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Evaluation of Ventilator-Associated Pneumonia Surveillance and Impact of VAP Care Bundle in Neonatal and Pediatric Intensive Care Unit of Punjab

Dr. Kiranjot Kaur Randhawa[1], Dr. Loveena Oberoi[2], Dr. Manmeet Kaur Sodhi[3], Dr. Sapna Batra[4]

[1]Senior Resident, Microbiology, Government Medical College, Amritsar, Punjab
[2]Professor and Head, Microbiology, Government Medical College, Amritsar, Punjab
[3]Professor and Head, Paediatrics, Government Medical College, Amritsar, Punjab
[4]Associate Professor, Microbiology, Government Medical College, Amritsar, Punjab

Abstract

Introduction: Ventilator-associated pneumonia (VAP) remains a significant cause of morbidity and mortality among critically ill neonates and children. Early diagnosis, microbiological surveillance, and implementation of care bundles are proven strategies to prevent VAP.

Objective: To conduct prospective surveillance of VAP, study microbial profiles with antibiotic resistance patterns, and evaluate the impact of VAP care bundle implementation in NICU and PICU patients.

Materials and Methods: A prospective interventional study was carried out at Government Medical College, Amritsar from January 2024 to February 2025 in three phases: pre-implementation, staff sensitization, and post-implementation. During the surveillance, the particulars of the patients including sociodemographic data, along with evolution of symptoms during hospitalization were recorded on a pre-designed proforma. The written informed consent was taken from all the patient's guardians participating in the study. Endotracheal aspirates were collected, processed, and antimicrobial susceptibility testing was done as per CLSI guidelines.

Statistical Analysis: For statistically significance, p value of less than 0.05 was considered statistically significant.

- Chi square Test (x2)= (O-E)2/E where O = observed and E = Expected
- P value (probability value)

Results: 160 ventilated patients were included. The VAP incidence rate decreased significantly from 48.46 to 37.6 per 1000 ventilator days after bundle implementation (p=0.0025). A significant decrease in Device Utilization Ratio was observed from 0.37 to 0.24. Gram-negative bacilli predominated, with Klebsiella spp., Acinetobacter spp., and Pseudomonas spp. as major isolates.

Conclusion: The structured implementation of a VAP prevention bundle significantly reduced the incidence rate. Continued training, surveillance, and antibiotic stewardship are essential to sustain outcomes.

Introduction

Healthcare-associated infections (HAIs) pose a serious burden on patient safety, with VAP being the second most common device-associated infection in neonatal and pediatric ICUs.

CDC defines Ventilator-associated pneumonia (VAP) as a pneumonia where the patient is on mechanical ventilation for > 2 consecutive calendar days on the date of event, with day of ventilator placement being Day 1* AND the ventilator was in place on the date of event or the day before. *If the ventilator was in place prior to inpatient admission, the ventilator day count begins with the admission date to the first inpatient location. [1]

Based on onset, VAP has been classified into Early and Late onset ventilator associated pneumonia. VAP occurring in the first four days of endotracheal intubation is called as early-onset VAP generally caused by pneumococcus, *Hemophilus influenzae*, methicillin susceptible *Staphylococcus aureus*(MSSA),etc. Ventilator-associated pneumonia which occurs after four days of mechanical ventilation is referred to as Late-onset VAP. Mostly caused by multidrug resistant hospital pathogens- *Pseudomonas aeruginosa, Acinetobacter baumannii, Escherichia coli*, *Klebsiella* and methicillin resistant *Staphylococcus aureus*(MRSA).[2,3]

The incidence rate of VAP in Asian countries have been reported on an average 10.8 per 1000 ventilator days.[2,3,4] The incidence is high in elderly and neonate patients, surgically treated and immunocompromised patients.[5,6,7] The crude mortality associated with pneumonia is 67.4% in India.[8]

The risk factors identified as independent risk factors for the development of VAP are tracheal intubation, bronchopulmonary dysplasia, low birth weight, premature infants, mechanical ventilation, transfusion, reintubation, enteral feeding, length of stay in the NICU, and parenteral nutrition.[9]

Due to immature immunity and longer ventilation, neonates and pediatric patients are the most vulnerable groups in hospital. [10] The present study was conducted to survey the incidence of VAP in pediatric ICU before and after care bundle implementation and to evaluate the impact of care bundle in ICU.

Materials and Methods

Study Design & Setting:

A prospective study was conducted in the Department of Microbiology, Government Medical College, Amritsar during the period of one year and 2 months (1st January 2024- 28th February 2025). Pediatric patients(including neonates from 0-28 days age) admitted in Pediatric and Neonatal Intensive care units were included in the study. The particulars of the patients including sociodemographic data, alongwith evolution of symptoms during hospitalization were recorded on a pre-designed proforma.The study Phases were:

- Phase 1: Pre-implementation surveillance (6 months)
- Phase 2: Staff sensitization (2 months)
- Phase 3: Post-implementation surveillance (6 months)

Surveillance data was collected in pre-formed performa in accordance with the guidelines given by CDC, in NICU & PICU patients mechanically ventilated for >48 hours with clinical and radiological criteria. Endotracheal aspirates were cultured on blood agar and MacConkey agar. Isolates were identified by standard microbiological techniques. Antibiotic susceptibility was determined by Kirby-Bauer disc diffusion.

Surveillance data was collected for VAP cases, which were included in study, based on the following defination[1]:-

1. Window Period:

The 7-day timeframe in which all criteria of the case definition must be met. It includes the date of the first positive case definition criteria and the 3 calendar days before and the 3 calendar days after[FIGURE 1].

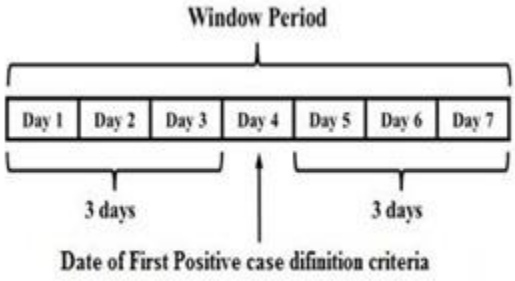

FIGURE 1

2. Date of Event:

The date when the first criteria used to meet the case definition occurs for the first time within the window period.

3. Present on Admission:

An infection with a date of event ≤ 2 calendar days after the hospital admission date (where the date of hospital admission is Day 1) is classified as present on admission. All VAP cases which on mechanical ventilation for >2 calendar days were included in the study[FIGURE 2].

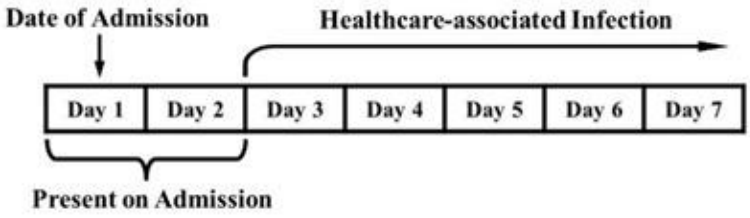

FIGURE 2

4. Event Timeframe:

A 14-calendar day timeframe (where the date of event = Day 1) during which a primary HAI event is considered to be ongoing and no new infections of that same primary HAI type are reported.

5. Ventilator day

Denominator data is calculated as the number of patients on ventilator in each ICU under surveillance, each day.

The record of the number of patients in the surveillance unit, who were on mechanical ventilator ,was maintained by the ICU staff.

6. Patient day

Denominator data is calculated as the total number of patients per day in the unit under surveillance.

7. VAP Rate

The VAP rate per 1000 ventilator days is calculated by dividing the number of VAPs by the number of ventilator days and multiplying the result by 1000 (ventilator days).

VAP Rate per 1000 ventilator days = $No.\ of\ VAPs/\ No.of\ Ventilator\ Days$ X 1000

8. Device Utilization Ratio

The Ventilator Utilization Ratio is calculated by dividing the number of ventilator days by the number of patient days.

DUR = $No.\ of\ Ventilator\ Days / No.\ of\ Patient\ Day$

The implementation of VAP care bundle was incorporated by various educational methods including presentations and lecture in ICU. The care bundle included were as follows:-[3]

1. Adherence to hand hygiene
2. Aseptic techniques of intubation
3. Elevation of head of the bed
4. Daily oral care with chlorhexidine 2% solution
5. Subglottic suctioning
6. Implementation of cuffed endotracheal tube.

Statistical Analysis:

The Statistical Package for Social Science (SPSS) software, manufactured by IBM in Chicago, USA, version 20.0, was used to do the final analysis after the data was entered into a Microsoft Excel spreadsheet. For statistically significance, p value of less than 0.05 was considered statistically significant.

Results

Out of 160 cases, pediatric patients were included in the study 98 patients in pre-implementation phase and 62 in post-implementation phase.

TABLE 1:- MONTH-WISE SURVEILLANCE

VARIABLES/MONTHS	TOTAL PATIENTS ON VENTILATOR	NUMBER OF VENTILATOR DAYS	CULTURE POSITIVE	DEVICE UTILISATION RATIO	RATE OF VAP(per 1000 ventilator days)
JANUARY 2024	24	192	10	0.53	52
FEBRUARY 2024	14	98	5	0.28	51.02
MARCH 2024	23	163	8	0.50	49
APRIL 2024	12	83	4	0.27	48.2
MAY 2024	8	64	3	0.19	46.87
JUNE 2024	17	136	8	0.38	58.8
SEPTEMBER 2024	9	54	2	0.23	37
OCTOBER 2024	23	142	5	0.30	35
NOVEMBER 2024	13	83	3	0.30	36
DECEMBER 2024	8	48	2	0.24	41.6
JANUARY 2025	4	24	1	0.23	41
FEBRUARY 2025	5	25	1	0.16	40

Highest VAP rate was observed in June 2024 followed by January 2024, in pre-implementation phase. Lowest VAP rate was observed in October 2024 followed by November 2024 in post-implementation phase.[TABLE 1]

TABLE 2: DISTRIBUTION OF VAP BASED ON AGE

AGE	VAP CASES IN PRE-IMPLEMENTATION PHASE	VAP CASES IN POST-IMPLEMENTATION PHASE
0-28 DAYS	**22(57.89%)**	**8(57.14%)**
1-12 MONTHS	**10(26.31%)**	**4(28.57%)**
>1 YEAR	**6(15.78%)**	**2(14.28%)**
MEAN AGE	**5.79 MONTHS**	**5.57 MONTHS**

Most cases in pre-implementation phase belonged to age group 0-28 days, with 57.89%(22/38), followed by the age group 1-12 months with 26.31%(10/38) cases. Most cases in post-implementation phase belonged to age group 0-28 days with 57.14%(8/14), followed by age group 1-12 months with 28.57%(4/14) cases.[TABLE 2]

Total Ventilator days: Total ventilator days in pre-implementation phase were 784 which dropped to 372 in post-implementation phase.(p=0.0015)[TABLE 3]

VAP incidence rate: A total of 52 patients(38 in pre-implementation phase and 14 in post-implementation phase) developed VAP out of 160 patients included in the study. The VAP incidence rate decreased from 48.46 to 37.6 per 1000 ventilator days. (p=0.00025)[TABLE 3]

Device Utilisation Ratio: The Device Utilisation ration reduced from 0.37 in pre-implementation phase to 0.24 in post-implementation phase. These findings were statistically significant.(p=0.005)[TABLE 3]

TABLE 3:- COMPARISON OF PARAMETERS IN THE PHASES

PARAMETER	PRE-IMPLEMENTATION PHASE	POST-IMPLEMENTATION PHASE	P-VALUE
MALE	21	9	0.28
FEMALES	17	5	0.51
NUMBER OF PATIENTS ON VENTILATOR	98	62	0.0003
TOTAL VENTILATOR DAYS	784	372	0.0015
NUMBER OF PATIENT DAYS	2100	1552	0.0026
DEVICE UTILISATION RATIO	0.37	0.24	0.005

CULTURE POSITIVITY	38.77%	22.58%	0.036
VAP INCIDENCE RATE	48.46	37.6	0.0025

Mechanical ventilator days:-

Maximum VAP cases were observed with mechanical ventilator days of > 5 days. [TABLE 4]

TABLE 4:- DISTRIBUTION OF VAP BASED ON MECHANICAL VENTILATOR DAYS

MECHANICAL VENTILATOR DAYS	NUMBER OF VAP IN PRE-IMPLEMENTATION PHASE	NUMBER OF VAP IN POST-IMPLEMENTATION PHASE
3 DAYS	8/30	3/19
3-5 DAYS	10/32	4/20
>5 DAYS	20/36	7/23

Microbiological analysis: The isolates obtained in pre-implementation phase were *Klebsiella* species(47.36%), followed by *Acinetobacter* species(34.21%), *Escherichia coli* (7.89%) *Pseudomonas* species(7.89%) and CONS(2.63%). The isolates obtained in post-implementation phase were *Klebsiella* species and *Acinetobacter* species being equally predominant with 35.71% cases followed by *Pseudomonas* species(21.42%) and *Escherichia coli*(7.14%).[TABLE 5]

TABLE 5:-VAP CASES BASED ON BACTERIAL ISOLATES

ORGANISM ISOLATED	VAP CASES IN PRE-IMPLEMENTATION PHASE	VAP CASES IN POST-IMPLEMENTATION PHASE
Klebsiella species	18(47.36%)	5(35.71%)
Acinetobacter species	13(34.21%)	5(35.71%)
Escherichia coli	3(7.89%)	1(7.14%)
Pseudomonas species	3(7.89%)	3(21.42%)
CONS	1(2.63%)	0
P value	0.002	0.37011

TABLE 6: ANTIMICROBIAL RESISTANCE PROFILE OF MICRO-ORGANISMS AGAINST COMMONLY USED ANTIBIOTICS

ANTIMICROBIALS	PRE-IMPLEMENTATION PHASE	POST-IMPLEMENTATION PHASE
Amikacin	24(63.15%)	10(71.42%)
Ciprofloxacin	31(81.57%)	8(57.14%)
Gentamycin	23(60.52%)	9(64.28%)

Meropenem	23(60.52%)	4(28.57%)
Piperacillin-Tazobactam	28(73.68%)	7(50%)
Cefepime	26(66.15%)	9(64.28%)
Aztreonam	13(10.15%)	3(15.78%)

Maximum resistance was seen with ciprofloxacin followed by piperacillin-tazobactam, cefepime, amikacin, gentamycin, meropenem and aztreonam among isolates of pre-implementation phase. The isolates in post-implementation phase showed maximum resistance to amikacin followed by gentamycin, cefepime, ciprofloxacins, meropenem and aztreonam.[TABLE 6]

Discussion

Ventilator Associated Pneumonia have been a rising global health care concern especially in neonates leading to increased morbidity and mortality in the hospitalised patients particularly in intensive care units. Despite advancements in diagnostic techniques and antimicrobial therapies, the burden of VAP persists, especially in resource-limited settings where infection control practices may vary. The mortality due to VAP can be decreased by implementation of a set of care bundles in the intensive care units of the hospitals by the health care workers.

Our data showed that neonates (aged 0–28 days) consistently accounted for over 57% of VAP cases, both before and after bundle implementation[TABLE 2]. This highlights their heightened vulnerability due to multiple physiological and clinical factors. Vijay et al. also found that neonates and infants had the highest VAP incidence in their pediatric ICU cohort. Their findings were consistent with ours, attributing the vulnerability to factors like prolonged ventilation and frequent invasive interventions in this age group.[11] Tripathi et al. conducted a detailed study on neonatal VAP in a tertiary NICU. It was noted that neonates—especially preterm infants—had immature immune systems, reduced mucociliary clearance, and higher rates of ventilator dependency, all of which contributed to increased infection risk.[12] These findings support the need for early identification of risk factors and prompt implementation of VAP bundles, particularly for neonates.

Male children represented a higher proportion of VAP cases in both phases—55.26% before and 64.28% after intervention[TABLE 3]. While the difference was not statistically significant, the trend of male predominance is worth noting. A study by Liu et al. explored the gender-based differences in neonatal infections and found that male neonates had a higher susceptibility to infections, including VAP. The authors proposed potential reasons such as differences in immune responses and hormonal influences, particularly testosterone-mediated suppression of immunity during early neonatal life.[13]

During the surveillance, it was observed that the total number of ventilator days decreased from 784 to 372 (p=0.0015:statistically significant) indicating effectiveness of breathing techniques and early extubation protocols[TABLE 3]. This decrease is partly a result of better critical care procedures, daily sedation vacations, and readiness-to-wean evaluations. Kumar et al. observed a similar pattern and showed that regular use of VAP prevention techniques resulted in a significant decrease in ventilation time.[14]

The Device Utilization Ratio, is an essential indicator of ventilation reliance, dropped significantly from 0.37 to 0.24 (p=0.005)[TABLE 3]. A lower DUR suggests a decreased requirement for artificial ventilation, which is essential for avoiding VAP. Higher DUR was linked by Dutta et al. to an increased risk of VAP, especially in immunocompromised children and low-birth-weight neonates..[15]

The study had a crucial finding of the correlation between ventilator duration and the incidence of VAP.

There was no statistically significant (p-0.051) decrease[TABLE 4].Patients with >5 days of mechanical ventilator were observed to have developed VAP maximally. The post-implementation phase demonstrated decreased number of VAP cases due to effective implementation of VAP care bundle in the ICU. Study conducted by Rajashekhar et al. strongly confirms that the longer a patient remains intubated on a ventilator, the greater the chances of developing pneumonia in the lungs. In study, patients who developed VAP had been on ventilators for twice as long as those who didn't. This finding underlines the importance of early weaning and strict VAP prevention bundles.[16]

The incidence of VAP decreased significantly, from 48.46 to 37.6 per 1000 ventilator days (p=0.00025, statistically significant)[TABLE 3].The improvement after the intervention demonstrates that systematic, evidence-based approaches can provide quantifiable results, even though the incidence is still high. The components of the VAP care bundle implemented in implementation phase included strict hand hygiene, elevation of the head of the bed, daily oral care , aseptic suctioning techniques, subglottic suctioning, and the use of cuffed endotracheal tubes. Following the implementation of bundles with frequent inspections for compliance, Sharma et al. and Choudhary et al. have both found comparable success in pediatric intensive care units in India.[17,18] Our pre-implementation VAP rate is quite comparable to a research by Vijay et al. carried out at a tertiary pediatric intensive care unit in South India which reported VAP incidence of 41 per 1000 ventilator days . Their investigation strengthened the comparability of findings by using CDC criteria for VAP diagnosis and a similar patient group.[11] These comparisons not only validate our findings within the Indian context but also highlight the urgent need for sustained surveillance and aggressive prevention efforts across pediatric ICUs.

Across both phases of our study, Gram-negative bacilli dominated the microbial profile. *Klebsiella spp.* (47.36%) and *Acinetobacter spp.* (34.21%) were most prevalent pre-intervention followed by *Escherichia coli*(7.89%), *Pseudomonas*(7.89%) and CONS(2.63%).In post-implementation phase, *Klebsiella* (35.71%) and *Acinetobacter*(35.71%) were both predominant followed by *Pseudomonas*(21.42%) and *Escherichia coli*(7.14%)[TABLE 5]. There was no significant decrease (p-0.370). Sangale et al. investigated microbial trends in a pediatric oncology ICU and reported a similar dominance of Gram-negative organisms—particularly *Klebsiella* and *Acinetobacter.* These pathogens were associated with prolonged hospital stays and invasive procedures in immunocompromised children.[10] Vijay et al. also reported that Gram-negative bacilli, especially *Klebsiella* and *Pseudomonas*, were the most common organisms in pediatric ICUs. Their study linked these pathogens to biofilm formation and high resistance to conventional antibiotics.[11] These consistent trends underscore the critical need for early, culture-based identification and appropriate empiric therapy in managing VAP.

In the pre-implementation phase, highest resistance was observed against ciprofloxacin(81.57%), amikacin(63.15%) and meropenem(60.52%). In the post-implementation phase, although amikacin resistance increased slightly to 71.42%, resistance to ciprofloxacin(57.14%) and meropenem(28.57%) showed a notable decline[TABLE 6].These findings highlight the persistent issue of multidrug resistance in Indian ICUs. Sangale et al, in their pediatric oncology study, also reported high resistance to ciprofloxacin, cefepime and amikacin among *Klebsiella* and *Acinetobacter* isolates.[10] Vijay et al observed a similar trend, where over 70% of Gram negative isolates in PICU were resistant to third-generation cephalosporins and flouroquinolones.[11] The slight reduction in resistance to some antibiotics in our post-implementation phase may reflect improved empirical antibiotic choices based on culture reports, reduced duration of empirical broad spectrum antibiotic use, and reinforcement of antibiotic stewardship practices as part of the bundle implementation.

Overall, the surveillance data suggests a marked decline in VAP rates is observed from September 2024 onwards, with October and November showing rates as low as 35–36 per 1000 ventilator days, accompanied by lower device utilization ratios (0.23–0.30)[TABLE 1].High early-year VAP burden likely due to increased patient load and higher ventilator usage, gradual improvement mid-year possibly linked to enhanced adherence to prevention protocols, sustained reduction post-September, likely reflecting the positive outcome of VAP care bundle sensitization and monitoring. Despite some fluctuations, the general trend shows a reduction in VAP incidence, aligning with global efforts for VAP rate reduction in ICUs through standardized care practices. These findings resonate with multicentric studies from developing countries, where implementation of low-cost preventive bundles significantly reduced VAP incidence (Rosenthal et al., 2012)[19]. Moreover, such outcomes underscore the critical role of continuous staff education, surveillance, and feedback mechanisms in maintaining and improving infection control standards in ICUs

This research adds meaningful evidence to the global push for VAP prevention, especially in resource-limited settings like ours, where the challenges of infection control are even greater. It also highlights the need to keep training healthcare workers, regularly check adherence to protocols, and involve institutional leadership in building a culture of safety.

Conclusion

This study demonstrates the importance of continuous surveillance and bundled prevention strategies in reducing VAP rates in NICU and PICU patients. Multidisciplinary collaboration, regular training, and microbiological monitoring are vital for sustainable infection control.

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