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Ventilator-Associated Pneumonia and Mortality: the role of the SOFA Score

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ABSTRACT

Background: Ventilator-associated pneumonia (VAP) is a frequent infection in intensive care units and is associated with a high risk of morbidity and mortality, requiring the use of reliable prognostic tools to support clinical assessment and decision-making in critically ill patients.

Objectives: To evaluate the predictive capacity of the Sequential Organ Failure Assessment (SOFA) score for mortality in patients with ventilator-associated pneumonia (VAP) admitted to an intensive care unit (ICU).

Method: A retrospective epidemiological study conducted at a university hospital in the state of Paraná, including 39 adult patients diagnosed with VAP between 2019 and 2021. Clinical, laboratory, and outcome variables were analyzed using Epi Info™ version 7.2 software.

Results: The mean initial SOFA score was 8.76, and the final mean score was 6.39, with significantly higher values among patients who progressed to death ($p = 0.006$ and $p = 0.001$, respectively). Length of hospital stay showed a negative correlation with the final SOFA score ($\beta = -0.08$; $p = 0.62$). Gram-negative bacteria predominated, particularly Pseudomonas aeruginosa and Klebsiella pneumoniae.

Conclusion: The SOFA score proved to be useful for predicting mortality and for the longitudinal assessment of patients with VAP, standing out as an accessible and reproducible tool for clinical monitoring and decision-making in ICUs.

Descritores: Pneumonia Associada à Ventilação Mecânica, Indicadores de gestão, Enfermagem, UTI, Escores de Disfunção Orgânica.

INTRODUCTION

The Intensive Care Unit (ICU) is designed to provide care for critically ill patients who require specialized care and continuous monitoring. In these settings, the use of invasive devices is frequent to ensure patients' clinical stability. Among these devices, mechanical ventilation (MV) stands out as essential for respiratory support in patients with acute respiratory failure or acute exacerbation of chronic respiratory failure. Invasive mechanical ventilation, frequently performed through orotracheal intubation (OTI), is widely used in ICUs.[1]Although OTI is vital for maintaining airway patency and providing ventilatory support, it may compromise the natural defense mechanisms of the respiratory tract, thereby increasing the risk of infections.[2] A common complication associated with MV is ventilator-associated pneumonia (VAP), defined as a pulmonary infection that develops after 48 hours of intubation and initiation of mechanical ventilation.[3]

The diagnosis of VAP is complex and involves clinical, laboratory, and imaging criteria. VAP is generally considered when MV is used for more than 48 hours and is associated with signs such as fever, leukocytosis or leukopenia, changes in tracheal secretions, and new or progressive pulmonary infiltrates on imaging examinations.[3] Recent studies indicate that VAP is associated with mortality rates that may vary significantly, depending on factors such as the severity of the underlying disease and the presence of comorbidities.[4]

To assess severity and predict outcomes in critically ill patients, several scoring systems are used in ICUs. Among them, the Sequential Organ Failure Assessment (SOFA) stands out. It was developed by the Working Group on Sepsis-Related Problems of the Society of Critical Care Medicine (SCCM) and was originally described by Vincent and colleagues[5] in 1996, with the objective of quantifying organ dysfunction in septic patients.

The SOFA score evaluates six physiological systems—respiratory, cardiovascular, hepatic, coagulation, renal, and neurological—assigning scores ranging from 0 to 4 for each system according to the degree of impairment. The total score indicates the level of organ dysfunction and, consequently, the risk of mortality.[5,6]

In the Brazilian context, although the SOFA score has not undergone a formal process of cross-cultural validation, its use is widespread in clinical and epidemiological studies conducted in national ICUs. It is recognized by institutions such as the Brazilian Association of Intensive Care Medicine (AMIB) as one of the recommended tools for prognostic assessment in critically ill patients.[7]

National and international studies demonstrate that higher SOFA scores are associated with an increased risk of mortality in patients with ventilator-associated pneumonia (VAP) and sepsis.[4,8]

Given the relevance of VAP and the need for effective tools to predict clinical outcomes, this study aims to evaluate the predictive capacity of the Sequential Organ Failure Assessment (SOFA) score for mortality in adult patients with a confirmed diagnosis of ventilator-associated pneumonia (VAP).

METHODS

This is a retrospective epidemiological study guided by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) tool,[9] conducted at a University Hospital in the state of Paraná, Brazil. The hospital is strategically located in the Eastern macroregion of the state of Paraná and serves the demands of the 3rd, 4th, and 21st Regional Health Departments of Paraná, which together cover 28 municipalities in the state. It is responsible for the central hub of the Campos Gerais region of Paraná and serves a population of approximately 750,000 inhabitants, playing an important role in providing medium- and high-complexity care to this population.[10]

The target population comprised all adult patients admitted to the hospital's Intensive Care Units (ICUs) between January 2019 and June 2021. The temporal scope of the analysis was defined based on the institutional availability of consolidated records. Data referring to the subsequent period (July 2021 to 2022)

were not included because they had not been made available to the research team in a timely manner for data collection, according to the schedule established by the Hospital Epidemiology and Infection Control Center (NUCIH).

The sample consisted of all patients who developed ventilator-associated pneumonia (VAP) during hospitalization in the analyzed period, totaling 39 individuals This characterized a census (non-probabilistic) sampling, as all eligible cases were included.

The inclusion criteria were as follows: patients aged 18 years or older, with a minimum ICU length of stay greater than 24 hours, under mechanical ventilation for more than 48 hours, and with a confirmed diagnosis of VAP according to clinical and microbiological criteria. Patients with missing data in the electronic medical records and those diagnosed with COVID-19 during the same period were excluded, in order to avoid biases resulting from the overlap of severe respiratory syndromes.

Data collection was carried out between June and October 2023 by undergraduate nursing students who had been properly trained, under faculty supervision. Information was obtained from secondary data recorded in the GSUS® (Unified Health System Healthcare Management) and Tasy® electronic systems, which are used for the hospital's clinical and administrative management.

The following variables were collected and analyzed: sociodemographic variables—sex (male/female) and age (in years); clinical variables—presence of comorbidities (yes/no), type of isolated microorganism (nominal variable), number of antibiotics used during treatment, and total duration of mechanical ventilation (in days); care-related variables—total ICU length of stay (in days) and year of hospitalization (2019, 2020, and 2021); outcome variables—discharge, transfer, or death; and main variables (prognostic outcomes), including initial SOFA score, calculated within the first 24 hours after the diagnosis of VAP, and final SOFA score, calculated within the last 24 hours before the outcome (discharge, transfer, or death).

The SOFA score was used as the main variable because it represents the degree of organ dysfunction and its prognostic potential for mortality. The comparison of mean SOFA values between outcome groups (discharge vs. death) was performed to determine its predictive capacity.

Data were organized in spreadsheet format using Microsoft Excel 2013® and subsequently subjected to descriptive and exploratory analyses using Epi Info™ software, version 7.2. To verify possible associations between variables, statistical analyses were performed considering statistical significance at $p < 0.05$. For differences between means and correlations, the parametric simple linear regression test was used. When variables did not meet the assumptions of normality and homoscedasticity, the nonparametric Kruskal–Wallis test was applied for differences between means, and Spearman's test was used for correlation analyses. The verification of statistical assumptions was performed using the Kolmogorov–Smirnov (K–S) normality test and Bartlett's test of sphericity for homoscedasticity.

In the present study, the variables that did not present a normal distribution were ICU length of stay (kurtosis = 0.078 and $p < 0.003$) and duration of mechanical ventilation (kurtosis = 0.076 and $p < 0.0027$). The variable that did not meet the assumption of homoscedasticity was outcome ($p < 0.001$).

This study is part of a broader research project and was approved by the Research Ethics Committee involving Human Beings, under CAAE no. 61430822.0.0000.0105, in compliance with the ethical and legal principles set forth in Resolution no. 466/2012 of the National Health Council.

RESULTS

A total of 39 patients diagnosed with ventilator-associated pneumonia (VAP) during hospitalization in an Intensive Care Unit (ICU) between January 2019 and June 2021 were included. The mean age was 58.72 ± 15.31 years, with a predominance of males (66.67%), a profile similar to that described in national and international studies reporting a higher incidence of VAP among adult and older men. The demographic and clinical characterization of the sample is detailed in Table 1.

Most patients (79.49%) had pre-existing comorbidities, particularly arterial hypertension and diabetes mellitus. Although these conditions did not demonstrate statistical significance in SOFA score values, they represent an important factor of clinical vulnerability. The mean ICU length of stay was 23.38 ± 15.62 days, while the mean duration of mechanical ventilation was 17.89 ± 12.47 days, highlighting the profile of critically ill patients with prolonged hospitalization.

Table 1. Demographic and clinical characteristics of patients with ventilator-associated pneumonia (VAP) at a University Hospital in Paraná, Brazil, from January 2019 to June 2021 (n = 39).

Variable	N (%) or Mean ± SD
Sex	
Male	26 (66,67%)
Female	13 (33,33%)
Age (years)	58,72 ± 15,31
Comorbidities	
Yes	31 (79,49%)
No	8 (20,51%)
ICU length of stay (days)	23,38 ± 15,62
Duration of mechanical ventilation (days)	17,89 ± 12,47
Year of hospitalization	
2019	12 (30,77%)
2020	16 (41,03%)
2021	11 (28,20%)
Clinical outcome	
Discharge	20 (51,28%)
Transfer	3 (7,69%)
Death	16 (41,03%)

Source: The authors, 2025.

The mean initial SOFA score was 8.76 ± 4.31, and the mean final SOFA score was 6.39 ± 3.75, demonstrating an overall reduction in organ dysfunction throughout hospitalization. This difference suggests clinical improvement among a proportion of patients, especially those who were discharged from the hospital.

In the comparative analysis between sexes, no statistically significant differences were observed for either the initial SOFA score ($p = 0.54$) or the final SOFA score ($p = 0.63$), indicating that sex did not influence disease severity or clinical progression. The β coefficient was 0.69 for the initial SOFA score and 0.92 for the final SOFA score, with no statistical relevance.

Among patients with comorbidities, the mean initial SOFA score was 9.62 ± 4.23, whereas among those without comorbidities it was 8.55 ± 4.05 ($p = 0.41$). A similar pattern was observed for the final SOFA score, with mean values of 6.36 ± 3.80 and 7.62 ± 3.71 ($p = 0.57$), respectively. The corresponding β coefficients were 1.07 and 1.26, both without statistical significance.

Regarding the year of hospitalization, the mean initial SOFA scores were 8.58 in 2019, 9.56 in 2020, and 8.05 in 2021 ($p = 0.62$), with a β coefficient of 1.18. For the final SOFA score, the means were 4.71, 7.92, and 7.75 ($p = 0.24$), with a β coefficient of 3.21, indicating no significant differences between the evaluated periods.

Age showed a weak and non-significant correlation with the initial SOFA score ($\beta = -0.01$; $p = 0.73$) and the final SOFA score ($\beta = 0.07$; $p = 0.12$), indicating that the severity of organ dysfunction did not vary

substantially according to age group.

ICU length of stay showed a negative correlation with the final SOFA score (β = −0.08; p = 0.62) and the initial SOFA score (β = −0.07; p = 0.39), suggesting that patients with longer ICU stays tended to show clinical improvement. Similarly, duration of mechanical ventilation showed β = −0.05; p = 0.52 for the initial SOFA score and β = −0.004; p = 0.18 for the final SOFA score, with no statistically significant correlation. These data are presented in Table 2.

Table 2. Mean initial and final SOFA scores and respective beta coefficients from simple linear regression analysis according to demographic and clinical variables of patients with ventilator-associated pneumonia (VAP) at a University Hospital in Paraná, Brazil, from January 2019 to June 2021 (n = 39).

Variable	SOFA Inicial (Média ± EP)	Coef. β	pvalor	SOFA Final (Média ± EP)	Coef. β	pvalor
Sex						
Male	8,31 ± 3,76	0,69	0,54*	6,31 ± 3,42	0,92	0,63*
Female	8,93 ± 4,67			6,42 ± 3,91		
Comorbidities						
Yes	9,62 ± 4,23	1,07	0,41*	6,36 ± 3,80	1,26	0,57*
No	8,55 ± 4,05			7,62 ± 3,71		
Year of hospitalization						
2019	8,58 ± 4,03	1,18	0,62*	4,71 ± 3,18	-	0,24*
2020	9,56 ± 4,45	1,37		7,92 ± 3,80	3,21	
2021	8,05 ± 4,12	-		7,75 ± 3,52	3,03	
Age (years)		-0,01	0,73*	β =0,07	0,07	0,12
ICU length of stay (days)		-0,07	0,39**	β = -0,08	-0,82	0,62**
Duration of MV (days)		-0,05	0,52**	β = -0,004	-0,004	0,18**
Clinical outcome						
Discharge	8,25 ± 4,21		0,006***			0,001***
Transfer	6,00 ± 3,46			3,67 ± 2,31		
Death	10,25 ± 4,73			5,66 ± 3,58		

Note: *p-value obtained using the F test. **p-value obtained using Spearman's test. ***p-value obtained using the Kruskal–Wallis test.

Source: The authors, 2025.

Among the identified etiological agents, infections caused by Gram-negative bacteria predominated (68%), with emphasis on Staphylococcus aureus (17.95%), Pseudomonas aeruginosa (10.26%), and Klebsiella pneumoniae (7.69%). Cases caused by Acinetobacter baumannii and Proteus mirabilis accounted for 5.13% each, while Enterobacter cloacae and Escherichia coli were identified in 2.56% of cases.

In 48.72% of episodes, cultures were negative or showed growth of non-significant flora, which may be related to prior antibiotic use, sample collection outside the optimal time window, or limitations in laboratory sensitivity. The detailed distribution and microbiological characterization of the isolated agents are presented in Table 3.

Table 3. Distribution and characterization of microorganisms isolated from patients with ventilator-associated pneumonia at a University Hospital in Paraná, Brazil, from January 2019 to June 2021 (n = 39).

Isolated microorganism	Type (Gram)	n	%
Staphylococcus aureus	Gram-positive	7	17,95%
Pseudomonas aeruginosa	Gram-negative	4	10,26%
Klebsiella pneumoniae	Gram-negative	3	7,69%
Acinetobacter baumannii	Gram-negative	2	5,13%
Proteus mirabilis	Gram-negative	2	5,13%
Enterobacter cloacae	Gram-negative	1	2,56%
Escherichia coli	Gram-negative	1	2,56%
Other microorganisms (not specified / negative culture)	—	19	48,72%
Total	—	39	100%

Source: The authors, 2025.

The predominant bacterial flora consisted of Gram-negative pathogens, with emphasis on Staphylococcus aureus and Pseudomonas aeruginosa, a microbiological profile similar to that described in Brazilian ICUs.

Of the 39 patients evaluated, 20 (51.28%) were discharged from the hospital, 3 (7.69%) were transferred, and 16 (41.03%) progressed to death. The initial SOFA score was significantly higher among patients who died (10.25 ± 4.73) compared with those who were discharged (8.25 ± 4.21) ($p = 0.006$), and the final SOFA score also differed significantly ($p = 0.001$), with mean values of 5.66 ± 3.58 (death), 3.67 ± 2.31 (transfer), and 2.23 ± 1.87 (discharge).

These findings reinforce the potential of the SOFA score as a prognostic marker of mortality, since higher values, both at the beginning and at the end of hospitalization, reflect persistent organ dysfunction and a lower probability of recovery. A reduction of two or more points in the score during hospitalization was observed only among survivors, indicating clinical improvement and a satisfactory therapeutic response.

Taken together, these findings support the use of the SOFA score as an accessible and reproducible tool for risk stratification and longitudinal monitoring in critically ill patients with ventilator-associated pneumonia, contributing to standardized care and evidence-based decision-making.

DISCUSSION

The present study analyzed the behavior of the SOFA score as a prognostic tool in patients with ventilator-associated pneumonia (VAP) admitted to an Intensive Care Unit (ICU), highlighting its relationship with clinical outcomes and associated factors. Among the 39 patients evaluated, males predominated (66.67%), and the mean age was 58.72 years, a profile similar to that described in the literature, in which men above middle age account for the majority of VAP cases.[4,11]

The mean initial SOFA score was 8.76 and the final SOFA score was 6.39, revealing a slight reduction over the course of hospitalization, which suggests clinical improvement in a proportion of surviving patients. The initial SOFA score represents the degree of organ dysfunction at the time of VAP diagnosis, whereas the final SOFA score reflects the clinical condition during the 24 hours preceding the outcome (discharge, transfer, or death). The comparative analysis between these two time points allows the identification of the clinical trajectory and the therapeutic response.

In this study, it was observed that patients who progressed to hospital discharge had a significantly

lower initial SOFA score (p = 0.006) and an even lower final SOFA score (p = 0.001) when compared with those who died, reinforcing the usefulness of the SOFA score as a prognostic marker. These results corroborate the findings of other authors,[4,8] who also identified a correlation between higher SOFA scores and increased mortality in patients with VAP.

The SOFA score quantifies dysfunction across six organ systems—respiratory, cardiovascular, hepatic, renal,

hematological, and neurological—allowing a dynamic assessment of severity. Thus, higher values reflect systemic deterioration and progressive organ failure. The downward trend in scores among survivors reinforces the importance of serial monitoring, as a decrease of two or more points is associated with improved prognosis.[5]

The presence of comorbidities was identified in 79.49% of patients, with a mean initial SOFA score of 9.62 among those with comorbidities and 8.55 among those without, a difference without statistical significance (p = 0.41). Although the final SOFA score was slightly higher in patients without comorbidities (7.62 versus 6.36; p = 0.57), this trend did not reach statistical relevance. Even so, the literature indicates that advanced age and chronic diseases are associated with an increased risk of organ dysfunction and mortality in VAP,[12] possibly due to reduced physiological reserves and a diminished immune response.

The year of hospitalization showed slight variation in SOFA scores, with 2020 presenting the highest final SOFA score (7.92), followed by 2019 (4.71) and 2021 (7.75). Despite the lack of statistical significance (p = 0.24), this temporal variation may be associated with the indirect impact of the COVID-19 pandemic on ICU care dynamics, as suggested by a 2021 study,[13] which reported increased infections and greater clinical severity during this period, even among patients not infected with SARS-CoV-2. Hospital overload and resource limitations may have negatively influenced clinical outcomes.

The mean ICU length of stay was 23.38 days, with a negative β coefficient (−0.08) in relation to the final SOFA score, indicating that patients with longer hospitalizations generally showed a reduction in the score over time, possibly reflecting therapeutic response and clinical stability. However, the p-value (0.62) was not significant. Another study[14] observed the opposite result, with an increase in SOFA score according to the duration of mechanical ventilation, associating prolonged hospitalizations with greater severity and mortality. This discrepancy may be explained by differences in population profiles, management practices, and timing of VAP diagnosis across studies.

The mean duration of mechanical ventilation was 17.89 days, also without a significant correlation with the final SOFA score (β = −0.004; p = 0.18). This finding may be related to the use of institutional protocols for early weaning and active respiratory physiotherapy, practices that reduce the duration of mechanical ventilation and the severity of organ dysfunction.

In the microbiological analysis, the presence of multiple pathogens was observed, with emphasis on Staphylococcus aureus (17.95%) and Pseudomonas aeruginosa (10.26%), both widely recognized as being associated with VAP. The diversity of isolated microorganisms—including Klebsiella pneumoniae, Acinetobacter baumannii, and Proteus mirabilis—demonstrates the etiological complexity of the infection and the need for individualized therapy. These findings partially differ from those reported by two authors,[15,16] who indicated a higher prevalence of Acinetobacter baumannii and Klebsiella pneumoniae in Asian ICUs. Such differences may reflect regional microbiological characteristics, infection control policies, and rational antimicrobial use.

Regarding outcomes, 51.28% of patients were discharged from the hospital, 7.69% were transferred, and 41.03% progressed to death. The observed mortality rate falls within the range reported in previous studies on VAP in Brazilian and international ICUs, varying between 30% and 50%.[4,8] The significant differences in SOFA scores between outcome groups reinforce its potential as a sensitive prognostic indicator, capable of early identification of patients at increased risk of clinical deterioration.

Considering the SOFA score values, it is observed that SOFA is an important indicator for patients with VAP, as it reflects the criticality of their clinical condition. Notably, higher SOFA scores, both initial and final, have a direct implication for outcome results.

The results obtained indicate that the SOFA score is a reliable tool applicable to clinical practice in ICUs, allowing risk stratification, longitudinal monitoring, and support for decision-making. Its systematic use may assist in resource prioritization, revision of prevention protocols, and planning of individualized interventions, especially in patients with multiple comorbidities or infections caused by resistant microorganisms.

Despite the consistent findings, this study presents limitations inherent to its retrospective design and small sample size, which restrict the generalizability of the results and the performance of more robust multivariate analyses.

Data loss in electronic medical records and the pandemic period also affected data completeness. Nevertheless, the consistency of the results with the literature strengthens the hypothesis that the SOFA score can be used as a predictor of mortality in patients with VAP.

The findings suggest the need for multicenter prospective studies with larger samples and predictive analyses (e.g., logistic regression, ROC curves, and calibration) to determine optimal cutoff points and to evaluate the performance of SOFA across different ICU profiles. In addition, investigations integrating SOFA with other indices (such as APACHE II, EVARUCI, or the Charlson Comorbidity Index) may improve the accuracy of mortality prediction and guide clinical management in a more targeted manner.

In summary, the present study demonstrated that higher initial and final SOFA scores are associated with increased mortality, whereas reductions in scores over the course of hospitalization indicate clinical improvement and a greater chance of survival. Thus, the SOFA score is confirmed as an essential tool in the prognostic assessment of critically ill patients with VAP, contributing to decision-making, patient safety, and improvement in the quality of care in ICUs.

CONCLUSÃO

The analysis demonstrated that the SOFA score has clinical relevance in predicting outcomes in patients with ventilator-associated pneumonia (VAP) admitted to intensive care units. Patients who progressed to death presented significantly higher mean initial and final SOFA scores, evidencing an association between greater organ dysfunction and worse prognosis.

Although variables such as sex, presence of comorbidities, duration of mechanical ventilation, and type of isolated microorganism did not show statistical significance, the SOFA score stood out as a robust indicator for risk stratification and longitudinal monitoring of these patients.

The findings reinforce the usefulness of SOFA as a tool to support clinical decision-making, allowing early identification of organ deterioration and guiding more targeted therapeutic interventions.

However, limitations such as the small sample size and data loss during the pandemic period restrict the generalizability of the results. Prospective and multicenter studies with larger samples are recommended to further elucidate the prognostic role of SOFA in patients with VAP and to validate its cutoff points for mortality prediction.

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Study approved by the Research Ethics Committee of the State University of Ponta Grossa, Certificate of Presentation for Ethical Consideration (CAAE): 61430822.0.0000.0105.

CONFLICT OF INTERESTS
There are no conflicts of interest to declare.