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# Ventilator Associated Pneumonia in Critically Ill Pediatric Patients – A Literature Overview

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***Abstract:*** Understanding the multifactorial nature of ventilator-associated pneumonia (VAP) and implementing comprehensive preventive measures are essential in reducing its incidence and improving patient outcomes in ICU settings. It poses a serious problem, especially among mechanically ventilated patients in intensive care units (ICUs), and is notably prevalent in neonatal intensive care units (NICUs). VAP is one of the most common healthcare-associated infections along with central line-associated bloodstream infection and catheter-associated urinary tract infection. Respiratory illnesses have increased rates of mortality and morbidity being difficult to treat. Nevertheless, using algorithms for prevention and diagnosis can increase survival rates.

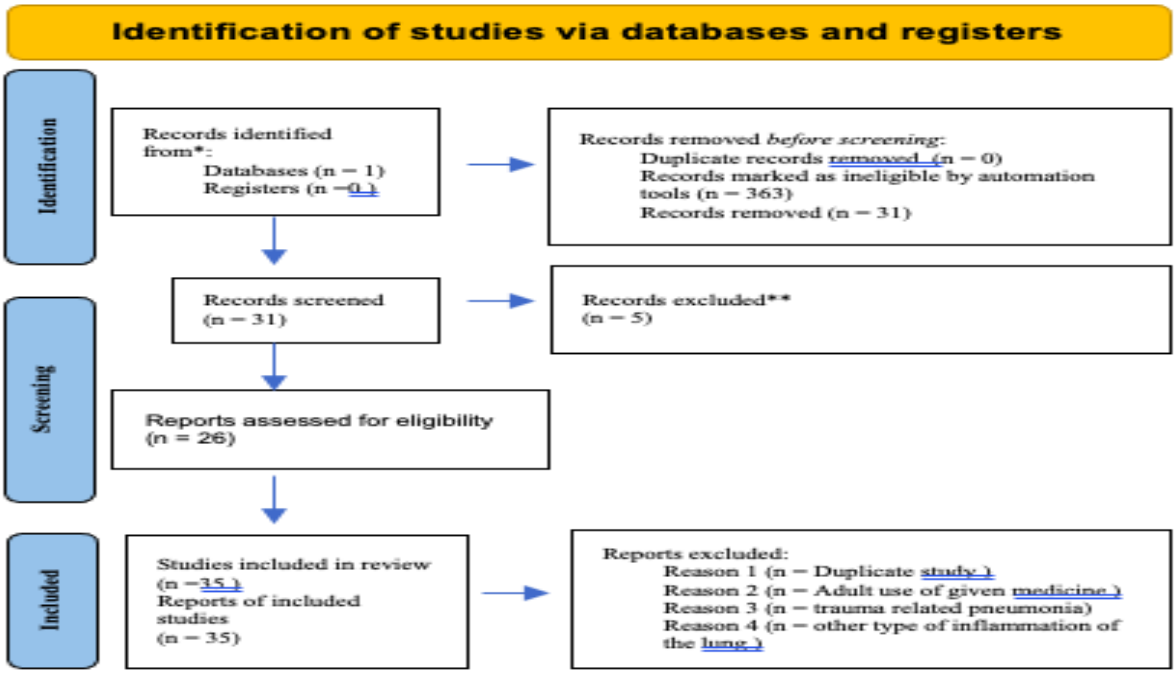
***Keywords:*** Critical, Pediatric, VAP, Hygiene

## INTRODUCTION

Ventilator-associated pneumonia (VAP) is a significant concern in healthcare, particularly for patients who have been on mechanical ventilation for over 48 hours. This condition not only poses a substantial financial burden on already strained healthcare systems but is also one of the most common healthcare-associated infections (HAIs), especially among newborns in neonatal intensive care units (NICUs). The pathogen profile of VAP often includes antibiotic-resistant bacteria, which complicates treatment and underscores the importance of early diagnosis and prevention. Preventive measures such as strict hygiene practices, careful management of ventilation equipment, and targeted antibiotic use are critical in reducing the incidence of VAP.

## PURPOSE

The aim of this study is to identify the risk factors involved in the pathogenesis of VAP, to determine whether specific pathogens are associated with this respiratory condition and their response to antibiotics, to establish any diagnostic features of VAP, and to explore applicable preventive measures.




(Fig 1. PRISMA Flow diagram)

## MATERIALS AND METHODS

This overview was based on extensive research conducted using the "PubMed" database exclusively, chosen to ensure that the literature reviewed is authentic and comes from a reliable source. The initial key phrase utilized for automatic searching was “ventilator associated pneumonia in intensive care units” resulting in 394 papers whereas the automatic filter of including criteria mentioned above selected 31 papers. Including criteria were summed up to abstract, meta-analysis, review, systematic review, newborn: birth-1 month, infant: birth – 23 months, infant 1-23 months, preschool child: 2-5 years, child 6-12 years. For a more eloquent approach, PRISMA Flow diagram (fig.1) and PRISMA Check List used to select data. Out of the mentioned number of papers, 5 were excluded for age range criteria, duplication of report, volutrauma related pneumonia or other type of inflammation of the lung. Subsequently, for the other 26 were made reports.

Furthermore, the reports were sorted considering the topic of research into: risk factor, statistics, prevention, pathogens, diagnosis and care bundles studies.

## LITERATURE REVIEW

Ventilator-associated pneumonia (VAP) can be diagnosed in people receiving mechanical ventilation for over 48 hours and acquiring pneumonia (1). Apart from being a substantial financial cost to an overburdened health care system (2) VAP is one of the most common healthcare-associated infections (HAI) and a serious problem among mechanically ventilated patients in intensive care units especially newborns admitted in neonatal intensive care units (NICUs) (3, 4, 5,6, 7, 8). A study conducted by the Department of Pediatrics, Raipur, India, concluded that VAP is the second most common HAI with a prevalence of 20-25%, surpassed only by central line-associated bloodstream infection (CLABSI) 25-30%. The other most common HAIs include catheter-associated urinary tract infection (CAUTI) 15%, and surgical site infection (SSI) 11% (5,9).

Tan B, Zhang F, and colleagues from the School of Public Health and Management, Chongqing Medical University, China, conducted a study that led to the conclusion that certain risk factors make pediatric patients especially neonates prone to developing VAP. The number one risk factor is the length of stay in the intensive care unit, followed by enteral feeding and mechanical ventilation. Interestingly enough, mechanical ventilation hosts, in their opinion, only have the third highest prevalence of VAP (10). A study conducted in Italy by Manzoni P, De Luca D, and colleagues discovered that the loss of Bifidobacteria and Lactobacilli spp. (gut commensals) can accelerate the proliferation of pathogenic microflora and abnormal gut colonization and so become a risk factor for VAP (11), confirming the hypothesis that enteral feeding increases the risk of VAP, mentioned by the Chinese team from Chongqing and that aspiration of gastric contents is a risk factor along immune deficiencies, mentioned by Yankov IV and Shmilev TI in their study (7).

A study conducted in Brazil by André Ricardo Araujo da Silva and colleagues from Federal Fluminese University from Brazil concluded in their research that no pathogens were related or associated with VAP (3). However, an Iranian from Tehran concluded that the main pathogenic bacteria for VAP in NICUs are Gram-negatives which unfortunately show a general decline in sensitivities to commonly used antibiotics (12). A Chinese study conducted by Tan B and colleagues from Chongqing Medical University confirms the information with their research: 77.6% gram-negative bacteria in their cultures, followed by Gram-positive bacteria (18.8% with penicilin resistance up to 99,1%) and also fungi (3.7%) (10). As evidence to back up the hypothesis of the Iranian study, McGrath EJ and Asmar BI from The Carmen and Ann Adams Department of Pediatrics, USA concluded in their study which drug-resistant pathogens are incriminated for VAP mentioning: spectrum β-lactamase producing Gram-negative organisms, vancomycin-resistant Enterococcus sp., extended-spectrum β-lactamase producing Gram-negative organisms, Klebsiella pneumoniae carbapenemase-producing strains multi-drug resistant Acinetobacter baumannii and methicillin-resistant Staphylococcus aureus (number one pathogen for CLABSI (9), as per a Columbia University, USA study(13).

As far as diagnosis is concerned, there is no gold standard protocol (14). However, for children younger than 1 year, correlating risk factors with radiographic findings, and at least 3 defined clinical signs of pneumonia along with worsening gas exchange can be enough for diagnosing VAP and beginning treatment (15). The most common manifestation of HAIs is fever in PICU, hence the appropriate targeted search to identify the cause of fever should be done (5).

Modern medicine continues to advance in preventive approaches to various illnesses, including VAP and contributed to impressive successes in reducing rates of healthcare-associated infections (16). Garland JS from St. Joseph Hospital, Glendale, Milwaukee, USA, noted in his research that the Centers for Disease Control and Prevention recommend suctioning the oropharynx around the endotracheal tube before adjusting or removing the tube to help reduce the risk of microaspiration of oropharyngeal secretions (17). Another research by Shmilev TI, Yankov IV from Medical University of Plovdiv, Bulgaria highlighted measures such as strict hand hygiene, use of protective clothing by attending staff, changing ventilator breathing circuits only when they malfunction or are visibly contaminated, preferring orotracheal intubation over nasotracheal intubation, and using endotracheal tubes with dorsal lumens for drainage of respiratory secretions, along with a standardized approach to patient care and staff training, are essential (6). Additional measures may include the use of lactoferrin, fluconazole, and nystatin and specific measures to prevent ventilator associated pneumonia (11). Nevertheless, there are certain concerns regarding the development of resistant strains of fungi and hepatotoxicity especially for fluconazole (8).

The literature reviewed highlighted a specific and proven effective type of both preventive and curative approach for VAP. Oral hygiene care (OHC) in intensive care units is an interesting topic discussed all over the world, proving this way its undeniable importance as per Parker LA from the

University of Florida, oral care guidelines for the neonatal intensive care unit have not been established (18) even if Ludovichetti FS emphasized the importance of good oral care bundles to mitigatethe bacteria proliferation in the bloodstream, and to prevent the development of VAP (19). Oral hygiene affects the well-being of intubated and ventilated pediatric patients and so dental plaque accumulation and bacterial colonization of the oropharynx specifically increase the risk of VAP in the PICU so apart from healthcare professionals always having in mind the importance of hygiene in the ICU, children must also be taught from early years of the significance of OHC, says Johnstone L in a research conducted in Auckland, New Zeeland (20). An English-Chinese collaborative research regarding both adults and children concluded that using chlorhexidine mouth rinse or gel in critically ill patients is associated with a reduction of odds of developing ventilator-associated pneumonia but unfortunately for children, there was no evidence of a difference between OHC with chlorhexidine and placebo for the outcomes of VAP (1).

Another very interesting topic regarding this type of mainly artificially induced pneumonia emphasized the risk of prolonged duration of mechanical ventilation as a consequence of morphine use. Fan C, Qi B, and Chen C from Xuzhou Children's Hospital highlighted the importance of analgesia and sedation guidelines, which needed to reduce in the amount of analgesics and sedatives administered to PICU patients, while not exposing them to pain and distress (21). In research by Grant MJ and colleagues from Primary Children's Medical Center, Salt Lake City, USA, VAP is mentioned as a sedation-related adverse effect along, post-extubation stridor with chest-wall retractions at rest, extubation failure, inadequate pain management, clinically significant iatrogenic withdrawal, unplanned endotracheal tube extubation, etc. (22).

Weaning from mechanical ventilation is another topic related to VAP. Extremely important is to implement specific ventilator care bundles as the median ventilator-associated pneumonia incidence decreased from 9.8 (interquartile range, 5.8-18.5) per 1,000 ventilator days to 4.6 (interquartile range, 1.2-8.6) per 1,000 ventilator days, shows a research by de Neef M and colleagues (23). However, standardization of clinical practice to avoid the risk of aspiration in the lungs, colonization of the respiratory tract with pathogenic microorganisms and contamination of respiratory equipment shows Niedzwiecka T in his research (24). Cough augmentation techniques when used in mechanically-ventilated critically ill people appear to result in few adverse events, concluded Rose L, Adhikari NK and colleagues (25), one of which is VAP, as 12

## DISCUSSIONS

It seems that VAP is a topic of interest for many medical centers and is researched extensively even for children's care which usually is less studied. However, there are few specific care algorithms and strategies resulting in a great need for continuous research, vital for improving patients outcome.

## CONCLUSIONS

Ventilator-associated pneumonia is a serious burden in the Intensive Care Units dedicated to children. Apart from usually being immunologically underdeveloped, risk factors such as enteral feeding and most importantly the length of stay in the ICU promote infection and its drastic consequences.

Regarding pathogens, Gram-negative bacteria are the first incriminated in the pathogenesis of VAP and usually from the β-lactamase-producing spectrum. Fungi and Gram-positive organisms are also present in bacterial cultures, also with a multi-drug resistance spectrum.

Prevention is a highly researched topic and hygiene is the number one solution for VAP profilaxis. Specifically, Oral hygiene care is discussed in multiple medical centers that discovered the importance of dental plaque accumulation and bacterial colonization of the oropharynx reduction. Clorhexidine seems to decrease the chances of developing VAP but research regarding children showed no real impact. Clinicians should also be careful when keeping pediatric patients sedated as long periods of opioid use require longer periods of ventilation becoming so a high risk factor for developing VAP.

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