role in the investigation of a child suspected of having tuberculosis. The CXR images of pulmonary tuberculosis are not diagnostic but are rather suggestive of tuberculosis. A CXR that is suggestive of pulmonary tuberculosis should always be used in conjunction with other features suggestive of tuberculosis including exposure to an infective tuberculosis case, symptoms suggestive of tuberculosis and a positive test indicative of tuberculosis infection (Mantoux skin test, IGRA). If at all possible appropriate specimens must be collected for culture and/or molecular confirmation of the diagnosis.

The CXR is also useful in children suspected of having extra-pulmonary tuberculosis especially TB meningitis and cervical lymph node disease. A CXR highly suggestive of tuberculosis often clinches the diagnosis.

SUMMARY

The CXR remains an important test in the investigation of children suspected of having tuberculosis. The clinician should be aware of the limitations of the CXR, the role the CXR plays in the diagnosis of childhood tuberculosis and the images that are highly suggestive of pulmonary tuberculosis. It is useful to remember that the CXR is a supportive and not a diagnostic investigation.

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SUGGESTED READING

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