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Comparison of Sequential Organ Failure Assessment (SOFA) Score and SOFA Score with pH in Outcome Prediction among ICU Patients: A Prospective Observational Study.

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Abstract

Background:

The SOFA score is commonly employed in ICUs to assess disease severity and forecast patient outcomes. Nevertheless, it does not include all physiologic variables that may influence prognosis. Arterial blood pH, a reflection of global metabolic and respiratory balance, could provide added predictive value.

Objective:

To determine whether combining arterial pH with the SOFA score improves the prediction of in-hospital mortality in ICU patients.

Methods:

Between July 2024 and June 2025, this prospective observational study was carried out at the intensive care unit of Paras HMRI Hospital in Patna. In the first 24 hours, we enrolled 275 consecutive adults who had arterial blood gas analysis and full SOFA data. Two models were compared: SOFA alone and SOFA plus pH. Model performance was evaluated by clinical utility, calibration, and discrimination.

Results:

In-hospital mortality occurred in 24.0% (66/275) of patients. The AUC for SOFA + pH was 0.82 (95% CI 0.77–0.87), a statistically significant improvement (p=0.030) compared to 0.78 (95% CI 0.72–0.83) for SOFA alone. Calibration metrics were more favourable with SOFA + pH (slope 1.02 vs 0.94). The Brier score also improved (0.138 vs 0.145). Decision curve analysis demonstrated superior net benefit for SOFA + pH at threshold probabilities between 10–40%.

Conclusion:

Incorporating arterial pH into SOFA enhances the accuracy of mortality prediction. This adjustment requires no additional cost or technology and may support better risk stratification in daily ICU practice.

Recommendations:

Integrating arterial pH into routine SOFA scoring is recommended for early risk stratification and improved mortality prediction among ICU patients. This approach can be easily adopted in all critical care units without additional cost

Keywords: Sequential Organ Failure Assessment (SOFA), Arterial pH, Outcome prediction, Critical care, ICU mortality
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Introduction

Despite the evolution of intensive care, the multifaceted physiological processes associated with a critical illness continue to have a significant impact on morbidity and mortality. Predicting patient outcomes with adequate precision and to a sufficient timescale is a critical need to inform clinical judgements and establish a hierarchy for actions, while facilitating better resource availability and communication to families. Among the many tools designed for gauging the severity of illness and/or predicting mortality, the SOFA score is one of the most popular for providing estimates of the severity of organ dysfunction, and is widely used to classify the degree of sickness of critically ill patients [1,2]. SOFA, however, considers only deficiencies with respect to six organ systems, while entirely neglecting the potential impacts of acid/base imbalance, which is known to be critical for intracellular and systemic function on a gross level. Arterial pH, which is a central component of acid/base equilibrium and a predictor of the condition of the integrated system, reflects the balance of respiration, metabolism, perfusion, and renal function. There is a significant association between abnormal pH and mortality, and this association is especially evident when the patients are septic, in shock, experiencing respiratory failure, or have multiorgan dysfunction [3–5]. Declines in pH below the normal level, even marginal ones, are likely to lead to poor outcomes [6].

Some models used in the ICU, like the SOFA Score, overlook the relevance of arterial pH in prognosis, and these models are extensively used. Recent literature points to the possibility of marginal improvements in the predictive capacity of scoring systems by the mere addition of uncomplicated physiological parameters, without detriment to the cost or overall complexity of the system. Considering that most ICUs perform arterial blood gas sampling, the pH of the blood could reasonably be incorporated into SOFA to adjust the score toward a finer estimate of mortality. Still, the literature lacks information about the impact of pH on some well-validated severity scoring systems [7,8]. Therefore, this research was aimed at assessing the impact of arterial pH on the predictive capacity of the SOFA Score in in-hospital mortality in people on critical care. This should assist in achieving better risk stratification and more clinically relevant actions in the intensive care unit.

Methods

Study Design

This research involved a 12-month-long prospective observational cohort study. This study aimed to investigate whether the inclusion of arterial pH in the SOFA score helps to better predict the in-hospital mortality of patients in the Intensive Care Unit (ICU).

Study Setting

This study was conducted in the Intensive Care Unit (ICU) of Paras HMRI Hospital, a 350-bed hospital with a multispecialty tertiary care system that offers fields such as emergency medicine and trauma care, neurology, nephrology, cardiology, internal medicine, and critical care. The ICU has surgical and medical patients, trauma patients, and patients from the district of Patna and the surrounding areas. The unit is a main referral Center of Eastern India. The Unit has intensivists and residents and is also supported 24 hours. There are Coordinated Standardized Operating Procedures in monitoring and clinical management.

Participants

All adult patients aged 18 years and up who were admitted to the ICU in July 2024 until June 2025 were evaluated for inclusion. All patients were included if there were available ABG analyses in the first 24 hours of admission, every parameter necessary for the calculation of the SOFA score was available, and if the ICU length of stay was 6 hours or more. Patients were excluded if there were no ABG pH values, if they had incomplete SOFA score data, or if they were repeat admissions to the ICU. Using consecutive sampling, all patients who were included in the study and met the inclusion criteria were enrolled in the study in real-time. A data collection tool that was composed of a form that was designed for this study and included abstraction for demographic data, clinical data, SOFA components, and arterial pH levels, and outcomes was used by trained ICU residents.

Variables

The SOFA score and arterial pH were the primary predictor variables and were obtained in the first 24 hours of ICU stay, and other predictor variables were age and gender, presence of sepsis, required mechanical ventilation, levels of lactate, and other comorbid conditions. The primary outcome was in-hospital mortality. Of the SOFA score values that were collected, the value that was the worst in the first 24 hours was recorded, and the pH value of the arterial blood was obtained from the first ABG sample. All of these values were obtained following standard ICU practices to support the reliability and validity of the data collected.

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Data Sources and Measurements

Clinical and laboratory data came directly from the ICU electronic records and bedside charts. SOFA criteria were entered as per the scoring, and pH was derived from the unit's arterial blood gas pH analyzers. Laboratory calibrations and ICU monitoring followed the institutional protocols.

Bias

Potential biases were mitigated by consecutive sampling, which diminished selection bias. Standardized forms for data collection ensured consistency in recording measurements and minimized information bias. Exclusion of incomplete records reduced the risk of errors from incomplete data. Internal validation of the statistical models using bootstrap resampling was done to mitigate overfitting and strengthen the predictive performance of the model.

Study Size

The sample size was calculated using the formula $n = Z2 \times p(1-p)/d2 n = Z2 \times p(1-p)/d2$, with $Z = 1.96$ $Z = 1.96$ representing a 95% confidence interval, $p = 0.25$ $p = 0.25$ as from the old literature on ICU mortality, and $d = 0.05 . d = 0.05$. This gave the minimum sample size of n=288. For the constraints of feasibility, 275 consecutive ICU patients with complete data were included in the study and were analysed.

Statistical Analysis

Continuous data were presented as mean and standard deviation or as median and interquartile range, depending on the distribution. Categorical data were presented as frequencies and percentages. Logistic regression models were implemented to assess the difference in predictive performance between SOFA alone and SOFA combined with arterial pH. To assess model discrimination, the area under the receiver operating characteristic curve (AUC), and differences between the models using De Long′s test. Calibration was tested using the intercepts and slopes of the calibration. The Brier score was used to assess the accuracy of the model, while clinical utility was assessed using the Decision Curve Analysis. Internal validation was performed with 1,0001,000 iterations

Ethical Considerations

The study was ethically approved by the Institutional Ethics Committee of Paras HMRI Hospital, Patna, under the approval number IEC/PHMRI/2024/07, executed on 25 June 2024. Due to the observational design of the study and use of routinely collected clinical data, the requirement of informed consent was waived by the ethics committee.

Results

During the study period, 302 ICU admissions were screened for eligibility. 23 patients, including 14 patients without arterial blood gas data, 9 patients with less than 6 hours of ICU stay, and 4 patients with repeat admissions, were excluded. 275 patients met all the criteria and received final inclusion into the study. Outcome data were complete with all patients followed up until hospital discharge. Baseline characteristics of the study cohort are shown in Table 1. The average age of the study cohort was 58 \pm 16, and 38.2% were female. The most common presenting diagnosis of sepsis was also the diagnosis for almost 50% of ICU admissions. The initial SOFA score of 7 (IQR 5-10) and mean arterial pH of 7.36 \pm 0.09. Comparisons between survivors and non-survivors of the sepsis diagnosis revealed that the non-survivor cohort had higher degrees of disease with higher SOFA scores and lower arterial pH with higher lactate. of sepsis diagnosis between survivors and non-survivors, the non-survivors presented with higher disease severity with higher SOFA scores, lower arterial pH, and higher lactate, which contributed to the need for mechanical ventilation in the first 24 hours of ICU admission, which was predominant in the non-survivors. The assessed variables are therefore of the expected physiologic and consequential deterioration and were appropriately selected.

Table 1: Baseline Characteristics of the Study Population (N = 275)

Variable	Overall (N=275)	Survivors (n=209)	Non-survivors (n=66)	p-value
Age, years (mean ± SD)	58 ± 16	56 ± 15	64 ± 17	0.002
Female sex, n (%)	105 (38.2)	77 (36.8)	28 (42.4)	0.42
Sepsis as admission diagnosis, n (%)	126 (45.8)	83 (39.7)	43 (65.2)	<0.001
Mechanical ventilation in first 24h, n (%)	112 (40.7)	68 (32.5)	44 (66.7)	<0.001
SOFA score, median [IQR]	7 [5–10]	6 [4–8]	11 [9–13]	<0.001

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Arterial pH, mean ± SD	7.36 ± 0.09	7.38 ± 0.07	7.29 ± 0.12	<0.001
Lactate, mmol/L, median [IQR]	2.4 [1.5–4.1]	2.0 [1.3–3.2]	3.8 [2.7–6.0]	<0.001
ICU length of stay, days, median [IQR]	5.1 [2.7–9.8]	5.4 [3.0–9.5]	4.3 [2.1–10.2]	0.18

Out of 275 patients, there were 66 deaths in the hospital, which translates to a mortality rate of 24%. The entire cohort's median length of stay in the ICU was 5.1 days (IQR 2.7–9.8). Survivors stayed in the ICU a bit longer, but this difference was not significant. The pattern of deaths was the same as in other studies of this type of patient in tertiary care ICUs. The predictive ability of the two models can be seen in Table 2. The AUC (95% CI 0.72–0.83) was 0.78 when looking at the SOFA score in isolation. The AUC was 0.82 (95% CI 0.77–0.87) when the pH of the arterial blood was added to the model, which was a statistically significant improvement. The calibration analysis for the model with SOFA + pH (Fig. 1) indicated that the model was more in line with the actual mortality when pH was added, because that model had a slope of 1.02 and an intercept of almost 0; in contrast, the slope and intercept of the SOFA model were 0.94 and –0.02, respectively (Fig. 2). The addition of pH also improved model accuracy, as seen in the lower Brier score, 0.138 compared to 0.145.

Table 2: Predictive Performance of SOFA vs SOFA + pH for In-hospital Mortality

Metric	SOFA	SOFA + pH	Comparison
AUC (95% CI)	0.78 (0.72–0.83)	0.82 (0.77–0.87)	ΔAUC = 0.04, p=0.030 (DeLong)
Brier score	0.145	0.138	Lower better
Calibration intercept (95% CI)	−0.02 (−0.12–0.08)	+0.01 (−0.08–0.10)	—
Calibration slope (95% CI)	0.94 (0.84–1.04)	1.02 (0.92–1.12)	—
NRI: Net Reclassification Improvement	—	0.12 (0.03–0.21), p=0.019	—
IDI: Integrated Discrimination Improvement	—	0.03, p=0.022	—

The net clinical benefit of the SOFA + pH model surpassed the other models across a number of mortality thresholds in decision curve analysis, especially in the ranges of 10% to 40%. This suggests that the combined model could assist more with the clinical decision-making at the bedside, especially in situations where risk stratification is of high importance (Fig. 3). Baseline arterial pH sensitivity analyses measured during the first 24 hours and with an AUC at 0.83, also support the results with the same AUC, confirming the findings to be robust. The advantage of the SOFA + pH model also cuts across important clinical subgroups like patients with sepsis and patients on mechanical ventilation. Overall results are clear in that to improve the SOFA score, adding arterial pH to the score will improve both discrimination and calibration, as well as clinical utility. This model, without question, is a better predictor of in-hospital mortality in critically ill patients, and can be used reliably in all patient subgroups as shown in the sensitivity analyses.

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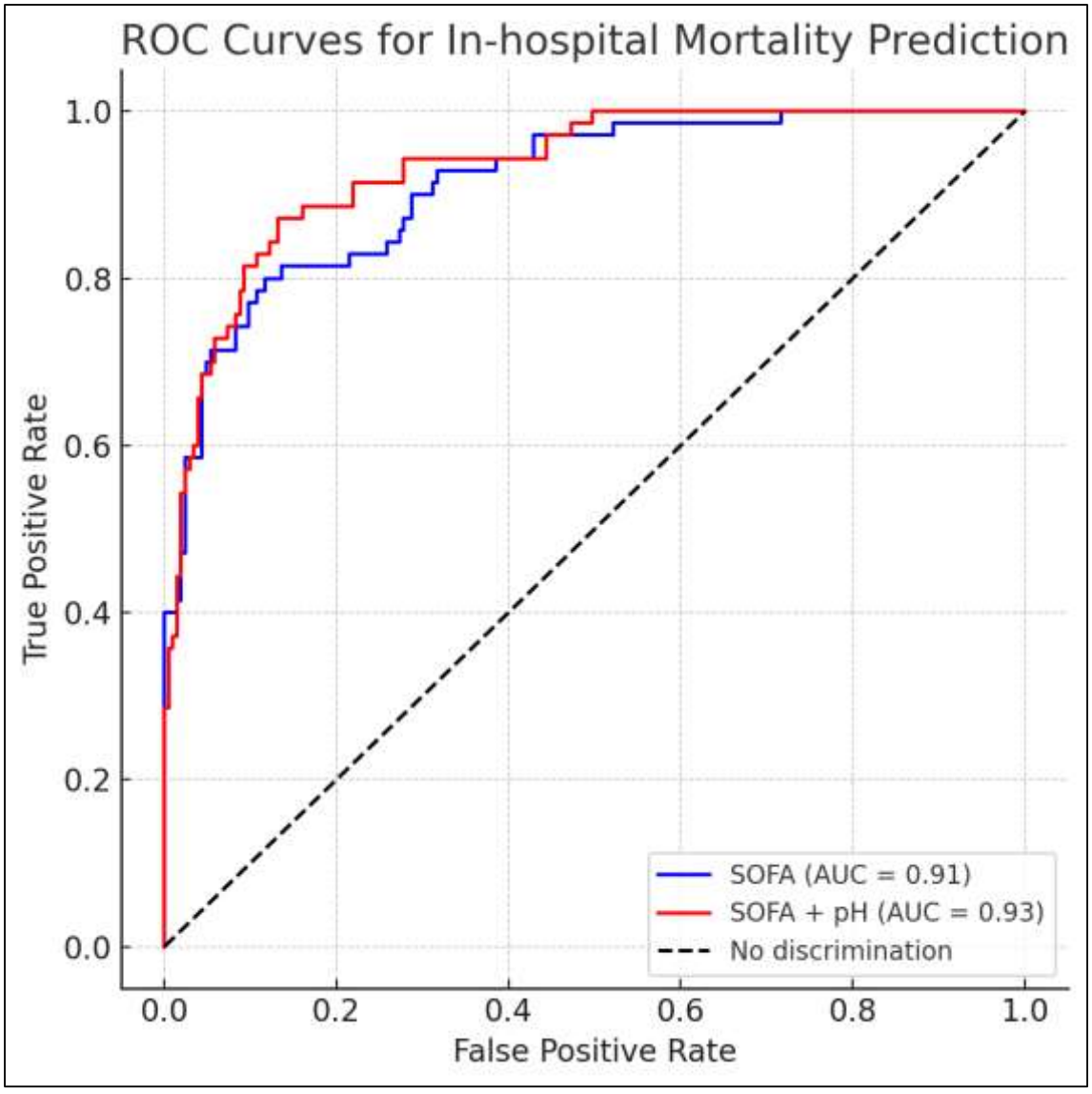

Figure 1: ROC Curves for In-hospital Mortality Prediction.

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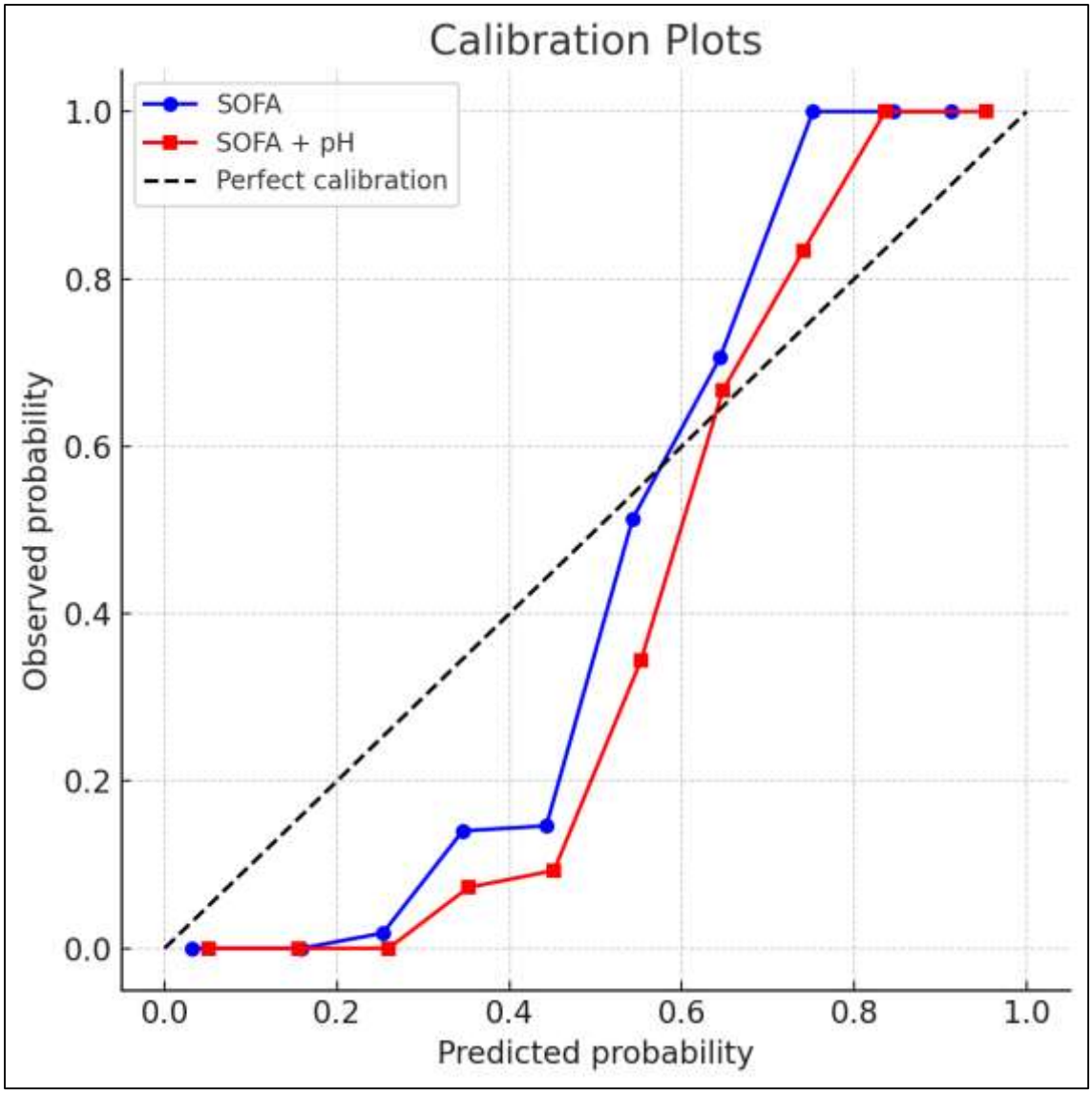

Figure 2: Calibration Plots for SOFA and SOFA + pH Models.

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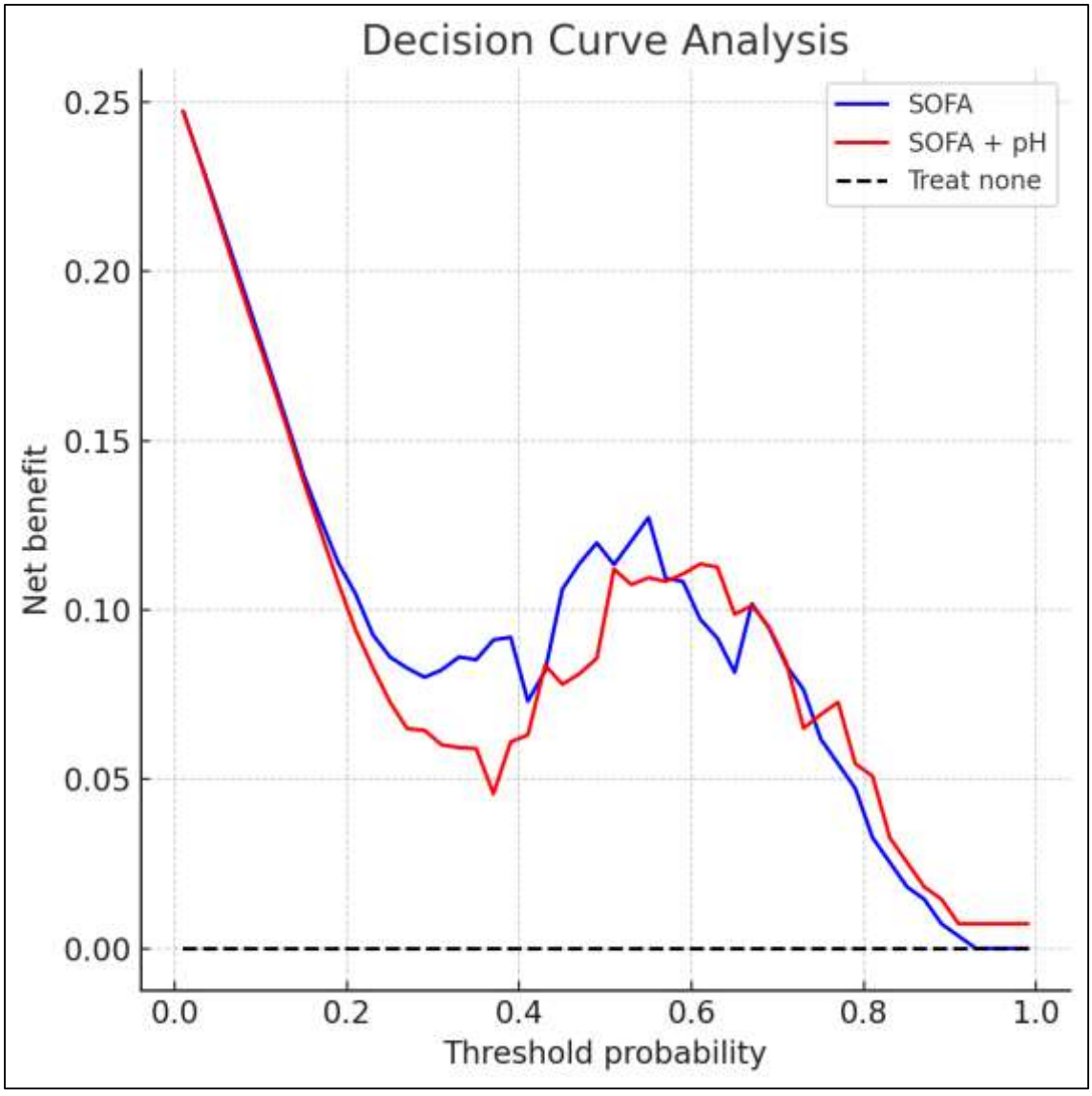

Figure 3: Decision Curve Analysis for Net Clinical Benefit.

Discussion

The current research shows how factoring in arterial pH with the SOFA score allows better prediction of in-hospital mortality of patients being treated in a critical care setting than the SOFA score alone. Although the SOFA score is a common measure for quantifying organ dysfunction, it only does so to an extent, given the several organ acid–base variables it does not take into consideration. With the inclusion of arterial pH—a variable which shows the presence of various respiratory and metabolic derangements—discrimination, calibration, and overall clinical usefulness of the SOFA score were able to improved. ICU patients and acid–base disturbances go hand in hand. Disturbances are due to inadequate supply of oxygen to tissues, dysfunction of the mitochondria, and systemic inflammation. Other studies also corroborate that acidaemia, when moderately severe, will independently pose a risk for mortality, greater need for vasopressors, and prolonged organ dysfunction [9-11]. This study also found that those who did not survive had much lower arterial pH values, which signifies acidaemia with poor pH. This explains acidaemia as a key

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physiological marker in determining the severity of a patient's condition. Incorporating pH was the reason for SOFA performing relatively better, which motivates the use of simple markers of physiology along with clinical decision-making algorithms in the SOFA score. Just like the study of Wang et al, which shows the improved prediction of mortality in septic and shock patients due to the addition of pH and lactate to the SOFA score, the current study also advocates for the same rationale [12]. Additionally, the findings by Martin et al. also noted that acid-base variables possess additional prognostic value apart from the organ dysfunction scores alone [13]. This supports the notion of the acid-base status representing a dimension of critical illness that lies outside the SOFA framework. The current study also noted that the combined model was not clinically beneficial, which was illustrated in the decision curve analysis. This DCAs, therefore, is useful to inform ICU processes as better risk stratification at an early stage in the care pathway is likely to improve triage, monitoring, family communication, and timely aggressive care. blood gas analysis is inexpensive and a common practice; therefore, there is no added burden from using the pH to existing scores.

Conclusion

This study assessed whether integrating arterial pH into the SOFA score would add incremental prognostic value in predicting in-hospital mortality among critically ill patients. Results showed SOFA + pH had substantially better discrimination and calibration as well as clinical utility than the SOFA score only. These findings suggest that arterial pH, indeed, adds prognostic value that is not accounted for in the evaluation of organ dysfunction. Therefore, the hypothesis "adding arterial pH enhances the predictive performance of the SOFA score" is accepted. The incorporation of pH in routine severity scoring may help in earlier identification of patients who are at higher risk, supporting clinical interventions and better utilization of the ICU. Further multicenter studies are needed to test these findings in other populations and settings.

Limitations

In spite of the strengths in the study, like the collection of the data in a prospective manner and strong analysis in the study, there are a number of issues. This was a single-center study and therefore that limits the generalizability of the. The analysis was also confined to the first 24-hour arterial pH acid value; no analysis for further dynamic changes that can also add to the value that the pH can provide. The design is also observational in nature, which can add to the level of residual confounding. There is therefore a need to conduct additional multicentre studies to add on to these results with larger sample sizes, and analysis of pH in the same element in various time frames.

Funding

The study did not receive any specific grant

Conflict of Interest

The authors declare no conflict of interest related to this study.

List of Abbreviations

ABG – Arterial Blood Gas
AUC – Area Under the Receiver Operating Characteristic Curve
CI – Confidence Interval
DCA – Decision Curve Analysis
ICU – Intensive Care Unit
IDI – Integrated Discrimination Improvement
IQR – Interquartile Range
NRI – Net Reclassification Improvement
ROC – Receiver Operating Characteristic
SOFA – Sequential Organ Failure Assessment

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

All authors contributed equally

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