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RESEARCH ARTICLE (ORIGINAL)

Determinants of invasive ventilator-associated pneumonia in an intensive care unit of a central hospital

Determinantes da pneumonia associada à ventilação invasiva numa unidade de cuidados intensivos de um hospital central

Determinantes de la neumonía asociada a la ventilación invasiva en una unidad de cuidados intensivos de un hospital central

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Abstract
Background: Healthcare-associated infections are a prevalent issue in health systems that affect everyone. The incidence and prevalence of healthcare-associated infections depend on the context in which they occur. An example of this is ventilator-associated pneumonia in intensive care units.
Objective: To analyze the determinants of ventilator-associated pneumonia in an intensive care unit of a central hospital in northern Portugal.
Methodology: A retrospective, descriptive-correlational quantitative study was conducted with 705 patients admitted to the ICU of the hospital under investigation.
Results: The results show that male gender, previous antibiotic use, endotracheal reintubation, level of consciousness, cuff pressure, ventilation time, injury, poisoning, and certain other consequences of external causes as admitting diagnosis are among the determinants of ventilator-associated pneumonia. Moreover, the incidence of ventilator-associated pneumonia was of 4.5%.
Conclusion: The study recommends the judicious use of antibiotics, limiting the duration of invasive ventilation, implementing ventilator weaning protocols, and auditing compliance with the care bundle for ventilator-associated pneumonia. This study sheds light on the prevention of ventilator-associated pneumonia and its recommendations contribute to better care and more effective and safer nursing interventions.

Keywords: cross infection; pneumonia, ventilator-associated; intensive care units; nursing

Resumo
Enquadramento: As infeções associadas aos cuidados de saúde (IACS) são uma problemática atual dos sistemas de saúde variando a sua incidência, prevalência do contexto de cuidados. A pneumonia associada à ventilação (PAV) é disso um exemplo ocorrendo em unidades de cuidados intensivos (UCI).
Objetivo: Analisar determinantes da PAV, em doentes internados numa UCI de um hospital central do norte de Portugal.
Metodologia: Estudo descritivo-correlacional e retrospetivo, com base nos registos de 705 doentes internados na UCI.
Resultados: Constituíram-se determinantes da PAV o sexo masculino, tratamento prévio com antibiótico, reintubação endotraqueal, nível de consciência, pressão de cuff, tempo de ventilação, diagnóstico de entrada lesões, envenenamento e algumas outras consequências de causas externas. A incidência de PAV foi de 4,5%.
Conclusão: O uso criterioso de antibióticos, o menor tempo possível de ventilação invasiva, a implementação de protocolos de desmame ventilatório e auditorias ao cumprimento da *bundle* da PAV podem contribuir para melhores cuidados e intervenções de enfermagem mais eficazes e seguras.

Palavras-chave: infeção hospitalar; pneumonia associada ao ventilador; unidade de terapia intensiva; enfermagem

Resumen
Marco contextual: Las infecciones asociadas a los cuidados sanitarios (IACS) son un problema actual en los sistemas sanitarios, y su incidencia y prevalencia varían en función del entorno asistencial. Un ejemplo de ello es la neumonía asociada a la ventilación mecánica (PAV), que se da en las unidades de cuidados intensivos (UCI).
Objetivo: Analizar los determinantes de la PAV en pacientes ingresados en la UCI de un hospital central del norte de Portugal.
Metodología: Estudio descriptivo-correlacional y retrospectivo, basado en los registros de 705 pacientes ingresados en la UCI.
Resultados: Los factores determinantes de la PAV fueron el sexo masculino, el tratamiento antibiótico previo, la reintubación endotraqueal, el nivel de consciencia, la presión del manguito, el tiempo de ventilación, el diagnóstico de entrada de lesiones, la intoxicación y algunas otras consecuencias de causas externas. La incidencia de PAV fue del 4,5%.
Conclusión: El uso prudente de antibióticos, el menor tiempo posible de ventilación invasiva, la aplicación de protocolos de destete del ventilador y las auditorías de cumplimiento del paquete de PAV pueden contribuir a mejorar los cuidados y a que las intervenciones de enfermería sean más eficaces y seguras.

Palabras clave: infección hospitalaria; neumonía asociada a la ventilación; unidad de cuidados intensivos; enfermería

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Introduction

Semmelweis played a crucial role in the prevention and control of puerperal infections in hospitals (Carraro, 2004), becoming a reference in the fight against hospital-acquired infections, also known as healthcare-associated infections (HAIs).

The World Health Organization (WHO) defines HAIs as infections that patients acquire during their hospital stay, which were not present or incubating at the time of admission (World Health Organization, 2016). According to a multicenter European study, the WHO estimates that over 50% of patients in intensive care units (ICUs) have infectious diseases, with the majority of them being healthcare-associated (WHO, 2016). HAIs have significant impacts on care delivery, society, families, and individuals, as they increase the demand for human, financial, and material resources, prolong hospital stays, and increase readmissions.

Ventilator-associated pneumonia (VAP) is the most common HAI in ICUs (Guillamet & Kollef, 2015) due to the diversity of factors associated with its development. Hence, our study aimed to analyze the determinants of VAP in patients admitted to an ICU at a central hospital in northern Portugal.

Background

The definition of hospital-acquired infections has expanded, and today HAIs are a broader concept. According to the WHO, a HAI is an infection "occurring in a patient during the process of care in a hospital or other healthcare facility which was not present or incubating at the time of admission" (WHO, 2016). Similarly, Jadot et al. (2018) define HAIs as infections that affect individuals when they are admitted to, visit, or work in a hospital or outpatient department, as well as infections acquired in clinics and other healthcare facilities where individuals go. Healthcare providers widely recognize the presence of HAIs, and reducing their incidence is of great interest to them due to the increased risk of patient comorbidities and mortality. The rise in antimicrobial resistance, immunocompromised patients, those with nutritional deficits, and patient exposure to invasive procedures and devices (Pina et al., 2013) have led to an increased risk of mortality. This has resulted in longer hospital stays and increased consumption of resources, leading to higher costs.

HAIs harm patients' quality of life and their safety as well as that of professionals, being estimated that around 1.4 million people acquire an HAI globally (WHO, 2009). In Portugal, the number of deaths associated with HAIs increased successively between 2010 and 2014, from 2,973 to 4,606 (Direção-Geral da Saúde [DGS], 2018). The literature classifies four types of HAIs (Pina et al., 2013): Lower Respiratory Tract Infections (LRTI); Urinary Tract Infections (UTI); Surgical Site Infections (SSI); and Bloodstream Infections (BSI).

In 2014, the Portuguese PPCIRA - Program for the Prevention and Control of Infections and Antimicrobial Resistance implemented a multimodal strategy to promote standard infection control precautions (SICPs) that health professionals should adopt in order to reduce the risk of infection and cross-transmission (Ministério da Saúde [MS] & DGS, 2017) by using preventive measures appropriate for each type of infection. For instance, to prevent VAP, it is crucial to disinfect and take appropriate care to limit contamination when using tubes, ventilators, and humidifiers; avoid changing respiratory tubes; avoid the use of antacids and H_2 inhibitors; perform sterile tracheal suction; and elevate the head of the bed during care delivery (Goulão, 2014).

VAP is one of the most prevalent HAIs in ICUs and directly affects critically ill patients who require invasive mechanical ventilation (IMV; Hellyer et al., 2016; MS & DGS, 2018). Its diagnosis is based on the onset of pneumonia occurring 48 hours after endotracheal intubation, with no suspicion of this condition on admission, and up to 72 hours after endotracheal extubation (Rodrigues et al., 2016). According to the American Thoracic Society (ATS) and the Infectious Diseases Society of America (IDSA), VAP accounts for almost half of all cases of hospital-acquired pneumonia (2005). Rawal et al. (2018) report that VAP is one of the most common HAIs, being associated with increased morbidity and mortality, increased mechanical ventilation time, increased ICU days, and responsible for a mortality rate of more than 50%. Hunter (2012) also reports that approximately 50% of all antibiotics administered in ICUs are for treating VAP. However, the incidence of VAP varies across studies. Ramirez et al. (2012) report that patients undergoing mechanical ventilation have rates of VAP ranging from 9% to 67%, whereas Klompas et al. (2014) observe that only 5% to 15% of patients undergoing mechanical ventilation (MV) develop VAP.

The leading causes of VAP are related to medical devices (namely endotracheal tubes [ETT]), cuff pressure, nasogastric tubes, prolonged IMV, aspiration of ventilator circuit condensate, endotracheal reintubation, secretion pooling in the posterior oropharynx, oral mucosal infections, dental infections, immunosuppression status, level of consciousness, age, nutritional status, polytrauma (thoracic and cervical), severity of clinical situation on admission, infections in other organs or previous respiratory pathology (namely chronic obstructive pulmonary disease), antibiotic use in the previous 30 days, and use of vasoactive drugs, being worth noting among these the existence of modifiable and non-modifiable factors (Alecrim et al., 2019; Feng et al., 2019; Rodrigues et al., 2016; Sethi, 2019).

The technological and scientific advances in the field of intensive care medicine have led to the development of a range of invasive life support interventions that are vital for critically ill patients (Cruz & Martins, 2019). MV is one of these supports, and it can be noninvasive (NIMV) or invasive (IMV; Melo et al., 2014). It should be noted that invasive interventions carry preventable risks.

One of the most effective measures for preventing HAIs is the use of care bundles. In Portugal, the Directorate-General for Health (DGS) has established a care bundle with

six interventions aimed at preventing VAP (Portugal, 2015; 2017).
Preventing HAIs resulting from the use of MV must be a key concern for health professionals, since most of the complications arising from this type of ventilation can be prevented or treated quickly, along with others that can be mitigated (Sole et al., 2013). The prevention of VAP is an indicator of the quality of nursing care, and the implementation of prevention protocols reduces the infection rate by 50% or more, highlighting the need to adopt good practices based on scientific evidence (Matos & Sobral, 2010). Therefore, nurses must develop evidence-based practices through simple and cost-effective interventions that reduce the likelihood of VAP (Wood & Winters, 2011).

Research question

What are the determinants of invasive ventilator-associated pneumonia in an intensive care unit of a central hospital in northern Portugal?

Methodology

This was an observational, cross-sectional, descriptive-correlational, and retrospective study (Fortin, 1999) carried out in a multipurpose ICU of a central hospital in northern Portugal.
The study sample comprised the records of patients admitted to the unit between 2016 and 2017. The inclusion criteria were to have been ventilated and have a record in the computer system. A total of 705 records were identified. The timeframe was defined based on the data availability of the record system and the fact that it had been upgraded, thus being considered a mature system during the selected timeframe.
To collect the data, the Information and Communication Systems and Technologies Service of the institution where the study was conducted was asked to provide the data available in various computer programs (including B-ICU Care® from B-Simple® and SClinico®), taking into account the variables of interest for our study. Based on the literature review, the following were identified: socio-demographic variables (gender and age); clinical characteristics (e.g., prehospital illness, previous antibiotic use, chronic respiratory disease, cuff pressure; ETT position, use of 0.2% chlorhexidine mouth rinse, presence of nasogastric tube), invasive ventilation time, invasive ventilation mode, endotracheal reintubation, level of consciousness, white blood cell count, protein level, albumin level, admitting diagnosis, APACHE II level, and infection in other organs.
The variables were categorized as categorical or quantitative, depending on how they were loaded into the computer system.
Descriptive statistical techniques were used to process the data based on the variables and their respective scales of measurement. In the bivariate analysis, the two-sample independent *t*-test (parametric test), the Kolmogorov–Smirnov test or the Shapiro–Wilk test (normality of distribution), and the Levene's test (homogeneity of variances) were applied for the quantitative variables. When assumptions were not met, the U-Mann-Whitney test was used. The Chi-squared test of independence and Fisher's exact test were applied for nominal variables. Logistic regression was used to evaluate the variables that determine VAP.
Some clinical data were not available, and it was assessed whether there were differences in missing data between the VAP and non-VAP groups, which was not the case. The IBM SPSS Statistics, version 27.0, for Windows, was used for the analysis and a significance level of 5% was considered appropriate.
Our study was approved by the institution's Board of Directors after receiving a favorable opinion from the Ethics Committee (number 29/21). Informed consent was not obtained because patients' names and contact information could not be accessed. The institution was provided with a guarantee of identity and data protection, thus ensuring the confidentiality and anonymity of the patients and the institution.

Results

The sample for our study consisted of 705 patients registered in the institution's record system, ranging in age from 16 to 92, with a mean age of 61.5 ± 16.2 years and a median age of 64 years. Of the participants, 50.8% were aged between 25 and 64 years, 46.8% were over 65 years, and the remaining were under 24 years. The majority of the participants were male (59.7%).
Regarding the analytical condition upon admission, the white blood cell count (n = 705) ranged from 0.01 x10^9/L to 465.63 x10^9/L, with a mean of 14.25 x10^9 ± 20.63 x10^9/L and a median of 11.49. The total protein (n = 694) ranged from 19g/L to 105g/L (mean 54.95 ± 1.03/L and median 55.5), and the albumin (n = 702) ranged from 4.70 to 51.6 g/L (mean 28.43 ± 7.11 and median 28.5). In regards to patient severity (n = 703), the participants' level of consciousness (measured by the Glasgow Scale) ranged from 3 to 15, with a mean of 9.93 ± 4.93 and a median of 11. The disease severity (assessed by the APACHE II score) ranged from 0 to 52, with a mean of 23.28 ± 9.04 and a median of 23.
The diagnoses were classified according to the International Classification of Diseases (ICD 10). Upon admission, the most prevalent conditions were circulatory system diseases (31.5%), followed by injury, poisoning, and certain other consequences of external causes (16.3%), respiratory system diseases (15.7%), and digestive system diseases (12.6%). Of the patients in our study's sample, 78.9% were admitted for medical reasons, 15.2% were admitted for unscheduled surgical procedures, and the remaining were admitted for scheduled surgical procedures. The majority of patients (92.8%) had no previous antibiotic use and had no infections in other organs (64%). Pneumonia was the most frequent infection,

accounting for 12.5% of cases. It is important to note that this diagnosis was not considered as VAP since it did not meet the diagnostic criteria. Abdominal infections and urinary infections followed, accounting for 7.5% and 4% of cases, respectively. It is worth mentioning that almost all patients (99.6%) did not have any chronic respiratory disease.

Regarding the care bundle for VAP prevention (n = 705; Table 1), 86% used 0.2% chlorhexidine mouth rinse, 90.2% had a nasogastric tube, 2.0% underwent endotracheal reintubation, and 90.6% did not have the appropriate head of bed elevation - 30°/45°.

Table 1

Distribution of absolute frequencies of the use of 0.2% chlorhexidine mouth rinse, elevation of the head of the bed, presence of a nasogastric tube, and occurrence of endotracheal reintubation, as well as the statistical inferences based on the VAP diagnosis

		VAP		*p-v*alue	odds ratio
		No	Yes		
		N	*N*		
Use of 0.2% chlorhexidine mouth rinse	No	96	3	.605	-
	Yes	577	29		
Head of bed elevation (30°/45°)	No	610	29	1.000	-
	Yes	63	3		
Presence of nasogastric Tube	No	64	5	.354	-
	Yes	609	27		
Endotracheal reintubation	No	669	22	< .001	76.023
	Yes	4	10		

Note. VAP = Ventilator-associated pneumonia; *N* = Number of cases; *p*-value = Significance.

Upon analyzing the cuff pressure records, our study observed that the minimum pressure ranged from 0 to 35 cm H_2O (with a mean of 24.59 ± 7.23 and a median of 26, with the 75th percentile corresponding to 28) and the maximum pressure ranged from 0 to 363 cm H_2O (with a mean of 36.22 ± 30.79, and the 25th percentile and median coinciding at 25 and the 75th percentile at 34). The length of ventilation in days ranged from 0 to 79 days (mean 8.55 ± 10.43 days and median 4.63 days). Out of the 705 records, 32 individuals developed VAP (Table 2), resulting in a VAP incidence rate of 4.5%.

The analysis of the factors associated with VAP revealed gender differences (X_1^2 = 13.313; *sig* = 0.000), with a higher incidence observed in male participants who were approximately seven times more likely to develop VAP.

Table 2

Contingency table for VAP according to gender and the results of the Chi-squared test of independence

		VAP		*p-value*	Odds ratio
		No	Yes		
		N	*N*		
Gender	Female	281	3	< 0.001	6.929
	Male	392	29		

Note. VAP = Ventilator-associated pneumonia; *N* = Number of cases; *p*-value = Significance.

There were no differences in age between the groups. However, if the significance level is relaxed to 10%, the mean age of those who developed VAP is lower (56.68 ± 18.55 vs. 61.75 ± 15.97).

The blood count ("white blood cells") and biochemistry ("total proteins" and "albumin") analysis did not reveal any significant differences, nor did the analysis of clinical severity. Regarding the level of consciousness, when considering the left-tailed test (t_{701} 1.833; *sig* = 0.034), a statistically significant difference was observed that translated into lower mean scores in patients who developed VAP.

Additionally, our study also found differences concerning previous antibiotic use (Table 3; Fisher: *sig* = 0.000), with patients who underwent previous antibiotic treatment developing VAP more frequently than others (approximately 49 times more).

Table 3

Contingency table for VAP according to previous antibiotic use and the results of the Chi-squared test of independence.

		VAP		*p*-value	odds ratio
		No	Yes		
		N	*N*		
Previous antibiotic use	No	644	10	< 0.001	48.85
	Yes	29	22		

Note. VAP = Ventilator-associated pneumonia; *N* = Number of cases; *p*-value = Significance.

Our study also noted that the most common diagnoses among patients who developed VAP were injury, poisoning, and certain other consequences of external causes and circulatory system diseases, but without significant differences being observed. Nevertheless, the admitting diagnosis of injury, poisoning, and certain other consequences of external causes showed some differences (X_1^2 = 27.442; sig = 0.000), as demonstrated in Table 4.

Table 4

Distribution of absolute frequencies of the admitting diagnosis as well as the statistical inferences according to the VAP diagnosis.

	VAP		*p*-value
	No	Yes	
	N	*N*	
Injury, poisoning, and certain other consequences of external causes	99	16	0.000

Note. VAP = Ventilator-associated pneumonia; *N* = Number of cases; *p*-value = Significance.

Out of the individuals diagnosed with VAP, 71.9% were medically admitted and 28.1% were admitted for unscheduled surgery. The incidence of VAP was independent of the type of admission (X_1^2 = 5.907; sig = 0.055). Regarding bundle procedures and endotracheal reintubation, there were significant differences concerning VAP in those who underwent reintubation (Fisher: sig = 0.000). These patients were approximately 76 times more likely to develop VAP (Table 5).

Table 5

Distribution of absolute frequencies of endotracheal reintubations as well as the statistical inferences according to the VAP diagnosis

		VAP		*p*-value	odds ratio
		No	Yes		
		N	*N*		
Endotracheal reintubations	No	669	22	< 0.001	76.023
	Yes	4	10		

Note. VAP = Ventilator-associated pneumonia; *N* = Number of cases; p-value = Significance.

Our study also identified significant differences in minimum cuff pressure between patients who developed VAP and those who did not (U = 6282.5; *sig* = 0.002). The mean score was lower in patients who developed VAP (218.66) compared to those who did not (319.48; Table 6). Conversely, for maximum cuff pressure, the mean score was significantly higher in patients who developed VAP (418.18) compared to those who did not (308.76; U = 5829.5; *sig* = 0.001). Regarding ventilation time, significant differences (t_{703} = -7.098; sig = 0.000) were observed as patients who developed an infection were also those ventilated for longer periods (20.91 ± 16.94 versus 7.96 ± 9.65).

Table 6

Descriptive measures and inferential statistics of the level of consciousness based on VAP diagnosis

	VAP				*p*-value
	No		Yes		
	M	*SD*	*M*	*SD*	
Minimum cuff pressure	24.82	6.99	20.26	10.66	0.025*
Maximum cuff pressure	36.06	30.97	39.40	27.40	0.562
Ventilation time (d)	7.96	9.65	20.91	16.943	<0.001*

Note. VAP = Ventilator-associated pneumonia; M = Mean; SD = Standard Deviation; p-value = Significance.

Logistic Regression Model

After the bivariate analysis was conducted, a model was constructed to predict the risk of developing VAP, including the variables in which differences were observed. Logistic regression using the Enter method revealed that the level of consciousness (b_{lc} = -0.055; χ^2*Wald* (1) = 0.886; *sig* = 0.347), minimum cuff pressure (b_{minpc} = -0.051; χ^2*Wald* (1) = 2.657; *sig* = 0.103), maximum cuff pressure (b_{maxpc} = 0.003; χ^2*Wald* (1) = 0.141; *sig* = 0.707) and gender (b_{gender} = 1.269; χ^2*Wald* (1) = 2.596; *sig* = 0.107) did not show a statistically significant effect on the logit of the probability of developing VAP. On the other hand, previous antibiotic use ($b_{antibio}$ = 4.007; χ^2*Wald* (1) = 41.876; *sig* = 0.000), injury, poisoning, and certain other consequences of external causes as admitting diagnosis (b_{injury} = 1.826; χ^2*Wald* (1) = 10.811; sig = 0.001), occurrence of endotracheal reintubation (b_{reint} = 3.355; χ^2*Wald* (1) = 14.240; *sig* = 0.000) and ventilation time in days (b_{time} = 0.05; χ^2*Wald* (1) = 4.213; *sig* = 0.040) had a statistically significant impact on the logit of the probability of a patient developing VAP, according to the adjusted Logit model (G^2 (8) = 134.383; *sig* = 0.000; χ^2*Wald* (8) = 2.716; p = 0.951; R^2_{CS} = 0.193; R^2_{RN} = 0.605; R^2_{MF} = 0.558). Using the Forward: LR method, a new statistically significant model was adjusted with only the variables of previous antibiotic use, injury, poisoning, and certain other consequences of external causes as admitting diagnosis, occurrence of endotracheal reintubation, and ventilation time in days. According to this model, the probability of developing VAP (Y = 1) increases exponentially with ventilation time, meaning that the odds ratio of developing VAP compared to not developing VAP increases by 6.7% for each day of ventilation. For patients with previous antibiotic use, the odds of developing VAP are always higher than for those who have not received antibiotics (58.964 to 1); for patients with an admitting diagnosis of injury, poisoning, and certain other consequences of external causes, the odds are always higher than for those without this diagnosis (7.443 to 1); and for patients who have undergone endotracheal reintubation, the odds of developing VAP are also higher (28.861 to 1). The model correctly classified 96.6% of the participants, revealing a sensitivity of 50% and a specificity of 98.8%. The results suggest that the model is useful for classifying new observations and has a good discrimination ability (ROC c = 0.958; *sig* = 0.000). The results obtained enable several conclusions to be drawn about the determinants associated with VAP (Table 7).

Table 7

Summary of the Model coefficients and their significance

	B	S.E.	χ^2*Wald*	df	Sig.	Exp(B)
Previous antibiotic use (1)	4.007	0.619	41.876	1	0.000	54.990
Injury. poisoning. and certain other consequences of external causes as the admitting diagnosis (1)	1.826	0.555	10.811	1	0.001	6.211
Level of consciousness on admission	-0.055	0.058	0.886	1	0.347	.947
Endotracheal reintubation (1)	3.355	0.889	14.240	1	0.000	28.637
Minimum Cuff Pressure	-0.051	0.031	2.657	1	0.103	.950
Maximum Cuff Pressure	0.003	0.007	0.141	1	0.707	1.003
Ventilation time in days	0.050	0.024	4.213	1	0.040	1.051
GENDER_C (1)	1.269	0.788	2.596	1	0.107	3.558
Constant	-5.204	1.384	14.126	1	0.000	0.005

Note. B = Estimate of the coefficient associated with the variable; S.E = Standard error; χ^2*Wald* = Wald chi-square; df = Degrees of freedom; Sig = Significance, Exp (B) = Exponentiation of the B coefficient.

Discussion

VAP is a serious complication that can affect patients under IMV. In 2015, the DGS introduced a care bundle aimed at preventing VAP. Over time, the incidence of VAP has decreased, and in 2017, it reached its lowest value of 6.6% (DGS, 2018).

Contrary to the literature, where older age seems to be one of the risk factors (Feng et al., 2019; Rodrigues et al., 2016), in our study it only becomes significant when we relax to a 10% level of significance, where the age of the group with VAP is lower than the group without this diagnosis. This may be related to the hospital's geographical location, where the population is predominantly young. Additionally, gender was found to be significantly associated with a higher incidence of VAP in male participants. These results differ from those of Rodrigues et al. (2016), where the predominance was in female participants. This difference is possibly due to the fact that our sample was composed of more men.

Our findings show an association between the diagnosis of VAP and previous antibiotic use. According to several authors (Feng et al., 2019; Rodrigues et al., 2016), recent antibiotic therapy and the use of vasoactive drugs are determinants of VAP. In our study, patients who were previously treated with antibiotics were more likely to develop VAP (approximately 49 times more likely), which may be explained by the altered balance of the microbiome and the resistance of microorganisms such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Acinetobacter spp*., and *Enterobacter spp*. (Niederman & Craven, 2005).

Our study also indicates that individuals who undergo endotracheal reintubation are approximately 76 times more likely to develop VAP. This may be due to the aspiration of secretions into the oropharynx as a result of ineffective airway defense, which is consistent with findings from other studies where VAP occurred in 10 to 20% of ICU patients who underwent endotracheal reintubation (Hellyer et al., 2016). Feng et al. (2019) and Rodrigues et al. (2016) also add nasogastric tubes and IMV as determinants of VAP.

The findings obtained by our study through logistic regression are also revealing, as they show that previous antibiotic use, injury, poisoning, and certain other consequences of external causes as admitting diagnosis, the occurrence of endotracheal reintubation, and the ventilation time in days are statistically significant for the development of VAP, confirming what Miller (2018) has stated. Also, regarding the determinants, it was observed that the probability of developing VAP increases with the ventilation time and that for each day of ventilation, the probability of developing VAP increases by 6.7%. Matos and Sobral (2010), as cited in Safdar et al. (2005), state that artificial airways can contribute to VAP due to their direct access to the lower airways, interference with the coughing mechanism, and promotion of mucociliary dysfunction, which can leave the patient unable to prevent aspiration. The secretions that pool in the subglottic region act as a reservoir for bacterial growth, causing inflammation of the airways and promoting colonization, which damages the epithelium. Aspiration of this bacterial content can occur when there is relaxation of the cuff, tracheal spasms, stimulation of the patient, reactivity due to decreased sedation, or mobilization of the patient during care delivery. Regarding antibiotic use, individuals who have used antibiotics are more likely to develop VAP. This is because previous antibiotic use in the last 30 days significantly increases the likelihood of infection by antibiotic-resistant organisms (Sethi, 2019). Sethi (2019) also identifies previous antibiotic use as a risk factor for hospital-acquired pneumonia, such as VAP. Furthermore, the literature confirms that antibiotics can affect the development of HAIs. Early-onset VAP, up to day 5, is caused by antibiotic-sensitive microorganisms (*Staphylococcus aureus* sensitive to oxacillin, *Haemophilus influenzae,* and *Streptococcus pneumonia*; Goulão, 2014),

whereas late-onset VAP, after day 5, is usually caused by antibiotic-resistant microorganisms (Niederman & Craven, 2005).

Finally, our study noted that a patient with an admitting diagnosis of injury, poisoning, and certain other consequences of external causes is always more likely to develop VAP than a patient without such diagnosis, and the same is true for patients who have undergone endotracheal reintubation. Endotracheal intubation is a determining factor in VAP (Feng et al., 2019; Miller, 2018; Rodrigues et al., 2016). According to Hellyer et al. (2016), VAP affects 10 to 20% of patients who undergo endotracheal intubation and MV in ICUs.

This study had some limitations. Since it was retrospective, the information was obtained from computer records, and doubts arose about their accuracy, particularly regarding the bed head elevation, cuff pressure, and other infections. Also, there was a problem with the interoperability of the systems (B-ICU Care® by B-Simple® and SClinico®), which forced the use of scattered information.

Conclusion

The results of our study allow the identification of the risk factors for the development of VAP, namely gender, previous antibiotic use, decreased level of consciousness, endotracheal reintubation, minimum cuff pressure, and ventilation time. Using logistic regression, we found that previous antibiotic use, injury, poisoning, and certain other consequences of external causes as admitting diagnosis, the occurrence of endotracheal reintubation, and ventilation time in days were statistically significant for the development of VAP. Moreover, we observed that the probability of developing VAP increases exponentially with the duration of MV and that for each day of MV, the probability of developing VAP increases by 6.7%.

Our results also indicate that several modifiable determinants can be minimized by the care provided by health professionals, particularly through the implementation of the care bundle for VAP, as well as, the regular and continuous training of health professionals to update and consolidate knowledge and procedures. Therefore, our study recommends: VAP care bundle audits; endotracheal extubation as early as possible to avoid prolonged invasive ventilation (but with criteria to prevent reintubation); the establishment of ventilator weaning protocols; close and proactive patient monitoring to avoid accidental extubation (especially during the period of reduced sedation); the promotion of NIMV whenever possible as an alternative to reintubation; the assessment and optimization of cuff pressure (to 20-30 mmH_2O whenever possible) at least three times a day; caution against excessive/ prolonged or uncritical antibiotic prescribing; and accurate and thorough recordkeeping to foster good continuity of care and safeguard potential legal issues and future research studies.

We also suggest that further studies should be conducted with more recent records, as the comparison of records from different years is important to understand the evolution and changes that occurred, as well as the implementation of an observational study to verify compliance with the care bundle for VAP, the development of the study in other ICUs, and the introduction of other variables (e.g., length of use of norepinephrine or other vasopressors).

Author contributions

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