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Original Article

Educational technology in the implementation of measures to prevent ventilator-associated pneumonia

Tecnologia educativa para implementação de medidas de prevenção de pneumonia associada à ventilação mecânica
Tecnología educativa en la implementación de medidas de prevención de neumonía asociada a ventilación mecánica

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Corresponding author:
E-mail: teixeira.silvalorena@gmail.com
Address: Farquar Avenue, 2986. Edifício Rio Jamari, Curvo III, Pedrinhas, Porto Velho, Rondônia, Brazil.

Lorena Teixeira da Silva[1]
Mitzy Tannia Reichembach Danski[1]
Leticia Pontes[1]
Rosa Maria Ferreira de Almeida[2]
Heric Maia Gomes[1]
Karina Pinheiro Teixeira dos Reis[1]
Rafaele Oliveira Bonfim[3]

[1]Federal University of Paraná, Curitiba, Paraná, Brazil.
[2]Federal University of Rondônia, Porto Velho, Rondônia, Brazil.
[3]Federal University of São Paulo, Ribeirão Preto, São Paulo, Brazil.

ABSTRACT

Background and Objectives: Ventilator-associated pneumonia (VAP) is associated with high mortality rates, increased length of hospital stay, and higher costs. Implementing bundles of measures is recommended to reduce the incidence of VAP; however, a lack of adequate training is a barrier to implementing these measures. This study aims to evaluate the effect of educational technologies on the implementation of a VAP prevention bundle among a multidisciplinary team in an adult ICU. **Methods:** This is a before-and-after experimental study evaluating a multidisciplinary educational intervention with the implementation of the VAP bundle in an adult ICU, conducted from June 2023 to February 2024. The study was organized into three phases: phase I pre-intervention, phase II educational intervention, and phase III post-intervention. **Results:** 320 assessments of adherence to VAP prevention measures were conducted, and 34 ICU professionals participated in the educational activities. Following the intervention, there was a significant increase in overall adherence to the package of measures (from 22.6% to 43.3%, P<0.001). A reduction in the incidence density rate (ID) of VAP was identified after the intervention (from 12.9 to 9.8 per thousand days of mechanical ventilation).**Conclusion:** Educational interventions positively impact adherence to the set of measures. The knowledge gained during the study interventions was applied in patient care practice, resulting in a reduction in VAP ID in the analyzed scenario.

Keywords: *Intensive Care Units. Pneumonia Ventilator Associated. Patient Care Bundles. Evidence-Based Nursing. Biomedical Technology.*

RESUMO

Justificativa e Objetivos: As pneumonias associadas à ventilação mecânica (PAV) estão relacionadas a altas taxas de mortalidade, aumento de dias de internação e elevação de custos. A implementação de conjuntos de medidas é recomendada para diminuir a incidência de PAV; contudo, a falta de treinamento adequado é uma barreira para a implementação dessas medidas. O presente estudo tem o objetivo de avaliar o efeito de tecnologias educativas na implementação de *bundle* de prevenção de PAV junto à equipe multiprofissional em UTI Adulto. **Métodos:** Trata-se de um estudo experimental do tipo antes e depois, que avalia uma intervenção educativa multiprofissional com a implementação do *bundle* de PAV em uma UTI adulta, realizado de junho de 2023 a fevereiro de 2024. O estudo foi organizado em três fases: fase I de pré-intervenção, fase II de intervenção educativa e fase III de pós-intervenção. **Resultados**: Foram realizadas 320 avaliações de adesão às medidas de prevenção de PAV, e 34 profissionais da UTI participaram das atividades educativas. Após a intervenção, houve um aumento significativo na adesão total do pacote de medidas (de 22,6% para 43,3%, P<0,001). Foi identificada uma redução da taxa de densidade de incidência (DI) de PAV após a intervenção (de 12,9 para 9,8 por mil dias de ventilação mecânica). **Conclusão:** As intervenções educacionais impactam positivamente a adesão ao conjunto de medidas. O conhecimento obtido durante a realização das intervenções do estudo foi aplicado na prática de cuidado ao paciente, o que resultou na redução da DI de PAV no cenário analisado.

Descritores: *Unidade de Terapia Intensiva. Pneumonia Associada à Ventilação Mecânica. Pacotes de Assistência ao Paciente. Enfermagem Baseada em Evidências. Tecnologia em Saúde.*

RESUMEN

Justificación y Objetivos: La neumonía asociada a la ventilación mecánica (NAV) se asocia con altas tasas de mortalidad, mayor duración de la estancia hospitalaria y mayores costos. Se recomienda implementar paquetes de medidas para reducir la incidencia de NAV; sin embargo, la falta de capacitación adecuada es una barrera para la implementación de estas medidas. Este estudio tiene como objetivo evaluar el efecto de las tecnologías educativas en la implementación de un paquete de prevención de NAV entre un equipo multidisciplinario en una UCI de adultos. **Métodos:** Este es un estudio experimental de antes y después que evalúa una intervención educativa multidisciplinaria con la implementación del paquete de NAV en una UCI de adultos, realizado de junio de 2023 a febrero de 2024. El estudio se organizó en tres fases: fase I preintervención, fase II intervención educativa y fase III postintervención. **Resultados:** Se realizaron 320 evaluaciones de adherencia a las medidas de prevención de NAV y 34 profesionales de la UCI participaron en las actividades educativas. Después de la intervención, hubo un aumento significativo en la adherencia general al paquete de medidas (del 22,6% al 43,3%, P < 0,001). Se identificó una reducción en la tasa de densidad de incidencia (ID) de NAVM tras la intervención (de 12,9 a 9,8 por cada mil días de ventilación mecánica). **Conclusión:** Las intervenciones educativas influyen positivamente en la adherencia al conjunto de medidas. Los conocimientos adquiridos durante las intervenciones del estudio se aplicaron en la práctica asistencial, lo que resultó en una reducción de la ID de NAVM en el escenario analizado.

Palabras Clave : *Unidades de Cuidados Intensivos. Neumonía Asociada al Ventilador. Paquetes de Atención al Paciente. Enfermería Basada en la Evidencia. Tecnología Biomédica.*

INTRODUCTION

Healthcare-associated infections (HAIs) are a major public health problem, impacting morbidity and mortality rates, healthcare costs, and the quality of healthcare services.[1]

Ventilator-associated pneumonia (VAP) is among the most common HAIs, potentially accounting for more than 29% of identified HAIs.[2] VAP is considered to be present when pneumonia begins after 48 hours of invasive ventilation use. To identify this infection, different methods are used, such as symptom assessment, imaging exams, laboratory and microbiological tests, and analysis of respiratory changes.[3]

A literature review presenting studies from various origins, including South America, North America, Asia, and Europe, shows incidence rates of VAP that ranged from 7 to 43 per thousand days of mechanical ventilation, reflecting mortality rates of up to 66.9%.[4] The occurrence of these infections is related to increased length of hospital stays and higher hospitalization costs, which can reach more than 2 times the usual cost.[5,6]

In this context, both international and national guidelines recommend the adoption of different types of technologies, continuing education, and epidemiological surveillance based on indicators for the prevention of HAIs.[7,8] The implementation of the practice of sets of measures, commonly called bundles of measures, is recommended, and can considerably reduce the incidence of HAIs.[9,10] However, lack of knowledge or adequate training is cited as a barrier to the implementation of prevention measures. of VAP.[11]

Therefore, the present study aims to evaluate the effect of educational technologies in the implementation of a VAP prevention bundle with the multidisciplinary team in the Adult ICU of a public hospital in Porto Velho – RO, Brazil.

METHODS

This is an experimental before-and-after study of an educational intervention with a multidisciplinary team, implementing the VAP bundle in an Adult ICU from June 2023 to February 2024. The study was conducted in a seven-bed Adult ICU in a public hospital located in the state of Rondônia, in the municipality of Porto Velho. The main demand for care at this institution is for tropical and infectious diseases.

This study was carried out in three phases: Phase I - pre-intervention (conducted from June to September 2023), Phase II - intervention (educational intervention during the month of October 2023) and Phase III - post-intervention (November 2023 to February 2024). The study has an experimental design, encompassing a group of repeated measures evaluated before and after the intervention in an ICU unit.

Phases I and III comprised the collection of data regarding the incidence density (ID) of ventilator-associated pneumonia (VAP) and adherence rate to the study site bundle. The bundle items were evaluated in all beds occupied by mechanically ventilated patients admitted to the unit during phases I and III. The adherence rate to the bundle measures was observed through the following strategies: Oral hygiene: assessed by verifying proper checking of the nursing prescription; head elevation: direct observation of the angle at which the patient was positioned in bed; daily sedation reduction: verification of the concentration and flow rate of sedative medications offered to the patient through evaluation of the medical prescription and fluid balance records; verification of extubation possibility: performed through evaluation of the medical prescription and the record in the physiotherapist's clinical progress notes in the electronic medical record; cuff pressure measurement 20-30 cm H2O: verified in the patient's electronic medical record through the progress notes recorded by the physiotherapist; Maintenance of the mechanical ventilation system: direct observation of the characteristics of the ventilation circuit, including the barrier filter and other system elements. Adherence to the bundle (all measures simultaneously) was considered when all items comprising the package of measures were performed simultaneously within 24 hours of care for the respective patient evaluated. The DI of phase I (pre-intervention) and III (post-intervention) was calculated using data provided by the Infection Control Service of the co-participating institution.

In phase II (intervention), the VAP prevention bundle was presented to the adult ICU multidisciplinary team through an educational strategy, using educational technologies in the expository-dialogue class model with the aid of videos from the IRASTIS website.[12] The activities were conducted for approximately 45 minutes and carried out during the respective work shifts of the professionals and addressed the following topics: what is the VAP prevention measures package; importance of implementing the measures package; the importance of the multidisciplinary team in VAP prevention; This study presented adherence rates to VAP prevention measures and VAP Incidence Density (ID) identified before the intervention (Phase I).

All healthcare professionals working in the unit during Phases I and II were invited to participate in the intervention. Professionals on vacation, leave, or absence, and professionals who did not attend the educational intervention meetings were excluded from this study. There were no changes in the professionals working in the unit during the research. The professionals participating in the study were those

responsible for the application and recording of one or more evaluated prevention measures; however, the data collection was performed by the principal investigator.

The bundle presented was developed based on national recommendations and guidelines.[8] The bundle consisted of a package of six measures: Regular oral hygiene in patients using invasive ventilation; elevation of the head of the bed, maintaining it between 30° and 45°; daily reduction of sedation; daily assessment of extubation feasibility; assessment and maintenance of cuff pressure (endotracheal tube balloon) ensuring a pressure of 20 to 30 cmH2O; and maintenance of the invasive ventilation system according to recommended protocols.

The statistical analysis of the data was performed descriptively regarding the incidence density (ID) of VAP and adherence rate to the bundle. For the comparison of adherence rates, the bundle measures were obtained in the pre- and post-intervention phases, and the data were analyzed using the Jamovi project software (version 2.6), using the McNemar test. This test is indicated for comparing proportions of continuous variables with two independent groups. The analysis was conducted with a significance level of 5% and a confidence interval of 95%. In the proposed study, the intervention does not function as the predictor variable, as it is applied to all study subjects. Thus, the predictor variable will be time, evaluated at two points in time: before and after the intervention. Among other things, the justification for conducting an experimental design study is the existence of substantial evidence regarding the benefits of certain interventions, making it unethical to create a control group that does not receive the intervention.

The ethical principles established by Resolutions No. 466/2012 and 510/2016 of the National Health Council were duly followed. The related project received approval from the partner institution and was duly approved by the Research Ethics Committee of the Federal University of Paraná on 05/31/2023, under CAAE: 67757923.7.0000.0102 and Opinion No. 6.092.823.

RESULTS

320 assessments of adherence to VAP prevention measures were carried out, with 186 assessments in phase I (pre-intervention) and 134 assessments in phase III (post-intervention) performed at the study site. In phase II (intervention), 34 professionals from the ICU multidisciplinary team participated.

Regarding the profile of patients using mechanical ventilation admitted to the unit during the study, a majority were male, with a mean age of 46 years (SD ± 15 years), and pulmonary tuberculosis stands out as the most frequent pathology in this population (Table 1).

Table 1. Profile of patients using mechanical ventilation admitted to the study site during the pre (I) and post (II) intervention phases.

Variables	Phase I (17) N (%)	Phase III (10) N (%)
Gender		
Male	10 (58.8)	8 (80)
Female	7 (41.2)	2 (20)
Pathologies		
Pulmonary tuberculosis	9 (52.9)	2 (20)
Acute renal failure	1 (5.9)	-
Acute respiratory failure	1 (5.9)	-
Tetanus	1 (5.9)	1 (10)
Neurotoxoplasmosis	2 (11.6)	1 (10)
Non-tuberculous mycobacterial infection	1 (5.9)	-
Urinary tract sepsis	1 (5.9)	-
Pneumocystosis	1 (5.9)	1 (10)
Neurological syndrome to be clarified	-	1 (10)
Syphilis	-	1 (10)
Septic shock	1(10)	1 (10)
Neurocryptococcosis	-	1 (10)
Paracoccidioidomycosis	-	1 (10)

In phase II (intervention), a total of 34 healthcare professionals were included; the majority were female (26). The average age of the professionals was 42 years (SD ± 8 years), with the largest number being nursing technicians (20). There were no participants with doctoral degrees (Table 2). Regarding professional experience in the ICU, all participating professionals had more than two years of experience in the field. All medical professionals, nurses, and physiotherapists were specialists in intensive care.

Table 2. Characteristics of the professionals participating in the intervention phase (phase II).

Variables	N (%)
Gender	
Male	8 (23.5)
Female	26 (76.5)
Professional Category	
Doctor	5 (14.7)
Nurse	5 (14.7)
Nursing Technician	20 (58.8)
Physiotherapist	4 (11.8)
Education Level	
Technical Level	20 (58.9)
Postgraduate	13 (38.2)
Master's Degree	1 (2.9)
Doctorate	0 (0)

Regarding the VAP prevention measures evaluated, four measures showed high adherence at the pre-intervention time, with emphasis on routine oral hygiene (90.9%), head elevation (88.2%), cuff pressure measurement (91.4%), and maintenance of the ventilation system (88.2%). However, daily sedation reduction (34.9%) and daily extubation assessment (27.4%) showed low adherence, and consequently, the total adherence rate to the measures was also low (22.6%) in the pre-intervention period (Table 3).

It should be mentioned that during data collection, the researchers had difficulty finding records of the measures performed by the multidisciplinary team. Such data were often not included in medical records or prescriptions, which contributed to the low adherence results.

After the intervention, there was an increase in the adherence rate of all measures evaluated. Oral hygiene measures (96.3%), head elevation (97.8%), cuff

pressure measurement (94.0%), and maintenance of the ventilation system (87.3%) maintained the highest adherence rates. Daily sedation reduction and daily extubation assessment measures, despite continuing to show low adherence, showed significant improvement (with rates of 59.0% and 53.7%, respectively) compared to the pre-intervention phase. After the intervention, a significant increase in adherence to the bundle (adherence to all measures simultaneously) was identified, rising from 22.6% to 43.3% (<0.001) (Table 3).

Table 3. Adherence to the VAP prevention bundle before (Phase I) and after intervention (Phase III).

Evaluated Measures	Phase I (186) N (%)	Phase III (134) N (%)	*P**
Oral hygiene	169 (90.9)	129 (96.3)	0.297
Head of bed elevation	164 (88.2)	131 (97.8)	0.002
Daily sedation reduction	65 (34.9)	79 (59.0)	<0.001
Daily extubation assessment	51 (27.4)	72 (53.7)	<0.001
Cuff pressure measurement	170 (91.4)	126 (94.0)	0.378
Ventilation system maintenance	164 (88.2)	117 (87.3)	0.817
Adherence to the bundle (All measures simultaneously)	42 (22.6)	28 (43.3)	<0.001

Abbreviation: *McNemar test. VAP: Ventilator-Associated Pneumonia.

The microorganisms related to the diagnosed VAP cases were identified through tracheal aspirate culture, being: Proteus mirabilis and Pseudomonas aeruginosa (one case) both in the same sample, Klebsiella pneumoniae (two cases), Acinetobacter sp. (one case) and Moraxella sp (one case) in phase I and Pseudomonas aeruginosa (two cases) and Klebsiella pneumoniae (one case) in phase III.

DISCUSSION

The sociodemographic and epidemiological profiles of patients admitted to the ICU in this study are similar to other Brazilian settings and are consistent with current literature, given that a considerable portion of patients treated in ICUs, as well as those affected by infectious diseases, are male and are 40 years of age or older.[13]

The fight against tuberculosis (TB) remains a major challenge for public health in Brazil, with the persistent difficulty of access to diagnosis and treatment of the disease aggravated by the health and social crisis related to the Covid-19 pandemic.[14] Therefore, considering that the study was conducted in a referral hospital for the care of users affected by infectious and tropical diseases, it was expected that a significant percentage of patients would have human immunodeficiency virus (HIV) infection and consequently opportunistic pathologies, especially pulmonary tuberculosis.

The professionals participating in the intervention phase have relevant characteristics. All participating professionals had more than two years of experience in the field, and all professionals working in higher education positions (doctors, nurses, and physiotherapists) had a specialization in intensive care. Thus, the professional profile was favorable, since higher academic qualifications in intensive care units and years of experience are associated with a good level of knowledge about VAP prevention.[11, 15]

Regarding microorganisms related to VAP, our study corroborates the literature that shows that bacteria such as Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, and Acinetobacter baumannii are frequently associated with VAP, and most of these isolates have been identified as multidrug-resistant organisms.16, 17 Therefore, the accurate identification of the causative microorganism through appropriate culture methods and reliable sensitivity testing is essential for initiating appropriate treatment within a favorable timeframe for the best outcome.

Regarding the items in the ventilator-associated pneumonia (VAP) prevention measures package, this study presented results similar to current publications regarding oral hygiene, head elevation, and cuff measurement, identifying high adherence rates, while daily sedation reduction and, consequently, extubation feasibility assessment, are commonly identified as the least adhered measures.[18,19] These findings may be related to the ease of execution or the professional category responsible for carrying out each measure, since the measures with higher adherence can be considered simple and easy to apply by a single professional. Measures with lower adherence, on the other hand, require more complex, multidisciplinary assessments, including medical decision-making.

Performing oral hygiene through chemical and mechanical processes using a 0.12% or 2% concentration of oral chlorhexidine is a relatively simple, yet strongly recommended procedure. However, for this measure to be effective in reducing the risk of infections caused by the multiplication of microorganisms in the oral cavity, it is crucial to ensure the uniformity and effectiveness of the oral hygiene procedure by implementing specific evidence-based protocols.[20] In this study, oral hygiene maintained high adherence rates, reaching 96.3% after the intervention.

The position of the head of the bed showed a

significant improvement in adherence after the intervention. The practice of elevating the patient's head between 30º and 45º, widely adopted in ICU settings, even though it is widely suggested by several authors and indicated by Brazilian and international guidelines and manuals, still needs robust scientific studies to support it.[8] In theory, placing the body at the aforementioned angle can improve the ventilation-perfusion ratio, help expand the lungs, and reduce the risk of microaspirations. Although this position seems beneficial, there are suggestions, albeit with reservations, for the use of larger angles, between 30º and 60º, in order to prevent Ventilator-Associated Pneumonia (VAP). However, more detailed and precise studies are suggested to confirm these benefits.[21]

The measurement and adequacy of cuff pressure is of significant importance, since pressures lower than 20-30 cm H2O can contribute to greater difficulty in positive pressure mechanical ventilation and make microaspiration episodes possible. In this context, the use of mechanisms that allow continuous monitoring of cuff pressure (orotracheal tube balloon) is even suggested, as adequate maintenance of cuff pressure reduces the incidence of VAP, reduces the risk of aspiration, reduces the duration of mechanical ventilation and reduces the length of stay in the ICU.22 The results showed high rates of adherence to the measurement and adequacy of cuff pressure. These results may be related to the active presence of the physiotherapist in the unit, since in this study this variable was collected exclusively from the physiotherapist's care records.

The reduction of sedation and verification of the possibility of extubation, despite having low adherence in this study as well as in the world literature, are of great importance because they are directly linked to the main risk factors for VAP, which are the duration of mechanical ventilation and the length of hospital stay. Consequently, the earlier sedation is withdrawn and extubation is performed, the less time the patient is susceptible to developing VAP. Therefore, emphasizing improved adherence to sedation minimization measures and spontaneous breathing trials can significantly impact VAP rates.[19]

This study identified a significant increase in the overall adherence rate to the measures after the intervention, but it remains below the recommended targets (95%) and even other similar studies that presented rates of 55% to 94%.[18,19-23]

Regarding the VAP rate, the present study showed a reduction in the VAP rate after an intervention based on educational technologies, when compared to the pre-intervention rate, as did similar studies. The implementation of quality improvement that included strategies based on staff training, changes in practices and, above all, action with hospital units to reinforce the safety culture should potentially reduce VAP rates.24 The survey of numerous studies employing a multidimensional approach shows that it is possible to achieve significant reductions in VAP rates when six components are incorporated: package of measures, education, surveillance, monitoring of compliance with VAP prevention recommendations, internal reporting of VAP rates and performance feedback.[25]

Although we find large variations in VAP DI rates around the world (from 7 to 43 per thousand days of mechanical ventilation), the rates identified in the present study ranged from 12.9 per thousand days of mechanical ventilation to 9.8 per thousand days of mechanical ventilation. Economic differences, which can lead to a lack of advances and availability of resources in some regions, may be a reason for the higher VAP rate in some countries. Differences in study settings, such as patient profiles and whether the unit was surgical or clinical, may also be another likely reason for the large variation in VAP rates.⁴ However, adopting evidence-based preventive strategies can potentially reduce VAP rates and associated costs, as well as improve patient outcomes in different economic and structural settings.[25]

In conclusion, educational interventions have a positive impact on adherence to the VAP prevention bundle. The knowledge gained during the study interventions was applied in patient care practice and clinical routine, resulting in a reduction in the incidence density of VAP in the analyzed setting.

As limitations, we point out that this manuscript is an excerpt from a master's thesis available in the digital collection:
https://acervodigital.ufpr.br/handle/1884/95612.
Furthermore, the lack of research like this, conducted in infectious disease hospitals, hinders discussions, since the populations assisted in institutions with this profile have specific pathologies and extrinsic factors that interfere with the incidence of VAP. We also emphasize that the short period of time this study was conducted limits the results obtained, and future studies with a longer duration will allow for a better assessment of the sustainability of the results obtained by similar interventions.

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AUTHORS' CONTRIBUTIONS

Lorena Teixeira da Silva contributed to the bibliographic research, abstract writing, introduction, methodology, discussion, interpretation and description of results, table preparation, conclusions, review, and statistics. **Mitzy Tannia Reichembach Danski** contributed to project management,

bibliographic research, abstract writing, introduction, methodology, discussion, interpretation and description of results, conclusions, review, and statistics. **Leticia Pontes** contributed to project management, bibliographic research, abstract writing, introduction, methodology, discussion, interpretation and description of results, conclusions, review, and statistics. **Rafaele Oliveira Bonfim** contributed to abstract writing, methodology, interpretation of results, conclusions, review, and statistics. **Heric Maia Gomes** contributed to abstract writing, review, and statistics. **Rosa Maria Ferreira de Almeida** contributed to project management, bibliographic research, review, and statistics. **Karina Pinheiro Teixeira dos Reis** contributed to bibliographic research, abstract writing, introduction, methodology, discussion, interpretation and description of results, conclusions, review, and statistics.

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