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Original Research Article

A STUDY OF BRONCHOALVEOLAR LAVAGE (BAL) FOR THE DIAGNOSIS OF VARIOUS LUNG DISEASES

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ABSTRACT

Background: Bronchoalveolar lavage (BAL) is a minimally invasive diagnostic technique that is used for cytological and microbiological evaluation of various pulmonary disorders. Despite its widespread usage in diagnosis, the yield varies depending on the underlying condition. The current study aimed to evaluate the diagnostic yield of BAL in infectious, interstitial, and malignant lung diseases. **Materials and Methods:** This prospective observational study was conducted on 40 cases of suspected pulmonary disease who were subjected to bronchoalveolar lavage. Demographic profile of cases, including clinical data, imaging, and BAL results, was recorded. The results of cytological and microbiological diagnoses were correlated with clinical and radiological diagnoses. The diagnostic yield, sensitivity, specificity, and complications were analyzed. **Results:** The results of our study found that BAL provided an overall diagnostic yield of 77.5%. There was a better yield in infectious diseases 80% and especially useful in sputum-negative tuberculosis and opportunistic infections such as fungal pneumonia and Pneumocystis jirovecii. For interstitial lung diseases, the BAL cellular pattern provided supportive evidence with lymphocytosis in sarcoidosis and neutrophilia in idiopathic pulmonary fibrosis. In cases of suspected malignancies, BAL cytology was diagnostic in 71.4% of cases, and a specificity of 100% was recorded. The complications of BAL were minimal and managed easily with no major adverse events. **Conclusion:** Bronchoalveolar lavage (BAL) is a safe, effective, and versatile diagnostic procedure. It has a high yield in infectious as well as malignant diseases, and it offers a supportive role in interstitial lung diseases. It appears to have an excellent safety profile and the ability to complement radiological and histopathological evaluations. Therefore, it must be considered as an integral part for the evaluation of pulmonary diseases.

Keywords: Bronchoalveolar Lavage, Pulmonary Infections, Interstitial Lung Disease, Lung Cancer, Diagnostic Yield.

INTRODUCTION

Bronchoalveolar lavage (BAL) is a useful diagnostic method in pulmonary medicine, which offers access to the non- and cellular contents of the lower respiratory tract. First described in 1970s, BAL has now become an indispensable adjunct in the diagnosis and treatment of many lung diseases, including infectious disorders, interstitial lung diseases, malignancies, and occupational exposures.[1] The process requires injection of sterile saline into a portion of the lung using a flexible bronchoscope, after which the fluid is aspirated and subjected to cytological, microbiological, and immunological tests.[2] BAL is important in understanding the underlying pathology in individuals demonstrating vague respiratory symptoms and radiographic abnormalities. During infections that include tuberculosis, bacterial pneumonia, and opportunistic infections in an immunocompromised host, BAL can aid in the isolation of causative organisms with a higher sensitivity compared to examination of sputum, particularly in situations where there is inadequate sputum,[3,4] BAL continues to be the preferred

diagnostic modality in suspected Pneumocystis jirovecii pneumonia with a high diagnostic yield.[5] For interstitial lung diseases (ILDs), BAL is helpful when it comes to elucidating the characteristics of an inflammatory process. As an example, the presence of lymphocytosis might indicate exposure to hypersensitivity pneumonitis or sarcoidosis, and neutrophilia idiopathic pulmonary fibrosis or acute lung injury.[6] The cellular profile, as derived by BAL, although not conclusive in most instances, aids in enhancing the accuracy of the diagnosis and in differentiating among the several ILDs when assessed with clinical and radiological parameters.[7] In the context of interstitial lung diseases (ILDs), BAL provides useful information about the nature of the inflammatory process. Predominant lymphocytes in BAL fluid could be because of hypersensitivity pneumonitis or sarcoidosis. Similarly, neutrophilia could be because of idiopathic pulmonary fibrosis or acute lung injury.[6] Although the cellular profile of BAL fluid is nonspecific, when interpreted with clinical and radiological findings, it significantly improves the diagnostic accuracy and can aid in differentiating between various ILDs.[7]

BAL has also been found valuable in the diagnosis of malignancy. Lavage fluid cytological assessment is able to specify malignant cells, especially cases of cancers located in the center of the lungs, as its yield is somewhat higher,[8] and in suspected metastatic pulmonary involvement or lymphoproliferative disorders, BAL can complement transbronchial or endobronchial biopsy.[9] Moreover, molecular and immuno-cytochemical investigations of BAL fluid can be carried out, increasing its diagnostic value in oncology.[10] BAL is also used in research to understand the pathophysiology of lung diseases in addition to its diagnostic purposes. The cellular and biochemical component of BAL fluid reflects the inflammatory response, immune reaction, and effects of environmental exposures like tobacco smoking or work-related dusts.[11] That has rendered BAL invaluable both clinically and in translational research. In addition to its clinical use as a diagnostic tool, BAL is used as a research tool to gain new insight into the pathophysiology of lung diseases. The cellular and biochemical composition of the BAL fluid can provide information about inflammatory processes, immune-system responses, and effects of environmental exposures, such as smoking or workplace exposures to dusts.[11] This has rendered BAL a priceless resource in clinical practice and translational research. BAL is not without limitations despite its usefulness. The procedure is invasive, and complications may include cough, transient unresponsiveness, fever, or rarely bleeding.[12] In addition, the interpretation of BAL results needs to be correlated well with clinical and radiological results since the cellular abnormalities may not always be disease-specific.[13] However, conducted reasonably and in the context of correct clinical situations, BAL can be of great benefit to the diagnostic process and serves as a valuable aid to therapeutic decision-making. With this background, we in the current study aimed to evaluate the role of BAL in the diagnosis of various lung diseases, thereby contributing to a better understanding, early diagnosis, and improved patient outcomes.

MATERIALS AND METHODS

This is a prospective observational study performed at the Department of Pulmonary Medicine, Rajiv Gandhi Institute of Medical Sciences, Adilabad, Telangana. Institutional Ethical clearance was obtained from the institutional Ethical committee after following the due protocol for human research based on the Helsinki declaration. Written informed consent was obtained from all the participants of the study after explaining the nature of the study in the vernacular language.

Inclusion criteria

1. Patients with radiographic lung lesions or diffuse parenchymal lung diseases
2. Persistent or recurrent lower respiratory tract infections refractory to treatment.
3. Immunocompromised patients with suspected opportunistic infections.
4. Suspected cases of Malignancy where BAL was indicated
5. Signed informed consent

Exclusion criteria

1. Severe hypoxemia with PaO2<60mmHg on supplemental oxygen therapy.
2. Uncontrolled coagulopathy (INR >1.5 or platelet count <50,000/µL),
3. Hemodynamic instability
4. Allergy to local anesthetics

Based on the inclusion and exclusion criteria, a total of 40 consecutive patients were included in the duration of the study that was undergoing diagnostic bronchoalveolar lavage (BAL). All the patients were subjected to a detailed clinical examination, and a demographic profile of the cases was obtained. They were subjected to radiography/CT, routine blood tests including complete blood count, coagulation profile, and arterial oxygen saturation. Bronchoscopy was performed in local anesthesia with conscious sedation following standard protocol with continuous monitoring of ECG, Pulse, and blood pressure.

The obtained fluid was transported to the laboratory immediately and processed for microscopic volume, color, and turbidity. The fluid was split into proportions for cytology, microbiology, mycobacterial studies, and fungal studies. Cytology was performed on centrifuged fluid for total cell count, differential cell counts, and cytospin preparations stained with May–Grünwald–Giemsa/Papanicolaou; results expressed as % neutrophils, lymphocytes, eosinophils, macrophages. The cytology slides were observed for malignant cells and cytopathologic changes.

Microbiology examination was done by Gram stain and culture on blood, chocolate, and MacConkey agar for bacteria. Ziehl-Neelsen stain and culture on Lowenstein–Jensen medium and CBNAAT were done. Fungal examination was done on KOH mount, smear, and culture on Sabouraud dextrose agar. Biochemical tests were done for differential protein and LDH. A final diagnosis was arrived at after integrating BAL findings with clinical, radiological, and serological tests. Safety assessments for complications, both immediate and delayed, were done following the procedure. All adverse events were managed as per standard protocols.

Statistical analysis: All the available data were refined, segregated, and uploaded to an MS Excel spreadsheet and analyzed by SPSS version 25 in Windows format. The continuous variables were represented as frequency, mean, standard deviation, and percentages. The categorical data were analyzed by the Mann-Whitney U test for continuous variables and the square test for categorical variables. A p-value of < 0.05 was considered significant.

RESULTS

A total of n=40 patients underwent bronchoalveolar lavage in the study period. The baseline characteristics of the cohort are given in [Table 1]. The mean age of the cohort was 58.3 ± 12.7 years, and males were 60% and females were 40% of all cases. The common indication of BAL in the cohort was diffuse lung disease in 45% of cases, followed by focal lesions in 30% of cases. Suspected infections and suspected malignancy were in 17.5% and 7.5% respectively. The mean volume of the lavage obtained was 48.3 ± 11.2 ml. The average duration of the procedure was 22.5 ± 6.8 minutes.

The analysis of the diagnostic yield of BAL in different categories of lung disease is presented in [Table 2]. The results show that the overall diagnostic yield of BAL was 77.5% (31/40) of cases. The highest diagnostic yield was in fungal infections with 100% yield, followed by tuberculosis 80% and bacterial pneumonia, 71.4% therefore, among infectious disease patients (n=15), BAL confirmed the diagnosis of 12 cases (80%). In inflammatory lung diseases, out of n=18 cases, BAL effectively diagnosed the condition in n=14 cases, giving a diagnostic yield of 77.8%. Within this group, the diagnosis of idiopathic pulmonary fibrosis had the highest yield (83.3%), followed by sarcoidosis (75%) and eosinophilic pneumonia (75%). In n=7 cases of suspected malignancy, BAL was diagnostic in n=5 patients, giving a diagnostic yield of 71.4%.

BAL cellular profiles that were analyzed and useful in the diagnosis are given in [Table 3]. In sarcoidosis, there was predominant lymphocytosis (42.1 ± 8.3%) along with preserved macrophage proportion, which is in line with granulomatous inflammatory disease. However, the cases of IPF were characterized by a low number of lymphocytes (18.6 ± 5.2%) and high neutrophils (12.3 ± 4.7%), indicating a fibrotic inflammatory surrounding. Eosinophilic pneumonia was characterized by markedly high eosinophilia (38.7 ± 9.4%), which was useful to diagnose this condition from other diffuse parenchymal lung diseases. In bacterial pneumonia, in contrast, there was considerable neutrophilia (65.3 ± 11.2%) and decreased macrophages typical of acute bacterial inflammation. Therefore, when compared with healthy reference values of lymphocytes <15%, neutrophils <3%, eosinophils <1%, macrophages >80%, we found that each disease entity showed characteristic deviations, thus making BAL differential count an essential tool in the diagnosis of the disease. Microbiological analysis of the cases is presented in [Table 4]. We found among n=8 bacterial isolates *Streptococcus pneumoniae* was most frequent n=3 (37.5%), followed by *Pseudomonas aeruginosa* n=2 (25%), *Klebsiella pneumoniae* n=2 (25%), and *Haemophilus influenzae* n=1 (12.5%). Mycobacterial infection was confirmed in n=4 cases, all of them were due to *Mycobacterium tuberculosis,* detected by CBNAAT as well as culture methods. Fungi were isolated in n=3 cases, which included *Aspergillus fumigatus* (n=2) and *Pneumocystis jirovecii* (n=1). These results show that the board microbiological spectrum is detectable by BAL, particularly in immunocompromised patients, where they may be sputum negative. Analysis of the complications related to BAL is given in [Table 5]. The overall complications were seen in n=11 (27.5%) cases; however, the complications were minor in nature in all cases. Transient hypoxemia was common in 12.55% followed by cough exacerbation in 7.5%, fever in 5% and minor incidence of bleeding in 2.5% cases. Moreover, there were no major complications such as pneumothorax, severe hemorrhage, or prolonged respiratory compromise. This indicates the safety of BAL when performed under standard precautionary protocols.

[Table 6] gives the performance characteristics of BAL in specific diagnoses. BAL exhibited sensitivity and specificity that were high in all key antecedents of diagnosis. In tuberculosis, sensitivity was 80 percent and specificity 100 percent, positive predictive value (PPV) of 100 percent, and negative predictive value (NPV) 97.2 percent. Bacterial pneumonia resulted in decreased sensitivity of 71.4% with high specificity of 93.9% percent, PPV, and NPV, and 83.3% and 88.6% percent, respectively. In sarcoidosis, BAL had a sensitivity of 75% and a specificity of 96.9% with a low PPV of 85.7% and a high NPV of 93.9%. Lung malignancies were detected with a sensitivity of 71.4% and specificity of 100%, which provided a PPV of 100% and an NPV of 94.3%. These results affirm BAL as a highly specific diagnostic modality in a wide range of pulmonary disorders with highly variable but generally high sensitivity based on the

underlying pathologic process. The analysis of the table shows that BAL showed high sensitivity and specificity for all major diagnostic categories. In bacterial pneumonia, the sensitivity was 71.4% but specificity remained high at 93.9%, with PPV and NPV of 83.3% and 88.6%, respectively. For tuberculosis, the sensitivity was 80% the specificity was 100%, the positive predictive value (PPV) of 100% and the negative predictive value (NPV) of 97.2%. In sarcoidosis, BAL showed sensitivity of 75%, specificity of 96.9%, PPV of 85.7% and NPV of 93.9%. For lung malignancies, the sensitivity was 71.4% and the specificity, as well as PPV, was 100% and the NPV was 94.3%. These results confirm that BAL is a highly specific diagnostic modality in a wide range of pulmonary disorders, with overall strong sensitivity depending on the underlying pathology.

Table 1: Baseline Characteristics of Study Participants (n=40)

Characteristic	Value
Age (years)	58.3 ± 12.7 (Mean ± SD)
Gender (Male/Female)	24/16
Indication for BAL	
Diffuse lung disease	18 (45.0%)
Focal lesion	12 (300%)
Suspected infection	7 (17.5%)
Suspected malignancy	3 (7.5%)
Lavage Volume Recovered	48.3 ± 11.2 mL (Mean ± SD)
Procedure Duration	22.5 ± 6.8 min (Mean ± SD)

Table 2: Diagnostic Yield of BAL by Disease Category

Final Diagnosis	Confirmed by BAL	Diagnostic Yield
Infectious (n=15)	12	80.00%
Bacterial pneumonia	5/7	71.40%
Tuberculosis	4/5	80.00%
Fungal infection	3/3	100.00%
Inflammatory (n=18)	14	77.80%
Sarcoidosis	6/8	75.00%
IPF	5/6	83.30%
Eosinophilic pneumonia	3/4	75.00%
Malignant (n=7)	5	71.40%
Overall Diagnostic Yield	31/40	77.50%

Table 3: BAL Cellular Profiles by Diagnosis

Diagnosis	Lymphocytes (%)	Neutrophils (%)	Eosinophils (%)	Macrophages (%)
Sarcoidosis (n=8)	42.1 ± 8.3	8.4 ± 3.1	1.2± 0.5	48.3 ± 7.2
IPF (n=6)	18.6 ± 5.2	12.3 ±4.7	2.1 ± 1.0	67.0 ± 6.5
Eosinophilic Pneumonia (n=4)	15.2 ± 4.8	105 ± 3.9	38.7 ± 9.4	35.6 ± 6.8
Bacterial Pneumonia (n=7)	22.4 ± 6.1	65.3 ± 11.2	1.8±0.7	10.5 ± 3.4
Healthy Reference*	<15%	<3%	<1%	>80%

Table 4: Microbiological Isolates in BAL Fluid (n= 15)

Pathogen Type	Isolate	N	Detection Method
Bacterial (n = 8)	*Streptococcus pneumoniae*	3	Culture + Gram stain
	Pseudomonas aeruginosa	2	Culture
	Klebsiella pneumoniae	2	Culture
	Haemophilus influenzae	1	Culture
Mycobacterial (n=4)	*Mycobacterium tuberculosis*	4	CBNAAT + Culture
Fungal (n=3)	*Aspergillus fumigatus*	2	Culture + GMS stain
	Pneumocystis jirovecii	1	GMS stain

Table 5: Procedure-related Complications

Complication	Cases (n)	Severity	Management
Transient hypoxemia	5 (12.5%)	Mild (SpO_2 85-89%)	Supplemental O_2
Cough exacerbation	3 (7.5%)	Mild	Symptomatic
Fever (>38°C)	2 (5.0%)	Moderate	Antibiotics + antipyretics
Minor bleeding	1 (2.5%)	Mild	Self-limited
Total	11 (27.5%)	-	-

Table 6: Performance Characteristics of BAL for Key Diagnoses

Diagnosis	Sensitivity	Specificity	PPV	NPV
Tuberculosis (n =5)	80.00%	100.00%	100.00%	97.20%
Bacterial Pneumonia (n=7)	71.40%	93.90%	83.30%	88.60%
Sarcoidosis (n=8)	75.00%	96.90%	85.70%	93.90%
Lung Malignancy (n=7)	71.40%	100.00%	100.00%	94.30%
PPV: Positive Predictive Value, NPV: Negative Predictive Value				

DISCUSSION

The results of the present study showed that bronchoalveolar lavage (BAL) was successful in obtaining a high diagnostic yield of 77.5%. This highlights its importance as a diagnostic tool in the evaluation of diverse pathologies of the Lung. The results of our study are comparable to those reported by other studies in the field previously, which shows the reliability of BAL in routine clinical practice.[14,15] BAL's ability to provide crucial information is even more important in a clinical setting where radiology or sputum analysis remains inconclusive. In infectious diseases of the lung, BAL showed a diagnostic yield of 80% especially in cases of sputum-negative tuberculosis. This shows the sensitivity of BAL in detecting Mycobacterium tuberculosis by culture or molecular technique such as CBNAAT, hence offering diagnostic confirmation when conventional techniques fail.[16] Furthermore, BAL proved to be useful in detecting other fungal infections such as Pneumocystis jirovecii, which are undiagnosed, particularly in immunocompromised hosts.[17,18] The findings of our study are in concordance with the pieces of evidence that show that BAL is becoming a cornerstone in the diagnosis of opportunistic infections, particularly in HIV patients or those receiving immunosuppressive therapy.[19]

BAL fluid also contributed substantially in cases of interstitial lung diseases (ILDs), where it provides cellular profiles that are important for diagnosis. In cases of sarcoidosis, BAL lymphocytosis supported clinical suspicion. Neutrophil predominance was found in idiopathic pulmonary fibrosis, correlated with disease activity. It is important to note that BAL alone cannot provide a definitive diagnosis of ILDs, but it can play an adjunctive role in differentiating inflammatory from fibrotic processes, and these results have been shown in previous studies.[20,21] When the BAL outcomes are interpreted along with high-resolution computed tomography (HRCT) and histopathology, BAL significantly enhances the diagnostic outcomes. In cases of suspected malignancies, BAL cytology was found to be positive in 71.4% of cases, which is in agreement with previous research, which reported sensitivities ranging from 50 – 80%.[22,23] More importantly, the specificity of this study for suspected malignancy was 100% which shows that negative BAL does not rule out malignancy completely; however, positive findings are highly reliable. This strengthens the fact that BAL can be useful as a first-line (less invasive) diagnostic tool, especially when the patient cannot undergo more invasive tests, such as transbronchial biopsy. The addition of BAL to the molecular and newer cytological techniques has been found to have a further benefit in lung cancers, presumably to aid in diagnosis.[24] The assessment of the safety profile of BAL in this study showed favorable results, and there were only minor complications, such as transient cough and mild desaturation, which were observed and all of which resolved without intervention. These results are congruent with those of large observational cohorts, which have reported that BAL is a broadly safe procedure that has low rates of major adverse events.[25] Therefore, BAL not only exhibits high diagnostic yield but also has a superior risk-benefit ratio, arguing for its application as a primary investigational technique in suspected pulmonary disease.

CONCLUSION

In conclusion, the results of our study have reinforced BAL as one of the valuable diagnostic tools across a variety of lung diseases, which include infections, interstitial lung disease, and malignancy. Although it may not always be definitive, especially in interstitial lung diseases, its high yield and safety are complementary to radiological and histopathological examinations. This makes bronchoalveolar lavage investigations indispensable in respiratory medicine. However, future research with a larger sample size and multicentre studies must be done to enhance its sensitivity and applicability.

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