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Original Article

Diagnostic Yield of Bronchoalveolar Lavage in Sputum-Negative Presumptive Pulmonary Tuberculosis: A Cross-Sectional Study

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ABSTRACT

Background: Diagnosis of sputum-negative pulmonary tuberculosis (PTB) is challenging due to low bacillary load and inadequacy of sputum samples, leading to delayed treatment initiation. Bronchoalveolar lavage (BAL) offers a potential diagnostic alternative in such patients.
Objectives: To evaluate the diagnostic yield of BAL in sputum-negative presumptive PTB and to correlate BAL results with clinical and radiological features.
Materials and Methods: A descriptive cross-sectional study was conducted on 150 presumptive PTB patients with negative sputum smear/CBNAAT or sputum-scarce condition. All patients underwent detailed clinical assessment, chest imaging, flexible bronchoscopy, and BAL testing using AFB smear, CBNAAT (Xpert MTB/RIF), and mycobacterial culture.
Results: BAL AFB positivity was observed in 52.66% of patients, while CBNAAT detected Mycobacterium tuberculosis in 54.67% of cases. Radiological findings such as cavitation, nodular opacities, and tree-in-bud patterns showed statistically significant association with both AFB and CBNAAT positivity ($p < 0.001$). Most affected patients belonged to the 20–40-year age group, with a predominance of males. Smoking and diabetes mellitus were the most common risk factors.
Conclusion: BAL significantly improves microbiological confirmation in sputum-negative PTB and enhances diagnostic accuracy, particularly when guided by radiological abnormalities. BAL with CBNAAT should be integrated into diagnostic protocols for sputum-negative PTB to achieve early confirmation and timely treatment.

Keywords*: Bronchoalveolar lavage, CBNAAT, sputum-negative tuberculosis, AFB smear, pulmonary tuberculosis.*

INTRODUCTION

Tuberculosis (TB) is a chronic infectious disease caused primarily by *Mycobacterium tuberculosis* (MTB). Despite decades of scientific progress and public health efforts, TB continues to be one of the most threatening communicable diseases worldwide. In 2019 alone, the infection resulted in approximately 1.2 million deaths, ranking it among the ten leading causes of mortality globally (1). Pulmonary tuberculosis (PTB) constitutes the majority of diagnosed TB cases. Of all TB patients reported globally in 2018, nearly 85% were diagnosed with PTB, yet only 55% of these could be bacteriologically confirmed using conventional diagnostic techniques such as smear microscopy or rapid tests (1).

TB disproportionately affects low-income settings and regions with significant healthcare disparities. The highest prevalence continues to be reported from Asian countries, with India remaining the largest contributor to global TB incidence (2). In 2015, an estimated 10.4 million new cases were detected worldwide, out of which nearly 2.8 million occurred in India (2). A persistent cough lasting more than two weeks, fever, weight loss, hemoptysis, and abnormal radiographic findings are among the typical features suggestive of PTB. However, TB pathogenesis manifests in both latent and active forms, adding complexity to its diagnosis, management, and epidemiological control (3). Latent TB infection remains clinically silent, without radiological or microbiological evidence, but nearly 10% of untreated latent cases progress to active disease, and up to half of these may be fatal if not treated adequately (3).

Diagnostic Challenges in Pulmonary Tuberculosis

The diagnostic evaluation of PTB relies on microbial, molecular, radiological, and clinical parameters. Although sputum smear microscopy remains one of the most widely used diagnostic modalities, its sensitivity varies significantly, especially in patients who are unable to produce sputum or those with paucibacillary disease (4). Negative sputum does not exclude PTB, and such cases often require further diagnostic work-up. Delayed diagnosis may allow continued disease transmission for several weeks (5). The challenge intensifies when patients are unable to provide adequate sputum samples or have negative results even on advanced nucleic acid amplification tests, such as CBNAAT. It has been reported that nearly 40–60% of clinically suspected TB cases may fall into this diagnostic dilemma (6).

Radiological Evaluation and the "Presumptive PTB" Concept

Radiology plays a crucial role in supporting TB diagnosis, particularly when sputum tests are either negative or inconclusive. Certain imaging characteristics—such as cavitation, consolidation, tree-in-bud opacities, and upper lobe infiltrates—strongly suggest tuberculosis. Primary TB often displays mediastinal or hilar lymphadenopathy, whereas post-primary TB in adults more frequently exhibits upper lobe cavitation and consolidation (7). However, radiological changes alone may still lack specificity, as several other lung conditions may mimic TB. This uncertainty has resulted in the clinical classification of patients as "presumptive pulmonary TB," requiring further evaluation by direct sampling of the lower respiratory tract.

Role of Bronchoscopy and Bronchoalveolar Lavage (BAL)

Flexible bronchoscopy with bronchoalveolar lavage (BAL) has emerged as an essential diagnostic approach for sputum-negative presumptive PTB. By enabling direct visualization of bronchial mucosa and obtaining targeted fluid samples from affected segments, BAL significantly increases the probability of bacteriological confirmation (8). The technique allows collection of samples adequate for smear microscopy, culture, and CBNAAT, especially in cases where sputum collection methods fail or prove inconclusive (8). BAL has demonstrated a high sensitivity in ruling out active tuberculosis and is particularly valuable for cases with minimal sputum production or radiological suspicion despite negative smear tests (9). Beyond detecting MTB, BAL provides additional diagnostic value in excluding alternative causes of pulmonary disease, evaluating coexisting pathology, and assessing the severity of infection. With improved sample quality and diagnostic yield, bronchoscopy-based assessment is considered a pivotal tool for early diagnosis and prompt initiation of antitubercular therapy, thereby reducing morbidity and transmission (9).

Given the limitations of sputum-based diagnostics, the expanding role of BAL, and the continuous need for early confirmation of TB, there is a compelling need to correlate BAL diagnostic findings with clinical and radiological patterns in sputum-negative presumptive PTB. Establishing such correlations may streamline diagnostic decisions, improve patient outcomes, reduce treatment delays, and strengthen TB control and prevention strategies in high-burden regions.

METHODOLOGY

Study Design and Setting

This was a **descriptive cross-sectional study** conducted in the Department of Respiratory Medicine at the Pacific Institute of Medical Sciences, Udaipur, Rajasthan, over an 18-month period (10). The study included patients who had clinical and radiological findings suggestive of pulmonary tuberculosis but remained **sputum smear-negative or CBNAAT-negative**, or were unable to produce sputum (10).

Study Population

Patients presenting as **presumptive PTB** underwent a structured clinical evaluation, radiological assessment, and diagnostic bronchoscopy with bronchoalveolar lavage (BAL) for microbiological confirmation (11).

Inclusion Criteria

Patients were eligible if they had:

- Clinical symptoms indicating PTB such as chronic cough, fever, weight loss, hemoptysis, or loss of appetite (12).
- Radiological abnormalities suggestive of PTB on chest X-ray or CT scan, such as cavitation, consolidation, tree-in-bud appearance, nodules, mediastinal lymphadenopathy, or collapse (13).
- Sputum smear AFB-negative and/or CBNAAT-negative results, or sputum-scarce status (11).

Exclusion Criteria

Patients were excluded if they:

- Had microbiologically confirmed TB prior to bronchoscopy,
- Were pregnant,
- Declined written informed consent,
- Had contraindications to bronchoscopy such as severe hypoxemia or bleeding risk (10,14).

Data Collection
Clinical Evaluation
Demographic details, presenting symptoms, comorbidities (diabetes mellitus, hypertension, COPD, chronic liver disease, immunocompromised states), smoking habits, and alcohol intake were recorded using a predesigned proforma (12).

Radiological Assessment
Chest X-ray and CT scan findings were systematically documented, including:
- Cavitary lesions
- Consolidation
- Nodular opacities
- Tree-in-bud appearance
- Mediastinal lymphadenopathy
- Collapse

These findings were later correlated with BAL diagnostic yield (13).

Bronchoscopy and BAL Procedure
A flexible fiber-optic bronchoscope was introduced trans-orally or trans-nasally under local anesthesia and mild sedation. Based on radiological abnormalities, the most affected segment was identified, and sterile saline (20–40 mL aliquots) was instilled, then suctioned to collect BAL fluid (15).

BAL samples were submitted for:
- Ziehl–Neelsen (ZN) AFB smear
- CBNAAT (Xpert MTB/RIF)
- Mycobacterial culture (Lowenstein–Jensen medium)
- Cytology (when indicated)

These investigations aimed to detect MTB and rifampicin resistance when present (15,16).

Laboratory Evaluation
- **ZN Smear**: Performed for rapid AFB identification (16).
- **CBNAAT**: Provided MTB DNA detection and rifampicin resistance assessment (16).
- **Culture**: Considered the reference standard; confirmed viable MTB growth and enabled drug susceptibility (17).
- **Cytology**: Assisted in identifying non-tubercular conditions such as malignancy or inflammatory disorders (15).

Statistical Analysis
Data were analyzed using standard statistical software.
- Continuous variables were expressed as **mean ± SD**.
- Categorical variables were compared using **Chi-square test** or **Student's t-test**.
- A **p-value ≤ 0.05** was considered statistically significant (10).

RESULTS
A total of **150 patients** with sputum-negative presumptive pulmonary tuberculosis underwent bronchoscopy with bronchoalveolar lavage (BAL). Clinical, radiological, and BAL findings are presented below.

Demographic Characteristics
1. Age Distribution of Patients
The majority (59.34%) belonged to the **20–40-year age group**, representing the economically productive population.

Table 1: Age Distribution of Patients

Age Group (Years)	**No. of Patients**	**Percentage (%)**
20–30	**43**	**28.67**
31–40	**46**	**30.67**
41–50	**31**	**20.67**
51–60	**19**	**12.66**
>60	**11**	**7.33**
Total	150	100

2. Gender Distribution
Males were more commonly affected (61.33%), possibly due to lifestyle risk factors and occupational exposure

Table 2: Gender Distribution

Gender	No. of Patients	Percentage (%)
Male	**92**	**61.33**
Female	**58**	**38.67**
Total	150	100

3. Distribution According to Occupation:

Manual workers (56.66%) formed the largest group, indicating TB association with low socioeconomic and physically demanding occupations.

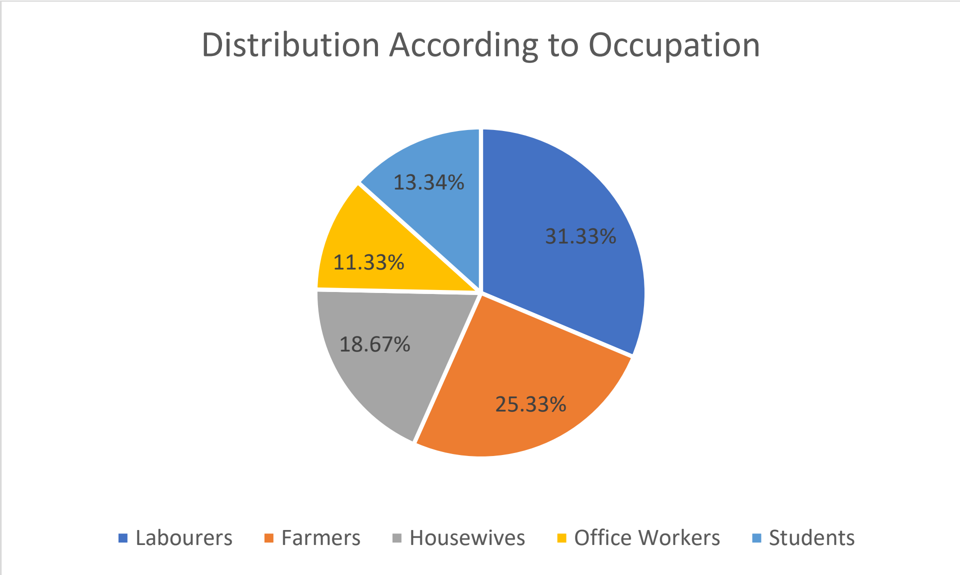

Fig1: Distribution According to Occupation:

4. Distribution of Patients According to Risk Factors:

Smoking and tobacco chewing were predominant risk factors **among the study population**.

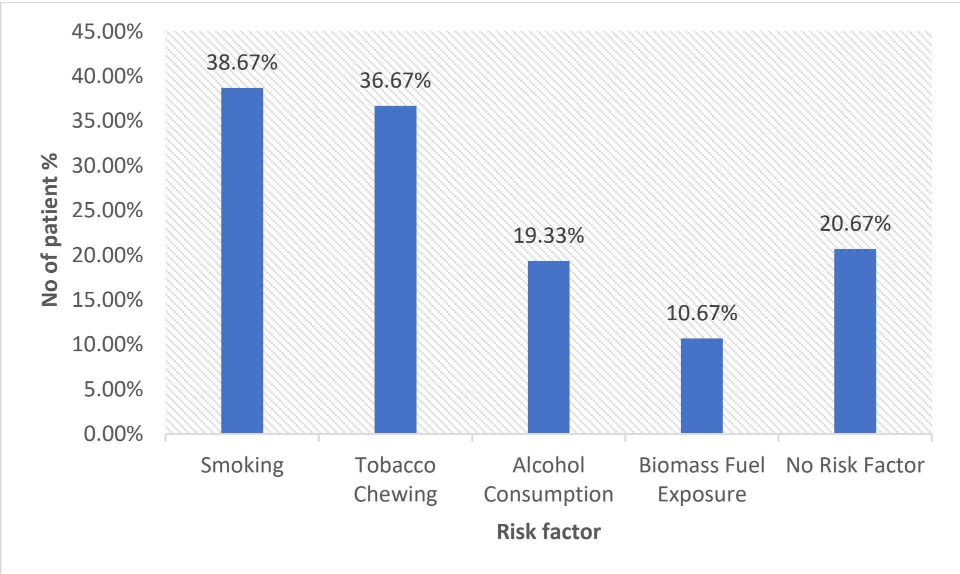

Fig 2: **Distribution of Patients According to Risk Factors**

5. Distribution of Patients According to Comorbidities:

Diabetes (22%) was the most frequent comorbidity, which is associated with higher TB susceptibility

Table 3: Distribution of Patients According to Comorbidities

Comorbidity	No. of Patients	Percentage (%)
Diabetes Mellitus	**33**	**22**
Hypertension	**21**	**14**

COPD/Bronchial Disease	**18**	**12**
Liver Disease	**6**	**4**
HIV	**2**	**1.33**
No Comorbidity	**70**	**46.67**

6. Symptom Distribution

Cough (96%) and **breathlessness (78.66%)** were the most common presenting complaints.

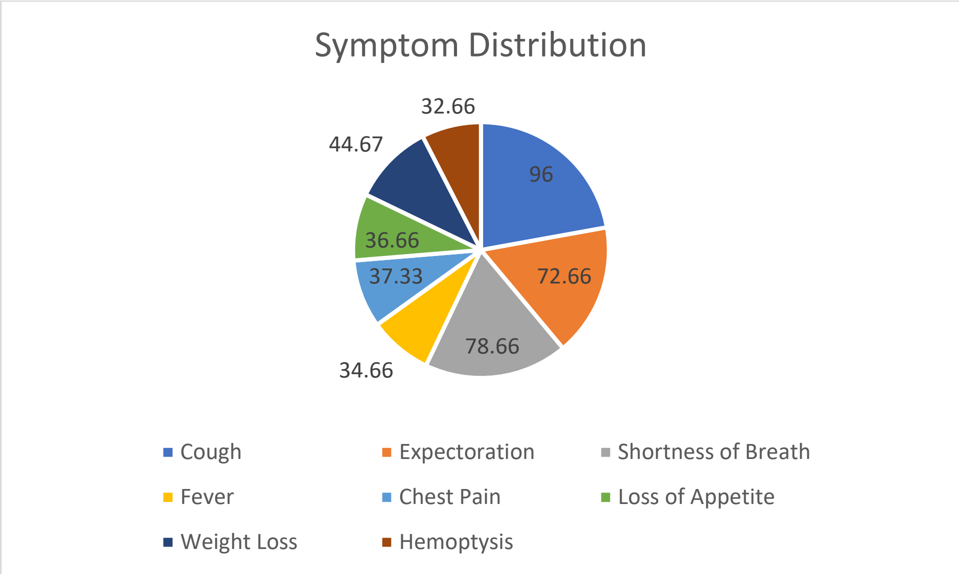

Fig 3: Symptom distribution

7. BAL AFB Status Distribution Among Patients

More than half the patients (52.66%) demonstrated **AFB positivity** on BAL despite being sputum smear–negative. This highlights BAL's diagnostic yield for MTB detection.

Table 4: BAL AFB Status Distribution Among Patients

BAL AFB Status	No. of Patients	Percentage (%)
Positive	**79**	**52.66**
Negative	**71**	**47.33**
Total	150	100

8. BAL CBNAAT Status Distribution Among Patients:

CBNAAT demonstrated **higher detection (54.67%)**, reinforcing molecular testing superiority in sputum-negative TB diagnosis.

Table 5: BAL CBNAAT Status Distribution Among Patients:

CBNAAT Result	No. of Patients	Percentage (%)
Positive	**82**	**54.67**
Negative	**68**	**45.33**
Total	150	100

9. Distribution of Radiological Findings Among Study Participants:

Consolidation (72%) and **cavitation (46.67%)** were the most frequent radiological abnormalities.

Table 6: Distribution of Radiological Findings Among Study Participants

Radiological Finding	No. of Patients	Percentage (%)
Cavity	**70**	**46.67**
Consolidation	**108**	**72**
Tree-in-Bud	**54**	**16**
Mediastinal LN	**47**	**31.33**
Nodules	**42**	**28**
Collapse	**12**	**8**

10. Comparison of Radiological Findings with BAL CBNAAT:
A statistically significant association was observed between **CBNAAT positivity and cavitation, nodules, and tree-in-bud pattern**, indicating these findings strongly predict microbiological confirmation

Table 7: Comparison of Radiological Findings with BAL CBNAAT

Radiological Finding	BAL CBNAAT Positive (n=82)	BAL CBNAAT Negative (n=68)	p-value
Cavity Present	58 (70.73%)	12 (17.65%)	<0.0001
Consolidation	49 (59.76%)	59 (86.76%)	0.0002
Tree-in-Bud	24 (29.27%)	0 (0.00%)	<0.001
Mediastinal LN	27 (32.93%)	20 (29.41%)	0.64
Nodules	35 (42.68%)	7 (10.29%)	<0.001
Collapse	8 (9.76%)	4 (5.88%)	0.38

11. Comparison of Radiological Findings with BAL AFB Report:
BAL AFB positivity was strongly correlated with **cavitation, nodules, and tree-in-bud**, reinforcing their role as strong predictors of bacteriologically confirmed TB.

Table 8: Comparison of Radiological Findings with BAL AFB Report

Radiological Finding	BAL AFB Positive (n=79)	BAL AFB Negative (n=71)	p-value
Cavity	55 (67.07%)	15 (22.06%)	<0.0001
Consolidation	46 (56.10%)	62 (91.18%)	<0.0001
Tree-in-Bud	21 (25.61%)	3 (4.41%)	0.0001
Mediastinal LN	24 (29.27%)	23 (33.82%)	0.70
Nodules	32 (40.51%)	10 (14.08%)	0.0003
Collapse	6 (7.59%)	6 (8.45%)	0.85

DISCUSSION

The present study evaluated the diagnostic performance of bronchoalveolar lavage (BAL) among sputum-negative presumptive pulmonary tuberculosis (PTB) cases and examined its association with clinical and radiological characteristics. Smear microscopy remains the most widely utilized tool for TB diagnosis globally; however, its diagnostic yield decreases substantially in patients with low bacillary burden and in those unable to produce sputum (18). This limitation supports the need for alternative diagnostic strategies in suspected PTB.

In the current study, BAL AFB positivity was recorded in **52.66%**, while CBNAAT detected MTB in **54.67%** of cases. These findings align with previous data indicating that BAL enhances diagnostic yield in sputum-negative TB (19). The higher detection rate with CBNAAT compared to smear microscopy reflects its ability to detect MTB genetic material and identify rifampicin resistance rapidly, which aids early treatment decisions (20). Thus, BAL-based CBNAAT represents a useful supplement in smear-negative PTB.

Significant association was noted between BAL positivity and radiological abnormalities, particularly **cavitation, nodular opacities, and tree-in-bud appearance**. These imaging features have been strongly associated with active MTB replication and endobronchial spread (21). On the other hand, isolated consolidation without cavitation showed weaker association with BAL positivity, likely due to overlapping imaging features with other pulmonary infections, reinforcing the need for microbiological confirmation (22). Therefore, radiology alone is insufficient for definitive diagnosis, particularly in smear-negative cases.

Most patients belonged to the younger age group (20–40 years), and males constituted the majority. This demographic distribution is consistent with epidemiological trends linking TB risk to occupational exposure, delayed health seeking, and lifestyle determinants such as smoking and tobacco use (18,23). Diabetes mellitus was the most common comorbidity in this study, which correlates with evidence indicating impaired immune response and increased susceptibility to TB in diabetic individuals (24). These findings support targeted screening of high-risk subgroups to improve early diagnosis.

BAL provided diagnostic advantages by permitting retrieval of samples from affected segments and reducing contamination from upper airway flora. In addition to microbiological testing, BAL enabled cytological assessment to identify alternative causes such as malignancy or inflammatory pathology, supporting rational treatment decisions (25). Given the substantial proportion of smear-negative individuals who remain infectious or undiagnosed, integrating BAL into diagnostic algorithms may improve case detection and reduce transmission.

CONCLUSION

Bronchoalveolar lavage (BAL) demonstrated a significant diagnostic yield in sputum-negative presumptive pulmonary tuberculosis. More than half of the study population showed microbiological positivity on BAL smear and CBNAAT, supporting its role as an adjunctive test in cases where sputum-based diagnosis is inconclusive. Radiological features, particularly **cavitation, nodularity, and tree-in-bud pattern**, showed a strong association with BAL positivity, indicating their importance in guiding bronchoscopic sampling.

Demographic and clinical parameters, including male predominance, younger age groups, smoking habits, and diabetes mellitus, were consistent with known risk predictors for tuberculosis. BAL further facilitated cytological evaluation in selected cases, allowing differentiation from other pulmonary diseases and avoiding unwarranted therapy.

Incorporation of BAL, especially with CBNAAT, into diagnostic pathways for sputum-negative patients can enhance early confirmation of tuberculosis, reduce diagnostic delay, and assist in timely initiation of antitubercular treatment. These findings support a **radiology-guided, BAL-based diagnostic approach** for smear-negative pulmonary tuberculosis in high-burden settings.

REFERENCES

1. World Health Organization. Global tuberculosis report 2020. Geneva: WHO; 2020.
2. World Health Organization. Global tuberculosis report 2016. Geneva: WHO; 2016.
3. Frieden TR, Sterling TR, Munsiff SS, et al. Tuberculosis. Lancet. 2003;362(9387):887-899.
4. World Health Organization. Treatment of tuberculosis: guidelines for national programmes. 3rd ed. Geneva: WHO; 2003.
5. MacNeil A, Glaziou P, Sismanidis C, Date A, Maloney S, Floyd K. Global epidemiology of tuberculosis and progress toward meeting global targets. MMWR Morb Mortal Wkly Rep. 2020;69:281-285.
6. Lewinsohn DM, Leonard MK, LoBue PA, et al. Official ATS/IDSA/CDC practice guidelines: diagnosis of tuberculosis in adults and children. Clin Infect Dis. 2017;64:111-115.
7. Andreu J, Cáceres J, Pallisa E, Martinez-Rodriguez M. Radiological manifestations of pulmonary tuberculosis. Eur J Radiol. 2004;51:139-149.
8. Freund O, Hadad Y, Lagziel T, Friedman-Regev I, Kleinhendler E, et al. Added value of bronchoalveolar lavage for TB diagnosis in high-risk hospitalized patients with negative sputum. Adv Respir Med. 2024;92:15-24.
9. Koraa EE, Abdel-Fattah EB, El-Touny RM. Diagnostic yield of BAL GeneXpert in smear-negative and sputum-scarce pulmonary TB. Egypt J Chest Dis Tuberc. 2021;70:469-473.
10. Dubey S, Gaikwad N, Meshram S, Bagrecha M. Diagnostic yield of bronchoalveolar fluid/bronchoscopy among sputum AFB and CBNAAT negative presumptive tuberculosis patients. Int J Res Med Sci. 2021;9:546–551.
11. Koraa EEDA, Abdel-Fattah EB, El-Touny RM. Diagnostic yield of bronchoalveolar lavage GeneXpert in smear-negative and sputum-scarce pulmonary tuberculosis. Egypt J Chest Dis Tuberc. 2021;70:469–473.
12. Frieden TR, Sterling TR, Munsiff SS, et al. Tuberculosis. Lancet. 2003;362(9387):887–899.
13. Andreu J, Cáceres J, Pallisa E, Martinez-Rodriguez M. Radiological manifestations of pulmonary tuberculosis. Eur J Radiol. 2004;51:139–149.
14. World Health Organization. Treatment of tuberculosis: guidelines for national programmes. 3rd ed. Geneva: WHO; 2003.
15. Kalawat U, Sharma KK, Reddy PNR, Kumar G. Study of bronchoalveolar lavage in clinically and radiologically suspected cases of pulmonary tuberculosis. Lung India. 2010;27(3):122–124.
16. Koraa EEDA, Abdel-Fattah EB, El-Touny RM. Diagnostic yield of BAL GeneXpert in smear-negative pulmonary TB. Egypt J Chest Dis Tuberc. 2021;70:469–473.
17. Castro AT, Mendes M, Freitas S, Roxo PC. Diagnostic yield of sputum microbiological analysis in pulmonary TB. Rev Port Pneumol. 2015;21(4):185–191
18. World Health Organization. Global tuberculosis report 2016. Geneva: WHO; 2016.
19. Dubey S, Gaikwad N, Meshram S, Bagrecha M. Diagnostic yield of bronchoalveolar fluid among sputum AFB and CBNAAT negative presumptive TB patients. Int J Res Med Sci. 2021;9:546–551.
20. Koraa EEDA, Abdel-Fattah EB, El-Touny RM. Diagnostic yield of BAL GeneXpert in smear-negative and sputum-scarce pulmonary TB. Egypt J Chest Dis Tuberc. 2021;70:469–473.
21. Andreu J, Cáceres J, Pallisa E, Martinez-Rodriguez M. Radiological manifestations of pulmonary tuberculosis. Eur J Radiol. 2004;51:139–149.
22. Castro AT, Mendes M, Freitas S, Roxo PC. Diagnostic yield of sputum microbiological analysis in pulmonary TB. Rev Port Pneumol. 2015;21(4):185–191.
23. MacNeil A, Glaziou P, Sismanidis C, Date A, Maloney S, Floyd K. Global epidemiology of tuberculosis and progress toward meeting global targets. MMWR Morb Mortal Wkly Rep. 2020;69:281–285.
24. Gowda NC, Ray A, Soneja M, Khanna A, Sinha S. Evaluation of Xpert MTB/RIF in sputum-scarce patients. Lung India. 2018;35:295–300.
25. Kalawat U, Sharma KK, Reddy PNR, Kumar G. Study of bronchoalveolar lavage in clinically and radiologically suspected pulmonary tuberculosis. Lung India. 2010;27:122–124.