ORIGINAL RESEARCH

The nursing workload assessed through the Nursing Activities Score as a predictor for the occurrence of ventilator-associated pneumonia in an adult intensive care unit

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Received: February 14, 2019 **Accepted:** June 5, 2019 **Online Published:** June 25, 2019
DOI: 10.5430/jnep.v9n9p104 **URL:** https://doi.org/10.5430/jnep.v9n9p104

ABSTRACT

Objective: Evaluate the relation of nursing workload, evaluated by the Nursing Activities Score (NAS), with the occurrence of Ventilator-associated Pneumonia (VAP) in an Intensive Care Unit (ICU) and the impact of VAP on hospitalization costs.
Methods: Retrospective cohort study in Adult ICU of a high complexity Brazilian university hospital. The profile, outcomes, costs, and daily NAS from patients were collected. We also proposed some workload indicators based on NAS daily evaluation.
Results: The study included 195 patients, 27.17% diagnosed with VAP. VAP was more prevalent in patients diagnosed with trauma on admission. The total costs of care were higher for VAP patients. In all multivariate models tested were predictive for VAP: the patient's intubation that occurs in days prior of the ICU admission day (higher risk if occurs in days prior the ICU admission day) and ventilation time prior ICU (higher risk if higher time). We found others predictors, but these were dependent on the model tested. Additional risk predictors were tracheostomy, propofol use, neuromuscular blocker use and the higher NAS from admission. The protective factors found were the percentage of adequacy of the assignment based in NAS that measure if the workload measured by the NAS was offered and the increment in NAS during the ventilation time.
Conclusions: The offering of an adequate nursing work scale (adequate number of professionals for the care), as a function of the nursing workload measured by the NAS, could be effective in the reduction of VAP, hospital stay time and hospital costs.

Key Words: Healthcare-associated infections, Hospital costs, Risk factors, Sizing, Nursing staff

1. INTRODUCTION

Ventilator-associated pneumonia (VAP) is defined as the infection that begins after 48-72 hours of endotracheal intubation and invasive mechanical ventilation, being the most common healthcare-associated infection (HAI) in intensive care unit (ICU), with a prevalence varying from 24% to 50%

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and overall mortality of 13%.[1–6] It is, therefore, a serious complication that may have an impact on the length of stay and hospital costs. The increase in the incidence of this HAI, according to several authors, is related to the inadequate number of nursing professionals who provide the minimum necessary assistance to the patient.[7–12]

The ICU hospitalization can represent up to 30% of hospital budget costs, with human resources accounting for a large share of these costs.[13] In this context, it is very important to determine the adequate proportion of nursing professionals per patient and the fundamental workload to optimize outcomes related to the promotion of patients' health. This would also improve the financial management of hospitals. However, if staffing is inadequate to meet patient care needs, these costs may be even greater as a result of the increase in the number of cases of HAI's and other adverse events.[14, 15]

With the objective of determining the correct staffing, which addresses the number of nursing professionals per patient per day, some instruments have been used to estimate nursing workload, providing information so as to dimension the team in an economically efficient way, but ensuring safe patient care. One of these tools used in ICUs is the Nursing Activities Score (NAS), based on the real-time assessment of the duration of nursing activities as well as the analysis of the use of resources and nursing interventions to predict the workload to be dispensed by nursing staff for each patient during one day.[15, 16] The NAS does not regard the severity of the patients' illnesses or their profiles.

Thus, the present study aims to evaluate the relation between the nursing workload measured through the Nursing Activities Score and the occurrence of ventilator-associated pneumonia, and its influence on hospitalization costs in an adult intensive care unit.

2. METHODS

2.1 Type of study, location and ethical considerations

This is a retrospective cohort study conducted in a non-specialized Adult ICU of a highly complex Brazilian university hospital with 525 beds, of which 30 beds are in the non-specialized Adult ICU evaluated here. The "Hospital de Clínicas de Uberlândia" is located in Uberlândia, Minas Gerais state, Brazil. Data were obtained from the medical records of patients hospitalized in the Adult ICU from January to June 2014, period in which the NAS was evaluated daily for all patients in the unit. Patients necessarily met two inclusion criteria: patients older than 18 years and who underwent mechanical ventilation for more than 48 hours during the stay in the ICU.

The study was conducted in accordance with Brazilian Resolution 466 of 2012 of the National Health Council[20] and in accordance with the ethical principles of the Declaration of Helsinki for medical research involving humans. It was submitted and approved by the Ethics and Research Committee of the Federal University of Uberlândia (number: CAAE: 43409414.8.0000.5152).

2.2 VAP and patients data collection procedures

The diagnosis of VAP was based on the criteria established by the American Thoracic Society and Infectious Diseases Society of America, which include: mechanical ventilation for a time equal to or greater than 48 hours; chest x-ray with new or progressive pulmonary infiltrate associated with at least two clinical or laboratory abnormalities, including leukocytosis (> 10,000 mm^3) or leukopenia (< 4,000 mm^3); change in appearance of tracheal secretion; ventilatory worsening identified through the evaluation of the PaO_2/FiO_2 relation; fever (> 38 ^oC) or hypothermia (< 35 ^oC); and auscultation compatible with airspace consolidation. The period prior to the suspicion of VAP was always used as a reference.[17] The diagnosis of VAP was confirmed by the medical team responsible for the study, who reassessed all the x-rays and carefully checked the clinical and laboratory information contained in the medical records for the diagnosis of all patients.

The data collected for each patient on the day of admission in the ICU (first 24 hours) was: age; gender; admission diagnosis (categorized in clinical, trauma, surgical and neurological); presence of invasive blood pressure, presence de delayed bladder cateterism, mean arterial pressure, presence of coagulopathy, pneumothorax. For all patients, the intubation was evaluated if it occurred on the day of admission in the ICU or before. In the ICU stay, the invasive procedures evaluated were: use of antibiotics; use of neuromuscular blockers and corticosteroids; length of stay before ICU admission, length of ICU stay; time of mechanical ventilation (prior to ICU and in ICU); if medication was used for sedation and analgesia; results of laboratory tests; results of cultures, the antibiogram and also the therapy adopted; Acute Physiology and Chronic Health Evaluation (APACHE II), Simplified Acute Physiology Score 3 (SAPS 3). For each patient we collected the hospitalization costs, considering the amount paid by the Brazilian Public Health System for the entire hospital stay. That was transformed in US$ based on the exchange rate of the day of discharge from the hospital.

2.3 Nursing Activities Score measurements

The NAS[15] was evaluated at all days of ICU stay for all patients. As the NAS was obtained from medical records and patient forms it was not possible to obtain the values of each sub-item of the NAS. We considered the day of VAP

diagnosis as the event of interest and, for the other patients, two days after extubation (which represents the period of VAP risk). Form the daily NAS, we obtained some derived measurements that describe the Nursing Workload in the ICU during the hospitalization (see Table 1). We also measured the number of hours of nursing in the work schedule during the period of interest to calculate the percentage of adequacy of said schedule. The nursing team that attends in the ICU has 85 nursing technicians and 25 nurses, with a NAS median of 56.80 (mean = 58.85), there is a deficit of 28.86% in the nursing staff with a dependency on 3.06 nursing professionals per month per bed.[18, 19] Normally the ratio of nursing staff to patients in the hospital studied here is one professional to each two patients as proposed by Brazilian legislation. During the study, we accompany this scale of work, but this ratio is altered very eventually by the low sizing of staff of the institution, as presented previously.

Table 1. Nursing workload measurements calculated from daily NAS

Abbreviation	Indicator name	Description
NAS-ad	NAS from admission	Refers to the first day of NAS evaluation in the ICU. Unit: points.
NAS-a	NAS amplitude	The NAS amplitude until the event of interest in the ICU, obtained by subtracting the maximum NAS from the minimum NAS. Unit: points.
NAS-m	mean NAS	The mean NAS up to the event of interest. Unit: points.
NAS-cv	coefficient of variation of NAS	The coefficient of variation of NAS was calculated in the period of interest. Unit: %, percentage.
NAS-i	NAS increment	The NAS increment score was calculated by subtracting the maximum NAS (obtained from the second day of hospitalization until to the event of interest) from the NAS from admission. Unit: points.
NAS-ri	NAS relative increment	The NAS-ri was obtained by dividing the NAS-i by the admission NAS and multiplied by 100. Unit: %, percentage.
NAS-Δ	Delta NAS	The delta NAS, measures the increase or decrease in the NAS score, which was calculated by subtracting the NAS of the day of the event of interest from the admission NAS. Positive values indicate an increase in workload and negatives indicate a decrease in workload. Unit: points.
NAS-rΔ	Relative Delta NAS	Resulted from the division of the NAS-Δ by the NAS from admission and multiplied by 100. Unit: %, percentage.
NAS-paas	Percentage of adequacy of the assignment scale	The percentage of adequacy of the assignment scale was calculated as a function of the workload predicted by the NAS and the number of hours of nursing offered to each patient (number of nursing hours in the work schedule or assignment scale). For this we calculated the number of hours of nursing attributed in the work schedule during the period of interest named SNHWS (Sum of the nursing hours in work schedule), that is, the sum of the number of hours of nursing care provided in the ICU. Additionally, the workload was also predicted by the sum of the NAS in the period of interest divided by 100 and multiplied by 24. This predicted workload was named PNHNAS (Predicted nursing hours by NAS). On the other hand, to evaluate the Percentage of adequacy of the assignment scale based in NAS (NAS-paas), the SNHWS was divided by PNHNAS and multiplied by 100. Values smaller than 100 indicate that the predicted workload was not offered, if values are greater than 100, it indicates that the workload predicted by the NAS was met in the assignment of the schedules. Unit: %, percentage.

2.4 Statistical analysis

To compare the data from the quantitative variables between patients with VAP and without VAP, continuous data from each group were tested for normality by the Kolmogorov-Smirnov Lilliefors test. As most data did not present normality (Gaussian distribution), the medians were compared by the unpaired Wilcoxon test. The association between presence or absence of PAV with qualitative variables was tested with the Independence Chi-Square test with continuity correction (when expected frequencies were greater than five) or Fisher's Exact test (other cases). The significance of 5% was adopted.

For the prediction of VAP occurrence, data from the pre-

dictor variables were initially adjusted to univariate logistic regression models. For variable selection, we used the results of the univariate analysis from a reduced dataset (data and results not showed). We included all the predictor variables that had statistical significance for the estimated parameters ($p \leq .100$). Based on this selection, we obtained these variables from all patients. We did not include variables where data were absent for any patient. Based on this previous analysis, the predictors were included in multivariate models with all variables. After the adjustments, the Odds Ratio was calculated with confidence interval of 95% (Odds Ratio adjusted). For the reduced models, the backward variable selection method was used, with exclusion criterion based on the probability of the Wald test ($p < .050$).

Some multivariate models were tested. They are: Model 1 (full model based on all predictors from ICU stay); Model 2 (reduced model based on all predictors from ICU stay); Model 3 (full model based on all predictors present at patient admission in the ICU); Model 4 (reduced model based on all predictors present at patient admission in the ICU). The reduced models were proposed since in the clinical case conduction of the patients it is easier to focus on less variables.

3. Results

The study included 195 patients, the majority being male, with a mean age of about 52 years. For comparison, the patients were grouped into two groups: patients with and without diagnosis of VAP. Fifty-three patients (27.17%) were diagnosed with VAP. There was no statistically significant difference between the groups with and without VAP in relation to gender ($p = .152$), age ($p = .799$), the APACHE severity scores ($p = .485$) and SAPS ($p = .480$), as well as the outcomes of discharge and death in the ICU ($p = 1.000$). A significant difference was observed in relation to the hospitalization diagnosis in admission, with the highest trauma diagnosis in the VAP group ($p = .049$).

Table 2. Baseline characteristics of patients in mechanical ventilation of the adult ICU evaluated for VAP

Trait	Ventilator-Associated Pneumonia		Statistics
	without (n = 142)	with (n = 53)	χ^2 (p)
Gender (%, n)			
Male	61.27 (87)	73.58 (39)	2.051 (.152)
Female	38.73 (55)	26.42 (14)	
Diagnosis of hospitalization (% yes, n)			
Clinical	40.85 (56)	35.85 (17)	0.221 (.638)
Surgical	51.41 (75)	54.72 (26)	0.063 (.802)
Trauma	16.20 (23)	30.19 (16)	3.888 (.049)
Neurological	17.61 (26)	24.53 (11)	0.779 (.377)
ICU Outcomes (%, n)			
Discharge from ICU	63.38 (90)	62.26 (33)	0.000 (1.000)
Death in ICU	36.62 (52)	37.74 (20)	
Trait (unit)	Mean ± Standard error (Median)		Z (p)
Age (years)	52.58 ± 1.67 (55)	51.98 ± 2.58 (56)	-0.254 (.799)
APACHE II (points)	18.35 ± 0.72 (17)	19.06 ± 1.07 (18)	-0.698 (.485)
SAPS 3 (points)	63.59 ± 1.17 (61)	61.13 ± 2.21 (62)	-0.706 (.480)

Note. *Z*: *Z* statistic based on the Mann-Whitney test; X^2: Chi-square statistical based on the Chi-Square test; *p*: probability. The patient may have more than one hospitalization diagnosis.

The patients with VAP diagnosis had more Rocuronium Bromide use (7.55% versus 1.41%, $p = .048$), propofol use (79.25% versus 52.82%, $p < .001$), tracheostomy presence (71.7% versus 20.42%, $p < .001$), the intubation occurs in days prior of the day of admission in the ICU (96.23% versus 36.62%, $p < .001$), higher mean arterial pressures (median 90 versus 80, $p = .029$), higher time the ventilation prior to ICU admission (median 10 days versus 0 days, $p < .001$), higher total ventilation time (median 17 versus 8, $p < .001$), higher ICU hospitalization time (median 28 days versus 14.5 days, $p < .001$), higher hospitalization time (median 41 days versus 27 days, $p < .001$). For the other variables, no difference in the groups was detected (see Table 3).

The daily hospitalization cost was the same in the two groups ($p = .760$). There was a statistically significant difference

between the group with and without VAP in relation to total hospitalization costs, being the total cost higher in the group with VAP, median US$ 11,951.27, versus the patients without VAP with median US$ 9,160.38 (p = .005) (see Table 3).

Table 3. Univariate analysis of some measurements to predict the risk of VAP in an adult ICU

Trait	without VAP		with VAP		χ^2 (p)
	No (%, n)	Yes (%, n)	No (%, n)	Yes (%, n)	
Rocuronium Bromide use	98.59 (140)	1.41 (2)	92.45 (49)	7.55 (4)	(.048)
Presence of invasive blood pressure	52.82 (75)	47.18 (67)	37.74 (20)	62.26 (33)	2.94 (.087)
Propofol use	47.18 (67)	52.82 (75)	20.75 (11)	79.25 (42)	10.16 (.001)
Tracheostomy presence	79.58 (113)	20.42 (29)	28.30 (15)	71.70 (38)	42.74 (< .001)
Presence of delayed bladder catererism	16.20 (23)	83.80 (119)	5.66 (3)	94.34 (50)	2.85 (.091)
Presence of coagulopathy	84.51 (120)	15.49 (22)	73.58 (39)	26.42 (14)	2.38 (.123)
Pneumothorax	96.48 (137)	3.52 (5)	90.57 (48)	9.43 (5)	1.69 (.193)
Corticosteroid use	66.20 (94)	33.80 (48)	52.83 (28)	47.17 (25)	2.40 (.121)
Intubation occurs in days prior of the day of admission in the ICU	63.38 (90)	36.62 (52)	3.77 (2)	96.23 (51)	52.66 (< .001)
Trait	**Mean ± SE**	**R (Median)**	**Mean ± SE**	**R (Median)**	***Z* (*p*)**
Mean arterial pressure (value)	83.12 ± 1.41	40-130 (80)	88.03 ± 2.12	48-128 (90)	-2.18 (.029)
Adherence to oral hygiene (%)	73.69 ± 2.5	0-100 (81.83)	82.18 ± 2.54	0-100 (85.71)	-1.27 (.204)
Ventilation time prior ICU (day)	1.54 ± 0.28	0-26 (0)	13.87 ± 1.73	0-59 (10)	-10.34 (< .001)
Ventilation time in ICU (day)	9.16 ± 0.67	1-40 (6)	8.49 ± 0.76	1-29 (7)	-0.59 (.554)
Ventilation time (day)	10.31 ± 0.72	2-40 (8)	22.36 ± 1.99	9-80 (17)	-6.74 (< .001)
Time prior ICU (day)	18.95 ± 2.06	0-164 (11)	16.17 ± 3.41	0-79 (10)	-0.04 (.972)
Time in ICU (day)	18.1 ± 1.17	1-86 (14.5)	30.89 ± 2.8	10-89 (28)	-4.82 (< .001)
Time in hospital (day)	37.05 ± 2.46	1-191 (27)	47.06 ± 3.30	15-117 (41)	-3.27 (.001)
Daily Cost (US$)	428.92 ± 43.77	(325.39)	332.35 ± 23.53	(337.85)	-0.305 (.760)
Total Cost (US$)	10,681.29 ± 630.24	(9,160.38)	14,255.28 ± 1,218.56	(11,951.27)	-0.278 (.005)

Note. Z: *Z* statistic based on the Mann-Whitney test; R: range (minimum-maximum), SE: standard error, χ^2: Statistical χ^2 based on the Chi-Square test, p: probability.

The nursing workload indicators showed differences in the patients with and without VAP only for some indicators (see Table 4). The patients with VAP show higher values of NAS-ad (median 59.70 versus 52.70), NAS-m (median 57.57 versus 52.93) indicating higher nursing workload; and showed lower values of NAS-paas (median 87.37% versus 94.74%) indicating that for these patients the schedule is not associated with the nursing workload necessities. The increased workload in the admission and in the mean NAS value increased the risks or VAP acquisition (OR = 1.12 and OR = 1.5, respectively), while offering adequate schedule or nursing hours to patient care decreased the PAV acquisition risk (OR = 0.86). Besides that, the patients without VAP showed higher values to NAS-i (median 1.40 versus 0) and NAS-ri (median 2.67 versus 0), indicating that patients with elevated increase in the NAS showed lower risks to VAP acquisition (OR = 0.93 and OR 0.96, respectively).

Some multivariate models were tested to predict VAP occurrence, as shown in Table 5. We proposed these models based on clinical application of the data. We proposed two models with all data from ICU stay. In model 1 (full model based on all the predictors for VAP occurrence during ICU stay), the risk predictors found for VAP were intubation occurs in days prior of the ICU admission day (p = .022, OR = 11.60, CI95% = 1.41-95.23), the use of propofol (p = .018, OR = 6.79, CI95% = 1.40-33.04), the presence of tracheostomy (p = .009, OR = 9.58, CI95% = 1.78-51.59) and ventilation time prior to ICU admission (p = .015, OR = .17, CI95% = 1.02-1.33). In model 2 (reduced model based on all predictors for VAP occurrence during ICU stay) the predictors were intubation occurs in days prior of the ICU admission day (p = .039, OR = 6.55, CI95% = 1.10-39.89), the use of rocuronium bromide (p = .015, OR = 70.51, CI95% = 2.28-2177) the use of propofol (p = .017, OR = 5.44, CI95%

= 1.35-21.83), the presence of tracheostomy (p = .013, OR = 5.79, CI95% = 1.44-23.22) and the ventilation time prior to ICU admission (p = .009, OR = 1.16, CI95% = 1.04-1.30). Only two predictors were found as protective to VAP occurrence and were the NAS-paas (p < .001, OR = 0.82, CI95% = 0.74-0.91) and the NAS-i (p = .025, OR = 0.89, CI95% = 0.80-0.98).

Table 4. Univariate analysis of the nursing workload measurements based in NAS to predict the risk of VAP in an adult ICU

Trait*	without VAP		with VAP		*Z (p)*	Statistics	
	Mean ± SE	Median	Mean ± SE	Median		*OR (LL-UL)*	*p*
NAS-ad	54.28 ± 0.62	52.70	62.25 ± 1.25	59.70	-5.73 (< .001)	1.12 (1.07-1.17)	< .001
NAS-i	4.02 ± 0.74	1.40	1.00 ± 0.68	0	-3.58 (< .001)	0.93 (0.88-0.99)	.023
NAS-ri	7.89 ± 1.40	2.67	1.96 ± 1.11	0	-3.69 (< .001)	0.96 (0.93-0.99)	.016
NAS-m	53.69 ± 0.10	52.93	60.39 ± 1.07	57.57	-5.53 (< .001)	1.15 (1.09-1.21)	< .001
NAS-paas	95.68 ± 0.76	94.74	85.01 ± 1.31	87.37	-6.21 (< .001)	0.86 (0.81-0.9)	< .001
NAS-a	9.01 ± 0.91	6.00	7.07 ± 0.90	6.50	-0.71 (.481)	0.98 (0.94-1.01)	.224
NAS-cv	5.16 ± 0.40	3.27	4.28 ± 0.50	4.14	-0.78 (.436)	0.95 (0.89-1.03)	.227
NAS-Δ	-0.83 ± 0.54	0	-2.31 ± 0.94	0	-1.33 (.185)	0.96 (0.92-1.01)	.161
NAS-rΔ	-0.97 ± 0.97	0	-3.06 ± 1.44	0	-1.21 (.226)	0.98 (0.95-1.01)	.250

*See Table 1 for traits description; *Z: Z* statistic based on the Mann-Whitney test; SE: standard error *p*: probability, OR: Odds-Ratio, LL: lower limit of 95% confidence interval from OR, UL: upper limit of 95% confidence interval of OR.

We also proposed two models with data available at ICU admission or the first day in the ICU, since this predictor could easily show the future risk of VAP diagnosis and serve as guide to healthcare changes and preventive actions or treated in clinical case conduction of the patient. In model 3 (full model), the significant predictors of risk found for VAP were the intubation occurs in days prior of the ICU admission day (p = .018, OR = 7.88, CI95% = 1.41-43.95), ventilation time prior to ICU admission (p < .001, OR = 1.30, CI95% = 1.14-1.47) and the NAS-ad (p = .001, OR = 1.11, CI95% = 1.04-1.18). Finally, in model 4 (reduced model based on all predictors present at patient admission), the same predictors of model 3 were observed with the intubation occurs in days prior of the ICU admission day (p = .018, OR = 7.66, CI95% = 1.43-41.13), ventilation time prior to ICU admission (p < .001, OR = 1.30, CI95% = 1.16-1.46) and the NAS-ad (p = .001, OR = 1.10, CI95% = 1.04-1.16).

The models have good adjustments to the data. Model 1 presented R2 Nagelkerke of 81.4%; with a probability of general accuracy of 93.3%, accuracy for the occurrence of VAP of 84.9% and correct answers for the absence of VAP of 96.5%. Model 2 presented R2 Nagelkerke of 78.2%; with a probability of general accuracy of 90.8%, accuracy for the occurrence of VAP of 79.2% and correct answers for the absence of VAP of 95.1%. Model 3 presented R2 Nagelkerke of 70.6%; with a probability of general accuracy of 90.8%, the occurrence of VAP of 75.5% and correct answers for the absence of VAP of 96.5%. Model 4 presented R2 Nagelkerke of 67.7%; with a probability of general accuracy of 90.3%, the occurrence of VAP of 77.4% and correct answers for the absence of VAP of 95.1%.

4. Discussion

The patient's profile in the study is similar, with no differences in severity scores and outcomes between the groups with and without VAP. However, patients diagnosed with hospitalization due to trauma had a higher incidence of VAP. The increase in the risk of VAP in these patients, especially those who presented severe trauma, is due to the fact that since trauma is an emergency and intubation is unplanned, time limited and is often performed in situations of high stress. Besides, this is an invasive procedure that compromises the lower respiratory tract defense barriers. Thus, there is a risk of non-performance of an adequate technique which, consequently, increases the risk factor for the development of VAP. In addition, this trauma patient profile is also subjected to several other invasive procedures and transportation in the emergency care that is not always adequate.[10,21] Ventilator-associated pneumonia is common in trauma patients but is independently associated with death in less severely injured trauma patients, and prevention of VAP in less severely injured trauma patients should increase survival.[22]

Table 5. Full and reduced multivariate models of prediction of risk of VAP in an adult ICU

Model	Predictor	*Bi*	*p*	*OR*	*LL*	*UL*
Full ICU Predictors	Intubation occurs in days prior of the day of admission in the ICU	2.45	.022	11.60	1.41	95.23
	Propofol use	1.92	.018	6.79	1.40	33.04
	Tracheostomy presence	2.26	.009	9.58	1.78	51.59
	Ventilation time prior to ICU (day)	0.15	.027	1.17	1.02	1.33
	Trauma hospitalization diagnosis	1.33	.130	3.76	0.68	20.93
	Rocuronium Bromide use	4.31	.123	74.25	0.31	17728
	Presence of invasive blood pressure	0.75	.313	2.12	0.49	9.10
	Presence of delayed bladder catheterization	0.30	.794	1.36	0.14	13.20
	Presence of coagulopathy	0.53	.585	1.70	0.25	11.32
	Corticosteroid use	1.08	.169	2.93	0.63	13.57
	Mean arterial pressure (value)	0.01	.547	1.01	0.97	1.06
	NAS-paas (%)	-0.37	.120	0.69	0.43	1.10
	NAS-m (points)	-0.24	.495	0.78	0.39	1.58
	NAS-i (points)	-0.11	.252	0.90	0.74	1.08
	NAS-ad (points)	0.04	.747	1.04	0.82	1.32
	Adherence to oral hygiene (%)	0.004	.823	1.00	0.97	1.04
	Pneumothorax presence	0.61	.856	1.84	0.003	1308
	Constant	36.14	.363			
Reduced ICU Predictors	Intubation occurs in days prior of the day of admission in the ICU	1.88	.039	6.55	1.10	38.98
	Rocuronium Bromide use	4.26	.015	70.51	2.28	2177
	Propofol use	1.69	.017	5.44	1.35	21.83
	Tracheostomy presence	1.76	.013	5.79	1.44	23.22
	Ventilation time prior ICU (day)	0.15	.009	1.16	1.04	1.30
	NAS-paas (%)	-0.20	< .001	0.82	0.74	0.91
	NAS-i (points)	-0.12	.025	0.89	0.80	0.98
	Constant	13.38	.004			
Full Admission Predictors	Intubation occurs in days prior of the day of admission in the ICU	2.07	.018	7.88	1.41	43.95
	Ventilation time prior ICU (day)	0.26	< .001	1.30	1.14	1.47
	NAS-ad (points)	0.11	.001	1.11	1.04	1.18
	Trauma hospitalization diagnosis	0.89	.155	2.44	0.71	8.38
	Presence of invasive blood pressure	0.84	.142	2.32	0.76	7.10
	Mean arterial Pressure (value)	0.01	.565	1.01	0.98	1.04
	Sex (1: Female)	-0.78	.199	0.46	0.14	1.50
	Constant	-11.15	< .001			
Reduced Admission Predictors	Intubation occurs in days prior of the day of admission in the ICU	2.04	.018	7.66	1.43	41.13
	Ventilation time prior ICU (day)	0.26	< .001	1.30	1.16	1.46
	NAS-ad (points)	0.09	.001	1.10	1.04	1.16
	Constant	-9.02	< .001			

Note. Bi: i-th coefficient estimative from the model parameters; *OR*: Odds-Ratio, *LL*: lower limit of 95% confidence interval from *OR*, *UL*: upper limit of 95% confidence interval of *OR*; *p*: probability associated to the parameter estimative.

A significant increase in total hospitalization costs was also observed in the group of patients with VAP, which corroborates the increase in hospital costs for patients with HAI. In this sense, it is important to highlight that a study showed that HAI in ICU was associated to doubling of the total cost of hospitalization when compared to patients who did not develop HAI during hospitalization.[23] A study showed that patients with VAP had significantly longer hospital stays with 21 days versus 11 days ($p < .0001$) and incurred in higher hospital costs, US$ 6,250.92 against US$ 2,598.84 ($p < .0001$);[24] which corroborates our results. Another study found similar results and showed that the mean cost of hospitalization was US$ 99,598 for patients with VAP and US$ 59,770 for patients without VAP, resulting in an absolute difference of US$ 39,828.[25] The mean cost of antibiotic use per patient was US$ 1,514.79 for the same ICU studied here in the other study, where patients with HAI were evaluated.[26] Although these studies are not comparable by as the baselines are not equals and the hospital adopted different staffing models and healthcare activities are likely to be different, they reinforce the findings that the presence of HAI (including VAP) increases hospital stay time and costs.

Another multicenter study, conducted at nine hospitals in Europe, showed that in an attempt to reduce costs, nursing staff cuts were made, consequently decreasing the offer of nursing workload. This led to worse patient outcomes and, ironically, cost increases.[27] In this sense, the present study showed that the nursing workload can influence the incidence of VAP and consequently hospital costs. In this sense, the evidence is increasing that the nursing workload is as a predictive variable to infection, adverse events and costs and other outcome variables in healthcare that could indirectly lead to higher costs for hospitals.[28,29] Since the public health system in Brazil pays hospital costs as a function of hospitalization time, specialized activities and type of unit, the impact of VAP on hospitalization time (about 14 days more in the infirmary and hospital), the impact of VAP on hospitalization time is perhaps the most important factor in cost assessment, since the measurement of the real costs in public services is difficult.

In all the multivariate models tested by us, the predictive variables to VAP occurrence were intubation the previous day of ICU admission and the time of ventilation before ICU admission. The two risk factors demonstrated that the way healthcare is provided before ICU admission can directly interfere in the risk of VAP in the ICU. Specifically to nursing, it is inferred, therefore, that the nursing staff was reduced in the hospitalization units when compared to the number of professionals in the ICU, which demonstrates that when the adequacy of sizing is not possible, it can lead to an increase in number of adverse events, such as VAP.[30] In the hospital studied here, the emergency room had a deficit and a necessity of increase of 51.63% in nursing staff, compared to 28.86% increase in ICU; evidencing the reduced staff in initial hospital admission.[19] In addition, in some units of the hospital of which ICU patients originate, they presented low adequacy in the number of nursing professionals dedicated to patient care.[19] Probably the low nursing training related to patient healthcare also could explain the effects of ventilation time in these units, leading to an increase in the risk of VAP.[19] Similar results were found for other HAI in the same ICU studied here, where insertion of the central venous catheters outside the ICU increased the chances of infection in the subclavian and jugular routes (OR: 2.25 and 0.27); and the chances of infection in the jugular route increased with tracheostomy presence (OR: 3.83).[31] Additional studies are necessary to try to explain the factors related to higher risk in these patients mainly related to patient care before admission in the ICU.

Other studies show that the impact of location of intubation in predicting the risk of VAP could be discrepant in trauma patients comparing prehospital and trauma room intubation, and some cases are significant only when other variables are included in the models, as chest injury (crude OR 1.16 $p = .600$, adjusted OR 0.17, $p < .003$).[32]

In the univariate analysis, the measurements of NAS show good capacity to predict the occurrence of VAP. The NAS-ad, NAS-i, NAS-ri, NAS-m and NAS-paas were associated of VAP occurrence. The NAS-ad, NAS-m show that high demand for nursing care is a predictive factor of VAP, reinforced by the NAS-paas, since the high values where the schedule is adequate reduce the risks of VAP. Offering an adequate number of nursing professionals is an excellent form of reducing the chances of VAP, probably because of the adequate execution of technical care related to intubation and ventilator state. We were not able to say what care measured by NAS is associated with VAP by not registering NAS sub-items in the medical charts or forms, which should be included in future studies.

We observed a increasing of 6.7 points or 96.48 minutes in NAS based in mean of NAS or an increase of 4.64 points or 66.82 minutes based in median of NAS. As the study was retrospective, it was not possible to obtain which NAS sub-items suffered additions due to VAP, since there are no records of the subitems in the records. Offering adequate nursing hours of care during all ICU stays proved to be necessary to prevent VAP, since the study demonstrates that nurses estimated that the standard ventilator bundle requires a median of 115 min per patient per day, although the majority

of nurses did not perceive that other patient care tasks were delayed.[33]

The publics, federatives and Brazilian hospitals following the legislation to scale the nursing professionals, following in the ratio of two patients to each professional. Even knowing the workload or scientific evidences that demonstrate improvement in patient outcomes by providing better healthcare (in the case studied here offer more professionals to care from patients), public institutions are unable to change this situation (two patients to each nursing professional). The institutions have no autonomy to hire professionals from any area, once there is a need for the government's consent. However, studies such as the presented here can support the request for vacancies by nursing professionals, and together with the increase in workload studies and better scientific evidences, together can support the construction of public policies that determine a better allocation of professionals in hospital units. Brazilian literature is still lacking in studies that measure the impact of the patient's clinical profile on the nursing workload and even other professionals.

In the two multivariate models presented in admission in the ICU and in the univariate model, it is verified that the NAS of admission (NAS-ad) is a predictor of VAP, that is, the higher the workload required at admission, the higher the risk of VAP. Patients with high NAS in admission probably require the attention from the team that could be planning better healthcare.

In the reduced model of ICU stay, the percentage of adequacy of the assignment (NAS-paas), showed that the more appropriate the work schedule measured by the NAS, the lower the risk of VAP. It also showed that the higher the increase in NAS (NAS-i) in relation to admission, the lower the risk of VAP. The hypothesis for this fact is that larger increments alert the team, which facilitates adjustment of the schedules and of healthcare. However, this situation does not occur with minimal changes, which may go unnoticed by the team. The compliance with preventive VAP actions in patients with low nursing workload measured by the Nursing Activites Score was lower compared to patients with higher levels of nursing workload.[34]

The results of this research are in line with results verified in other studies.[30, 34–36] In one of these studies, carried out with 195 patients, 43 (22%) developed HAI and, as in the present study, an excessive nursing workload was identified as a risk factor for HAI (OR: 11.41; p .019).[30] A meta-analysis, which included 38 studies, showed that in only 7 (18%) of the cases studied, it was not possible to observe a statistically significant relationship between variables that measure nursing team size and HAI rates.[35] In another study, a high positive correlation was also found between workload variables and the rate of adverse events.[36]

The use of sedatives as propofol as well as neuromuscular blockers, whose utilization is quite common in the ICUs, is also verified as predictors for VAP. Such drugs are known to have several immunomodulatory effects on de-fense cells, and in vitro studies have shown that high concentrations of propofol may interfere with human neutrophil functions such as chemotaxis and phagocytosis, suggesting a greater risk for infection.[37, 38]

The tracheostomy presence was also a risk factor for VAP. This finding is still contradictory in the literature since some studies suggest that tracheostomy would reduce the incidence of VAP by facilitating bronchial lavage and weaning from mechanical ventilation. On the other hand, other studies relate tracheostomy to the longer period of me-chanical ventilation, as well as longer ICU stay, leading to a higher risk of acquiring other infections.[37–43]

We have no assumption that nursing workload is the unique contributor related to nursing for the results of any patient outcomes. Other aspects related to nursing such as team qualification, degree of training, level of knowledge, form of work and the impact of students in educational institutions can interfere with patient's outcomes. Unfortunately, in retrospective studies such as our, these variables are difficult to evaluate by the low records of this data. Future and prospective studies could consider these and other aspects related to workload from professionals.

5. Conclusion

The present study allowed us to conclude that the total cost of hospitalization is higher in the group with VAP mainly related to longer hospital stay time. The risk of VAP increases in patients who were intubated before the day of admission in the ICU, tracheostomized, had used a neuromuscular blocker, had used propofol, had higher time of mechanical ventilation in pre-admission in the ICU, and higher NAS admission. Patients requiring higher measured nursing workload in admission in ICU (higher NAS-ad) show higher risks of VAP. Also patients with higher increment in NAS during mechanical ventilation in ICU and higher Percentage of Adequacy of the assignment based in NAS (NAS-paas) that measure if the workload measured by NAS was offered in the ICU (if 100% all workload measured was offered in the ICU) show lower risk of VAP. The NAS and their derivate metrics were effective in showing the relation between nursing workload and suitability in the design and the reduction of VAP.

ACKNOWLEDGEMENTS

We would like to thank the entire Intensive Care Unit team at the Universidade Federal de Uberlândia for support during the study. The study was part of the PhD of the first author in the Post-graduation Program in Health Sciences, Federal University of Uberlândia.

CONFLICTS OF INTEREST DISCLOSURE

The authors declare that there is no conflict of interest.

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