

Applicability of SAPS 3 and APACHE II scores in a Cardiac Intensive Care Unit: a prospective study

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Abstract

Background: Prognostic scores such as the Simplified Acute Physiology Score (SAPS) and the Acute Physiology and Chronic Health Evaluation (APACHE) are essential for assessing performance and predicting mortality in Intensive Care Units (ICUs).

Objectives: To evaluate the performance of SAPS 3 (including the Latin America [LA] and Brazil [BR] versions) and APACHE II in predicting mortality in a cardiac intensive care unit (CICU).

Methods: Prospective cohort of patients admitted between June 2022 and May 2024, followed until discharge or death. Data were extracted from electronic medical records. The relationship between observed and predicted mortality was calculated using the Standardized Mortality Ratio (SMR), and discrimination was assessed by the Receiver Operating Characteristic (ROC) curve.

Results: A total of 573 patients were included, 288 (50%) with three or more comorbidities, median age 63 years [IQR: 53–72], and 344 (60%) male. Cardiovascular diseases accounted for 76% of admissions. Overall mortality was 15%. Mean SMR values were: 0.52 (95% CI: 0.32–0.72) for SAPS 3; 0.40 (95% CI: 0.26–0.54) for SAPS 3 Latin America (AL); 0.79 (95% CI: 0.41–1.16) for SAPS 3 Brazil (BR); and 0.86 (95% CI: 0.42–1.29) for APACHE II. The analysis of the area under the curve (AUC) was 0.805 for SAPS 3 and its adapted versions, and 0.704 for APACHE II.

Conclusions: SAPS 3, particularly SAPS 3 Brazil (BR), demonstrated greater accuracy than APACHE II. Despite mortality being above the national average, the SMR indicated that observed mortality was lower than predicted, suggesting good care performance in the unit.

Keywords: Intensive Care Units; Cardiology; Simplified Acute Physiology Score; APACHE; Hospital Mortality.

Introduction

During the 1950s, the demand for specialized care grew with the advancement of medicine and medical technologies, driving the development of units dedicated exclusively to intensive monitoring and life support.¹ Due to the profile of patients admitted to these sectors, who present greater severity and clinical complexity, mortality rates and hospital costs are also higher when compared to hospitalization outside this environment.²

The assessment of disease severity and the prediction of prognoses are essential in the organization of intensive care

units (ICUs). The definition of objective criteria to evaluate patient prognosis is necessary for the proper planning of material and human resources.^{3,4} In general, mortality in ICUs ranges from 10% to 30%, and may be higher in severe cases, reaching up to 50%.⁴ In contrast, mortality in non-intensive hospitalizations is significantly lower, ranging from 1% to 5%.⁵

Prediction scores are tools that use clinical information collected at patient admission to estimate the probability of death during hospitalization. These tools have two main characteristics: discrimination and calibration. Discrimination shows the score's ability to differentiate patients at higher risk of dying from those who are likely to survive. Calibration, on the other hand, indicates whether the number of deaths predicted by the score is close to what actually occurs in practice. Thus, a score may be very good at separating patients with higher and lower risk (good discrimination) but still overestimate or underestimate the total number of predicted deaths (poor calibration).

Among the most used prognostic indices for predicting ICU mortality are the Acute Physiology and Chronic Health

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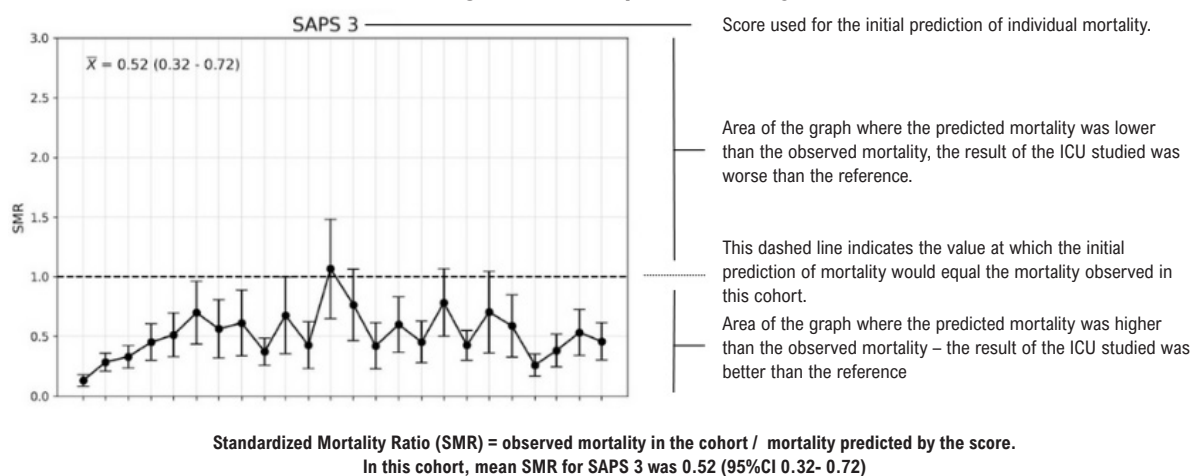
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Central Illustration: Applicability of SAPS 3 and APACHE II scores in a Cardiac Intensive Care Unit: a prospective studyINTERNATIONAL JOURNAL OF
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SCIENCES**Standardized Mortality Ratio (SMR) - comparison of mortality in an intensive care unit, taking into account patient severity**

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Evaluation II (APACHE II), introduced in 1981, and the Simplified Acute Physiological Score 3 (SAPS 3). Both allow quantification of patient severity and stratification of death risk by assigning a score based on physiological variables collected at the beginning of hospitalization – within the first 24 hours for APACHE II and within the first hour for SAPS 3. Their scoring scales range from 0 to 71 for APACHE II and from 16 to 217 for SAPS 3. The most recent version, SAPS 3, was published in 2005 based on an international cohort of 16,784 patients and included an equation adapted for Latin America (SAPS 3 AL), later validated and customized for the Brazilian population (SAPS 3 BR) in 2024.⁶⁻⁸ In Brazil, the data required for calculating SAPS 3 are collected according to the guidelines of the National Health Surveillance Agency (ANVISA) and the Brazilian Intensive Care Medicine Association (AMIB).⁹⁻¹² Adjusted mortality rates, obtained from predictions provided by these prognostic scores, have been used to assess the quality of care delivered by health services in countries such as the United Kingdom and Australia, also allowing comparisons between ICUs of different locations and levels of complexity.¹³

Despite the widespread use of these prognostic indices, their performance in intensive care units specialized in cardiology within the Latin American context remains underexplored. Consequently, there is a lack of studies validating the performance of these scores through comparative analysis between predicted and observed mortality, which is a fundamental step for a reliable assessment of their applicability.

The main objective of this study is to evaluate the results of the SAPS 3 prognostic scores, including their versions adapted for Latin America and Brazil, as well as APACHE II, in predicting mortality among patients in a Cardiac Intensive Care

Unit (CICU), and to compare them with observed mortality. Additionally, the study aimed to analyze the discriminatory ability of each model in the population studied.

Methods

This is a prospective cohort study based on data from an ICU in a quaternary-level institution under the federal public administration, recognized as a reference center for high-complexity cardiovascular care, located in the city of Rio de Janeiro (Brazil). The CICU has 10 operational beds, including one respiratory isolation bed for aerosol precautions, and is dedicated to the care of clinical patients over 18 years of age.

Inclusion criteria were: (1) patients aged over 18 years; (2) hospitalization period prospectively monitored between June 2022 and May 2024. Exclusion criteria were: (1) admissions and discharges outside the study period (inadequate timeframe); (2) incomplete or improperly filled patient data; (3) length of stay less than 24 hours in the CICU; and (4) patients transferred to another ICU.

The study was approved by the Research Ethics Committee under registration number 82367224.8.0000.5272 (CAAE), to ensure the anonymity of research participants regarding the use of their data. Considering the characteristics of the study, obtaining a signed informed consent form was waived.

Data Collection

The assessment of mortality risk, calculated using the selected prognostic indices, was based on data collected within one hour after admission to the CICU. Clinical and laboratory data from the first hour of admission were extracted

from the electronic medical records in the institution's MV 2000 System and entered into an electronic research form in Research Electronic Data Capture (REDCap®). The following demographic and clinical variables were collected: age, sex, previous comorbidities, primary ICU admission diagnosis, and length of stay in the CICU.

Statistical Analysis

Continuous variables were described using mean and standard deviation or median and interquartile range (IQR), percentages, and frequencies, according to data distribution, which was assessed using the Kolmogorov-Smirnov test. To compare the groups of patients who survived and those who died, Odds Ratios (OR) with 95% confidence intervals (95% CI) were calculated. The Mann-Whitney test was applied for variables with non-normal distribution, and categorical variables were compared between groups using Pearson's chi-square test or, when indicated due to small frequencies, Fisher's exact test. The discriminatory power of the different scores was evaluated by calculating the area under the ROC curve (Receiver Operating Characteristic, AUC). The significance level adopted was 5% ($p < 0.05$).

For all patients included in the study, the prognostic scores SAPS 3 (in its global, Latin America, and Brazil versions) and APACHE II were calculated. These scores work like a "prediction of the future": they estimate, at the time of admission to the unit, the probability that the patient will die during that hospitalization. From these individual estimates, the risk of all patients is summed, resulting in an average expected mortality for the entire group. This value is then compared to the actual mortality observed in the hospital using an indicator called the Standardized Mortality Ratio (SMR).

The SMR is defined as the ratio between the number of observed deaths and the number of expected deaths. Therefore, an SMR below 1 means that fewer deaths occurred than predicted by the score, while an SMR above 1 indicates

that observed mortality exceeded the score's prediction. An SMR equal to 1 indicates that observed mortality was exactly as predicted by the model. This comparison allows for a fair assessment of the unit's performance, considering that its patients may be more or less severe than those in other hospitals. In other words, the SMR adjusts the analysis for clinical risk, showing whether the team achieved better, worse, or similar results compared to what would be expected for that patient profile.

The REDCap database was organized using Microsoft Excel 2007, where the calculation of indicators was performed, along with the creation of figures and tables. Statistical analyses were carried out using Jamovi, R, and Python software.

Results

In this two-year cohort, 676 patients were admitted to the CICU. Of these, 573 (88%) were included in the study after applying the inclusion and exclusion criteria. The eligibility flowchart is presented in Figure 1.

The clinical and demographic characteristics of the patients included are shown in Table 1, divided into subgroups of patients who were discharged from the unit and those who died. The most prevalent comorbidities were systemic arterial hypertension (SAH) at 64% and diabetes mellitus (DM) at 34%. In this population, more than 50% of patients had three or more comorbidities. Dilated cardiomyopathy was the only measured risk factor that showed statistical significance for predicting mortality (OR 2.46; $p < 0.001$). No statistically significant difference was observed between age and risk of death. Furthermore, patients discharged to the ward or home had a shorter length of stay compared to those who died in the unit (6 days [IQR: 3–9] vs. 11 days [IQR: 6–22]; $p < 0.001$), respectively. Cardiovascular diseases were the main cause of admission (76%), among which congestive heart failure accounted for 34%, followed by acute coronary syndrome (18%) and arrhythmias (14%) (Table 2).

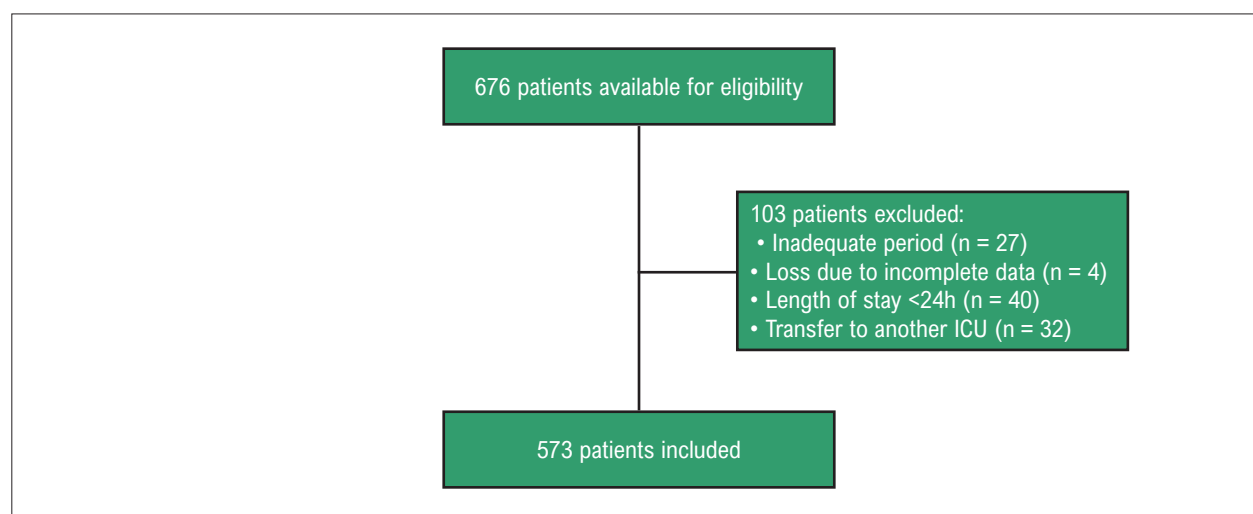


Figure 1 – Flowchart of eligibility; patients over 18 years of age who were admitted to the cardiac intensive care unit (CICU) between June 2022 and May 2024

Table 1 – Baseline patient characteristics

	High n=485 (85%)	Death n=88 (15%)	OR (95% CI)	p-value
Age (median [IQR*])	63 [53 - 72]	63 [53 - 72]	1.01 (0.99-1.02)	0.472
Female, n (%)	201 (41)	28 (32)	1.52 (0.94-2.46)	0.090
Hospital length of stay (median [IQR])	6 [3 - 9]	11 [6 - 22]	1.03 (1.02-1.04)	<0.001
SAH†, n (%)	308 (63)	58 (66)	1.11 (0.69-1.79)	0.666
Type 2 DM‡, n (%)	166 (34)	30 (34)	0.99 (0.62-1.60)	0.980
DLP§, n (%)	87 (18)	16 (18)	1.02 (0.56-1.83)	0.956
BMI > 30 Kg/m², n (%)	38 (8)	7 (8)	1.02 (0.44-2.36)	0.969
CKD//, n (%)	72 (15)	18 (20)	1.48 (0.83-2.62)	0.185
Hypothyroidism, n (%)	35 (7)	8 (9)	1.29 (0.57-2.87)	0.540
Lung diseases, n (%)	23 (5)	1 (1)	0.23 (0.03-1.73)	0.154
Atherosclerosis, n (%)	59 (12)	11 (13)	1.03 (0.52-2.05)	0.929
HFrEF¶, n (%)	88 (18)	22 (25)	1.50 (0.88-2.57)	0.135
HFpEF#, n (%)	29 (6)	3 (3)	0.55 (0.17-1.86)	0.341
Arrhythmia, n (%)	106 (22)	20 (23)	1.05 (0.61-1.81)	0.856
Valvulopathy, n (%)	51 (11)	10 (11)	1.09 (0.53-2.24)	0.812
Mental illnesses, n (%)	12 (2)	2 (2)	0.92 (0.20-4.17)	0.910
Dilated cardiomyopathy, n (%)	61 (13)	23 (26)	2.46 (1.42-4.25)	0.001
0 comorbidity, n (%)	39 (8)	3 (3)	-	-
1 comorbidity, n (%)	94 (19)	17 (19)	2.35 (0.65-8.48)	0.191
2 comorbidities, n (%)	114 (23)	18 (20)	2.05 (0.57-7.35)	0.269
≥ 3 comorbidities, n (%)	238 (49)	50 (57)	2.73 (0.81-9.19)	0.104

†SAH: Systemic arterial hypertension; ‡DM: Diabetes Mellitus; §DLP: Dyslipidemia; //CKD: Chronic kidney disease; ¶HFrEF: heart failure with reduced ejection fraction; #HFpEF: heart failure with preserved ejection fraction; *IQR: interquartile range

The median SAPS 3 score for patients included in this cohort was 55 points [49–63], and for APACHE II, 12 points [9–16]. The predicted mortality at the time of admission to the unit was significantly higher among patients who died compared to survivors across all measured prognostic scores (Figure 2).

Figure 3 shows the monthly SMR throughout the study period, where the dashed line indicates an SMR equal to 1; values above 1 indicate mortality higher than predicted, and values below 1 indicate mortality lower than predicted. For each score studied, the respective mean SMR and its confidence intervals are displayed.

When evaluating the discriminatory power for the mortality outcome – that is, the ability to correctly distinguish patients who will die from those who will survive – it was observed that the area under the ROC curve (AUC) was 0.805 for SAPS 3 and its adapted versions (Latin America and Brazil), and 0.704 for APACHE II (Figure 3).

Discussion

Modern ICUs consume a large portion of healthcare system resources, requiring advanced technology for the diagnosis and treatment of critically ill patients.¹⁴ The application of prognostic scores in mortality prediction is important for cost-effectiveness analysis, performance evaluation, and planning of these units.¹⁵

The “UTIs Brasileiras” project, developed by the AMIB in collaboration with Epimed Solutions®, included more than 900,000 patients across 407 hospitals and 886 ICUs, predominantly private (70%).¹⁶ Of these, less than 15% were cardiology or coronary units.

The population in our study is characterized by high complexity, due to being part of a quaternary hospital, the overlap of comorbidities among the patients studied, and the higher mortality rate (15%) and length of stay (median

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Table 2 – Distribution and frequency of diagnoses on admission, n = 573

	Total n (%)
Heart diseases	433 (76)
CHF*	192 (34)
ACS†	101 (18)
Arrhythmia	83 (14)
Heart valve disease	30 (5)
Aortic disease	10 (2)
Congenital diseases	17 (3)
Infection	40 (7)
Lung diseases	38 (7)
Neuronal diseases	22 (4)
Renal diseases	19 (3)
Other diseases	12 (2)

*CHF: congestive heart failure; †ACS: acute coronary syndrome

of 11 days) observed in this study—both greater than those reported in the *UTIs Brasileiras* project¹⁵ (9.5% and 3 days, respectively). Despite a similar median age compared to the national average (63 vs. 66 years), the admission etiology is primarily cardiological (76% vs. 21%), with a predominance of men (60% vs. 50%), and a higher median SAPS 3 score at CICU admission (55 [49–63]) compared to the national project (47 [39–58]).¹⁶

A direct comparison of crude ICU mortality can be inaccurate without adjusting for patient severity, which may overestimate this metric, especially in units treating more complex patients. Therefore, the analysis of the SMR provides a more reliable assessment of performance. In our study, the average SMR consistently remained below 1 for all models (Figure 2), indicating that the number of observed deaths was lower than predicted by the prognostic scores. This finding suggests that, despite the high-complexity profile of the patients treated, the effectiveness of care exceeded the expectations of the models. It is important to note that the SMR shows fluctuations over time, reflecting statistical uncertainties and clinical variations, such as the mortality peak observed in April 2023, possibly related to a critical event, such as disease outbreaks.

In our study, it was observed that the different prediction models did not perform the same. There was variation in the average values of the SMR among the three versions of SAPS 3 and APACHE II (Figure 3). In the international models, the SMR was lower than expected. This indicates that these models overestimated the risk of death for patients in this cohort – in other words, they “predicted more deaths than actually occurred.” This difference is understandable, as the original SAPS 3 was developed using data from patients in several countries and may not accurately reflect the specific conditions and characteristics of hospitals and patients in

Brazil, such as disease profiles, access to resources, and medical practices adopted in ICUs.

On the other hand, SAPS 3 Brazil was adjusted to the national reality and therefore tends to provide more realistic predictions for the studied unit, considering factors typical of the Brazilian healthcare system and the patients treated here. Furthermore, differences in treatment protocols, institutional structure, and patient severity may also explain why each score shows slightly different results – something that has already been observed in other studies comparing the performance of these models in diverse contexts.¹⁷

ROC curve analyses evaluate discriminatory points for mortality prediction, serving as an important tool to identify patients at higher risk of unfavorable outcomes. For SAPS 3, scores between 57 and 61 show sensitivity and specificity combinations of 80% and 71%, respectively. The analysis of the AUCs revealed a significant difference between SAPS 3 (0.805) and APACHE II (0.704) ($p = 0.00149$), reinforcing the superior discriminatory ability of SAPS 3 in the studied population. In practical terms, the closer the AUC value is to 1.0, the greater the model’s accuracy in correctly identifying patients at risk of death. Values near 0.5 indicate performance similar to chance, while values above 0.8 are considered good and above 0.9, excellent.¹⁸ Thus, the result of 0.805 demonstrates that SAPS 3 has a considerably higher accuracy than APACHE II (0.704) in distinguishing between patients with a greater or lesser likelihood of dying during hospitalization. In clinical practice, this means that SAPS 3 can “see” more clearly which patients are in critical condition, allowing resources and care strategies to be prioritized more effectively. This difference is relevant not only from a statistical standpoint but also from a clinical perspective, as it improves the team’s ability to anticipate risks and plan preventive interventions, directly impacting patient safety and the quality of care within the ICU.

The reason why the different versions of the SAPS 3 score (global, Latin America, and Brazil) presented the same AUC value is that all of them use the same physiological and demographic variables collected from patients in the original cohort to estimate the risk of death. In other words, the information base that feeds the calculation is identical, differing only in the mathematical calibration models applied afterward. Therefore, the score’s ability to correctly distinguish who has a higher or lower probability of dying (known as discrimination) is the same across the three versions, reflected in a single AUC value.

What changes among them is the calibration, that is, the adjustment of the relationship between the predicted risk and the risk observed in a given population. The regional versions, Latin America and Brazil, apply equations adapted to the epidemiological and healthcare realities of their populations, aiming to more accurately estimate the expected proportion of deaths. This difference in calibration explains the variations observed in the SMR for each model. Figure 4 illustrates the ROC curves corresponding to the evaluated scores, visually demonstrating the discriminatory performance of each one.

In different contexts, the performance of prognostic scoring systems may vary. Studies indicate that, with regard

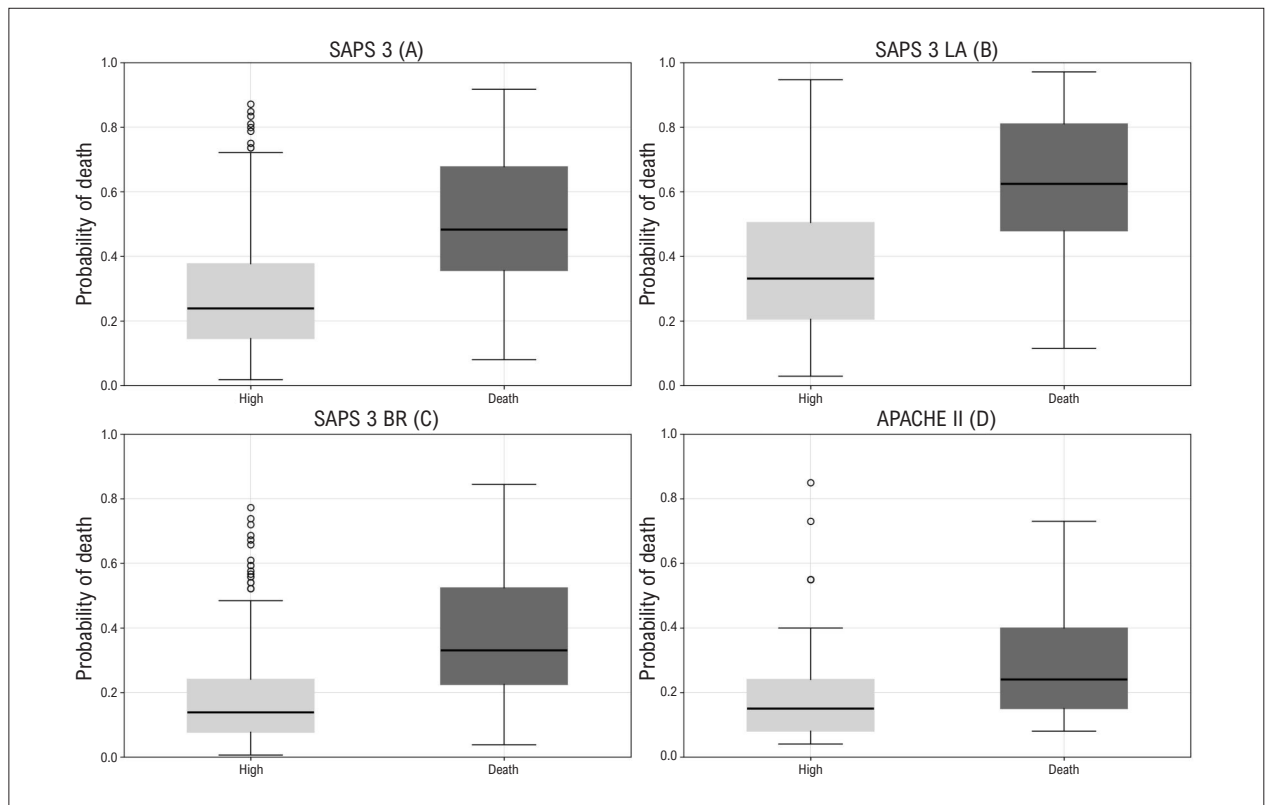


Figure 2 – Distribution of death probabilities according to outcome; predicted mortality according to different prognostic scores in ICU patients, stratified by outcome (discharge or death). (A) SAPS 3, (B) SAPS 3 Latin America (LA), (C) SAPS 3 Brazil (BR), (D) APACHE II

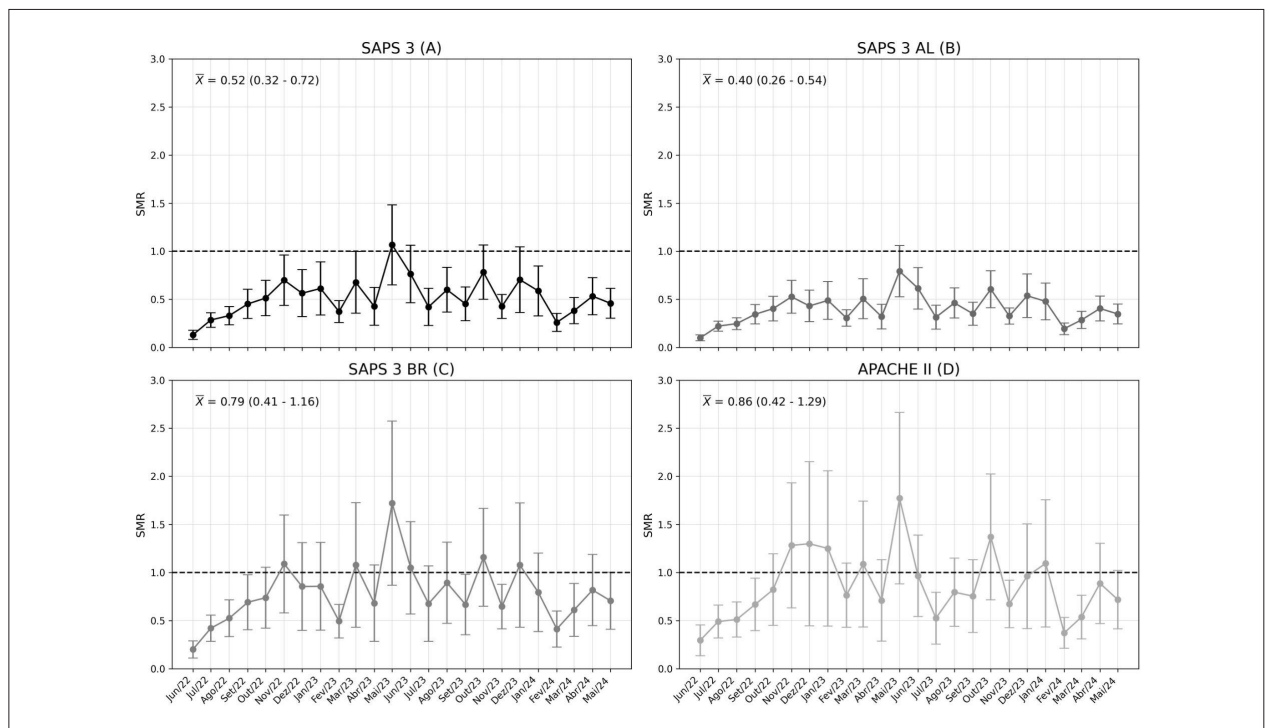


Figure 3 – Standardized mortality ratio (SMR) for different prognostic scores in the cardiac intensive care unit (CICU); (A) SAPS 3, (B) SAPS 3 Latin America (LA), (C) SAPS 3 Brasil (BR), (D) APACHE II.

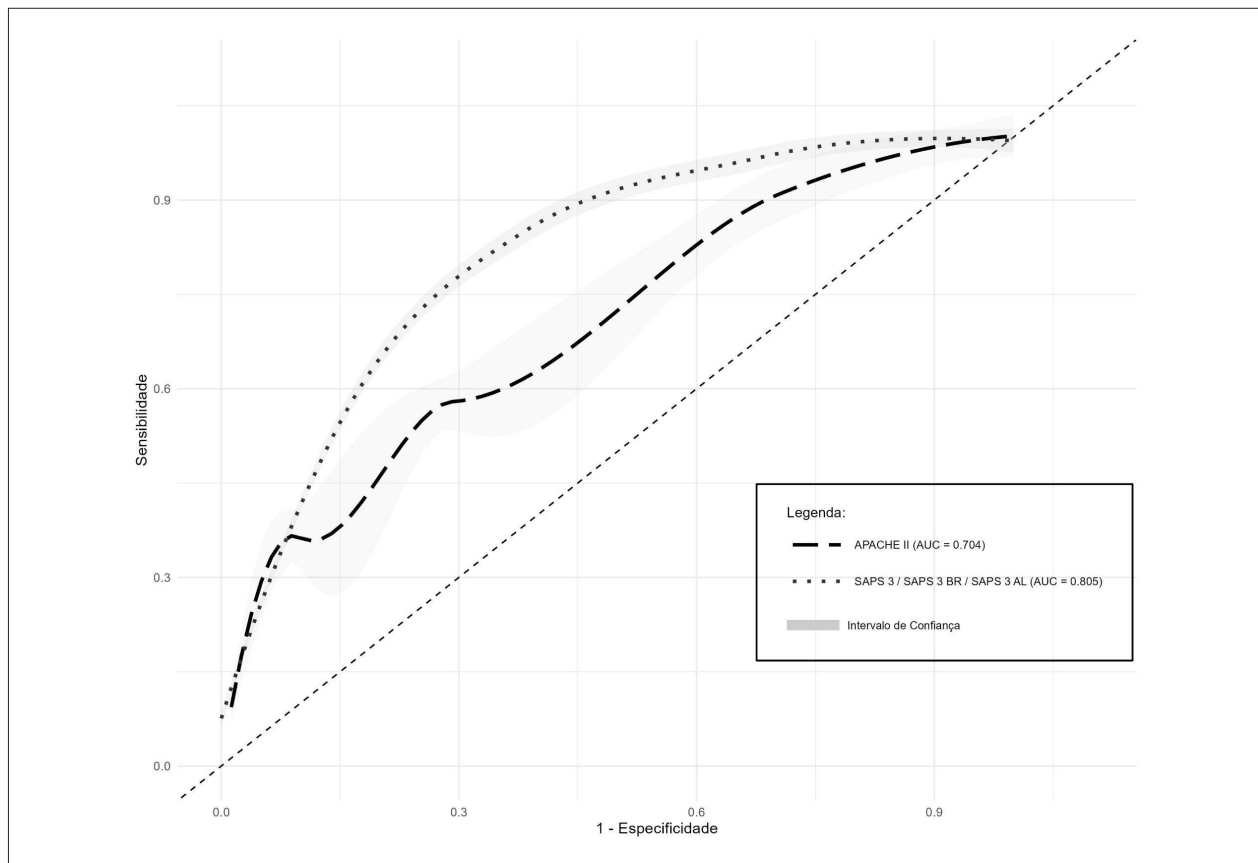


Figure 4 – ROC curve for prognostic scores: SAPS 3, SAPS 3 Latin America (LA), SAPS 3 Brazil (BR): AUC = 0.805 (95% CI: 0.756–0.854); and APACHE II: AUC = 0.704 (95% CI: 0.645–0.763). The dashed line represents the reference line (AUC = 0.5)

to SAPS 3, there is greater confidence in predicting mortality in general and medical ICUs, due to its updated model that incorporates both global and regional severity factors.^{19–25} Given the practicality of calculating the SAPS 3 index, its inclusion in ICU routines is suggested for identifying patients with a higher probability of mortality, thereby contributing to the assessment of overall patient severity and the predictability of resource utilization.²⁶

This study has some limitations that should be considered. First, since it was conducted in a single CICU of a high-complexity center, our findings may not be entirely generalizable to other contexts, such as institutions with different patient profiles and resources. The superiority of SAPS 3 may be specific to this population with a high prevalence of cardiovascular diseases. Additionally, we emphasize the conceptual limitation that prognostic scores are tools for group analysis and not for guiding individual clinical decisions. A patient's score is an important piece of information in the overall context, but it does not replace clinical judgment in determining the therapeutic plan.

Conclusion

In this study, the SMR showed that, although the mortality observed in the CICU of a quaternary hospital was

on average higher than the national rate, it remained lower than the mortality predicted at admission, as estimated by different prognostic scores, as illustrated in the central illustration. This finding highlights the effectiveness of the care provided in the unit analyzed. Among the models evaluated, SAPS 3 – particularly in its version adapted for Brazil – demonstrated superior predictive performance compared with SAPS 3 global, SAPS 3 Latin America, and APACHE II. The analysis of the AUC reinforced the usefulness of SAPS 3 as a tool for discriminating clinical events and supporting care planning in high-complexity units. Taken together, the results emphasize the importance of applying updated prognostic scores adjusted to the regional context to improve the performance assessment of ICUs, as well as to enhance individual severity analysis and support clinical decision-making in critically ill patients.

Author Contributions

Conception and design of the research: Lachtermacher S; analysis and interpretation of the data: Luna LC; statistical analysis: Correia MG, von Doellinger VR; writing of the manuscript: Pinheiro RP; critical revision of the manuscript for intellectual content: Tura B.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Instituto Nacional de Cardiologia under the protocol

number 82367224.8.0000.5272. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

Availability of Research Data

All datasets supporting the results of this study are available upon request from the corresponding author.

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