

Feasibility of transitioning from APACHE II to SAPS III as prognostic model in a Brazilian general intensive care unit. A retrospective study

Viabilidade da transição do APACHE II para o SAPS III como modelo prognóstico em uma unidade de terapia intensiva geral no Brasil. Um estudo retrospectivo

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PALAVRAS-CHAVE:

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ABSTRACT

CONTEXT AND OBJECTIVE: Prognostic models reflect the population characteristics of the countries from which they originate. Predictive models should be customized to fit the general population where they will be used. The aim here was to perform external validation on two predictive models and compare their performance in a mixed population of critically ill patients in Brazil.

DESIGN AND SETTING: Retrospective study in a Brazilian general intensive care unit (ICU).

METHODS: This was a retrospective review of all patients admitted to a 41-bed mixed ICU from August 2011 to September 2012. Calibration (assessed using the Hosmer-Lemeshow goodness-of-fit test) and discrimination (assessed using area under the curve) of APACHE II and SAPS III were compared. The standardized mortality ratio (SMR) was calculated by dividing the number of observed deaths by the number of expected deaths.

RESULTS: A total of 3,333 ICU patients were enrolled. The Hosmer-Lemeshow goodness-of-fit test showed good calibration for all models in relation to hospital mortality. For in-hospital mortality there was a worse fit for APACHE II in clinical patients. Discrimination was better for SAPS III for in-ICU and in-hospital mortality ($P = 0.042$). The SMRs for the whole population were 0.27 (confidence interval [CI]: 0.23 – 0.33) for APACHE II and 0.28 (CI: 0.22 – 0.36) for SAPS III.

CONCLUSIONS: In this group of critically ill patients, SAPS III was a better prognostic score, with higher discrimination and calibration power.

RESUMO

CONTEXTO E OBJETIVO: Modelos prognósticos refletem as características da população dos países de onde eles são originários. Modelos preditivos devem ser customizados para se adequar à população geral onde eles serão utilizados. O objetivo aqui foi de realizar a validação externa de dois modelos preditivos e comparar o seu desempenho em uma população mista de pacientes graves no Brasil.

TIPO DE ESTUDO E LOCAL: Estudo retrospectivo em uma unidade de terapia intensiva geral brasileira.

MÉTODOS: Este é um estudo retrospectivo de todos os pacientes internados em uma unidade de terapia intensiva (UTI) mista com 41 leitos entre agosto de 2011 e setembro de 2012. A calibração (avaliada com o teste de Hosmer-Lemeshow *goodness-of-fit*) e a discriminação (avaliada como a área sob a curva) do APACHE II e do SAPS III foram comparados. A razão de mortalidade padronizada (SMR) foi calculada pela divisão do número de óbitos observados pelo número de óbitos esperados.

RESULTADOS: Um total de 3.333 pacientes internados na UTI foi registrado. O teste de Hosmer-Lemeshow *goodness-of-fit* demonstrou boa calibração para todos os modelos em relação a mortalidade hospitalar. Para a mortalidade intra-hospitalar, há um ajuste pior do APACHE II em pacientes clínicos. A discriminação foi melhor para o SAPS III para mortalidade na UTI e no hospital ($P = 0,042$). A SMR para toda a população foi de 0,27 (intervalo de confiança [IC]: 0,23-0,33) para APACHE II e de 0,28 (IC: 0,22-0,36) para SAPS III.

CONCLUSÕES: Neste grupo de pacientes graves, o SAPS III é o melhor escore prognóstico, com a maior discriminação e poder de calibração.

INTRODUCTION

Prognostic models reflect the population characteristics of the countries from which they originate. The development of the Acute Physiology and Chronic Health Evaluation II (APACHE II) system was based on a cohort of patients in the United States,¹ and it has been used in many intensive care units around the world. In contrast, the Simplified Acute Physiology Score III (SAPS III) was validated in a multicenter and multinational cohort study.²

Predictive models should be customized to fit the case-mix population where they will be used because the outcomes in the original databases and period from which the models were derived may be different from the databases of intensive care units (ICUs) using the models.^{3,4} It is not clear whether calibration of the established models for local circumstances would enhance their accuracy in stratifying patients.⁵

Although the methods have been reported to adapt well to different periods and case mixes, few studies have formally assessed the models' predictive accuracy when applied to new populations from other institutions or countries.⁶⁻⁹ In South America, SAPS III was calibrated with a level of 1.3 (i.e. the relationship between observed and predicted mortality was 1.3).^{2,10} Recently studies have validated SAPS III in different Brazilian cohorts of patients, obtaining good results.¹¹⁻¹³

Comparison between observed and predicted mortality rates could serve as an indicator of ICU performance, and lead to overall improvement in healthcare services. However, ICU profiles vary worldwide, depending on the proportions of medical and surgical patients, admission and discharge policies, availability of intermediate care units and staffing with intensive care specialists.¹³

Any transition from a well-established approach to a new one requires caution and validation. Changing APACHE II for SAPS III has some advantages and the most important is the fact that SAPS III is the only prognostic score that included a cohort of patients from South America in its development.

OBJECTIVE

In the present study, we aimed to perform external validation on two predictive models and directly compare their performance in an independent population of mixed critically ill patients.

METHODS

Data collection

This study was approved by the Ethics Committee of Hospital Israelita Albert Einstein and, because of the retrospective nature of the study, the informed consent requirement was waived. The data were collected from all patients admitted to a mixed 41-bed ICU in the tertiary-level private hospital in Brazil from August 2011 to September 2012.

Data were retrospectively collected using APACHE II only between August 2011 and December 2011, and using SAPS III only between May 2012 and September 2012. From January 2012 to April 2012, during a period of calibration, both scores were calculated for all patients admitted to the ICU and were collected for analysis. The data collection practices were standardized and performed by a trained nurse or physician. All data were checked for implausible and outlying values. The data included age, gender and type of admission (clinical, elective surgery or emergency surgery).

Study population

All ICU admissions were enrolled during the period analyzed. The exclusion criteria were: age < 18 years, missing data and not receiving ICU care. The admissions between January 2012 and April 2012 were used as a validation database to study the performance of APACHE II versus SAPS III for all admissions and in subgroups according to the type of admission.

Scores and predicted mortalities

The calculations of the individual scores for each model were based on the most disordered physiological values recorded during the first 24 hours of ICU admission for APACHE II and were based on the variables measured one hour before and after ICU admission for SAPS III. The mortality probabilities for APACHE II and SAPS III were calculated using the original equations.^{1,2}

Performance of the scores

The calibration of the scores was tested using the Hosmer-Lemeshow goodness-of-fit procedure, which was calculated by dividing the admissions into ten deciles according to the risk of death. The chi-square statistics were determined for each decile and summing the chi-square values for the ten deciles resulted in the test value.¹⁴ A high P value would indicate a good fit for the model. Hosmer-Lemeshow is a test for assessing agreement between the actual and predicted death rates. The discriminative ability of the models was assessed using receiver operating characteristic (ROC) curves and the respective areas under curves (AUC).¹⁵ The AUC is an expression of the model's ability to discriminate correctly between survivors and non-survivors.

The standardized mortality ratio (SMR) was calculated using the models by dividing the number of observed deaths by the number of expected deaths. Confidence intervals for the SMR were calculated to test the model's uniformity-of-fit, using the methods that have been put forward.¹⁶ The variables were compared between the three periods using analysis of variance (ANOVA). Calibration curves were constructed by plotting the predicted death rates stratified as 5% intervals of mortality risk (*x*-axis) versus observed death rates (*y*-axis). Finally, we constructed a model using Cox regression analysis with APACHE II and SAPS III as independent factors.

Statistical significance was defined as $P < 0.05$ and the results are presented as mean \pm standard deviation unless indicated

otherwise. All the statistical procedures were performed using the SPSS 20.0 statistical package (SPSS, Chicago, Illinois, USA).

RESULTS

Study population

A total of 3,333 ICU admissions were enrolled until the end of September 2012. The formation of the database is presented in Table 1. The characteristics of the population in the three periods are presented in Table 2. The ICU and hospital mortality

and the APACHE II score decreased over time, and the SAPS III score increased during the periods.

Table 1. Study database

Data gathered (admissions)	3,333
Age, years	65.47 ± 18.02
Type of admission, n (%)	
Clinical	2,155 (64.65)
Elective surgery	994 (29.82)
Emergency surgery	184 (5.53)
Study population, n (%)	
Apache II	1,495 (44.90)
Calibration (SAPS III + APACHE II)	425 (12.80)
SAPS III	1,413 (42.40)

APACHE II = acute physiology and chronic health disease classification system II; SAPS III = simplified acute physiology score III.

Calibration and discrimination

The Hosmer-Lemeshow goodness-of-fit statistics supported model fit for all in-ICU mortality models with the exception of APACHE II for patients in the calibration database undergoing elective surgery. For in-hospital mortality, there was worse fit for APACHE II among clinical patients during the first period and for SAPS III among patients in the calibration database undergoing elective surgery (Table 3). The calibration curves for APACHE II and SAPS III showed overestimation of the risk of death in all ranges of predicted mortality (Figure 1).

Discrimination, as tested by the AUC, among general and clinical patients, was better for SAPS III in relation to in-ICU and in-hospital mortality ($P = 0.042$) (Table 4). Figure 2 shows the ROC for SAPS III and APACHE II, for in-ICU mortality in the calibration database in different situations.

Standardized mortality ratio

The SMRs for the whole population were 0.27 (CI: 0.23 – 0.33) for APACHE II and 0.28 (CI: 0.22 – 0.36) for SAPS III. In the calibration database, the SMRs for APACHE II and SAPS III were 0.33 (CI: 0.22 – 0.50), and 0.36 (CI: 0.25 – 0.55), respectively.

Table 2. Characteristics of the study population

	APACHE II database		Calibration database		SAPS III database		P-value
	n = 1,495	%	n = 425	%	n = 1,413	%	
Type of admission, n (%)							
Clinical	1,061	70.96	246	57.90	848	60.00	
Elective surgery	332	22.20	38	8.90	44	3.10	< 0.0001
Emergency surgery	102	6.84	141	33.20	521	36.90	
Period	2011 (August – December)		2012 (January – April)		2012 (May – September)		
Age, years	65.76 ± 17.82		64.23 ± 7.99		65.53 ± 18.23		0.299
Mortality, n (%)							
ICU	127	8.50	29	6.80	73	5.20	0.002
Hospital	212	14.20	50	11.80	134	9.50	0.001
Length of stay in ICU, days							
Mean	–	–	3.61 ± 4.91	–	3.59 ± 5.42	–	0.930
Maximum	–	–	43.00	–	59.00	–	
Mean among survivors	–	–	3.28 ± 4.18	–	3.27 ± 4.79	–	0.977
Mean among non-survivors	–	–	8.17 ± 9.79	–	9.38 ± 10.66	–	0.598
Length of stay in hospital, days							
Mean	–	–	22.04 ± 30.53	–	18.73 ± 41.00	–	0.127
Maximum	–	–	217.00	–	792.00	–	
Mean among survivors	–	–	19.99 ± 27.88	–	16.98 ± 37.54	–	0.097
Mean among non-survivors	–	–	37.28 ± 43.00	–	34.26 ± 62.02	–	0.711
Scores							
APACHE II	18.20 ± 7.09	–	14.97 ± 7.72	–	–	–	< 0.0001
SAPS III	–	–	30.50 ± 17.00	–	45.62 ± 15.67	–	< 0.0001
Probability of death, %							
APACHE II	30.74 ± 19.22	–	20.56 ± 20.69	–	–	–	< 0.0001
SAPS III	–	–	18.59 ± 22.76	–	18.40 ± 20.04	–	0.864

ICU = intensive care unit; APACHE II = acute physiology and chronic health disease classification system II; SAPS III = simplified acute physiology score III.

Table 3. Model calibration assessed by means of Hosmer-Lemeshow goodness-of-fit statistics

Scores	In-ICU mortality			In-hospital mortality				
		Hosmer-Lemeshow	DF	P-value	Hosmer-Lemeshow	DF	P-value	
General	APACHE II	7.069	7	0.422	14.298	8	0.074	
	CD	APACHE II	6.052	8	0.641	6.247	8	0.620
		SAPS III	6.739	8	0.565	5.927	8	0.655
	SAPS III	8.508	8	0.385	5.340	8	0.721	
Clinical patients	APACHE II	6.849	7	0.445	17.915	8	0.022	
	CD	APACHE II	5.608	8	0.691	6.694	8	0.570
		SAPS III	5.688	8	0.682	4.588	8	0.801
	SAPS III	5.479	8	0.705	10.041	8	0.262	
Emergency surgery	APACHE II	14.262	8	0.075	4.372	8	0.822	
	CD	APACHE II	6.646	7	0.467	6.137	7	0.524
		SAPS III	1.534	7	0.981	4.732	7	0.693
	SAPS III	7.956	8	0.438	6.066	7	0.532	
Elective surgery	APACHE II	3.867	7	0.795	6.516	7	0.481	
	CD	APACHE II	16.413	8	0.037	8.569	8	0.380
		SAPS III	6.548	7	0.477	14.585	7	0.042
	SAPS III	0.459	8	1.000	10.734	8	0.217	

ICU = intensive care unit; APACHE II = acute physiology and chronic health disease classification system II; SAPS III = simplified acute physiology score III; DF = degrees of freedom; CD = Calibration database.

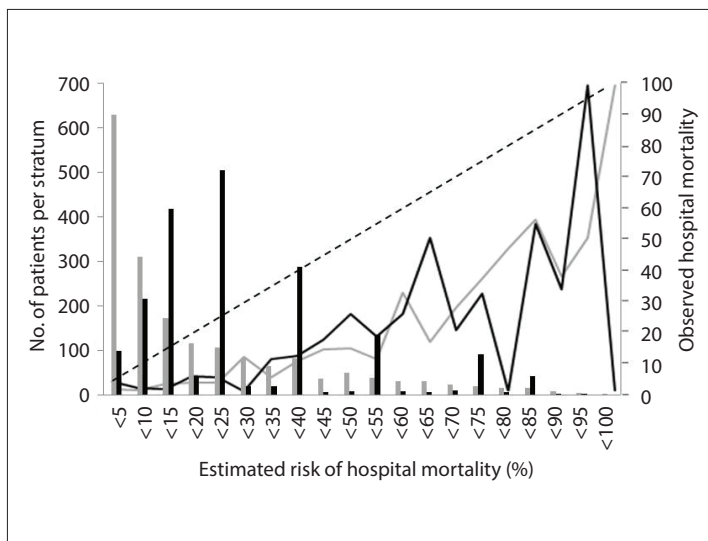


Figure 1. Calibration curve for APACHE II (black line and bar) and SAPS III (gray line and bar). The bars represent the number of patients in each risk group. The dashed diagonal line indicates ideal prediction (predicted = observed mortality).

For all models, the SMRs showed some variation across the spectrum of patients. The SMRs ranged from 0.24 to 0.46 for APACHE II, and from 0.09 to 0.31 for SAPS III. In the calibration database, the SMRs ranged from 0.13 to 0.38 for APACHE II, and from 0.18 to 0.40 for SAPS III (Table 5).

Cox regression model

The hazard ratios for in-hospital and in-ICU mortality using APACHE II as an independent factor were 1.08 (95% CI: 1.04 – 1.12)

Table 4. C-statistics (area under receiver operating characteristic curve) as measurement of discrimination between survivors and non-survivors (in-ICU and in-hospital)

Scores		Outcome		
		C-statistic (95% confidence interval)		
		In-ICU mortality	In-hospital mortality	
General	APACHE II	0.816 (0.777-0.856)	0.802 (0.770-0.834)	
	CD	APACHE II	0.842 (0.767-0.917)	0.784 (0.713-0.854)
		SAPS III	0.883 (0.818-0.949)	0.828 (0.767-0.890)
	SAPS III	0.872 (0.832-0.912)	0.832 (0.795-0.868)	
Clinical patients	APACHE II	0.817 (0.769-0.865)	0.817 (0.780-0.854)	
	CD	APACHE II	0.838 (0.761-0.915)	0.789 (0.710-0.868)
		SAPS III	0.886 (0.822-0.950)	0.827 (0.756-0.898)
	SAPS III	0.818 (0.765-0.871)	0.806 (0.765-0.848)	
Emergency surgery	APACHE II	0.847 (0.752-0.941)	0.799 (0.693-0.905)	
	CD	APACHE II	0.819 (0.590-1.048)	0.814 (0.578-1.049)
		SAPS III	0.862 (0.727-0.997)	0.858 (0.719-0.997)
	SAPS III	0.605 (0.459-0.751)	0.712 (0.524-0.899)	
Elective surgery	APACHE II	0.805 (0.702-0.908)	0.788 (0.709-0.867)	
	CD	APACHE II	0.622 (0.101-1.143)	0.599 (0.364-0.833)
		SAPS III	0.597 (0.208-0.986)	0.675 (0.502-0.848)
	SAPS III	0.983 (0.964-1.000)	0.736 (0.621-0.852)	

ICU = intensive care unit; APACHE II = acute physiology and chronic health disease classification system II; SAPS III = simplified acute physiology score III; CD = Calibration database.

and 1.09 (95% CI: 1.04 – 1.14), respectively. For SAPS III, the hazard ratios for in-hospital and in-ICU mortality were 1.03 (95% CI: 1.03 – 1.04) and 1.04 (95% CI: 1.03 – 1.06), respectively.

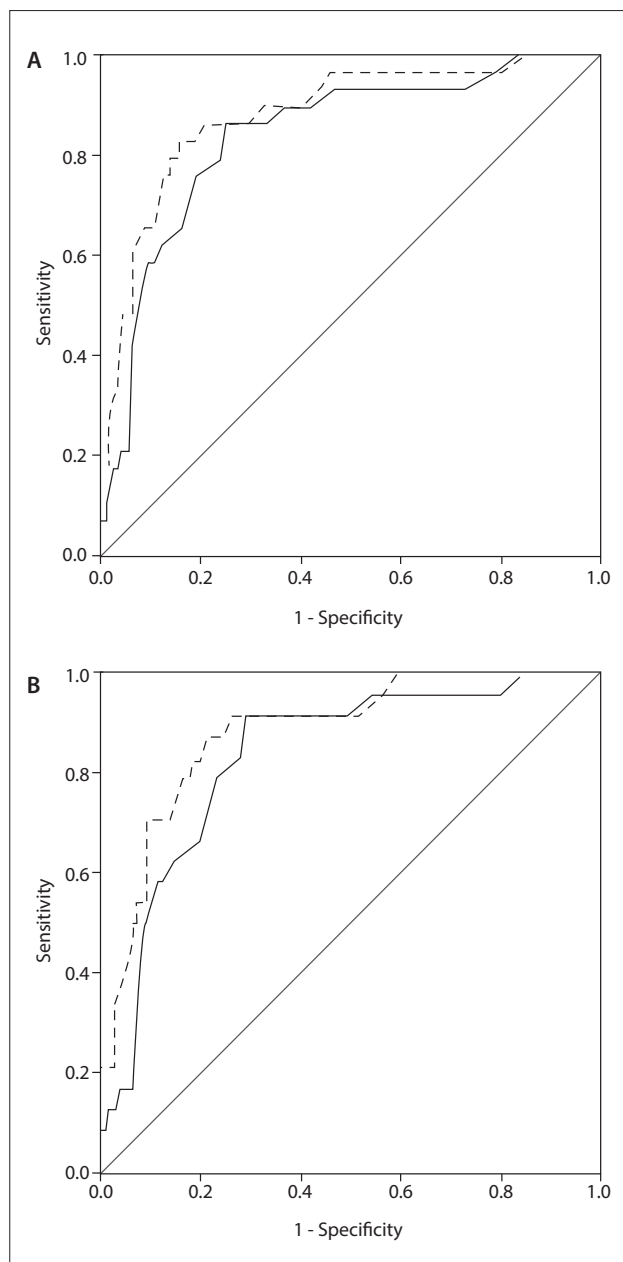


Figure 2. Receiver operating characteristic curve for APACHE II (black line) and SAPS III (black dotted line) in general population (A) and clinical patients (B).

DISCUSSION

The external validation of these two widely used prognostic models showed good discrimination and good calibration when applied to the same independent population of Brazilian ICU patients. The transition from APACHE II to SAPS III in this Brazilian ICU was feasible and, in some scenarios, SAPS III had even better performance than APACHE II.

The SAPS III score was developed using data from 16,784 patients.² However, it was not developed to be representative of all ICU patients, since it was developed in a cohort of general patients. Therefore, external validation is extremely important before applying this score to any type of patient. The cohort used for the conception of the SAPS III model involved patients from Brazilian ICUs, which might explain its superiority to APACHE II in our study. Also, the SAPS III model is based exclusively on data evaluated during the first hour of admission to the ICU.² Prognostic systems that include measurements during and/or after the first 24 hours of admission, like APACHE II, often reflect standard care and not the real clinical status of the patient.

Severity scores have the aim of measuring the severity of the disease of ICU patients and are proposed as tools to aid in outcome assessment and resource allocation. Furthermore, they are used for comparisons of outcomes and quality of care between ICUs.⁵

Our findings are supported by other studies published in the literature. Soares et al.¹¹ demonstrated that SAPS III had excellent discrimination in Brazilian ICUs and that APACHE II was unsatisfactory due to its lower discriminatory power and lack of calibration for some populations. However, they also found that SAPS III overestimated hospital mortality, as also found in our study. In a cohort of Brazilian patients, Silva Júnior et al.¹⁷ concluded that SAPS III is a useful tool for determining which patients will need more care, and for the evolution of high-risk surgical patients.

Alves et al.¹⁸ showed, among elderly patients admitted to an ICU, that SAPS III had excellent discrimination, but that the calibration was inadequate. Soares et al.¹² also showed that SAPS III had good discrimination and inadequate calibration among

Table 5. Standardized mortality ratio calculated using the prediction models according to type of admission (95% confidence interval)

Type of admission	APACHE II			Calibration database				SAPS III		
	Admissions (%)	Deaths (%)	SMR	Admissions (%)	Deaths (%)	SMR APACHE II	SMR SAPS III	Admissions (%)	Deaths (%)	SMR
Clinical	1,061 (70.9)	87 (8.19)	0.269 (0.22-0.34)	246 (57.8)	24 (9.80)	0.378 (0.25-0.59)	0.407 (0.26-0.63)	848 (60.0)	69 (8.13)	0.312 (0.24-0.40)
Elective surgery	332 (22.2)	25 (7.53)	0.241 (0.16-0.36)	141 (33.1)	2 (1.40)	0.135 (0.03-0.57)	0.183 (0.04-0.81)	521 (36.9)	3 (0.57)	0.093 (0.03-0.30)
Emergency surgery	102 (6.8)	15 (14.7)	0.460 (0.27-0.81)	38 (9.10)	3 (7.90)	0.327 (0.10-1.14)	0.324 (0.10-1.14)	44 (3.10)	1 (2.27)	0.151 (0.02-1.11)
Total	1,495 (100)	127 (8.50)	0.276 (0.23-0.33)	425 (100)	29 (6.80)	0.331 (0.22-0.50)	0.366 (0.25-0.55)	1,413 (100)	73 (5.20)	0.281 (0.22-0.36)

ICU = intensive care unit; APACHE II = acute physiology and chronic health disease classification system II; SAPS III = simplified acute physiology score III; SMR: standardized mortality ratio.

cancer patients. Costa e Silva et al.¹⁹ showed, in Brazilian critically ill patients with acute kidney injury, that SAPS III presented good discrimination and calibration performances, accurately predicting mortality in this group of patients. Finally, Nassar et al.¹³ demonstrated that SAPS III had good discrimination and inadequate calibration in a general cohort of Brazilian patients.

Our findings are supported by several studies that compared APACHE II with SAPS in different scenarios.²⁰⁻²² These scores have also already been used with other aims like estimation of prolonged mechanical ventilation in surgical patients.²³ In our hospital, we have a high number of liver transplantation procedures, and the performance of these scores in these population is a matter of debate.²⁴⁻²⁶ Also, one limitation of this study is that our hospital has a lower mortality rate than other institutions from Brazil and this makes it difficult to differentiate whether we have a score with bad performance or whether we have an ICU with excellent performance.

CONCLUSIONS

We showed, in a Brazilian cohort of critically ill patients, that SAPS III was a better prognostic score, with higher discrimination and calibration power. The transition from APACHE II to SAPS III was feasible in this scenario.

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