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Effectiveness of ventilator bundle in preventing ventilator-associated pneumonia, A quasi-experimental study

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Abstract

Background: Ventilator-associated pneumonia (VAP) is a leading cause of morbidity and mortality in intensive care units. This study evaluates the effectiveness of a ventilator bundle in preventing VAP among patients on mechanical ventilation.

Materials and Methods: A quasi-experimental study was conducted over one year in the Department of Pulmonary Medicine, Sambhram Institute of Medical Sciences, Kolar, fifty patients were divided into experimental (n=25) and control (n=25) groups. The experimental group received the ventilator bundle, while the control group received routine care. VAP was assessed using the modified Clinical Pulmonary Infection Score.

Results: The experimental group exhibited a significant reduction in VAP severity, with 28% showing no infection and only 12% experiencing severe infection compared to 0% and 68% in the control group, respectively. Statistical analysis revealed a significant difference in post-test scores ($p \leq 0.05$), confirming the effectiveness of the ventilator bundle.

Conclusion: The ventilator bundle significantly reduced the incidence and severity of VAP. Implementing such evidence-based interventions in ICU settings can enhance patient outcomes and reduce healthcare-associated infections.

Keywords: Ventilator-associated pneumonia, ventilator bundle, ICU, mechanical ventilation, infection prevention

Introduction

Ventilator-associated pneumonia (VAP) is a significant nosocomial infection that occurs in patients receiving mechanical ventilation for more than 48 hours through an endotracheal or tracheostomy tube. It is a subtype of hospital-acquired pneumonia (HAP) and poses a substantial challenge due to its high incidence and associated morbidity and mortality rates. Epidemiological studies indicate that VAP affects approximately 10–20% of mechanically ventilated patients, with an incidence rate of 5–40 cases per 1,000 ventilator days in intensive care units (ICUs) [1]. The risk of developing VAP increases with the duration of mechanical ventilation, with the highest risk occurring during the first five days [2].

The pathogenesis of VAP involves the invasion of the lower respiratory tract by pathogenic microorganisms, facilitated by aspiration of contaminated secretions, biofilm formation on endotracheal tubes, or hematogenous spread [3]. Common causative agents include Gram-negative bacteria such as *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, as well as Gram-positive bacteria like *Staphylococcus aureus* [4]. Predisposing factors include prolonged mechanical ventilation, inadequate hand hygiene, prior antibiotic use, and underlying comorbidities [5].

Effective management of VAP requires a multifaceted approach involving timely diagnosis, empirical antibiotic therapy, and supportive care. However, prevention is key, and evidence-based interventions, collectively termed the ventilator bundle, have been developed to reduce the incidence of VAP [6]. The ventilator bundle is a set of evidence-based practices implemented collectively to improve patient outcomes. Key components typically include maintaining head-of-bed elevation at 30–45 degrees, daily sedation vacations, peptic ulcer prophylaxis, deep venous thrombosis prophylaxis, and regular oral care with chlorhexidine [7]. Some adaptations of the bundle have also included subglottic secretion drainage, appropriate endotracheal tube cuff pressure, and early extubating strategies to further

mitigate risks [8, 9].

Studies have shown that consistent implementation of the ventilator bundle can significantly reduce the incidence of VAP, lower healthcare costs, and improve overall patient survival rates [10]. Despite this, challenges remain in ensuring adherence to the bundle across varying clinical settings, emphasizing the need for regular training and reinforcement of bundle compliance among healthcare staff [11].

This study investigates the impact of the ventilator bundle on the prevention of VAP among patients on mechanical ventilation.

Materials and Methodology

This study employed a quantitative evaluative approach to assess the effectiveness of a ventilator bundle on the prevention of ventilator-associated pneumonia (VAP) among patients on mechanical ventilation. The research design was a quasi-experimental post-test-only design. The population for this study comprised patients on mechanical ventilation admitted to the ICU of Department of Pulmonary Medicine, Sambhram Institute of Medical Sciences, Kolar, the study was conducted over a one-year period, i.e., from November 2020 to October 2021.

The sample included 50 patients on mechanical ventilators, with 25 patients each assigned to the experimental and control groups. Participants were selected using non-probability convenience sampling based on inclusion and exclusion criteria. Inclusion criteria were patients aged 20–60 years, both genders, and those on mechanical ventilation for less than 24 hours. Patients already diagnosed with fever, pneumonia, acute respiratory distress syndrome, or those intubated externally were excluded.

Ventilator bundle comprising of head-of-bed elevation to 30–45 degrees, closed suctioning, and position changes

every three hours were named as independent variables and incidence of VAP as measured using the modified Clinical Pulmonary Infection Score (CPIS) was the dependent variable.

Formal permissions were obtained from the hospital management. Ethical committee approval was taken from the institution’s ethical committee board. An informed verbal consent was acquired from caregivers. The experimental group received the ventilator bundle interventions, while the control group received standard care. Post-test assessments for both groups were conducted on the fourth day using CPIS.

Data were analyzed using descriptive and inferential statistics. Frequency and percentages were used to describe demographic variables. Mean and standard deviation measured VAP scores. The effectiveness of the ventilator bundle was analyzed using an unpaired t-test, and the association between demographic variables and VAP was assessed using the chi-square test.

Results

The findings of this study highlight the significant effectiveness of the ventilator bundle in preventing ventilator-associated pneumonia (VAP) among patients on mechanical ventilation. The experimental group demonstrated notably lower infection rates compared to the control group, with a substantial reduction in severe infections. While only 12% of patients in the experimental group experienced severe infections, the control group had 68% of patients in this category, indicating that the intervention was highly impactful in mitigating the severity of VAP. The higher proportion of patients with no infection or mild infection in the experimental group further underscores the success of the bundle in reducing VAP incidence.

Table 1: Distribution of Patients According to Their Demographic Variables

Demographic Variable		Experimental Group (n = 25)	Control Group (n = 25)
Age (in years)	20-30 years	8 (32%)	3 (12%)
	31-40 years	6 (24%)	5 (20%)
	41-50 years	5 (20%)	9 (36%)
	51-60 years	6 (24%)	8 (32%)
gender	Males	17 (68%)	18 (72%)
	Females	8 (32%)	7 (28%)
Reason for mechanical ventilation	CNS Disease	12 (48%)	8 (32%)
	Cardiac Disease	5 (20%)	4 (16%)
	Renal Disease	3 (12%)	5 (20%)
	Poisoning	4 (16%)	5 (20%)
	Others	1 (4%)	3 (12%)
Frequency of suctioning	2nd hourly	15 (60%)	8 (32%)
	3rd hourly	10 (40%)	9 (36%)
	4th hourly	0	8 (32%)
History of smoking	Yes	12 (48%)	14 (56%)
	No	13 (52%)	11 (44%)

The mean post-test scores and their statistical comparison provide robust evidence of the intervention's efficacy. The experimental group's mean score (1.6 ± 0.98) was significantly lower than the control group's (3.2 ± 1.70), as demonstrated by the t-value of 6.45, which exceeded the critical value at $p \leq 0.05$. This difference reflects the consistent implementation of evidence-based practices, such as head-of-bed elevation, regular suctioning, and position

changes, which likely disrupted the pathophysiological mechanisms contributing to VAP. Additionally, the absence of significant associations between demographic variables and VAP outcomes suggests that the effectiveness of the ventilator bundle was not influenced by age, gender, smoking history, or frequency of suctioning. This highlights the universal applicability of the bundle across diverse patient profiles.

Table 2: Post-Test Scores of Ventilator-Associated Pneumonia (VAP) in Experimental and Control Groups

Score	Experimental Group (n = 25)	Control Group (n = 25)
No Infection (0)	7 (28%)	0 (0%)
Mild Infection (1–2)	15 (60%)	8 (32%)
Severe Infection (3–5)	3 (12%)	17 (68%)

Table 3: Mean, Standard Deviation, and Mean Percentage of Post-Test Scores to compare efficacy of ventilator bundle

Group	Mean	SD	Mean%	Difference in Mean%	t-value	Table Value
Experimental (n=25)	1.7	0.89	28	35	6.54 (2.20
Control (n = 25)	3.3	1.71	61			

Discussion

Ventilator-associated pneumonia (VAP) is a prevalent and serious complication among patients on mechanical ventilation, contributing to increased morbidity, mortality, and healthcare costs. This study was undertaken to evaluate the effectiveness of a ventilator bundle—a set of evidence-based interventions—in reducing VAP incidence in a tertiary care setting.

The findings of this study align with similar research demonstrating the ventilator bundle's effectiveness. For example, a study by Resort *et al.* [11] reported that implementing ventilator bundles reduced VAP incidence by 45%, a result consistent with the significant reduction in severe infections observed in the experimental group in this study. Similarly, Blot *et al.* [10] emphasized that head-of-bed elevation and regular oral care significantly lowered VAP rates, which were key components in this study's intervention. A meta-analysis by Zegers *et al.* [12] also highlighted that ventilator bundles, when implemented consistently, led to significant reductions in ICU mortality and length of stay.

In contrast, studies such as Bouadma *et al.* [13] found variability in outcomes based on staff adherence, highlighting challenges in consistent implementation. Kalanuria *et al.* [5] emphasized that variations in VAP incidence can also arise due to differences in diagnostic criteria, which could explain discrepancies between studies. Unlike the findings of Kollef *et al.* [14], which identified gender and smoking as significant risk factors, this study found no association between these demographic variables and VAP outcomes.

One notable difference in this study is the higher proportion of mild infections in the experimental group compared to other studies, where complete elimination of infections was more frequently achieved. This could be attributed to differences in healthcare infrastructure, staffing ratios, or the duration of mechanical ventilation. Additionally, a systematic review by Lambert *et al.* [15] suggested that the addition of subglottic secretion drainage to ventilator bundles may further reduce infection rates, which was not included in this study's intervention.

Conclusion

This study demonstrates the significant effectiveness of the ventilator bundle in reducing ventilator-associated pneumonia (VAP) among patients on mechanical ventilation. The intervention led to a marked decrease in severe infections and improved patient outcomes in the experimental group compared to the control group. These findings emphasize the importance of implementing evidence-based practices in ICU settings to enhance patient safety and reduce morbidity. However, variations in

outcomes suggest a need for further research into patient-specific factors and adherence strategies. Standardizing ventilator bundle practices can play a pivotal role in optimizing healthcare delivery and minimizing VAP incidence globally.

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Conflicts of Interest

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

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