



RESEARCH ARTICLE

Diagnostic yield of endotracheal aspirate and bronchoalveolar lavage in ventilator-associated pneumonia: A single-centre study

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ABSTRACT

Ventilator-associated pneumonia (VAP) remains a significant cause of morbidity and mortality in critically ill patients. This study aimed to compare the diagnostic accuracy of endotracheal aspirate (ETA) with bronchoalveolar lavage (BAL) culture, considered the reference standard, in identifying the causative pathogens of VAP. This study was conducted as a cross-sectional study at Haji Adam Malik General Hospital, Medan, Indonesia. A total of 95 samples from mechanically ventilated patients were analysed using both ETA and BAL in similar institutions. The results demonstrated that 49 samples were positive by both ETA and BAL, while 11 were BAL-positive but ETA-negative, and 31 were ETA-positive but BAL-negative. The sensitivity of ETA culture was 81.67%, whereas specificity was 11.43%. The positive predictive value (PPV) was 61.25%, and the negative predictive value (NPV) was 26.67%, yielding an overall diagnostic accuracy of 55.79%. These findings highlight the moderate reliability of ETA in detecting VAP pathogens, with limitations in ruling out infection due to its low NPV. To conclude, the relatively high sensitivity and ease of use suggest that ETA remains a useful initial diagnostic tool, particularly in resource-limited settings, though confirmation with more definitive methods, such as BAL, is recommended to guide appropriate antimicrobial therapy.

Keywords: Antibiotic; microbial; pneumonia.

INTRODUCTION

Pneumonia is a parenchymal infection of the lungs that can lead to significant clinical consequences. Most cases are classified as either community-acquired pneumonia (CAP) or healthcare-associated pneumonia (HAP). Another important subtype is ventilator-associated pneumonia (VAP), which occurs at least 48 hours after endotracheal intubation and mechanical ventilation (Spalding *et al.*, 2017). VAP has a global incidence ranging from 5% to 40% and contributes to approximately 10% of mortality cases, particularly among patients in surgical intensive care units (ICUs) (Mumtaz *et al.*, 2023). It is associated with increased morbidity and mortality due to infection with more virulent and multidrug-resistant (MDR) bacterial strains, as well as biofilm-related pathogens. As a result, antibiotic options may be limited, often requiring the use of last-resort antibiotics (Kharel *et al.*, 2021).

Bronchoalveolar lavage (BAL) cultures are considered the most accurate method for identifying causative pathogens in VAP compared to endotracheal aspirates (ETA). However, in critically ill patients, bronchoscopy may be risky as it can compromise the airway and worsen the clinical condition. ETA, a less invasive method, is often preferred in these cases, although it may detect bacterial colonisation that occurs before actual infection (Chastre & Luyt, 2016). This study aims to compare the diagnostic accuracy of ETA and BAL in identifying bacterial pathogens responsible for VAP in hospitalised patients.

MATERIALS AND METHODS

Study location and inclusion criteria

This study was conducted in the tertiary referral centre Haji Adam Malik General Hospital, Medan, Indonesia, specifically in the Intensive Care Unit (ICU) during the year 2024. This hospital is considered the most significant hospital in the province of Sumatera Utara, receiving final referrals from the surrounding area. Inclusion criteria consisted of adult patients (aged 18 years or older) with invasive mechanical ventilation for more than 48 hours and demonstrated clinical and radiological signs consistent with pneumonia. The included patient must have ETA and bronchoalveolar lavage (BAL) cultures collected within the same timeframe. Exclusion criteria included a history of chronic lung diseases, severe immunocompromised conditions, non-BAL culture results, incomplete clinical data, or improperly processed culture samples.

Ventilator-associated pneumonia

The procedure began with a clinical and radiological evaluation of patients who met the inclusion criteria. The definition of ventilator-associated pneumonia (VAP) was based on previously published guidelines by the American Thoracic Society (ATS), which define VAP as new-onset pneumonia occurring in patients who have been on mechanical ventilation for more than 48 hours, within 72 hours prior to the BAL procedure (BAL quantitative culture more than $\geq 10^4$ CFU/ml) (Kalil *et al.*, 2016). Bacterial identification process entirely

used MALDI-TOF (Bruker Daltonics, Bremen, Germany), followed by antibiotic susceptibility test employed BD Phoenix 100 (Becton Dickinson Co., Sparks, Md). Commensal flora – such as *Candida* spp., *Neisseria* spp., oropharyngeal flora, enterococci, coagulase-negative *Staphylococcus*, *Streptococcus viridans* group, and yeasts – were not considered causative pathogens for VAP, as supported by prior literature.

Sample collection

Endotracheal aspirate (ETA) and bronchoalveolar lavage (BAL) fluid samples were collected from patients using standard protocols, as described in previously published studies. ETA samples were obtained using endotracheal tubes and sterile suction catheters, while BAL was performed with a flexible bronchoscope. Microbiological transport media were used to preserve the sample, and both aerobic and anaerobic culture media were employed for bacterial isolation. Microorganism identification was performed using Gram staining and standard biochemical tests. ETA samples were collected by inserting a sterile catheter through the endotracheal tube, taking precautions to avoid contamination with saliva. For the BAL procedure, 100 mL of sterile saline was instilled into the distal bronchial tree via bronchoscopy and then aspirated for microbiological analysis. All samples were transported promptly to the microbiology laboratory of a similar healthcare institution for culture and pathogen identification. The results of ETA and BAL cultures were subsequently compared to evaluate the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of ETA in diagnosing ventilator-associated pneumonia (VAP).

Statistical analysis and ethical approval

Diagnostic indicators, such as sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), were calculated to assess the diagnostic accuracy of tracheal secretion culture, using BAL culture as the reference standard, by using an online calculator provided by MedCalc Diagnostic Test Evaluation Calculator (https://www.medcalc.org/calc/diagnostic_test.php). All patients and their guardians provided consent for study enrollment without coercion. Ethical approval was granted by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Sumatera Utara (Reference No: 6259/UN5.2.1.1.45/PT.01.04/2024).

RESULTS

This study enrolled 95 critically ill patients, with the majority aged over 60 years (47.4%) and a male predominance (62.1%). The complete demographic characteristics are presented in Table 1. Results from bronchoalveolar lavage (BAL) and endotracheal aspirate (ETA) are depicted in Table 2 and 3. The culture results identified *S.maltophilia* as the predominant pathogen, isolated in approximately half of the study population, followed by *Pseudomonas aeruginosa* in BAL culture results. In comparison with ETA cultures, *A.baumannii* is the most common bacterial species (28.5%). No bacterial growth was more frequent in ETA results compared to BAL culture results (15.8% versus 4.2%).

Based on the diagnostic agreement between endotracheal aspirate (ETA) and bronchoalveolar lavage (BAL) cultures (Table 3), this study demonstrated the discordant findings of causative pathogens in VAP. Out of 95 total samples, 49 cases were positive by both ETA and BAL, while 11 cases were BAL-positive but ETA-negative. Meanwhile, 31 cases were positive by ETA but negative by BAL, and 4 cases were negative by both methods. The sensitivity of ETA culture compared to BAL as the reference standard was 81.67%, whereas the specificity was considerably lower at 11.43%. The positive predictive value (PPV) was 61.25%, and the negative predictive value (NPV) was 26.67%. Consequently, the diagnostic accuracy of ETA compared to BAL was 55.79%, suggesting moderate reliability of ETA in identifying VAP pathogens.

Table 1. Characteristic of Study Participants

Characteristics	Proportion N (%)
Age (Years)	
<20	7 (7.4)
21–40	9 (9.5)
41–60	34 (35.8)
>60	45 (47.4)
Gender	
Male	59 (62.1)
Female	36 (37.9)
Comorbidities	
No comorbidity	24 (25.3)
Heart failure	6 (6.3)
Diabetes mellitus type 2 (T2DM)	8 (8.4)
Renal Impairment	20 (21.1)
Malignancy	12 (12.6)
Cerebrovascular disease (CVD)	25 (26.3)

Table 2. Bacterial identification of species from BAL culture results

Bacterial species	Proportion N (%)
<i>Pseudomonas aeruginosa</i>	20 (21.1)
<i>Staphylococcus aureus</i>	1 (1.1)
<i>Stenotrophomonas maltophilia</i>	2 (2.1)
<i>Acinetobacter baumannii</i>	47 (49.5)
<i>Klebsiella pneumoniae</i>	7 (7.4)
<i>Escherichia coli</i>	4 (4.2)
<i>Klebsiella pneumoniae ssp pneumoniae</i>	7 (7.4)
<i>Citrobacter freundii</i>	1 (1.1)
<i>Enterobacter cloacae</i>	1 (1.1)
<i>Pseudomonas putida</i>	1 (1.1)
No growth	4 (4.2)
Total	95 (100)

Table 3. Bacterial identification of species from ETA culture results

Bacterial species	Proportion N (%)
<i>Pseudomonas aeruginosa</i>	19 (20.0)
<i>Staphylococcus aureus</i>	7 (7.4)
<i>Stenotrophomonas maltophilia</i>	2 (2.1)
<i>Acinetobacter baumannii</i>	27 (28.5)
<i>Acinetobacter nosocomialis</i>	1 (1.1)
<i>Klebsiella pneumoniae</i>	9 (9.5)
<i>Escherichia coli</i>	7 (7.4)
<i>Klebsiella pneumoniae ssp pneumoniae</i>	5 (5.3)
<i>Serratia marcescens</i>	1 (1.1)
<i>Corynebacterium striatum</i>	1 (1.1)
<i>Achromobacter xylosoxidans</i>	1 (1.1)
No growth	15 (15.8)
Total	95 (100)

Table 4. VAP agreement analysis between ETA and BAL

ETA	BAL		PPV/NPV (%)
	Positive	Negative	
Positive	49	31	PPV 61.25%
Negative	11	4	NPV 26.67%
Total	60	35	

ETA: Endotracheal aspirate; BAL: Bronchoalveolar lavage; VAP: Ventilator-associated pneumonia.

DISCUSSION

This study demonstrated the accuracy of ETA culture compared to BAL culture, the reference standard, in detecting microorganisms responsible for VAP. This type of infection is categorized as one of the most common nosocomial infections among patients receiving invasive mechanical ventilation. This research demonstrated ETA utilisation produces 81.67% of sensitivity but low specificity (11.43%). These results contribute to the urgent need for BAL for the confirmatory diagnostic tools to determine the causative pathogen species of VAP among critically ill patients to prevent increased morbidity and mortality rates in ICU settings (Forel *et al.*, 2012). The presence of VAP is not uncommon, and patients often suffer from a considerable delay in diagnosis. Additionally, antibiotic susceptibility testing using an improper sampling method can yield results that are associated only with colonisation, rather than the actual infection (Chastre & Luyt, 2016). Therefore, it is crucial to evaluate more efficient and reliable methods for the early detection of VAP (Ego *et al.*, 2015).

Several notable procedure-related adverse effects may occur with bronchoalveolar lavage due to its invasive nature and the maneuvers required during the examination. Although generally considered low risk when performed properly, patients may experience transient hypoxemia, bradycardia, and hypotension during the procedure, which may further exacerbate disease severity (Prebil *et al.*, 2014). From a cost perspective, bronchoalveolar lavage is associated with substantially higher expenses compared with endotracheal aspirate, making endotracheal aspirate a more feasible option in critically ill patients. In addition, endotracheal aspirate offers a faster turnaround time for conventional microbiological culture, with results typically available within approximately 72 hours (Mansour & Albendary, 2018).

The recent guidelines for VAP therapy also emphasise the abundant Gram-negative bacteria as causative pathogens, such as *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Acinetobacter baumannii*, which are more frequently implicated in infections among patients receiving mechanical ventilation (Campogiani *et al.*, 2020). Gram-negative pathogens exhibit notable virulence traits, including intrinsic resistance to several classes of antibiotics, the production of endotoxins, and the ability to form biofilms (Philippart *et al.*, 2015; Baidya *et al.*, 2021). This condition poses significant challenges in the management of VAP, particularly in intensive care settings, in which other comorbidities complicate treatment. Meanwhile, gram-positive bacteria, particularly *Staphylococcus aureus* and its Methicillin-Resistant variant (MRSA) strain, remain a significant threat in patients with VAP, despite having a lower prevalence compared to gram-negative bacteria (Sarda *et al.*, 2019). The presence of *Staphylococcus aureus* in ICU patients may indicate colonisation or a nosocomial infection that can worsen the patient's clinical condition. Several studies have confirmed that mucocutaneous screening swabs for patients admitted to the ICU can reduce mortality rates caused by MRSA infections (Lee *et al.*, 2015); this strategy is not generally implemented in the national insurance era. Therefore, managing infections in the ICU requires rigorous management with a strong emphasis on antimicrobial stewardship and close surveillance of resistance patterns.

This study demonstrated moderate diagnostic agreement between ETA and BAL cultures in identifying pathogens that cause VAP. Among 95 samples, 49 cases showed concordant positive results, while 42 were discordant. The PPV of ETA was 61.25%, indicating that when ETA yields a positive result, there is a fair likelihood of actual infection. However, the NPV was markedly low at 26.67%, demonstrating a significant limitation of ETA in ruling out infection. This low NPV suggests that a negative ETA result cannot be interpreted as the absence of VAP. Several studies have reported similar findings, emphasizing that isolated ETA result is insufficient

as a definitive diagnostic tool for VAP. One study assessed the agreement between ETA and BAL using Cohen's kappa and found a low agreement ($\kappa = 0.22$), with PPV and NPV of 62% and 61%, respectively, reinforcing the limited reliability of ETA (Scholte *et al.*, 2014). In contrast, another study reported higher diagnostic performance of ETA, with a PPV of 95.2% and NPV of 71.4%, though this may reflect variations in methodology or patient population (Azam *et al.*, 2025). Nevertheless, a separate study demonstrated the clinical implications of using BAL-guided antibiotic therapy, demonstrating a significantly higher improvement rate in patients whose treatment was based on BAL culture results compared to those guided by ETA (Bao *et al.*, 2023). These findings collectively suggest that while ETA may be useful for initial screening due to its accessibility, BAL remains a more reliable reference for guiding antibiotic therapy in VAP.

This study did not escape some limitations; first, the sample size was limited from a single tertiary hospital, which may restrict the generalizability of the findings. Second, the analysis was limited to a comparison between ETA and BAL cultures, without incorporating polymerase chain reaction (PCR) or other molecular diagnostic techniques. PCR-based testing was not performed because MALDI-TOF mass spectrometry was routinely used in our laboratory and has demonstrated considerable accuracy in bacterial species identification; however, the absence of molecular amplification methods may have reduced sensitivity for fastidious or low-burden pathogens. Third, several potentially relevant clinical factors, including prior antibiotic exposure and detailed comorbidity profiles, were not fully accounted for and may have influenced culture results. In addition, patients with chronic lung disease were deliberately excluded because of their higher likelihood of polymicrobial colonization and altered airway microbiota, which could confound culture interpretation; this exclusion may further limit the applicability of the findings to the general ventilated population. In addition, although BAL culture was used as the reference standard, it has inherent limitations related to sensitivity, invasiveness, and longer turnaround time, which may affect its reliability as a definitive diagnostic benchmark. Despite these limitations, the study provides valuable insight into the diagnostic utility of endotracheal aspirate, which demonstrated a sensitivity of 81.67 percent compared with bronchoalveolar lavage, supporting its continued role as a practical, lower-cost, and accessible initial diagnostic tool, particularly in resource-limited settings.

CONCLUSIONS

This study demonstrated that endotracheal aspirate (ETA) culture has a relatively high sensitivity (81.67%) but low specificity (11.43%) when compared to bronchoalveolar lavage (BAL) culture, serving as the reference standard, in diagnosing ventilator-associated pneumonia (VAP). While ETA offers a practical and less invasive sampling method, especially in critically ill patients, its limited specificity results in the potential for false-positive results due to airway colonization. Therefore, although ETA can serve as an initial diagnostic tool in settings where BAL is not feasible, clinicians should interpret its results cautiously and consider confirmatory testing to guide the appropriate use of antimicrobial therapy.

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Declaration of "Conflict of Interests"

The authors declare that they have no conflicts of interest related to this study.

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