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Diagnostic Yield of Flexible Bronchoscopy in a High-Burden Setting: Clinical Performance and Projected Public Health Utility at the District Level

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Abstract

***Background and Objectives:** Flexible bronchoscopy provides access to microbiological and histopathological diagnosis, but its real-world performance varies by disease and sampling strategy. We evaluated diagnostic yield in routine practice and modelled the likely district-level utility of bronchoscopy services.*

***Methods:** We conducted a single-centre retrospective analysis of 801 diagnostic bronchoscopies performed at a tertiary care teaching hospital in North India. Diagnostic yield and disease-specific sensitivity were calculated. Public health utility was modelled for a prototype district population of 1,000,000 using burden-based estimates for tuberculosis, lung cancer, and sarcoidosis.*

***Results:** The overall diagnostic yield was 75.65% (606/801). Targeted tissue acquisition consistently outperformed fluid cytology and visual inspection, while multimodal sampling maximized diagnostic capture. Disease-specific sensitivity was highest for sarcoidosis, followed by tuberculosis and lung cancer. Beyond these primary targets, fluid and tissue evaluation successfully identified a substantial burden of non-tubercular bacterial infections, invasive fungal pathogens, and rare occupational lung diseases. In the epidemiological model, bronchoscopy was projected to detect a significant annual burden of core respiratory cases.*

***Interpretation and Conclusions:** Multimodal bronchoscopic sampling delivers robust diagnostic performance in high-burden settings. Decentralizing these services to district hospitals can significantly narrow case detection gaps and facilitate targeted antimicrobial therapy. However, deploying bronchoscopic equipment must be paired with parallel investments in pathology and microbiology laboratory infrastructure to achieve optimal clinical impact.*

***Key words:** Biopsy, bronchoalveolar lavage, pulmonary, sensitivity and specificity, tuberculosis.*

Introduction

The Government of India is implementing a centrally sponsored scheme to establish new medical colleges by upgrading district and referral hospitals. Although this initiative seeks to decentralise specialized healthcare services, there is limited clarity regarding which diagnostic facilities should be incorporated at district level to optimize patient care and training[1].

Respiratory diseases remain a major public health burden in India, with substantial burdens of chronic respiratory disease, tuberculosis, lung cancer, and interstitial lung diseases[2-5]. Early diagnosis is therefore critical, particularly because sputum-negative pulmonary tuberculosis often requires bronchoscopy for microbiological confirmation, suspected lung cancer needs tissue-based diagnosis, and other focal pulmonary lesions may also require invasive sampling. Flexible bronchoscopy is a key diagnostic procedure in this setting, but yield varies substantially according to disease biology, lesion accessibility, and sampling strategy[6,7].

Despite the extensive bronchoscopy literature, important gaps remain. Many studies focus on a single disease or a single sampling method within highly selected patient groups, limiting applicability to routine clinical practice. In addition, few series from India have simultaneously evaluated bronchoscopy across a broad case-mix while also estimating its likely utility for district-level service planning. Published evidence also suggests that diagnostic yield improves when tissue-based sampling is aligned with lesion accessibility and pretest probability[6,7].

To address these gaps, we performed a comprehensive clinical audit of 801 diagnostic bronchoscopies at a tertiary care centre in North India. The primary aim was to define the independent and incremental diagnostic yields of standard sampling modalities and to establish disease-specific sensitivities. In addition, we used these clinical metrics in a burden-based epidemiological model to project the public health utility of decentralizing

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bronchoscopy services to district level.

Material and Methods

Study design and setting: We retrospectively analysed data from all consecutive diagnostic flexible bronchoscopies performed at the Department of Respiratory Medicine of a tertiary care teaching hospital in North India between 2022 and 2025. The study was designed as a retrospective diagnostic audit, and no additional interventions were introduced.

Participants: Adults aged 18 years or older who underwent diagnostic bronchoscopy during the study period were included. Patients were eligible for disease-specific sensitivity analyses only if they had a confirmed final diagnosis established either through bronchoscopy or through a composite reference standard that included clinical-radiological follow-up, response to appropriate empirical therapy, surgical pathology, or microbiological confirmation. Cases requiring advanced diagnostic interventions such as endobronchial ultrasound (EBUS) or cryobiopsy were excluded so that the study reflected the utility of standard flexible bronchoscopy in secondary-care settings.

Diagnostic definitions: A modality was considered diagnostic only if it provided definitive, actionable information. Malignancy was defined as cytological or histopathological evidence of cancer; atypia alone was considered non-diagnostic. Tuberculosis was counted positive if acid-fast bacilli (AFB) smear, Mycobacterium tuberculosis culture, or GeneXpert MTB/RIF was positive. Sarcoidosis was diagnosed only when non-caseating granulomas were identified in an appropriate clinical-radiological context and alternative causes were excluded.

Bronchoscopy procedures and specimen processing: Bronchoscopies were carried out by consultants and supervised trainees using standard video bronchoscopes (BF-P150, Olympus Medical Systems; and EB-1970TK, Pentax Medical). Sedation and topical anaesthesia adhered to institutional protocols. Sampling methods included bronchial wash/BAL, brush cytology, endobronchial biopsy (EBB), transbronchial lung biopsy (TBLB), and conventional transbronchial needle aspiration (cTBNA). For cTBNA, the puncture site was determined based on pre-procedure CT evaluation to target lymph nodes or masses via the working channel. For data analysis, bronchial wash and bronchoalveolar lavage (BAL) were grouped as a single sampling modality. Samples were processed according to standardised institutional laboratory protocols. All bronchoalveolar lavage (BAL) and wash specimens underwent acid-fast bacilli (AFB) smear, Gram stain, pyogenic culture, KOH mount, fungal culture, TB-PCR and CBNAAT testing. Mycobacteria Growth Indicator Tube (MGIT) liquid culture was performed in all cases. Cytology specimens from brushing or aspiration were processed using conventional smears. All biopsy specimens were fixed in formalin and processed for histopathology, with special stains, such as periodic acid-Schiff (PAS) or Grocott's methenamine silver (GMS) applied as required to differentiate granulomatous or fungal aetiologies.

Outcome measures: The primary outcome was the per-procedure diagnostic yield of each individual sampling modality. Secondary outcomes were the diagnostic yield of multimodal sampling combinations and the disease-specific sensitivity of flexible bronchoscopy for tuberculosis, lung cancer, and sarcoidosis.

Public health utility modelling: To estimate the possible effect of decentralizing bronchoscopy services, we modelled a standard prototype district with a population of 1,000,000. Disease-burden estimates were derived from national data. For tuberculosis, we used a national annual incidence of 187 per 100,000[3], applied an estimated pulmonary fraction of 80%, and then restricted the target population to the sputum-sparse subgroup, estimated at 40% of pulmonary tuberculosis cases. For lung cancer, we used a 5-year prevalence of 8.1 per 100,000[4]. For sarcoidosis, we used a midpoint prevalence of 36 per 100,000 (range 24 - 48)[5].

Statistical analysis

This was a descriptive audit. Categorical variables are presented as counts and percentages. Diagnostic yield for each modality was calculated as the proportion of procedures in which that modality yielded a definitive diagnosis. Disease-specific sensitivity was calculated as diagnosed cases divided by total confirmed cases. Exact 95% confidence intervals were estimated using the Clopper-Pearson method. Projected expected true positives were calculated as disease burden multiplied by disease-specific sensitivity.

Ethics

The study was approved by the Institutional Ethics Committee. As this was a retrospective audit using anonymised data, the requirement for individual informed consent was waived.

Results

A total of 801 diagnostic bronchoscopies were evaluated, with an overall diagnostic yield of 75.65% (606/801). Fluid-based sampling, through bronchial wash or bronchoalveolar lavage, was the most frequently used modality. Tissue acquisition techniques, including endobronchial biopsy, transbronchial lung biopsy, and conventional transbronchial

needle aspiration, were used selectively according to clinical and radiological indications. When standalone modalities were compared, targeted tissue acquisition consistently outperformed fluid cytology and visual inspection. Transbronchial lung biopsy showed the highest individual diagnostic yield (83.33%), while standalone visual inspection had the lowest yield (7.74%) (Table I).

Table I: Diagnostic yield of individual flexible bronchoscopy sampling modalities

Procedure	Number of cases where performed	Diagnostic success (n)	Yield (%)
Flexible bronchoscopy (standalone visual inspection)	801	62	7.74
Bronchial wash/BAL	757	453	59.84
Bronchial brush cytology	180	88	48.89
Endobronchial biopsy (EBB)	179	115	64.25
Transbronchial lung biopsy (TBLB)	48	40	83.33
Conventional transbronchial needle aspiration (TBNA)	27	14	51.85

Note: BAL, bronchoalveolar lavage; EBB, endobronchial biopsy; TBLB, transbronchial lung biopsy; TBNA, transbronchial needle aspiration.

Diagnostic performance improved significantly when multiple sampling modalities were combined. The highest yields were seen when standard visual inspection was combined with both fluid-based sampling and targeted tissue acquisition, highlighting the benefit of a stepwise increase in procedural complexity (Table II).

Table II: Incremental diagnostic yield of combined bronchoscopic sampling protocols

Procedure combination	N patients	Diagnostic hits	Yield (%)
Visual inspection + BAL	757	478	63.14
Visual inspection + BAL + Brush	174	125	71.84
Visual inspection + BAL + EBB	165	143	86.67
Visual inspection + BAL + TBLB	40	35	87.50
Visual inspection + BAL + Brush + EBB	121	109	90.08
Visual inspection + BAL + EBB + TBLB	4	4	100.00
Visual inspection + BAL + TBNA	25	14	56.00
Visual inspection + TBNA + EBB	6	6	100.00
Visual inspection + BAL + TBNA + EBB	5	5	100.00
Visual inspection + BAL + Brush + EBB + TBLB	2	2	100.00

Note: BAL, bronchoalveolar lavage; EBB, endobronchial biopsy; TBLB, transbronchial lung biopsy; TBNA, transbronchial needle aspiration.

Within this high-burden cohort, disease-specific sensitivity followed a consistent pattern for the primary conditions of interest. Diagnostic capture was highest for sarcoidosis at 97.50%, followed by pulmonary tuberculosis at 89.47% and lung malignancy at 84.91% (Table III).

Table III: Disease-specific diagnostic sensitivity of flexible bronchoscopy.

Disease entity	Total confirmed cases	Diagnosed by bronchoscopy	Sensitivity (%)
Sarcoidosis	40	39	97.50
Tuberculosis (TB)	133	119	89.47
Lung cancer	106	90	84.91

Beyond these core conditions, bronchoscopy successfully identified or definitively ruled out pathology in 358 additional cases. Normal endobronchial anatomy effectively excluded airway disease in 61 patients. Fluid-based evaluation frequently identified opportunistic and Gram-positive bacterial infections, including invasive fungal pathogens such as Aspergillus and Mucor. Biopsy modalities provided important histopathological confirmation for atypical and occupational lung diseases, such as hypersensitivity pneumonitis and silicosis. Standalone visual inspection also established definitive diagnoses in structural airway emergencies such as foreign body aspiration and fistulas. In contrast, standard evaluation did not yield a specific diagnosis in 164 cases that showed only non-specific inflammation, defining the point at which advanced diagnostic interventions become necessary (Table IV).

Table IV: Additional diagnostic outcomes and residual undiagnosed cases following bronchoscopy.

Finding	Number of Cases (n)
1. Bronchoalveolar lavage	268
Aspergillus infection	41
Gram positive infection	119
Acinetobacter	12
Klebsiella	20
Pseudomonas	7
Escherichia coli	5
Mucor	12
Nocardia	4
Pseudosporium	1
Burkholderia cepacia	1
Mycobacterium abscessus	1
Hydatid disease	4
Multiple bacterial infection	13
Multiple bacterial and fungal infection	12
Stenotrophomonas maltophilia	1
Pulmonary alveolar haemorrhage (diagnosed on sequential aliquots and iron laden macrophages)	15

2.	Biopsy	18
	Candida	1
	Granulomatous disease – Eosinophilic granulomatosis with polyangiitis	1
	Granulomatous disease – Hypersensitivity pneumonitis	6
	Granulomatous disease – Granulomatosis with polyangiitis	1
	Cryptogenic organizing pneumonia (Transbronchial lung biopsy)	4
	Talcosis	1
	Silicosis	1
	Pulmonary sclerosis haemangioma	1
	Amyloidosis (Endobronchial biopsy)	1
	Xanthoma (Endobronchial biopsy)	1
3.	Visual inspection	11
	Bronchoalveolar fistula	3
	Foreign body	5
	Post-inhalational burns	3
4.	Normal and undiagnosed	225
	Normal bronchoscopy	61
	Undiagnosed (non-specific inflammation)	164
5.	Total	522

Extrapolation of these clinical metrics to a standard district prototype of one million population highlighted the public health value of decentralizing bronchoscopy services. The model projected the greatest absolute benefit for tuberculosis case detection, while also showing substantial expected true-positive rates for sarcoidosis and lung cancer (Table V).

Table V: Projected annual diagnostic utility in a prototype district (population 1,000,000)

Disease entity	Estimated annual burden	Bronchoscopy sensitivity	Expected true positives (ETP)
Tuberculosis	598 cases	89.47%	535
Lung cancer	81 cases	84.91%	69
Sarcoidosis	360 cases	97.50%	351

Discussion

In this large single-centre audit of diagnostic flexible bronchoscopy, clinical performance varied substantially according to the sampling method used. The overall diagnostic yield of 75.65% reflects the strong clinical value of the procedure in a high-burden setting, where timely diagnosis has an important impact on patient outcomes. Multimodal bronchoscopy consistently performed better than single-technique sampling, showing the advantage of combining fluid-based, cytological, and histopathological methods during routine respiratory evaluation. The stepwise improvement in diagnostic capture with combined modalities suggests that a structured sampling strategy is important for maximizing yield, especially when initial visual inspection does not provide a diagnosis. This is particularly relevant in resource-constrained settings, where each procedure should be designed to obtain the highest possible diagnostic return.

The main strength of this study is the large dataset drawn from routine clinical practice rather than a highly selected trial population, along with an epidemiological model that may be useful for health administrators. However, several limitations should be considered when interpreting the findings. As the study was retrospective and done at a referral tertiary care centre, some selection bias for more difficult cases is likely. Transbronchial lung biopsy was probably performed in patients with more favourable anatomy, which may have increased its apparent diagnostic yield. The dataset also lacked consistent radiological details, so yields could not be stratified by lesion size or by central versus peripheral location. In addition, the high diagnostic sensitivities were achieved in a high-volume tertiary centre by experienced pulmonologists and laboratory support. Operator dependence is an important factor in bronchoscopy, and yields at newly established district-level facilities may initially be lower while clinicians gain experience[7]. Finally, the projection model was based on national average prevalence estimates, which may not fully reflect local disease patterns in individual districts[3-5].

These findings are broadly consistent with earlier bronchoscopy studies showing that diagnostic yield depends strongly on sampling technique, lesion accessibility, and disease biology[6,7]. In peripheral lesions, bronchoscopy is more effective when tissue-based or guided approaches are used[7,9]. The procedure also has an established role in sputum-negative pulmonary tuberculosis, where microbiological confirmation may otherwise be delayed[8], and more complete nodal sampling improves diagnostic performance in sarcoidosis[10]. The present study supports these established observations while also showing how these diagnostic pathways work together in a single high-throughput clinical setting. The results therefore reinforce the value of a multimodal approach when bronchoscopy is performed for diagnostically challenging disease.

The generalisability of these findings has important implications for the planned decentralisation of respiratory care.[1] The strong performance of tissue acquisition indicates that district hospitals equipped with bronchoscopes will also need pathology support to process biopsy specimens effectively. Likewise, the substantial number of non-

tubercular infectious diagnoses identified through bronchoalveolar lavage highlights the need for microbiology laboratories capable of culture, smear, and fungal workup. In several cases, the identification of bacterial and invasive fungal pathogens allowed a shift from empirical to targeted therapy, which is clinically important because it can reduce unnecessary broad-spectrum antimicrobial use and help clarify prognosis earlier. At the same time, the proportion of cases remaining undiagnosed after standard bronchoscopy defines a practical threshold for escalation to advanced diagnostic procedures. This helps local centres manage straightforward cases more efficiently while referring unresolved cases for further evaluation. Overall, these findings suggest that flexible bronchoscopy can make a meaningful contribution to district-level respiratory services, provided that procedural training and laboratory infrastructure are developed alongside the equipment itself. With appropriate support, decentralised bronchoscopy could reduce diagnostic delay for tuberculosis, sarcoidosis, and lung cancer, and improve access to definitive respiratory diagnosis in high-burden settings.

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