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PROSPECTIVE OBSERVATIONAL STUDY COMPARING SEQUENTIAL ORGAN FAILURE ASSESSMENT SCORE WITH PH AND SEQUENTIAL ORGAN FAILURE ASSESSMENT SCORE FOR OUTCOME PREDICTION IN ICU

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ABSTRACT

Background : The SOFA (Sequential Organ Failure Assessment) score is widely used in ICUs (Intensive Care Units) to assess organ dysfunction and predict patient outcomes. The addition of blood pH as a parameter may enhance its predictive accuracy. This study aims to compare the SOFA score with and without pH for prognosis, mortality prediction, and risk estimation of hospital death in ICU patients.

Methods : This prospective, observational clinical study included ICU patients aged 18 years and older who were admitted for more than 48 hours after obtaining informed consent. A thorough general and systemic examination was conducted, and routine investigations were performed based on clinical findings. The SOFA score and SOFA score with pH were calculated using laboratory data and patient characteristics at admission (0 hours) and 48 hours. Outcomes, including ICU length of stay, hospital length of stay, and survival status, were recorded. The predictive ability of the scores was analyzed and correlated with actual patient outcomes.

Results : The overall mortality rate in the study was 27%. The mean age of survivors and non-survivors was 63.47 and 62.0 years, respectively ($p = 0.725$), showing no significant difference. No difference was observed between survivors and non-survivors in terms of ICU and hospital stay ($p >$

0.05). The mean SOFA score at baseline was significantly higher in non-survivors (8.33 vs. 5.9; $p < 0.01$), and this difference increased at 48 hours (11.67 vs. 3.66; $p < 0.01$). Similarly, the SOFA score with pH at baseline was higher in non-survivors (10.11 vs. 7.49; $p < 0.01$), and the difference was more pronounced at 48 hours (14.63 vs. 4.29; $p < 0.01$). Receiver operating characteristic (ROC) curve analysis demonstrated that the predictive accuracy of the SOFA score with and without pH was higher at 48 hours compared to baseline. At 48 hours, the diagnostic accuracy of SOFA with pH (AUC = 0.994, $p < 0.01$) was slightly superior to SOFA alone (AUC = 0.988, $p < 0.01$). The sensitivity and specificity of SOFA >6 at baseline were 66.7% and 71.2%, respectively, with an overall diagnostic accuracy of 70%. For SOFA with pH >6 at baseline, sensitivity and specificity were 70.4% and 69.9%, respectively, with a diagnostic accuracy of 70%. At 48 hours, SOFA >6 had a sensitivity and specificity of 92.6% and 95.9%, respectively, with an overall accuracy of 95%. The addition of pH to SOFA further improved predictive performance, with SOFA + pH >6 at 48 hours achieving 100% sensitivity, 97.3% specificity, and 98% diagnostic accuracy.

Conclusion : Sequential assessment of organ dysfunction using the SOFA score is a highly reliable predictor of ICU patient outcomes. Evaluating the score at 48 hours significantly enhances its prognostic value. The inclusion of pH further improves the predictive accuracy. Therefore, we recommend using the SOFA score at admission and at 48 hours, with the addition of pH preferred for more accurate mortality prediction.

Keywords: SOFA Score, pH, ICU, Outcome Prediction, Mortality, Organ Dysfunction, Prognosis, Sequential Organ Failure Assessment.

INTRODUCTION

Critically ill patients often experience progressive, time-dependent organ dysfunction, ranging from mild impairment to irreversible organ failure. This clinical deterioration is recognized as an independent predictor of mortality, and early identification of patients at risk of worsening organ function could significantly improve outcomes.[1] Among these patients, those admitted to the ICU are particularly vulnerable to acute decompensation, making dynamic clinical assessment crucial for timely intervention.

The use of morbidity and mortality prediction systems has gained increasing importance in recent years. These systems help healthcare providers categorize patients based on their expected outcomes, allowing for targeted and aggressive management strategies, particularly in resource-limited settings. Additionally, these scoring systems serve as valuable comparative tools for assessing ICU performance.[2] Various scoring models have been developed to objectively evaluate a patient's clinical status and predict mortality.[2] However, many of these models involve complex variables, making them time-consuming and challenging to apply in routine clinical practice. Furthermore, previous studies indicate that some existing scoring systems may not be entirely suitable for ICU patients.[3]

The SOFA (Sequential Organ Failure Assessment) score, developed by Vincent et al.,[4] is a well-validated tool used to assess the severity of illness in critically ill patients by evaluating six organ systems.[5,6] It has been widely used for predicting both short-term and long-term mortality in ICU patients.[5,7]

One critical physiological parameter that influences patient outcomes is blood pH. The human body functions within a narrow alkaline pH range (7.35–7.45), and maintaining this balance is essential for normal physiological function. Acid-base homeostasis is primarily regulated by respiratory and metabolic mechanisms.[8] The respiratory response is rapid, occurring within minutes, while metabolic compensation takes hours to days to become fully activated.[9]

pH is also a major component of the APACHE-II scoring system, highlighting its importance in critical care assessment. Rajawat et al.,[10] demonstrated that both acidemia and alkalemia, regardless of whether they are of respiratory or metabolic origin, significantly impact ICU patient morbidity and

mortality. Furthermore, the rate of pH correction has been identified as a crucial factor in patient outcomes.

Given the established importance of pH as a prognostic marker, this study aims to incorporate pH as an additional parameter in the SOFA score to determine whether this modification enhances its predictive accuracy compared to the SOFA score alone.

Aims and Objectives

The aim of this study was to compare the SOFA score with and without pH for outcome assessment in ICU patients. The primary objective is to determine whether SOFA alone or in combination with pH serves as a better prognostic and mortality indicator. Additionally, the study aims to evaluate the effectiveness of SOFA versus SOFA with pH in estimating the risk of hospital death and assessing patient prognosis using these defined scoring systems.

MATERIALS AND METHODS

This prospective, observational clinical study was conducted in the Intensive Care Unit (ICU) of the Department of Critical Care Medicine at Holy Family Hospital and Research Centre, Bandra (West), Mumbai. The study included patients aged 18 years or older who were admitted to the ICU for more than 48 hours. The study was carried out over a period of one year, from March 2023 to February 2024.

Inclusion and Exclusion Criteria

The study included 100 patients aged 18 years or older who were admitted to the ICU for more than 48 hours. Patients were excluded if they were post-operative cases requiring elective ventilation, had acute coronary syndrome, were burn patients, or had terminal cancer.

Sample Size Calculation

Sample Size calculation using SAS9.2 for new study 3

Name of Study:Comparison of Sequential Organ Failure Assessment Score and Sequential Organ Failur
Score with pH in Outcome Prediction among ICU Patients: A Prospective Observational Study

Efficacy variable:Sensitivity of SOFA + pH at 48 hrs

Null Hypothesis H0:Sensitivity = 96.3% appro.(Ref.Agarwal A et al)

Alternative Hypothesis H1: Anticipated Sensitivity=90.0% appro.

Minimum Sample size = 98,Power= 80%,Alpha=0.05

Statistical test: Z test for Binomial Proportion.

19:27 Sunday, July 1, 2018

The POWER Procedure
Z Test for Binomial Proportion

Fixed Scenario Elements

Method	Normal approximation
Number of Sides	2
Null Proportion	0.963
Alpha	0.05
Binomial Proportion	0.9
Nominal Power	0.8
Variance Estimate	Null Variance

Computed N Total

Actual Power	N Total
0.802	98

The sample size was 98 patients, we had taken 100 patients for better validity of results.[11]

Data Collection Method

The study commenced after obtaining approval from the institutional ethical committee, and informed consent was taken from all participants. A total of 100 ICU patients aged 18 years or older, admitted for more than 48 hours, were included. Each patient underwent a thorough evaluation, including demographic data, detailed medical, surgical, and personal history, history of drug allergies, and a comprehensive general and systemic examination. Routine investigations were conducted based on clinical findings, along with parameters required for SOFA and SOFA with pH calculations, such as PaO2/FiO2 from ABG, platelet count, serum bilirubin, mean arterial pressure (NIBP/IBP monitor), pre-sedation GCS (Glasgow Coma Scale), serum creatinine, and pH from ABG. The SOFA scores, with and without pH, were recorded at admission (0 hours) and at 48 hours, with the highest SOFA score of the day documented. Pre-sedation GCS was used to assess neurological status in sedated patients. The calculated scores were correlated with actual outcomes, categorizing patients as survivors or non-survivors. All patient management followed the hospital's standard treatment protocols.

Statistical Analysis

Data was recorded in a pre-designed study proforma. Qualitative data was expressed as frequency and percentage, while quantitative data was represented as mean ± SD. An unpaired t-test was used to compare quantitative data between groups. ROC curve analysis determined diagnostic accuracy and optimal cut-off values for SOFA and SOFA with pH in predicting mortality. A p-value < 0.05 was considered statistically significant. Results were graphically represented where necessary. Statistical analysis was performed using SPSS Version 26.0, with Microsoft Excel 2021 used for graphical representation.

RESULTS

Outcome	**N**	**Percentage**
Survived	73	73.0%
Died	27	27.0%
Total	100	100.0%
Table 1: Distribution of Outcomes in ICU Patients		

Table 1 displays the overall outcomes among the 100 ICU patients studied, showing a survival rate of 73% and a mortality rate of 27%.

Outcome	**N**	**Mean**	**SD**	**t-value**	**P-Value**
Died	27	62.00	18.50	-0.353	0.725
Survived	73	63.47	18.43		
Table 2: Age Distribution among Survivors and Non-Survivors					

Table 2 compares the mean age and standard deviation between non-survivors and survivors. The p-value (0.725) indicates no significant age difference between the two groups.

Variable	**Outcome**	**N**	**Mean**	**SD**	**t-value**	**P-Value**
ICU Stay (days)	Died	27	7.93	9.89	1.6	0.113
	Survived	73	5.63	4.46		
Hospital Stay (days)	Died	27	7.93	9.89	-1.49	0.138
	Survived	73	10.55	6.87		
Table 3: Comparison of ICU and Hospital Stay among Survivors and Non-Survivors						

Table 3 presents the comparison of ICU and hospital stay durations between the two outcome groups. No statistically significant differences were observed ($p > 0.05$), indicating that length of stay did not differ markedly between survivors and non-survivors.

Variable	Outcome	N	Mean	SD	t-value	P-Value
SOFA_0	Died	27	8.33	3.01	4.05	<0.01
	Survived	73	5.90	2.52		
SOFA+pH_0	Died	27	10.11	3.30	3.75	<0.01
	Survived	73	7.49	3.02		

Table 4: Mean SOFA and SOFA with pH Scores at Baseline (0 Hours) among Survivors and Non- Survivors

Table 4 shows that both the SOFA score and the combined SOFA with pH score were significantly higher in non-survivors compared to survivors ($p < 0.01$), indicating a worse initial clinical status in those who did not survive.

Variable	Outcome	N	Mean	SD	t-value	P-Value
SOFA_48	Died	27	11.67	3.75	14.55	<0.01
	Survived	73	3.66	1.74		
SOFA+pH_48	Died	27	14.63	3.96	16.4	<0.01
	Survived	73	4.29	2.24		

Table 5: Mean SOFA and SOFA with pH Scores at 48 Hours among Survivors and Non-Survivors

Table 5 at 48 hours, both the SOFA and SOFA with pH scores increased significantly in non-survivors compared to survivors ($p < 0.01$). The higher scores at 48 hours underscore the worsening organ dysfunction in non-survivors.

Test Variable	Area	SE	P-Value	95% CI (Lower - Upper)
SOFA_0	0.738	0.057	<0.01	0.63 – 0.85
SOFA_pH_0	0.726	0.058	<0.01	0.61 – 0.84
SOFA_48	0.988	0.008	<0.01	0.97 – 1.00
SOFA_pH_48	0.994	0.005	<0.01	0.99 – 1.00

Table 6. ROC Curve Analysis for SOFA Score and SOFA with pH Score for Prediction of Mortality

Table 6 summarizes the ROC curve analysis, revealing that both the SOFA and SOFA with pH scores have improved diagnostic accuracy at 48 hours (AUC > 0.98) compared to baseline. Notably, the SOFA with pH score at 48 hours achieved the highest predictive accuracy.

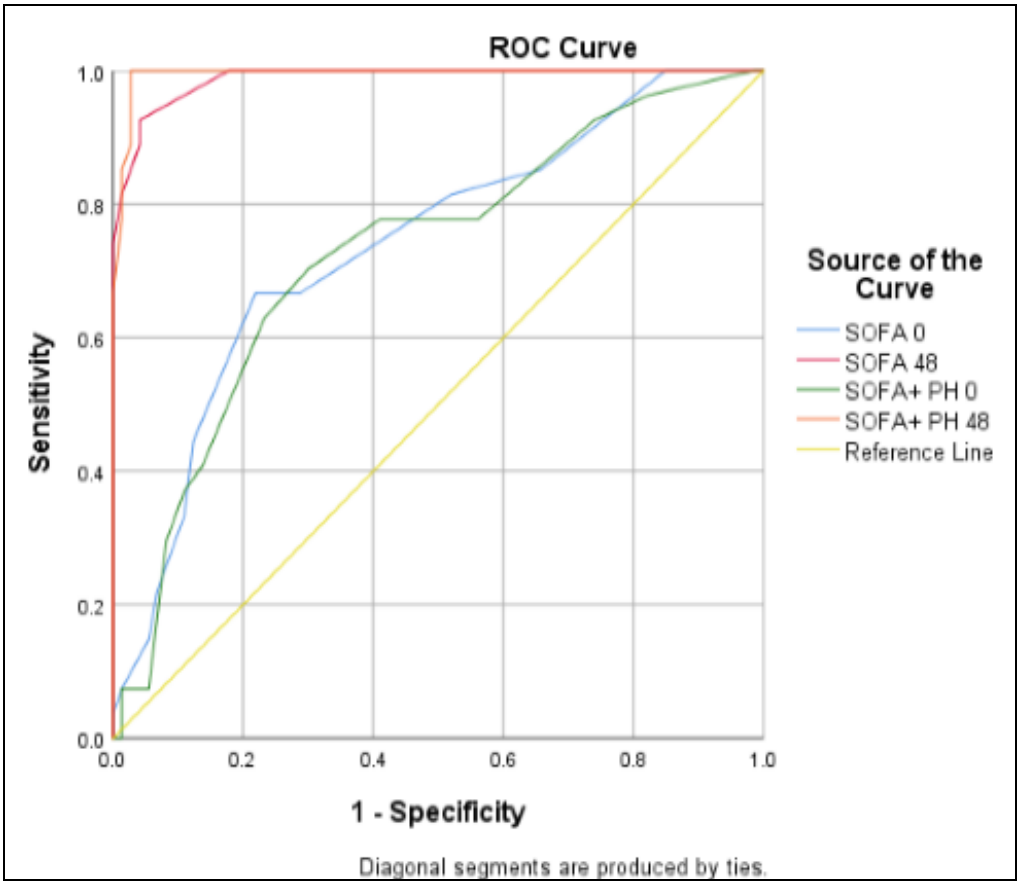

Figure 1

Score Type	Time	Sensitivity	Specificity	PPV	NPV	Accuracy	SMR
SOFA	Baseline	66.7%	71.2%	46.2%	85.2%	70.0%	0.69
SOFA	48 Hours	92.6%	95.9%	89.3%	97.2%	95.0%	0.96
SOFA + pH	Baseline	70.4%	69.9%	46.3%	86.4%	70.0%	0.66
SOFA + pH	48 Hours	100.0%	97.3%	93.1%	100.0%	98.0%	0.93

Table 7: Diagnostic Accuracy of SOFA and SOFA with pH Scores for Mortality Prediction

Table 7 compiles the diagnostic accuracy parameters for both the SOFA and the combined SOFA with pH scores at baseline and 48 hours. The results show that while both scores perform similarly at baseline, the SOFA with pH score at 48 hours demonstrates superior performance with 100% sensitivity, 97.3% specificity, and an overall diagnostic accuracy of 98%.

DISCUSSION

Critically ill individuals often experience a gradual deterioration of organ function, which can range from minor dysfunction to irreversible failure. This progressive decline is an independent predictor of mortality, emphasizing the need for early identification of patients at risk for severe organ damage. The use of morbidity and mortality prediction models has gained increasing significance in clinical settings, aiding healthcare professionals in categorizing patients based on anticipated outcomes. This stratification allows for targeted and intensive management, especially in resource-limited healthcare settings.

One such predictive model, the SOFA score, was developed by Vincent et al.,[4] to assess disease severity across six organ systems.[5,6] It has been validated for predicting both short-term and long-term mortality in ICU patients.[5,7] Given the body's tight regulation of pH within an alkaline range of

7.35–7.45, disruptions in acid-base balance can significantly impact physiological functions. The maintenance of pH homeostasis is achieved through rapid respiratory responses and slower metabolic compensation mechanisms.[8,9]

Our study aimed to compare the effectiveness of the SOFA score with and without pH in predicting mortality among ICU patients. A total of 100 patients admitted to the ICU for over 48 hours were included in the study, with SOFA and pH scores calculated at admission and at 48 hours. The overall ICU mortality rate in our study was 27%, which aligns with prior studies, including Said M et al. (20.44%) and Raith EP et al.[12,13] (18.7%), but is higher than that reported by Shahsavarinia K et al. (12%). However, Kilinc Toker et al.,[14] reported a significantly higher mortality rate of 52.3%.

A significant correlation was observed between higher SOFA scores and increased mortality. The mean SOFA score was significantly higher in non-survivors at both admission (8.33 vs. 5.9; $p<0.01$) and 48 hours (11.67 vs. 3.66; $p<0.01$). ROC curve analysis revealed that the predictive accuracy of the SOFA score for mortality improved over time, with a higher diagnostic accuracy at 48 hours (AUC – 0.988; 0.97-1.0; $p<0.01$). The sensitivity and specificity of a SOFA score >6 at admission were 66.7% and 71.2%, respectively, with an overall diagnostic accuracy of 70%. At 48 hours, the sensitivity and specificity increased to 92.6% and 95.9%, respectively, with an overall diagnostic accuracy of 95%. These findings are consistent with previous studies, including Bale et al.,[15] who reported a mean SOFA score of 6.96 in non-survivors at 48 hours ($p<0.001$), and Liu Z et al.,[16] who reported an AUC of 0.686 (95% CI, 0.661–0.710; $p<0.01$) for mortality prediction in ICU patients.

When pH was incorporated into the SOFA score, the predictive power improved further. The mean SOFA score with pH was significantly higher in non-survivors at admission (10.11 vs. 7.49; $p<0.01$) and 48 hours (14.63 vs. 4.29; $p<0.01$). ROC analysis showed that the predictive accuracy of SOFA with pH was superior to SOFA alone at 48 hours (AUC – 0.994; 0.99-1.0; $p<0.01$). The sensitivity and specificity of a SOFA score with pH >6 at admission were 70.4% and 69.9%, respectively, with a diagnostic accuracy of 70%. At 48 hours, the sensitivity and specificity increased to 100% and 97.3%, respectively, with an overall diagnostic accuracy of 98%. These results align with those reported by Agarwal AM et al.,[11] who found that while both SOFA and SOFA with pH were effective predictors at admission, the inclusion of pH improved predictive accuracy at 48 hours. Additionally, Samanta et al.,[17] highlighted the role of early pH changes in predicting 28-day ICU mortality, while Frantz TL et al.,[18] emphasized the relationship between pH variations and organ dysfunction.
Overall, our study reinforces the utility of the SOFA score as a reliable predictor of ICU mortality, particularly when assessed at 48 hours. The addition of pH further enhances the predictive accuracy of the SOFA score, making it a more effective tool for mortality prediction. Therefore, we recommend utilizing the SOFA score both at admission and at 48 hours, with the inclusion of pH as an additional parameter to improve prognostic accuracy in critically ill patients.

CONCLUSION

The study concludes that the SOFA score is a highly reliable tool for predicting adverse outcomes in ICU patients. When assessed 48 hours after admission, both SOFA scores—with and without pH—serve as strong predictors of patient outcomes. The addition of pH to the SOFA score further enhances its predictive accuracy, making it a more effective tool. Consequently, we recommend the routine use of the SOFA score at both admission and 48 hours post-admission, with the inclusion of pH for improved prognostic accuracy in critically ill patients.

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