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Comparing mini bronchoalveolar lavage and endotracheal aspirate in diagnosing bacterial pneumonia in the intensive care unit

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ABSTRACT

Objectives: Pneumonia is a major cause of morbidity and mortality among patients in the intensive care unit (ICU). Timely and accurate diagnosis is crucial for effective treatment, but lower respiratory tract sampling techniques vary in sensitivity and specificity. This study aims to compare the diagnostic accuracy of endotracheal aspirate (ETA) with mini bronchoalveolar lavage (mBAL) in detecting bacterial pneumonia in intubated patients, assessing sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of ETA against mBAL, the gold standard.

Methods: A cross-sectional comparative study was conducted at the ICU of Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan, over 7 months. Adult patients on mechanical ventilation with suspected or confirmed pneumonia were included. Both mBAL and ETA samples were collected under strict aseptic conditions.

Results: Out of 120 patients, 112 paired samples were analyzed. ETA exhibited a sensitivity of 81.1%, specificity of 92.1%, PPV of 95.2%, and NPV of 71.4%, with an overall accuracy of 84.8%. The most commonly isolated pathogens were *Acinetobacter* and *Klebsiella*. No serious adverse events occurred.

Conclusion: ETA is a cost-effective and reliable alternative to mBAL for diagnosing bacterial pneumonia in intubated ICU patients, but clinicians should carefully interpret negative results.

Introduction

Pneumonia remains a significant cause of morbidity and mortality among critically ill patients in the intensive care unit (ICU) [1]. The reported prevalence of pneumonia is 24% among hospitalized ICU patients [2]. Prompt and accurate diagnosis of pneumonia is essential for initiating appropriate treatment strategies and improving patient outcomes. However, diagnosing pneumonia in the ICU presents unique challenges due to factors such as altered immune responses, underlying comorbidities, and invasive mechanical ventilation [3,4]. Consequently, there is a critical need to identify reliable and efficient diagnostic techniques to aid in the early and accurate identification of pneumonia in this vulnerable patient population.

Traditionally, bronchoalveolar lavage (BAL) and endotracheal aspirate (ETA) have been widely used to obtain lower respiratory tract samples, invasively and non-invasively, respectively, for microbiological analysis in severe pneumonia. BAL involves the instillation and subsequent retrieval of fluid from a specific lung segment, whereas ETA involves aspirating secretions from the trachea (via endotracheal tube). These methods allow for direct sampling of the lower respiratory tract, enabling the detection and identification of causative pathogens. However, standard bronchoscopic BAL poses a risk of complications in critical patients, including hypotension, hypoxemia, bronchospasm, risk of bleeding in at-risk patients, and arrhythmias [5,6]. Additionally, bronchoscopic BAL requires technical skills and might be difficult to perform in low-income settings owing to the unavailability of instruments [7]. Hence, to circumvent many of these issues, a mini-BAL (mBAL) has been introduced as a potential alternative diagnostic technique for pneumonia in the ICU setting.

Mini-BAL involves the modification of bronchoscopic BAL by instilling a smaller volume of fluid (usually 20-50 ml) into the lung segment and retrieving it for analysis [8]. This modified technique offers several potential advantages over conventional BAL. Firstly, it is less invasive, potentially reducing patient discomfort and the risk of complications [9]. The smaller fluid volume used in mBAL may improve the detection of pathogens by reducing dilution effects [7].

For instance, a review study based on data from 217 pairs of bronchoscopic BAL and mBAL respiratory cultures across six research stud-

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ies, concluded that mBAL has a high sensitivity and specificity and can be utilized as an alternative to bronchoscopic BAL for diagnosing pneumonia [10].

In recent years, various studies have investigated the diagnostic performance of mBAL and its comparison to other techniques, including ETA, in diagnosing pneumonia in the ICU. These studies have shown promising results, suggesting that mBAL may be an effective and efficient alternative to conventional BAL and ETA [11,12].

Another study conducted in a Pediatric ICU in Turkey compared the results of ETA and mBAL in identifying organisms responsible for VAP. In comparison to endotracheal aspirate (ETA), this study showed that mBAL is simpler to use and more sensitive than ETA, with ETA's sensitivity, specificity, negative and positive predictive values of 100%, 50%, 100%, and 48% respectively [9]. mBAL and ETA have been proposed as simpler and safer alternatives to BAL. While mBAL is a less invasive technique that offers similar diagnostic capabilities, ETA is a more straightforward and widely used method. However, the diagnostic accuracy of these techniques relative to each other remains unclear. Therefore, this study aimed to compare the diagnostic accuracy of mBAL and ETA in detecting pathogens in intubated ICU patients with suspected or confirmed pneumonia.

Methods

This cross-sectional comparative study was conducted in ICU of SIUT Hospital, Karachi, Pakistan, over a period of 7 months, 29th Jan 2024 to 6th Aug 2024, following approval from the Institutional Ethical Committee. Data collection was done prospectively with convenience sampling among adult patients aged 18 years and older. Only mechanically ventilated patients who had suspected or confirmed pneumonia were included. Suspected pneumonia refers to a patient who had clinical symptoms such as cough, fever, dyspnea, and sputum production, either present upon admission to the ICU or developed during their ICU stay, particularly when supported by new or worsening respiratory parameters or suggestive imaging findings. Confirmed pneumonia was diagnosed when clinical symptoms were accompanied by radiological evidence (e.g., new or progressive infiltrates on imaging) and, microbiological confirmation through positive cultures of bacterial infection. Patients with severe hypoxemia (P/F ratio <100), severe bronchospasm, bleeding disorders, coagulopathy, or pneumonia in an immunocompromised host were excluded from the study.

The sampling procedures were conducted under strict aseptic conditions. ETA and mBAL samples were taken at the same time. ETA was taken first and after reoxygenation, mBAL sample was taken. There was a time difference of approximately 2 minutes between two samples. The sample was acquired within 24 hours of suspicion of pneumonia. Tracheal aspirate (ETA) samples were obtained using a suction catheter inserted through the endotracheal tube, followed by the application of suction while withdrawing the catheter. The entire procedure was performed within 15 seconds, and if necessary, saline lavage was used to facilitate secretion removal.

For mBAL, a nasogastric tube was inserted through the endotracheal tube and advanced until resistance was met, targeting the most compromised lung area as determined by imaging. The nasogastric tube was inserted through ETT with the tip curved toward the side of the lung that was most compromised according to the x-ray or computed tomographic scan. Approximately 30 ml of isotonic saline was instilled, and the aspirated fluid was collected and sent to the microbiology laboratory for quantitative culture.

Figure 1 shows the recruitment of patients in our study. In total, 120 pairs of samples were obtained, 08 pairs were discarded due to poor quality and 112 pairs of samples were included for final analysis and results. The sample size was calculated to be 105 considering the sensitivity as 100% and specificity 50% [12] and the prevalence of pneumonia in ICU 24% of patients taken from the previous study [2] with a margin of error of 12% and 95% confidence level.

This study was a single, blind study. Both procedures were performed by a well-trained operator and the samples were labeled as 1 for ETA and 2 for mBAL and samples were sent to laboratory for microbiological testing.

The samples were processed in a biosafety level 2 (BSL-2) cabinet. For mBAL specimens, centrifugation was performed, and the purulent portion was used for Gram staining and inoculation of culture plates. Quantitative cultures were incubated and examined at 24, 48, and 72 hours, with a colony count of $>10^4$ CFU/ml considered indicative of bacterial pneumonia. If it was a pure sample then even with less growth of 10^3-10^2 was considered.

For ETA, the specimen was processed as soon as possible in the BSL-2 cabinet. Centrifugation of the specimen was done. The purulent part was used for Gram staining and inoculation of plates. Enriched media was inoculated first followed by selective and differential media. Staphylococcus streak American Type Culture Collection 25923 was added to biofilm-associated protein for enhanced recovery of Haemophilus influenza. Plates were incubated and examined at 24,48 and 72 hours. Relevant tests were performed for the identification of the primary pathogen. Once the identification was done for organisms in mBAL and ETA, the antimicrobial sensitivity test was set as on either MHA, CHO, or biofilm-associated protein as per the requirement of the organism. The sensitivity of the respective organism was done by the Kirby Baeuer disk diffusion method according to Clinical & Laboratory Standards Institute guidelines [13].

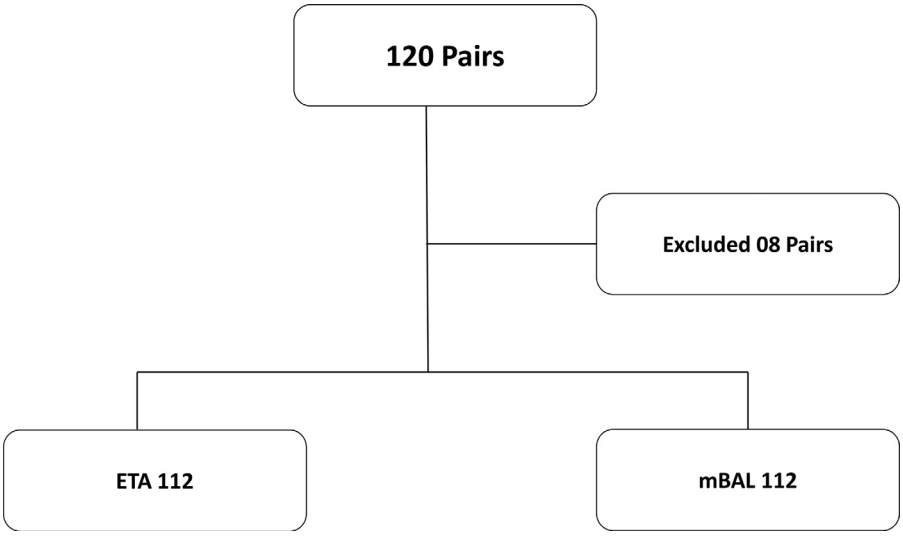

Figure 1. Recruitment flow chart.
ETA: endotracheal aspirate; mBAL: mini bronchoalveolar lavage.

Data were collected using a standardized proforma, capturing patient demographics, type of pneumonia, reason for ICU admission, indications for ETA and mBAL, and the results of cultures from both mBAL and ETA samples. The STARD (Standards for Reporting of Diagnostic Accuracy) checklist was followed as a standard for reporting diagnostic accuracy [14]. The primary outcome measure was the diagnostic accuracy of mBAL and ETA culture reports, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Results

Demographic and clinical characteristics of the study patients are summarized in Table 1. The study included 112 patients with a mean age of 43.8 ± 16.1 years and 66(58.9%) were males. The most common type of pneumonia admitted was hospital-acquired pneumonia (HAP) 65.2% followed by community-acquired pneumonia and ventilator-associated pneumonia (VAP). The most common reasons for ICU admission were respiratory failure and renal failure with sepsis (12.5%) followed by renal failure (10.7%), and post-surgical complications (7.1%). The primary indications for performing bronchoalveolar lavage (BAL) were significant airway secretions with new chest radiological infiltrates (13.4%) and significant airway secretions alone (12.5%).

Table 2 shows the organisms isolated from ETA and mBAL in our study. The results of all four organisms isolated are comparable to each other.

The diagnostic accuracy of ETA, using mBAL as the gold standard, demonstrated a sensitivity of 81.1%, a specificity of 92.1% with an overall accuracy of 84.82%.

We also calculated the Cohen's Kappa value for our sample which came out to be 0.68, any value between 0.61 to 0.8 indicates substantial agreement [15] (Table 3). Out of 112 samples, 14 (18.9%) were false negative.

Table 1
Patients characteristics.

Parameters	
Age (years), **mean ± SD**	43.8 ± 16.1
Age range (years)	18-90
Gender, n (%)	
Male	46 (41.1)
Female	66 (58.9)
Type of pneumonia n (%)	
Hospital-acquired pneumonia	73 (65.17)
Community-acquired pneumonia	27 (24.10)
Ventilator-associated pneumonia	12 (10.71)
Reason admission n (%)	
Respiratory failure + renal failure + sepsis	14(12.5)
Renal failure	12(10.7)
Respiratory failure + renal failure	12(10.7)
Post-surgery	8(7.1)
Respiratory failure	7 (6.3)
Respiratory failure + sepsis	7(6.3)
Renal failure + sepsis	7(6.3)
Others	45 (40.1)
Indications of respiratory sampling n (%)	
Significant airway secretions + new chest radiological infiltrates	15(13.4)
Significant airway secretions	14(12.5)
Admission with pneumonia + significant airway secretions + new chest radiological infiltrates	13(11.6)
Significant airway secretions + drop in oxygen saturation	9(8.0)
Significant airway secretions + drop in oxygen saturation + new chest radiological infiltration	9(8.0)
Others	52 (46.4)

n (%): number and percentage.

Discussion

The findings of this study highlight the diagnostic potential of ETA as a viable alternative to mBAL in intubated ICU patients with suspected/confirmed pneumonia. With an overall accuracy of 84.82%, and particularly high specificity (92.1%) and PPV (95.23%), ETA proved to be a reliable method for detecting pneumonia in our studied population. Although the sensitivity of 81.1% suggests that ETA may not detect all cases; however, it is sufficiently accurate for clinical use in many settings.

In a study by Ruiz et al. [16], there was no significant difference in the detection of microbial flora in ETA and BAL. But, in another study, there was a significant difference between the results of mBAL and ETA, in a pediatric population with VAP [12]. The ERS 2017 guidelines also recommended quantitative, invasive lower respiratory tract sampling (BAL, mBAL) over non-invasive sampling (i.e., ETA) for accurate diagnosis of HAP/VAP [4]. In 2012, Artuk et al. [17] also concluded that the use of mBAL is more useful than ETA in diagnosing VAP. However, IDSA 2016 guidelines issued a weak recommendation to use semi-quantitative, noninvasive sampling like ETA rather than invasive sampling to diagnose VAP [11].

In a study in 2022, the researchers used microbiome identification in BAL and ETA and suggested ETA is more useful than BAL in mechanically ventilated patients, even the samples from BAL did not offer any additional insights compared to ETA in the microbiota profiles [18]. According to a Canadian study in 2006, although the sensitivity of ETA was lower than that of BAL in detecting microorganisms, there was no significant difference in 28-day mortality, length of ICU stays, and ventilator-free days [19].

The sensitivity and specificity of our study were better than a similar study in 2006 [20], probably because of the proper protocolized sampling technique by skilled staff which included the clinical researcher himself and a respiratory therapist, with a good microbiology team, processing and reporting the samples in time, and possibly due to latest culture techniques.

However, the NPV of 71.42% in our study indicates a substantial risk of false negatives, which means a few cases of pneumonia may be missed if ETA results are interpreted without clinical considerations [21]. This finding underscores the importance of using clinical judgment, and considering additional diagnostic modalities is essential, especially in cases where ETA results are negative but clinical suspicion remains high. Clinicians should be cautious in interpreting negative ETA results, particularly in critically ill patients where the consequences of missed diagnoses can be severe. Therefore, IDSA recommends initiating antibiotics empirically in patients with severe pneumonia [17].

In our study, the most common organism isolated was *Acinetobacter* followed by *Klebsiella species* (Table 2), which are among the most prevalent causes of VAP/HAP [22,23]. The sensitivity and resistance patterns in both ETA and mBAL were also similar. The leading cause of bacterial pneumonia in European ICU studies is Gram-positive bacteria (*Staphylococcus aureus*, methicillin-resistant *S. aureus*, methicillin-sensitive *S. aureus*), followed by Pseudomonas and Acinetobacter [24].

Table 2
Common organisms.

	Endotracheal aspirate organisms n = 63 (%)	Mini bronchoalveolar lavage organisms n = 74 (%)
Acinetobacter	29 (46.0)	31 (41.8)
Klebsiella	20 (31.7)	30 (40.5)
Pseudomonas	7 (11.1)	8 (10.8)
Methicillin-resistant Staphylococcus aureus	2(3.2)	4 (5.4)
Others	5 (7.9)	1 (1.4)

n (%): number and percentage.

Table 3
Comparison of ETA gram stain and mBAL gram stain as gold standard along with Cohen's kappa value.

Parameter	mBAL gram stain		*P*-value
ETA gram stain	Positive	Negative	
Positive	60 (81.1%)	3 (7.9%)	<0.001
Negative	14 (18.9%)	35 (92.1%)	
Validity			
Sensitivity	81.1% (95% CI: 71.43% to 90.77%)		
Specificity	92.1% (95% CI: 83.52% to 100%)		
Positive predictive value	95.23%		
Negative predictive value	71.42%		
Accuracy	84.82%		
Cohen's kappa value	0.68		

CI: confidence interval; ETA: endotracheal aspiration; mBAL: mini bronchoalveolar lavage.

The strengths of this study include its relatively large sample size and the rigorous comparison of ETA to mBAL, considering mBAL as the gold standard. Our findings contribute to the growing body of evidence supporting the use of ETA in resource-limited settings, where the cost and complexity of performing BAL or mBAL may be prohibitive.

However, several limitations must be considered. The single-center design may limit the generalizability of our findings, and the exclusion of immunocompromised patients could have introduced selection bias. Additionally, while our study focused on the diagnostic accuracy of ETA and mBAL, it did not assess the impact of these diagnostic methods on patient outcomes, such as mortality or length of stay in the ICU. Future research should aim to address these gaps by conducting multicenter trials and exploring the clinical outcomes associated with different diagnostic strategies.

Conclusion

This study supports the use of ETA as a cost-effective and efficient alternative to mBAL for the diagnosis of pneumonia in intubated ICU patients, particularly in settings where resources are limited. While ETA offers a practical solution in many clinical scenarios, its limitations must be recognized, and clinicians should remain vigilant in cases where the diagnosis of pneumonia is uncertain. Further studies are recommended to validate these findings across diverse patient populations and clinical settings and to explore the impact of diagnostic methods on patient outcomes.

Declarations of competing interest

The authors have no competing interests to declare.

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Ethical approval

Ethical approval was taken prior to the recruitment of the first patient. The IRB number was assigned (IRB number: 498) and a letter obtained from the Ethical Review Committee.

Author contributions

Abdul Rehman Azam and Fakhir Raza Haidri concenptualized the study, did the literature review, analyzed and interpretated the data. Nazia Arain assissted in reviewing and interpretating the data. Abdul Rehman Azam, Fakhir Raza Haidri, Ali Nadeem and Sumera Imran drafted the article and revised it critically for important intellectual content. Ali Nadeem and Maheen Fahim assisted in literature review. All authors read and approved the final manuscript.

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