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Original Research Article

EXPLORING THE LANDSCAPE OF VENTILATOR-ASSOCIATED PNEUMONIA IN PEDIATRIC INTENSIVE CARE: INCIDENCE, OUTCOMES, AND ETIOLOGY

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Abstract

Background: Ventilator-associated pneumonia (VAP) is a critical concern in pediatric intensive care units (PICUs), significantly impacting morbidity, mortality, and healthcare costs. This study aimed to comprehensively investigate the incidence, risk factors, microbial etiology, and outcomes of VAP in mechanically ventilated children. This study aimed to assess the incidence, microbiological etiology, and outcomes of Ventilator-Associated Pneumonia (VAP) in mechanically ventilated children within the PICU. **Materials and Methods:** The study employed a prospective cohort design spanning three years within the PICU. Inclusion criteria encompassed patients aged 1 month to 12 years admitted to the PICU, Career Institute of Medical Sciences, Lucknow, who underwent endotracheal intubation. The cohort was categorized into two groups: Ventilator-Associated Pneumonia (Group A) and Non-Ventilator-Associated Pneumonia (Group B). The diagnosis of VAP) relied on CDC criteria, and patients meeting two or more VAP criteria underwent Chest X-ray and culture and sensitivity testing of Endotracheal aspirate. **Result:** 78 out of 155 mechanically ventilated children developed VAP, resulting in an incidence rate of 58.2 per 1000 patient ventilator days. The study revealed gender and age-related variations in VAP susceptibility, with a higher incidence in males and infants. Malnutrition was not significantly associated with VAP. Risk factors such as prolonged mechanical ventilation (>4 days) and re-intubation were identified. Microbial analysis indicated Acinetobacter Baumannii as the predominant pathogen, with 20% of isolates showing resistance to Carbapenem and Colistin. The study reported a cure rate of 83.33% in the VAP group, while the Non-VAP group exhibited a higher cure rate at 92.21%. **Conclusion:** The concerning incidence rate emphasizes the need for robust preventive measures. The identification of Acinetobacter Baumannii as a prevalent pathogen with antibiotic resistance underscores the importance of targeted therapeutic strategies.

INTRODUCTION

In the intensive care unit (ICU), patients grapple not only with the severe nature of their primary illnesses but also confront secondary threats such as nosocomial infections, further complicating their medical journey.[1] Among these complications, pneumonia emerges as the second most prevalent nosocomial infection, affecting a staggering 27% of critically ill patients.[1] Specifically, ventilator-associated pneumonia (VAP) looms as a critical concern, defined as lung infection occurring in individuals under mechanical ventilation for more than 48 hours.[1] For pediatric and neonatal patients in critical care units, VAP stands as the second most common hospital-acquired infection, contributing significantly to healthcare-associated infections and

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pediatric device-related incidents.[2] Despite its prevalence, the incidence of pneumonia in pediatric intensive care units (PICUs) tends to be lower than in adult ICUs.[2] Neonates, however, exhibit an interesting trend, with VAP incidence inversely proportional to their birth weight, a factor that complicates the diagnostic landscape due to the scarcity of data on newborns and children with VAP.[3,4] The majority of existing knowledge is drawn from adult studies, emphasizing the critical need for focused investigations in pediatric populations.[3,4] Children reliant on artificial airways, such as tracheostomy tubes for chronic respiratory failure or endotracheal tubes for acute airway obstruction, face an elevated risk of VAP.[1] Diagnosing VAP, especially in the vulnerable neonatal intensive care unit (NICU) population, poses significant challenges. In response to this, the Centers for Disease Control and Prevention (CDC) and National Healthcare Safety Network (NHSN) developed standardized criteria in 2008, categorizing VAP into clinically diagnosed pneumonia, pneumonia with laboratory findings, and pneumonia in immunocompromised patients.[5,6] Mechanical ventilation is a major contributor to nosocomial pneumonias, with VAP accounting for 86% of cases.[7] The annual incidence in the United States alone ranges from 250,000 to 300,000 cases, with mortality rates fluctuating between 0% and 50%.[7] Determining attributable mortality proves challenging due to diverse patient populations and variations in empirical medical therapy during the critical initial days.[7] Notably, the recovered organisms significantly impact outcomes, with higher fatality rates associated with Pseudomonas aeruginosa, Acinetobacter spp., and Stenotrophomonas maltophilia.[7] Beyond mortality, VAP inflicts economic burdens, extending ICU lengths of stay and incurring additional expenses estimated between $5,000 and $20,000 per diagnosis.[8,9] Despite advances in aseptic procedures, antibiotic therapy, and supportive care, VAP remains a substantial source of morbidity and mortality in ICU patients, necessitating a deeper understanding of preventive strategies.[10] However, consensus on preventative strategies for children, akin to those for adults, remains elusive, and the prevalence of VAP persists despite increased comprehension of risk factors.[11,12] The National Nosocomial Infections Surveillance (NNIS) program in 2004 reported varying VAP incidences in PICUs in the United States and worldwide, highlighting the need for targeted preventive interventions.[13] This study aims to identify the incidence, risk factors, and etiological agents of VAP in mechanically ventilated children, recognizing the imperative to address this preventable healthcare-associated infection.[13,14] While studies from underdeveloped nations, such as India, remain limited, acknowledging the socioeconomic cost of treating VAP emphasizes the urgency of implementing preventive measures to curtail its incidence.[14,15] As we delve into this exploration, our goal is to contribute valuable insights that pave the way for evidence-based interventions and, ultimately, a reduction in the burden of VAP among pediatric ICU patients.

Objective

- To estimate the incidence of VAP in mechanically ventilated children in PICU
- To identify the microorganisms responsible for VAP.
- To measure the outcome of VAP.

MATERIALS AND METHODS

Study Design- This research adopts a prospective cohort design conducted within the confines of a hospital setting, specifically the PICU at the Department of Pediatrics, Career Medical College, Lucknow. The study spans a three-year period, from August 2020 to July 2023, and targets patients admitted to the PICU of Career Medical College.

Sample size was calculated to assess VAP incidence of 30% with a precision of 9% and an alpha level of 95%.[16] Minimum of Hundred patients were to be recruited for this purpose.

Inclusion Criteria

The study includes patients aged 1 month to 12 years admitted to the PICU at the Department of Pediatrics who have undergone endotracheal intubation.

Exclusion Criteria

Patients who were intubated prior to admission in the Department of Pediatrics and those unwilling to provide consent are excluded from the study.

Study Protocol- The study protocol adheres to ethical standards, having obtained ethical clearance and informed consent from guardians or legal parents. The research unfolds in the Pediatric Intensive Care Unit at Career Medical College, Lucknow, employing a prospective cohort design with the enrollment of 155 patients. The patients are categorized into two groups: Group A representing Ventilator-Associated Pneumonia (VAP) and Group B representing Non-Ventilator-Associated Pneumonia (Non-VAP). The ventilators employed in the unit include Drager Evita 4 and Maquet Servo I, utilizing heated wire humidifiers with reusable circuits. Circuit and humidifier maintenance follows a protocol of chemical disinfection, with circuits changed every 72 hours or earlier if soiled.

Diagnosis and Criteria [Table 1]: The diagnosis of VAP relies on criteria provided by CDC.[17] Enrolled patients are daily assessed, and if they meet two or more VAP criteria, they undergo thorough investigations. Diagnostic criteria include radiological changes and a positive endotracheal aspirate semi-quantitative culture report.

Data Analysis- Statistical analysis is conducted using SPSS software (SPSS Inc., Chicago, IL, USA). Continuous variables are presented as mean (standard deviation) or range, while dichotomous

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variables are expressed as number/frequency. Analysis methods include Chi-square or Fisher's Exact test for dichotomous variables, Student t-test and Mann-Whitney U test for means comparison, and Spearman correlation with a 95% confidence interval. A significance threshold of $p < 0.05$ or 0.001 is applied.

RESULTS

Over the study period of three year from August 2020 to July 2023, a total of 210 children underwent mechanical ventilation in the PICU. These 210 children were assessed for eligibility for the present study. Out of these, 55 patients were excluded due to various reasons (Not giving consent, Intubated prior to admission in PICU etc.).

A total of 155 patients were therefore included in the study. Out of these 155 children, 78 developed VAP as shown in [Table 2 to 12].

Table 1: The clinical criteria for the diagnosis of VAP have been established by the NNIS and the CDC [17]

The criteria described may be used to diagnose vap in Children
Patients who are mechanically ventilated for more than or equal to 48 hours must have at least two abnormal chest radiographs and one of the following symptoms. In newborns less than one year, fresh or progressive and persistent infiltration, consolidation, cavitation, and/or pneumatoceles.
in patients without underlying pulmonary or cardiac disease (respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), one definitive chest radiograph is acceptable.
In addition to abnormal chest radiographs, a patient must exhibit at least one of the following symptoms: fever (>38°C) with no other known cause, leukopenia (<4,000) white blood cells [WBC]/mm3) or leukocytosis (≥12,000 WBC/mm3), and at least two of the following criteria: pulmonary eosinophilia, pulmonary eosinophilia, or pulmonary eosinophilia. New onset or worsening of cough, dyspnea, or tachypnea; rales or bronchial breath sounds; and worsening gas exchange (e.g., O2 desaturations [e.g., PaO2/FiO2 levels of ≤240], higher oxygen requirements, or increased ventilation demand).
Specific diagnostic criteria for VAP for infants ≤year of age and children >a and ≤12 years of age
1-year-old infants must exhibit deteriorating gas exchange (oxygen desaturations, increasing oxygen needs, or increased ventilator demand) and at least three of the following conditions: Temperature instability with no other recognised cause; newonset purulent sputum, change in sputum character, increased respiratory secretions, or increased suctioning needs; apnea, tachypnea, nasal flaring with retraction of chest wall, or grunting; wheezing, rales, or rhonchi; cough; and bradycardia (<100 beats/min) or tachycardia (>170 beats)
Children aged 1 to 12 must satisfy at least three of the following requirements: Fever (>38.4°C or >101.1°F) or hypothermia (37°C or 97.7°F) with no other recognized cause; leukopenia (4,000 WBC/mm3) or leukocytosis (15,000 WBC/mm3); new onset of purulent sputum, change in character of sputum, or increased respiratory secretions; rales or bronchial breath sounds; and worsening gas exchange

Table 2: Distribution of patients into groups

		n	**%**
VAP Group	Ventilator-Associated Pneumonia (VAP)	78	50.32
Non-VAP Group	Non-Ventilator-Associated Pneumonia (VAP)	77	49.68

Table 3: Comparison of frequencies of different age group in between VAP Group and Non-VAP Group

	VAP Group (n=78)		**Non-VAP Group (n=77)**		**Chi sq**	**p-Value**
	n	**%**	**n**	**%**		
<1 year	19	24.36	12	15.58	2.08	0.720
1-3 years	19	24.36	19	24.68		
4-6 years	20	25.64	22	28.57		
7-9 years	9	11.54	10	12.99		
10-12 years	11	14.10	14	18.18		

Table 4: Comparison of frequencies of gender in between VAP Group and Non-VAP Group

Gender	**VAP Group (n=78)**		**Non-VAP Group (n=77)**		**Chi sq**	**p-Value**
	n	**%**	**n**	**%**		
Male	45	57.69	52	67.53	1.78	0.182
Female	33	42.31	25	32.47		

Table 5: Comparison of frequencies of underweight in between VAP Group and Non- VAP Group

(Weight/Age)	**VAP Group (n=78)**		**Non-VAP Group (n=77)**		**Chi Sq**	**p-Value**
	n	**%**	**n**	**%**		
Above median	46	58.97	50	64.94	5.95	0.964
Between median to -1 SD	11	14.10	9	11.69		
Between -1 to -2 SD	8	10.26	7	9.09		
Between -2 to -3 SD	6	7.69	5	6.49		
Below <3 SD	7	8.97	6	7.79		

Table 6: Comparison of frequencies of reason for intubation in between VAP and non-VAP Group

Reason for Intubation	**VAP Group (n=78)**		**Non-VAP Group (n=77)**		**Chi sq.**	**p-Value**
	n	**%**	**n**	**%**		
Airway problem	46	58.97	57	74.03	4.92	0.086
Hypoxia	32	41.03	20	25.97		

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Hypoventilation	1	1.28	0	0.00		

Table 7: Comparison of frequencies of clinical attributes between VAP Group and Non-VAP Group

	Sign/symptoms	VAP Group (n=78)		Non-VAP Group (n=77)		Chi sq.	p-Value
		n	%	n	%		
1	Fever	60	76.92	14	18.18	51.26	<0.001
	Hypothermia	0	0.00	0	0.00	-	-
2	Leukopenia	0	0.00	0	0.00	-	-
	Leucocytosis	56	71.79	10	12.99	52.43	<0.001
3	New onset purulent sputum	57	73.08	1	1.30	82.21	<0.001
	Change in character of sputum	0	0.00	2	2.60	0.52	0.471
	Increased respiratory secretion	50	64.10	0	0.00	69.96	<0.001
	Increased suctioning requirement	50	64.10	0	0.00	69.96	<0.001
4	New onset cough	22	28.21	1	1.30	20.12	<0.001
	Worsening of cough	2	2.56	0	0.00	0.49	0.482
	Dyspnoea	0	0.00	0	0.00	-	-
	Apnoea	0	0.00	0	0.00	-	-
	Tachypnoea	0	0.00	0	0.00	-	-
5	Rales	0	0.00	2	2.60	-	-
	Bronchial breath sound	42	53.85	8	10.39	-	-
6	Worsening gas exchange	44	56.41	0	0.00	57.51	<0.001
	Increased oxygen requirement	36	46.15	0	0.00	43.74	<0.001
	Increased ventilator demand	0	0.00	0	0.00	-	-

Table 8: Culture positivity of endotracheal aspirate in VAP Group

		VAP Group (n=78)
	n	%
Culture positive	24	30.77
Culture negative	54	69.23

Table 9: Details of different organism in endotracheal aspirate of VAP Group

Organism in endotracheal aspirate	VAP Group (n =24)	
	n	%
Acinetobacter baumannii	19	79.17%
Acinetobacter johnsonii	1	4.17%
Acinetobacter jujuei	1	4.17%
Candid albicans	1	4.17%
Pseudomonas aeruiginosa	1	4.17%
Stenotrophomonas maltophilia	1	4.17%

Table 10: The frequencies of sensitivity of Acinetobacter in ET aspirate

Antibiotic Sensitivity Pattern of Acinetobacter Baumanii (n=24)		
	n	%
Cephalosporin resistant	14	58.33
Carbapenem resistant	10	41.67
Pan-resistant (Resistant to Colistin)	5	20.83

Table 11: Comparison of outcome in between VAP Group and Non-VAP Group

	VAP Group (n=78)		Non-VAP Group (n=77)		Chi sq.	p-value
	n	%	n	%		
Cured	65	83.33	71	92.21	5.54	0.625
Death	8	10.26	6	7.79		
LAMA	5	6.41	0	0.00		

Table 12: Mean total days of mechanical ventilation in between VAP Group and Non-VAP Group

	VAP Group (n=78)		Non-VAP Group (n=77)		t	p-Value
	Mean	±SD	Mean	±SD		
Total days of intubation	7.62	5.13	5.68	3.15	-2.83	0.005

Incidence Rate of VAP
Total number of VAP episodes = 78
Total number of days of mechanical ventilation of the 155 enrolled patients = 1340 days
Incidence rate = (Total number of VAP episodes / Total no. of days of MV) x
1000
= (78/1340) x 1000
=58.2 per 1000 patient ventilator days

DISCUSSION

VAP poses a significant challenge in PICUs, contributing to increased morbidity, mortality, and healthcare costs. This study focuses on understanding the various aspects of VAP in the PICU setting, including its association with demographic factors, risk factors, incidence, microbial etiology, and outcomes.

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Demographic Factors- The study begins by examining the association between the frequencies of gender and age groups in the VAP and Non-VAP groups. Gender distribution reveals a notable difference, with a higher percentage of males in the VAP group compared to the Non-VAP group. This aligns with the findings of previous studies, emphasizing the need to explore potential gender-specific susceptibilities to VAP.[18] Additionally, age distribution demonstrates variability, emphasizing the importance of considering age-related factors in VAP susceptibility. The higher incidence in infants corresponds with the literature, highlighting the vulnerability of this age group to respiratory infections.[18]

Malnutrition is a known risk factor for VAP, and this study assesses the association of different malnutrition levels between the VAP and Non-VAP groups. The analysis indicates that both groups are comparable in terms of malnutrition, with no significant differences based on weight/age ratio. This finding is consistent with the study by MA Safan et al., which identified malnutrition as a prevalent risk factor for VAP.

The study reports a relatively high incidence rate of VAP (52.8 per 1000 ventilator days) in comparison to other studies. The higher rate is attributed to factors such as a high patient load and insufficient enforcement of VAP prevention bundles. The comparison with studies like Jain V et al,[4] underscores the impact of variations in patient populations and preventive measures on reported VAP rates.

The study explores various risk factors for VAP, including the duration of mechanical ventilation (MV). The findings align with Awasthi S et al,[16] emphasizing that >4 days of MV is a significant risk factor for VAP. Re-intubation and the reasons for intubation are also examined, providing insights into factors influencing VAP development.

The microbial etiology of VAP is crucial for guiding appropriate treatment strategies. The study identifies Acinetobacter Baumannii and Pseudomonas aeruginosa as the primary causative organisms, consistent with the literature.[19,20] Understanding the prevalent pathogens aids in tailoring empirical antibiotic therapy.

Comparing outcomes between the VAP and Non-VAP groups, the study reveals a higher cure rate in the Non-VAP group, reinforcing the importance of preventive measures. Mortality rates, though higher in the VAP group, require careful interpretation due to the multifactorial nature of outcomes in critically ill patients.[21]

The association between the mean total days of intubation and VAP underscores the significance of minimizing the duration of intubation to mitigate the risk of VAP. Prolonged intubation is consistently identified as a risk factor in various studies.[16]

CONCLUSION

In this investigation, our primary objective was to elucidate the incidence of VAP among mechanically ventilated children in the PICU. The study unveiled a concerning incidence rate of VAP, standing at 58.2 cases per 1000 ventilator days. Among children diagnosed with VAP, microbial analysis from endotracheal aspirate cultures indicated a positive result in 30.77% of cases, Acinetobacter Baumanii emerged as the predominant organism responsible for VAP, and alarmingly, 20% of these isolates exhibited resistance to all tested antibiotics, including Carbapenem and Colistin. Regarding outcomes, the VAP group demonstrated a cure rate of 83.33%, whereas the Non-VAP group exhibited a higher cure rate at 92.21%.

Limitations: Despite these valuable findings, our study encountered several limitations that warrant consideration. The inclusion of patients solely from a single ICU impinges on the generalizability of our results. A larger sample size and a multicentric approach with heightened precision and accuracy are recommended to bolster the reliability of our interpretations. Additionally, the diagnosis of VAP relied on clinico-radiological criteria, which may introduce false positivity due to the overlap of signs and symptoms with routine conditions in prolonged mechanical ventilation. The utilization of non-bronchoscopic methods for microbiological isolation, particularly from ET aspirate, may imply tracheobronchial colonization rather than pneumonia.

In light of our study's revelations, several recommendations emerge. The high incidence of VAP underscores the pressing need for the strict implementation of VAP-bundle strategies in PICUs to mitigate its occurrence. Notably, a substantial proportion of microorganisms responsible for VAP exhibited multidrug resistance. Consequently, urgent attention is warranted to implement an 'Antibiotic Stewardship' program in PICUs, emphasizing judicious antibiotic use to combat the rise of multidrug-resistant pathogens.

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