

## Satellite Nodules with Pericavitary Consolidation Presenting As ‘Black Hole in the Starry Sky Pattern’ in HRCT Thorax: A Strong Predictor of Active Pulmonary Tuberculosis!

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**Abstract:** Pulmonary tuberculosis is the most common cause for cavitary lung disease in India. Radiological presentations in pulmonary tuberculosis are different and mainly depend on the immune status of hosts, durations of illness and underlying comorbidities. Consolidation, cavitation, pleural effusion, airways disease and lymphadenopathy are frequently reported in thoracic tuberculosis. In this case report, a 36-year male, presented with constitutional symptoms for 4 months duration with partial response to medical treatment received according to their knowledge and experience towards pneumonia, bronchial asthma and bronchitis. Radiological investigations documented inhomogeneous nodular infiltrates in the left upper zone which was underestimated due to presence of crepitations and wheeze. Recurrent, progressive and partially responding constitutional symptoms was the reason for referral to our center. We have further evaluated with HRCT thorax due to nodular opacities and persistent symptoms and documented black hole in the starry sky pattern’ which is first time described in medical literature. ‘Blackhole in starry sky pattern’ is described in the present case as a giant lung cavity mimicking black hole and a satellite nodule mimicking a starry sky pattern. Satellite nodules are defined as ill-defined to well demarcated nodular opacities with or without conglomeration around tuberculous consolidation or cavity. We have done induced sputum microbiological workup and documented acid-fast bacilli in sputum smear and MTB genome with rifampicin sensitivity in cartridge based nucleic acid amplification test. Treatment initiated with anti-tuberculosis (ATT) and recorded near complete radiological resolution, bacteriological cure after six months with good compliance. High index of suspicion is required while managing these cases with constitutional symptoms with Satellite nodules with pericavitary consolidation presenting as ‘black hole in the starry sky pattern’ in HRCT thorax to have successful treatment outcome.

**Keywords:** Pulmonary Tuberculosis, Satellite nodules, Pericavitary Consolidation, HRCT thorax, Starry sky appearance, Gene Xpert MTB/Rif.

## INTRODUCTION

Tuberculosis (TB) continues to be a major threat to global health. Cavitation is a dangerous consequence of pulmonary TB associated with poor outcomes, treatment relapse, higher transmission rates, and development of drug resistance. However, in the antibiotic era, cavities are often identified as the extreme outcome of treatment failure and are one of the least-studied aspects of TB [1]. Pulmonary tuberculosis can have diverse presentations ranging from cavitation, consolidation, tumorous lesions, coin lesions, lower lung filed tuberculosis and endobronchial and miliary nodules [2-12]. Similarly, non-tuberculous pathologies can present with abnormalities such as consolidations, nodules, cavitations mimicking tuberculosis [2-14]. Bronchoscopy is a very crucial interventional pulmonology technique in evaluating these cases [2-14]. High risk factors for tuberculosis would be advanced age, malnutrition, pregnancy, steroids exposure, diabetes mellitus and immunosuppression [9-14]. Tuberculosis in advanced stage may cause cardiac

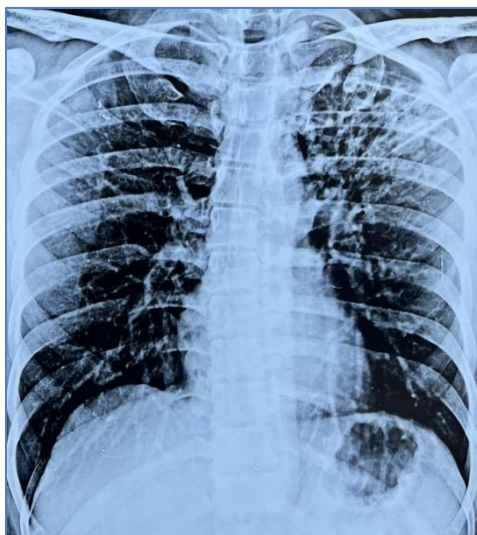
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dysfunction and systemic effects which will have poor outcome if timely treatment not received [15-17]. Final outcome in delayed treatment initiation may lead to destroyed lung as post tuberculosis sequel and proportionate number of cases may have lung function abnormalities irrespective of radiological outcome [18-22]. Tuberculosis may be misdiagnosed due to confusing or overlapping clinical and radiological features in high burden setting like India [23-29].

### Case Summary

36-year-old male, clerical staff, no addiction history, normotensive, non-diabetic, referred to our center by family physician for recurrent respiratory and generalized constitutional symptoms. He was having fever which is lasted for 4 months, intermittent, low to moderate grade without chills and rigors associated with minimal body ache and headache. He was treated as case of enteric fever for 2 months by family physician and later one month as bronchial asthma without laboratory workup documentation. He was having cough for 3 months, dry, intermittent, with minimal white sputum production. He has loss of appetite and weight loss over period of 3 months. He developed weakness and myalgia with fatigability for in last 2 months which is accompanied by shortness of breath on exertion. He was treated as case of post-viral bronchitis, bronchial asthma and pneumonia in last three months. His shortness of breath worsened and family physician referred to our center for further workup and expert management. Clinical examination revealed thin built male with normal vital parameters and general physical examination. Respiratory system examination documented vesicular breath sounds in all lung zones bilaterally. Adventitious breath sounds such as crepitations and wheezing heard over left infraclavicular and supraclavicular area. Other systemic examinations were normal. We have assessed past records of treatment as chest x-ray showing nodular opacities and increased inhomogeneous opacities as in left upper zone. (Image 1). Inhomogeneous infiltrates were treated in line with pneumonia, bronchitis with antibiotics and bronchodilators with partial response and clinical and radiological worsening.

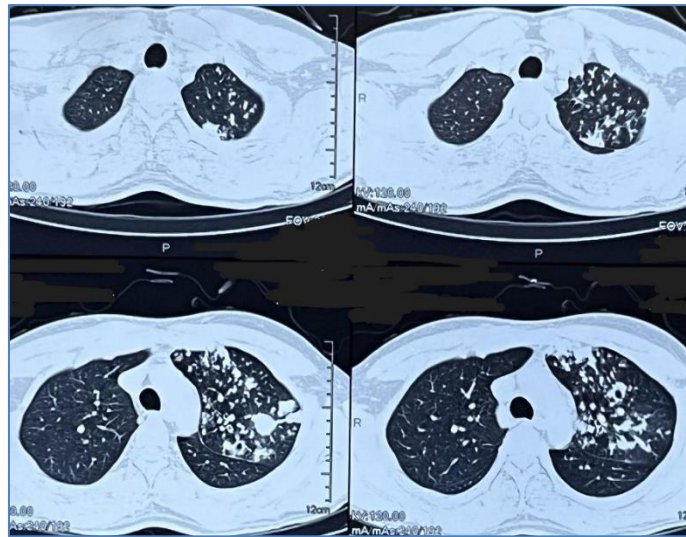


**Image 1: Chest x-ray PA showing inhomogeneous infiltrates left upper zone**

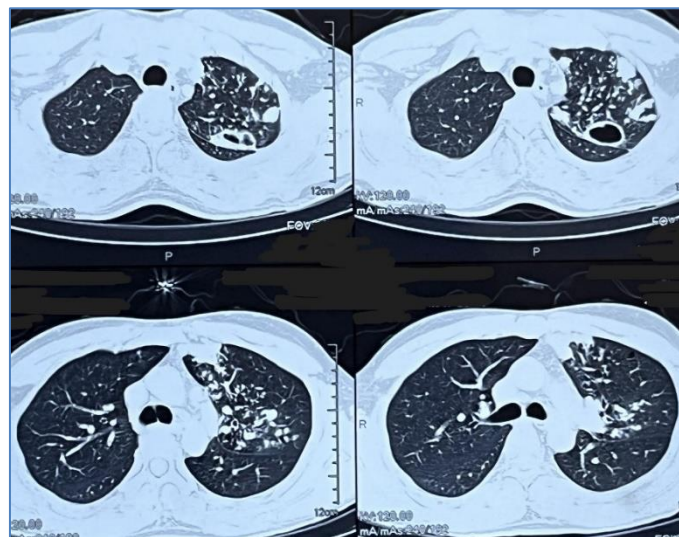
We have further evaluated with HRCT thorax for inhomogeneous infiltrates with doubtful nodular opacities in left upper zone.

### HRCT Thorax suggestive of- (Images 2-5)

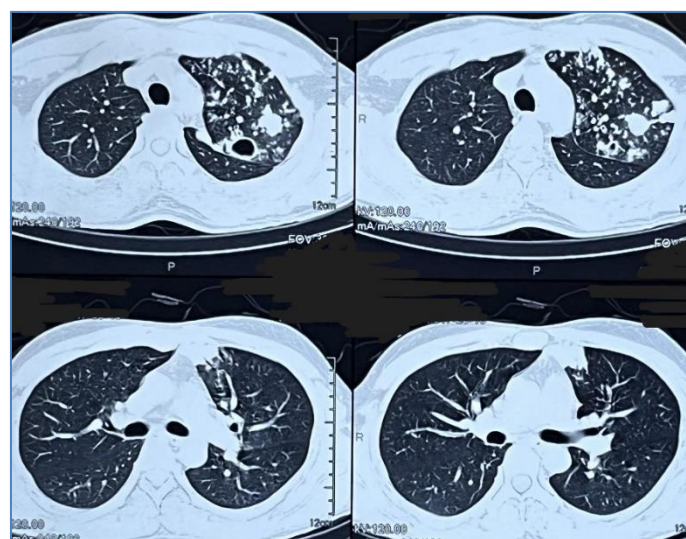
1. Nodular opacities with branching presenting 'tree in bud' pattern in left upper lobe posterior segment
2. Cavity with pericavitary consolidation and satellite nodules
3. 'Black hole in the starry sky pattern' presenting as Satellite nodules with pericavitary consolidation
4. Giant well defined cavity in posterior segment with randomly placed nodules and perilymphatic nodules
5. Satellite nodules are marker of random and perilymphatic nodules due to miliary, bronchogenic and lymphohematogenous spread of tuberculosis.



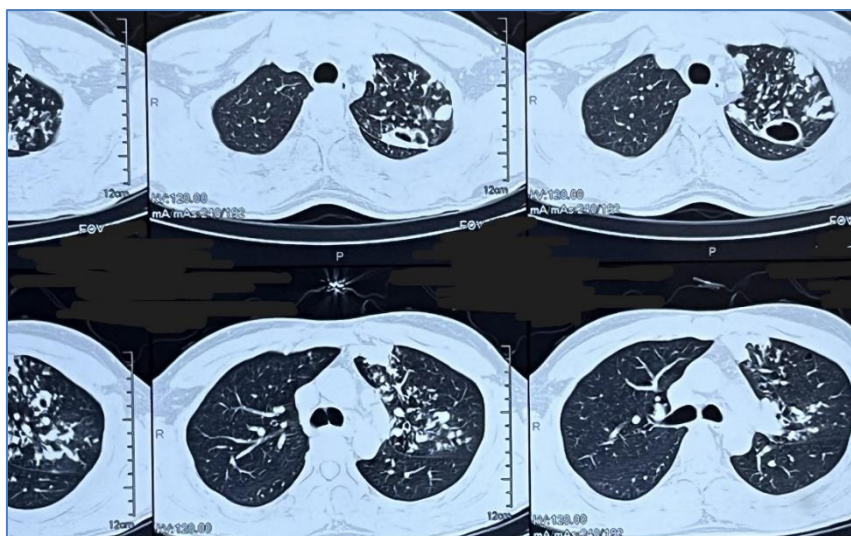
**Image 2: HRCT Thorax showing nodular opacities with branching presenting 'tree in bud' pattern in left upper lobe posterior segment**



**Image 3: HRCT Thorax showing cavity with pericavitary consolidation and satellite nodules**



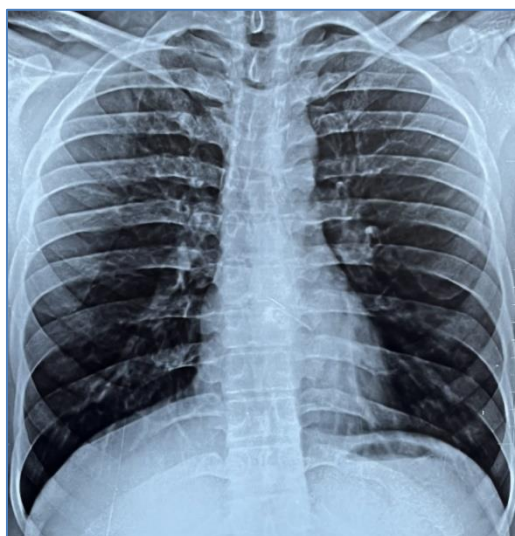
**Image 4: HRCT thorax showing 'black hole in the starry sky pattern' presenting as Satellite nodules with pericavitary consolidation**



**Image 5: HRCT thorax showing Giant to well defined cavity in posterior segment with randomly placed nodules and perilymphatic nodules**

As HRCT thorax was showing cavitory lung disease, we have further evaluated with induced sputum examination of early morning sample on two consecutive days. Induced sputum was thin, white and mainly salivary as per laboratory technician evaluation, and still we have advised to evaluate and workup for sputum microscopy and Gene Xpert MTB/RIF or CBNAAT test (cartridge based nucleic acid amplification test) as per NTEP (National tuberculosis elimination program). Sputum examination documented acid fast bacilli and TB Gene Xpert MTB/RIF test shown MTB genome (mycobacterium tuberculosis genome) and rpo-b (rifampicin-beta) mutation negative.

During hospitalization, we have started supportive care till final reports came with intravenous fluids and beta-lactam antibiotics. We have stopped antibiotics after sputum examination documented as tuberculosis and started ATT (Anti-tuberculosis treatment) as per weight band with Isoniazid, Rifampicin, Pyrazinamide, Ethambutol. He was tolerating antituberculosis treatment without any liver or renal dysfunctions. He was discharged to home after one week of treatment with four drug ATT. After 2 months of treatment, radiological response documented with clearance of radiological abnormalities.



**Image 6: Chest x-ray PA at 6 months showing complete resolution of lung parenchymal opacities**

After completion of intensive phase, he was shifted to continuation phase with Isoniazid, Rifampicin, Ethambutol without steroids. Radiological follow-up examination done at 6 months shown near complete resolution of infiltrates in left upper zone with normal lung parenchyma in both lung fields (Image 6). He tolerated complete course of ATT for six months as per National guidelines and documented 'cure' of tuberculosis. Sputum smear microscopy done at 2 months and six months documented absence of acid-fast bacilli and we confirmed as cure from disease. Clinical and

radiological response documented after completion of ATT with complete resolution of radiological abnormalities in chest X-ray.

## DISCUSSION

Tuberculosis remains a major global health issue affecting all countries and age groups. Radiology plays a crucial role in the diagnosis and management of pulmonary tuberculosis (PTB). A normal CXR has a high negative predictive value for the presence of active TB. On the other hand, presence of characteristic radiographic findings in appropriate clinical setting may be sufficient to diagnose TB even in the absence of sputum positivity; and no further investigation is required [30]. Temporal change over serial radiographs is frequently employed to assess response to ATT and evolution of new lesions may suggest reactivation in the proper clinical setting. No significant radiographic change over 4- to 6-month interval is termed “radiographically stable” disease and generally indicates disease inactivity [31].

### Role of radiology in tuberculosis:

- Radiology plays a crucial role in the diagnosis of active pulmonary tuberculosis (PTB).
- Imaging appearances of PTB depend on immune status.
- Radiological findings of PTB may mimic other diseases.
- CT findings correlate with sputum smear positivity.

### Radiological presentations of tuberculosis:

1. Patchy, poorly defined areas of heterogeneous consolidation are among the earliest manifestations of active PTB. The distribution is primarily in the apical and posterior segments of the upper lobes and less frequent in the apical segments of the lower lobes, with commonly more than one pulmonary segment involved. Tuberculous consolidation can be challenging to distinguish from bacterial pneumonia in absence of associated findings such as lymphadenopathy or cavitation and the lack of response to conventional antibiotics. In their evolution, these regions liquefy and form cavities by draining through the tracheobronchial tree. Cavitation affects about 50% of patients. The cavities are usually multiple and typically have thick, irregular walls, which become smooth and thin with successful treatment. Cavities may demonstrate air-fluid levels which can also indicate superinfection [32]. Satellite nodules around the tuberculoma, with typically smooth, sharply defined margins, may be present in up to 80% of cases [33].
2. Bronchogenic spread manifests as multiple, 2–4 mm centrilobular nodules and sharply marginated linear branching opacities, described as a “tree-in-bud” pattern. These have a tendency to coalesce in a segmental or lobar distribution, typically involving the lower lung zones and the peripheral areas of consolidation or cavities. Micronodules are difficult to identify on standard chest radiography, therefore CT is the imaging technique of choice to reveal early bronchogenic spread. The term “tree-in-bud” was first used to describe the characteristic appearance of the endobronchial spread of TB, however, it is not pathognomonic for active TB. Patchy areas of air trapping are also seen in some patients with tuberculous bronchiolitis [34, 35]. Other causes of tree-in-bud nodules include infections (bacterial, fungal, viral, or parasitic), bronchiolitis, aspiration or inhalation of foreign substances, connective tissue disorders, and neoplastic pulmonary emboli.
3. Characteristic findings of central airway TB include irregular circumferential wall thickening with luminal narrowing. Isolated tracheal disease is rare with most patients presenting with distal trachea, carina and proximal main stem bronchi involvement. The coexistence of tracheobronchial disease and lymphadenopathy is high in patients with active pulmonary TB. In the pathophysiology of tracheobronchial TB, peribronchial lymphatic spread seems more common than endobronchial spread from infected sputum. Bronchial stenosis occurs in 10–40% of patients with active tuberculosis and can lead to segmental or lobar atelectasis, lobar hyperinflation, mucoid impaction, and post-obstructive pneumonia [32, 36].
4. Miliary TB describes haematogenous dissemination, resulting in randomly distributed nodules which have uniform size between 1 and 4 mm. They may have a slight lower lobe predominance, often associated with intra- and interlobular septal thickening, and may coalesce to form focal or diffuse consolidation. Chest radiography is usually unremarkable at the onset of symptoms and the nodules only become discernible after 4 weeks. CT can reveal miliary disease before it becomes radiographically apparent. Miliary TB may be seen in association with typical parenchymal changes or may be the only pulmonary abnormality. Miliary disease has been reported to be associated with both childhood and immunocompromised adult infections, manifesting within 6 months of initial exposure. This pattern’s diffuse random distribution distinguishes it from the patchy centrilobular distribution of tree-in-bud. Other organs with high blood flow, such as the liver, spleen, bone marrow, adrenals and kidneys, are also frequently affected [32, 35-37].
5. Thick-walled cavity: thick-walled cavities are frequently seen in patients with early active TB and represent necrotizing consolidation in the early stage. Cavities, consolidations, and nodules in the upper lung fields suggest active TB in several prediction models. Cavity with air-fluid levels in tuberculous cavities have been reported to be an indicator of superimposed bacterial or fungal infection [38].

6. Clustered nodules: Large nodular opacities (1-4 cm) may result due to coalescence of smaller nodules. These usually have irregular margins and are surrounded by tiny satellite nodules. These may appear as nodular patches or masses on CXR. Such nodule clusters, especially in a peribronchial distribution are an indicator of active disease [38, 39].

#### **Importance of Giant cavity in Tuberculous cavity and its correlations with active disease:**

- Thick walled, partially communicating, irregular or bizarre shaped, single or giant with or without fluid level is marker of active pulmonary tuberculosis
- Thick-walled cavity is marker of pericavitary consolidation which is predictor of active pulmonary tuberculosis
- Thin-walled cavity is marker inactive disease and indicates healed disease. If cavity in non-collapsible and showed no or partial resolution, then these are risk for recurrent secondary infection or lung abscess. These old tuberculous healed cavities with fluid level are always risk for recurrent evaluation for active disease by treating physicians. These healed cavities with fluid level and sputum microbiological workup negative are called 'Open negative syndrome' which indicates persistent cavity and doubt of TB. As these are healed cavity, TB workup would be negative.
- Giant cavity is indicator of bronchogenic spread of disease and marker of active disease. These cavities are very well correlated with activity of tuberculosis and conformed by sputum microbiological workup.

#### **Importance of 'Satellite nodules' in Pulmonary Tuberculosis:**

- Satellite nodules are defined as ill-defined to well demarcated nodular opacities with or without conglomeration around tuberculous consolidation or cavity.
- Satellite nodules are marker of active pulmonary tuberculosis and rare in healed disease
- Satellite nodules indicates bronchogenic and lymphatic spread of tuberculosis from local tuberculosis consolidation or cavity
- Satellite nodules in cavitary lung disease usually occurs as a result of bronchogenic and lymphatic or hematogenous spread of disease
- Satellite nodules in tuberculous consolidation indicates lymphatic and hematogenous spread without bronchogenic spread of disease.
- Satellite nodules should be differentiated from Tree in bud opacities which is indicator of bronchogenic spread with bronchiolitis.
- Satellite nodules can be random as in miliary, and perilymphatic, subpleural or centrilobular which usually occurs due to lymphohematogenous spread of disease.

#### **'Black hole in the starry sky pattern' in HRCT thorax in Pulmonary Tuberculosis:**

- Black hole in starry sky pattern is described in present case as giant lung cavity mimicking black hole and satellite nodule mimicking starry sky pattern.
- Black hole with starry sky pattern is marker of active disease due to thick-walled lung cavity with randomly placed and perilymphatic nodules as documented in our case which is confirmed with sputum microbiological workup.
- This is first time described in medical literature. Many cavitary patterns such as tennis racket cavity, stepladder cavity, giant cavity is described in literature.
- Black hole with starry sky pattern is radiological illusion with underlying active pulmonary tuberculosis presenting as satellite nodules and cavitary lung disease.

## **CONCLUSION**

In the present case report, we have reported a 34-year male with constitutional symptoms treated as tropical pulmonary disease such as pneumonia and bronchial asthma in spite of nodular and inhomogeneous opacities in left upper zone. HRCT has documented classically described 'Black hole in the starry sky pattern' due to giant lung cavity and satellite nodules. We have confirmed active pulmonary tuberculosis by sputum microbiological workup. Clinical, radiological and microbiological cure documented after six months of ATT as per NTEP.

#### **Learning points:**

1. 'Black hole' in HRCT thorax is defined as thick walled single or giant cavity with dense opacity around the get black oval space i.e. air containing space with dense rim.
2. 'Starry sky pattern' in HRCT Thorax is defined as randomly placed nodular opacities presenting as discrete or conglomerated, interstitial and acino nodular opacities unilateral or bilateral adjacent to pulmonary cavities usually reported as satellite nodules.
3. Satellite nodules are defined as nodular opacities adjacent to pulmonary primary cavitary lung disease and indicator lymphatic local spread and active pulmonary tuberculosis.

4. Although tuberculosis is the leading cause of ‘cavity’ on chest radiograph globally, no radiological pattern is specific for tuberculosis. ‘Black hole in the starry sky pattern’ in HRCT thorax is an indicator of active Pulmonary Tuberculosis.
5. Inhomogeneous infiltrates with nodular opacities are nonspecific findings in asymptomatic cases. Persistent symptoms with nodular opacities need HRCT thorax to rule out underlying tuberculosis. Many Tuberculosis cases are still under evaluated and irrationally treated in spite of awareness by the government agencies due to lack of awareness of chest radiology and training of these techniques to the family physicians and general physicians. As of today, more than half of TB cases in India are treated as asthma, jaundice or nonspecific illness before they are diagnosed as pulmonary tuberculosis.
6. Proportionate number of tuberculosis cases in India are having cavities on chest radiographs, especially reactivation cases. Chest X-ray is less sensitive radiological investigation and HRCT thorax is the gold standard technique to evaluate cavitary lung disease. HRCT will help in identifying morphological features of cavity and anatomy and abnormalities of underlying lung parenchyma.
7. ‘Black hole in the starry sky pattern’ in HRCT thorax is not very commonly described in literature as a predictor of active pulmonary tuberculosis. We confirmed higher grades of bacteriological yields in AFB smear examination in cases with ‘Giant lung cavities with satellite nodules.’
8. Hence, an important clinical lesson is that, all the cases with ‘Black hole in the starry sky pattern’ in HRCT thorax should be analyzed thoroughly for underlying active pulmonary tuberculosis, as it indicates underlying active disease process due to *Mycobacterium tuberculosis*.
9. ‘Black hole in the starry sky pattern’ in HRCT thorax is a unique feature of pulmonary tuberculosis and more common but less evaluated due to lack of suspicion and due less HRCT imaging done in clinical practice.
10. Training of family physicians and general physicians to constitutional symptoms, diagnostic techniques and rational treatment options of tuberculosis is a must to tackle this easily treatable illness and ‘Disease of concern of Millenium’.

**Conflicts of Interest:** Nil

**Research Funding:** Nil

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