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# Model to estimate the nursing workload required by trauma victims on intensive care unit discharge

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**Abstract**

**Aim:** To validate a model to estimate the nursing workload required by trauma victims on intensive care unit (ICU) discharge.

**Background:** Identifying a reliable model of nursing workload measurement that can assist professionals.

**Methods:** A prospective cohort study conducted in 2010 (first phase) and 2015 (second phase) with 342 trauma victims admitted into the ICU of four hospitals located in São Paulo, Brazil. The original model was created during the first phase and included the Simplified Acute Physiology Score and New Injury Severity Score variables. Coefficients of determination ( $R^2$ ) were calculated to identify the reliability.

**Results:** The original model presented high reliability ( $R^2 = 44\%$ ) in the hospital of origin, and unsatisfactory performance ( $R^2 < 4\%$ ) in the other institutions. An improvement in  $R^2$  was observed after adjusting the coefficients for each hospital.

**Conclusion:** For the Nursing Activities Score prediction of survivors for ICU discharge, trauma centres must validate the original model with coefficient adjustments for their population, or preferably derive their own models.

**Implications for nursing management:** Although models are useful in predicting discharge of these ICU patients, for treatment continuity after critical care and for organising services, the study showed that they should be evaluated prior to use for nursing management.

**KEYWORDS**

clinical evaluation, intensive care units, nursing, survivors, workload, wounds and injuries

## 1 | INTRODUCTION

The World Health Organization recognizes trauma as a worldwide public health problem (WHO, 2016a). Data from the National Trauma Data Bank in the case analysis of 747 US hospitals showed that the intensive care unit (ICU) admission rate after emergency care was 18.28% in 2015 (American College of Surgeons, 2019) and can reach

about 50% of those admitted to hospitals that treat more complex patients (Prin & Li, 2016).

The ICU plays a relevant role in the survival chances of severely traumatized patients who require highly specific interventions, advanced technology and specialized human resources (Park et al., 2001). Within this context in the ICU, nursing workload is one of the most important determinants of patient safety (Carayon & Gürses,

2005), and an overload of professional activity negatively reflects on the provided care quality (Sochalski, 2004) and increases the risk of death (Kruk et al., 2018). In this sense, some measurement instruments of nursing workload have been developed in different countries with the purpose of facilitating nurses' clinical practice in determining the real need for care demanded by the patient, in the nursing team dimension and in the cost analysis of the unit (Vincent & Moreno, 2010).

Among these instruments of nursing workload, we highlight the Nursing Activities Score (NAS), which was launched in 2003 from a study of 99 ICU in 15 countries (Miranda, Nap, Rijk, Schaufeli, & Lapichino, 2003). The NAS has been translated into many languages and is currently in use in 12 countries (Padilha et al., 2015). This instrument analyses 23 nursing interventions distributed in seven categories: basic activities, ventilatory, cardiovascular, renal, neurological or metabolic supports and specific interventions. Each intervention has a weight in the final score translated by different scores for each performed intervention, and the sum of the weights expresses the percentage of time spent by the nurse per shift in direct or indirect patient care (Miranda et al., 2003).

There has been a significant increase in recent years in the use of NAS in clinical practice and in scientific studies (Lachance, Douville, Dallaire, Padilha, & Gallani, 2015) (Oliveira, Garcia, & Nogueira, 2016). There has also been recent growing interest in applying NAS to trauma victims (Nogueira, Domingues, Poggetti, & Sousa, 2014; Nogueira et al., 2015; Peng, Mayner, & Wang, 2014; Ragab, Torky, & Abdalla, 2013) and in predicting the continuity of care after leaving the ICU (Silva, Sousa, & Padilha, 2010, 2011).

Patients are referred to different units (semi-intensive, high dependency or ward) upon discharge from the ICU depending (among other factors) on the nursing workload. In this sense, the relevance of estimating the NAS on the last day of ICU hospitalization is important since the index enables identifying which unit the patient should be referred to (Silva, Sousa, & Padilha, 2010), and to predict survival outside the environment (Silva, Sousa, & Padilha, 2011), as well as to assist the nurses and managers of the units which will receive the patient in their planning of human resources to assure the care quality.

Considering this importance, a study carried out in a trauma centre identified a model to estimate the NAS on the last day of hospitalization in the critical unit through the trauma victims' data (Nogueira, 2012). Variables related to sociodemographic and clinical characteristics of patients, traumatic events and ICU admission were tested in the construction of this model. However, the case sample composed by trauma victims of a single institution was considered a limitation and possible study bias, thereby generating the need to apply this model in other institutions in order to identify its reliability in different contexts and types of trauma victims, since there is variation in the structure and processes among trauma care institutions, as well as differences in the severity, age and trauma mechanism of patients. Thus, this research aims to validate this model to estimate the nursing workload required by trauma victims upon discharge from the ICU.

## 2 | METHODS

### 2.1 | Study design

This is a prospective cohort quantitative study carried out in two phases. In the first phase, a model was derived to estimate the NAS on the last day of hospitalization in the critical unit through the trauma victims' data at the ICU admission. In the second phase, the validity of this model was tested in three institutions.

### 2.2 | First phase

#### 2.2.1 | Setting

Intensive care unit of trauma centre located in the city of São Paulo, Brazil, denominated in this study as hospital of origin. This hospital provides high complexity care to trauma victims.

#### 2.2.2 | Participants

At this stage of the study, the convenience sample consisted of 162 trauma victims admitted consecutively between 2010 and 2011 to this ICU with age equal to or greater than 18 years and minimum stay of 24 hr in the critical unit. We identified patients included in one of the categories of chapter XX (External Causes of Morbidity and Mortality) of the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (WHO, 2016b), as trauma victims. All patients who were readmitted to the unit who had initially been included in the case sample were excluded from the study, as were victims transferred from other hospitals.

The sample calculation for this phase was performed by analysing data from 20 patients distributed into three trauma severity categories according to the Injury Severity Score (ISS) (Baker, O'Neill, Haddon Jr, & Long, 1974) and the New Injury Severity Score (NISS) (Osler, Baker, & Long, 1997): score <16; score of 16 to 24; and score >24. In this evaluation, it was found that the minimum difference of NAS means between the three groups was eight points and the average standard deviation was 10. Assuming  $\alpha = 5\%$  and power = 90%, it was estimated that at least 34 patients would be necessary for each category, totaling approximately 100 victims. We chose to enlarge the sample size to ensure the power and significance level, even with minor differences.

#### 2.2.3 | Data collection

All data collectors were previously trained by the researchers. The collectors went to the ICU each day and identified patients who were admitted to the unit and who met the inclusion criteria for the study. All independent and dependent variables of this study were collected from the medical records. As some nursing activities were

not routinely recorded in care documentation, any doubts were promptly clarified with the nursing team. The NAS (primary outcome) was calculated in the last 24 hr of the patient's stay in the ICU.

## 2.3 | Data analysis

Linear regression with the stepwise backward selection process was used to identify the original model for estimating nursing workload required by survivors over the last 24 hr of ICU stay, according to the NAS. The independent variables analysed for elaboration of the model were as follows: age, gender, Charlson comorbidity index, external cause, ISS (Baker et al., 1974), NISS (Osler et al., 1997), Maximum Abbreviated Injury Scale—MAIS (AAAM, 2015), number and location of lesions according to the Abbreviated Injury Scale—AIS (AAAM, 2015)  $\geq 3$ , most severely injured body region, number of affected body regions, length of time between hospital admission and ICU, origin (emergency room, surgical centre and others), type of ICU admission (clinical and surgical programmed or not) and systems for assessing ICU patient severity [Acute Physiologic and Chronic Health Evaluation—APACHE II (Knaus, Draper, Wagner, & Zimmerman, 1985), Simplified Acute Physiology Score—SAPS II (Le Gall, Lemeshow, & Saulnier, 1993) and Logistic Organ Dysfunction System—LODS (Le Gall et al., 1996)]. In addition to these variables, the number of compromised systems and the type of organ failure according to LODS were analysed. The variance inflation factor (VIF) was calculated to diagnose the multicollinearity of the final model.

## 2.4 | Second phase

### 2.4.1 | Setting

Intensive care unit of three trauma centres located in the city of São Paulo, Brazil, denominated as H1, H2 and H3. All centres are units that provide high complexity care to trauma victims.

### 2.4.2 | Participants

The sample calculation for these centres was established considering the coefficient of determination value ( $R^2$ ) identified from the linear regression that derived the original model (study phase 1). Thus, the sample size was established as 180 patients (60 trauma victims per hospital) who met the same inclusion and exclusion criteria of the first phase of the study. The sample was by convenience, and the data in these institutions were collected consecutively between 2015 and 2016.

### 2.4.3 | Data collection

It was identical to phase 1 of the study.

## 2.4.4 | Measures

The model applied in this phase included the SAPS II and NISS indexes, variables identified as NAS predictors in the first phase of the study.

The SAPS II is a uniform and internationally accepted system for assessing ICU patient severity. This index analyses 12 physiological variables, as well as age, type of admission and presence of chronic disease. Each variable receives a score that is added and allows to identify the severity score and estimate the patient's risk of death (Le Gall et al., 1993). This index was calculated in the first 24 hr of ICU admission.

The NISS (Osler et al., 1997) is an anatomical index, which enables estimating the trauma severity through an evaluation of the injuries diagnosed in the victims and their scores on the AIS (AAAM, 2015). The AIS is a scale used to describe injuries resulting from trauma and to identify their severity in isolation. The injury list is presented in the AIS manual, which provides a code for each injury description and a severity score ranging from 1 (minor injury) to 6 (maximum severity injury). The NISS considers the three most severe injuries according to AIS for its calculation and can range from 1 to 75 (the higher the score, the more severe the patient). In this study, the NISS calculation was obtained from the injuries resulting from trauma recorded in the patient's hospital admission chart until the first 24 hr of ICU admission.

## 2.4.5 | Data analysis

Double-entry typing technique was used in preparing the datasheet. Correlation tests were performed, and  $R^2$  was identified in order to analyse the correlation of the original model results with the one observed in the institutions, being categorized as: low ( $R^2$ , around 1%), average ( $R^2$ , around 6%) and high ( $R^2$ , around 14%). According to Cohen's criteria, coefficients of determination above 14% determine high model reliability (Cohen, 1988). Multiple linear regression was used to derive the adjusted coefficients for the specific populations of the different institutions.

## 3 | RESULTS

### 3.1 | Sample characteristics

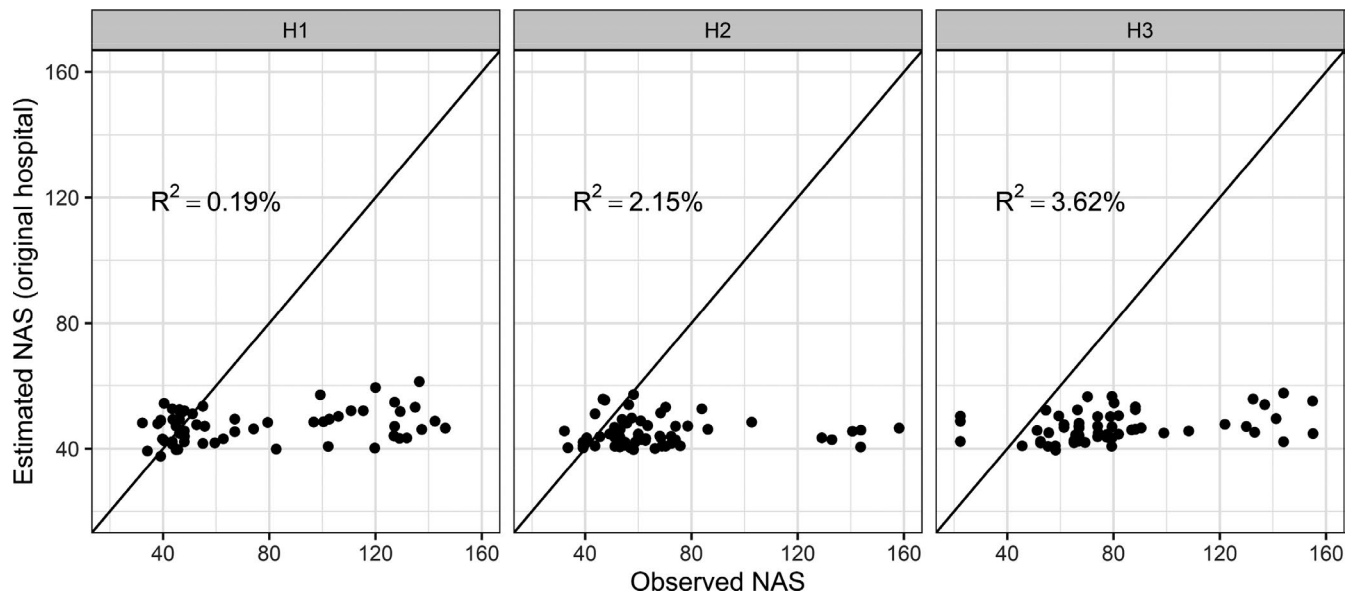
In the ICU of the four analysed institutions, there was high frequency of male patients (variation among hospitals from 75.0% to 83.3%), blunt trauma (variation from 83.3% to 97.5%), surgical centre origin (variation from 61.7% to 85.0%) and non-surgical admission (variation from 51.7% to 70.0%). Motorcycle accidents were the main external cause (30.2%) in the hospital of origin, and falls prevailed in other institutions (variation from 28.4% to 45.0%).

Table 1 shows that the mean age of the victims ranged from 37.2 (standard deviation—SD = 12.7) to 47.9 (SD = 23.3). Patients at the

| Variables               | H1          | H2          | H3          | Hospital of origin |
|-------------------------|-------------|-------------|-------------|--------------------|
|                         | Mean (SD)   | Mean (SD)   | Mean (SD)   | Mean (SD)          |
| Age                     | 41.7 (19.0) | 37.2 (12.7) | 47.9 (23.3) | 39.5 (18.4)        |
| SAPS II (risk of death) | 38.0 (24.9) | 20.9 (20.4) | 27.4 (22.0) | 16.5 (16.6)        |
| NISS                    | 16.8 (6.5)  | 20.7 (7.3)  | 23.7 (9.7)  | 25.8 (8.7)         |
| NAS (ICU discharge)     | 74.2 (36.3) | 66.7 (28.7) | 79.4 (33.1) | 45.2 (9.2)         |

Abbreviations: ICU, Intensive Care Unit; NAS, Nursing Activities Score; NISS, New Injury Severity Score; SAPS, Simplified Acute Physiology Score; SD, standard deviation.

**TABLE 1** Descriptive statistics of the variables age, SAPS II, NISS and NAS according to the institutions



**FIGURE 1** Correlation between the NAS on discharge estimated and observed in the institutions. Abbreviations: NAS, Nursing Activities Score;  $R^2$ , coefficient of determination value

hospital of origin had the lowest mean physiological severity according to SAPS II (16.5,  $SD = 16.6$ ) and the highest mean NISS trauma severity (25.8,  $SD = 8.7$ ). Regarding the NAS of the patients discharged from the ICU, it is noted that the victims from the hospital of origin demanded less workload than the patients of the other institutions.

### 3.2 | Model to estimate the nursing workload (study phase 1)

The linear regression result allowed us to identify the following equation to estimate the nursing workload required by trauma victims upon discharge from the ICU:

$$\text{NAS discharge} = 37.17 + 0.19 \times (\text{risk of death according to SAPS II at admission}) + 0.19 (\text{NISS}).$$

The VIF of SAPS II and NISS variables was 1.00027, indicating no collinearity between them.

### 3.3 | Validating the model to estimate the nursing workload (study phase 2)

The original model presented high reliability ( $R^2 = 44\%$ ) when it was applied at the hospital of origin. When this model was applied in the other institutions, the data in Figure 1 show that it obtained better performance in H3 ( $R^2 = 3.62\%$ ) than in H2 ( $R^2 = 2.15\%$ ) and in H1 ( $R^2 = 0.19\%$ ), but the coefficients of determination were low in the three hospitals.

Given these findings, the coefficients of the original model equation were adjusted for each institution.

Table 2 shows the adjusted regression coefficients (intercept, SAPS II and NISS) for each institution. It can be observed that the increase in SAPS II score in the three hospitals had a low impact on the nursing workload required by the patients discharged from the ICU, and we observed lower coefficients than the hospital of origin. In relation to NISS, it was identified that this variable had a greater influence on the NAS in H3 ( $\beta = 0.62$ ) than in the other institutions ( $\beta = 0.06$ -H2;  $\beta = 0.16$ -H1). The adjusted equations were then validated in the respective institutions from these results, as shown in Figure 2.

**TABLE 2** Adjusted regression coefficients of the NAS prediction model on ICU discharge for the institutions

| Equation components     | Coefficients of regression ( $\beta$ ) adjusted for the institutions |       |       | Standard error |
|-------------------------|--|-------|-------|----------------|
|                         | H1   | H2    | H3    |                |
| Intercept               | 48.46  | 55.28 | 52.03 | 6.58           |
| NISS                    | 0.16   | 0.06  | 0.62  | 0.27           |
| SAPS II (risk of death) | -0.05  | 0.09  | 0.04  | 0.11           |

Abbreviations: NISS, New Injury Severity Score; SAPS, Simplified Acute Physiology Score.

The data show an improvement in the coefficient of determination in all institutions, especially H3, which increased from 3.62% to 12.96% (Figure 2).

## 4 | DISCUSSION

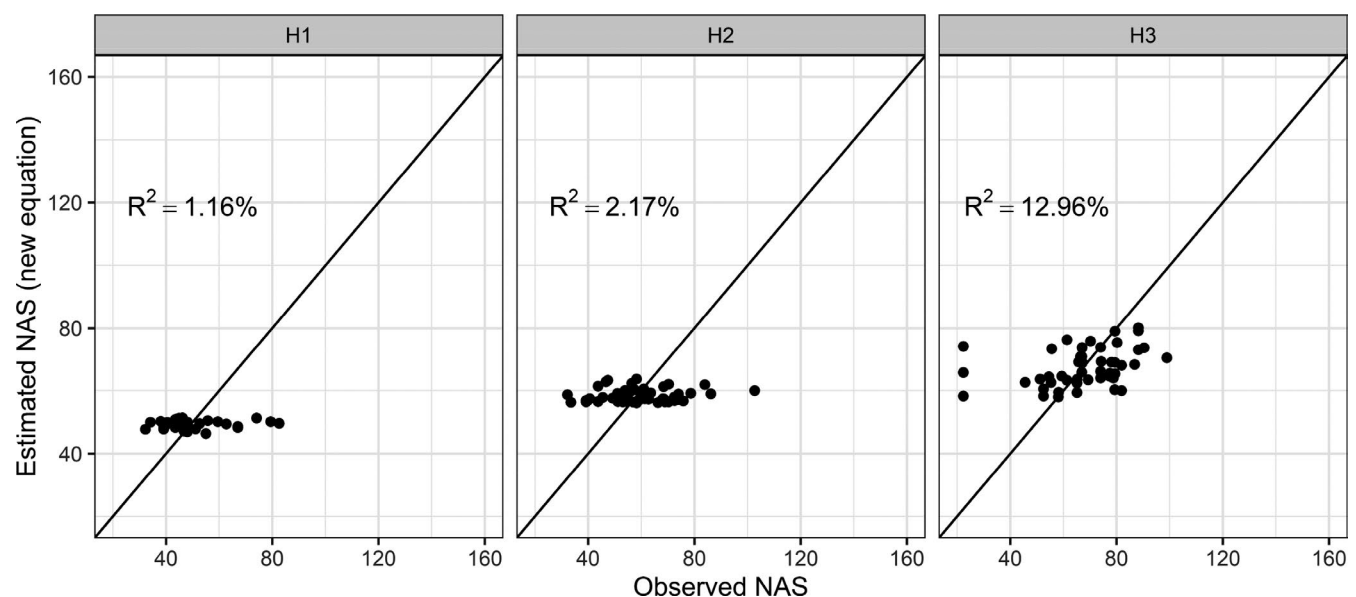
Data from the trauma population described in this study corroborate findings from the literature, which show a predominance of young adults, male patients and victims of blunt trauma submitted to surgical treatment (Kahl et al., 2013; Nogueira et al., 2014; Peng et al., 2014). Among external causes, the occurrence of falls has been growing considerably (Sise, Calvo, Spain, Weiser, & Staudenmayer, 2014) and the present investigation identified that this type of trauma was the most frequent in three of the four institutions analysed.

The NAS value at ICU discharge was lower in the hospital in which the original equation was derived (45.2,  $SD = 9.2$ ) than the other institutions where the variation was from 66.7 ( $SD = 28.7$ ) to 79.4 ( $SD = 33.1$ ). A study performed in 19 ICU in seven countries also identified a great degree of NAS variation between them (44.5% to 101.8%), and the authors attributed these differences

to the type of ICU and the characteristics of the patients (Padilha et al., 2015).

Structural differences in ICU services, discharge criteria, the lack of available beds, trauma characteristics (external cause, type of injury and severity), prognosis of the victims or other factors probably contributed to this NAS inequality among the institutions. In this study, we could verify differences between patients from the hospital of origin in relation to those from other institutions: higher frequency of motorcycle accidents, higher severity of trauma according to the NISS and lower SAPS II score. In addition, the patient/nurse relationship, a variable not investigated in the study, may also interfere with the NAS of these victims, since the instrument considers the activities performed by the nursing team and the reduced number of these professionals for taking care of the patients can affect the NAS (Miranda et al., 2003).

The original model indicated the SAPS II and NISS indexes as NAS predictors in the ICU discharge, reinforcing the relationship between severity and nursing workload in critical patients, as other authors have already demonstrated (Goulart, Aoki, Vegian, & Guirardello, 2014). A literature review indicated that the length of stay in the unit, severity and outcome were the most cited variables associated with the workload in the ICU (Meneguetti, Araújo, Nogueira, Gulin, &

**FIGURE 2** Correlation between the NAS upon discharge estimated and observed in the institutions. Abbreviations: NAS, Nursing Activities Score;  $R^2$ , coefficient of determination value

Laus, 2017). In trauma victims, the relation between nursing workload and physiological indexes of severity was analysed in an integrative review that identified that the greater the patient severity, the greater the demand for care (Nogueira & Domingues, 2018).

The model created at the hospital of origin presented high reliability ( $R^2$  44%). However, it showed unsatisfactory performance when applied in the different institutions with low  $R^2$  values (less than 4%). This result indicates that the model as proposed did not correctly estimate the NAS on discharge from the ICU, thus contraindicating its use in other institutions without prior evaluation of its performance.

An integrative review of the literature on one of the most widely used trauma severity indexes, the Trauma and Injury Severity Score (TRISS), and its modifications shows the need to adjust the equation's coefficients prior to its application in populations, which differ from the ones that were generated (Domingues, Nogueira, Settervall, & Sousa, 2015). In this sense, it was observed that there was a significant improvement of  $R^2$  only in H3, although it was inferior to one of the original hospitals (12.96% vs. 44%, respectively). Moreover, the adjustments did not show (as expected) an expressive tendency to improve the performance of all the models when adjustments were made to their coefficients.

In the original model, SAPS II and NISS had the same weight for NAS determination upon ICU discharge, and the nursing workload estimate increased by only 0.19 at each point in any of these indices. With the coefficient adjustments of the three other institutions, the SAPS II of ICU admission lost even more importance in this estimate for all models. Researchers question the influence of the initial physiological severity (at the time of patient admission into the ICU) in the NAS during the patient's stay in the ICU, since changes in the physiological conditions with a satisfactory response to the treatment alter the severity and make the values of the indices dynamic (Meneguetti et al., 2017). Despite possible changes in the physiological index values during ICU stay, it should be noted that the SAPS II index proposes to estimate the patient's risk of death during ICU stay with admission data (Le Gall et al., 1993).

Unlike physiologically based indices, the severity score of the trauma used in the model is constant and calculated after all lesions were identified and not influenced by the patient's response to treatment. Regarding the adjustments, the NISS coefficient was higher for one of the institutions (H3) than the hospital of origin (0.62 vs. 0.19), indicating that the trauma severity (estimated from the anatomical injuries) exerted greater weight in the NAS forecast. The region and type of traumatic injuries in the victims of this ICU (H3) may have contributed to this result. These aspects of injuries are directly related to implementing interventions that require high nursing time (monitoring activities, controls and hygiene procedures) and the need for a greater number of professionals for mobilization activities and positioning the patients (Nogueira et al., 2015) (Camuci, Martins, Cardeli, & Robazzi, 2014).

Studies show that models created, even with large samples, present different performances, sometimes unsatisfactory, when applied in other institutions/populations (Collins, Reitsma, Altman, &

Moons, 2015; Simões & Amorim, 2015). Besides that, the prognostic model generally performs better in the data set that originated the model than in other institutions/populations. Therefore, external validation is essential to support the generalization of the prognostic model and to provide evidence that the model can predict outcomes accurately (Collins et al., 2015; Simões & Amorim, 2015). In addition, the time between designing and validating a model in other settings can influence its performance due to the ongoing of treatment and technology used to treat severe trauma victims.

Finally, the results indicated that the original model does not present adequate performance to be indiscriminately applied in different services. Therefore, trauma centres should validate the model analysed in this study [ $NAS = 37.17 + 0.19$  (SAPS II risk of death at admission) +  $0.19$  (NISS)] with coefficient adjustments for their population for the NAS prediction of ICU discharge survivors, or derive their own models if necessary.

## 5 | LIMITATIONS

Data collection at H1, H2 and H3 institutions mainly involved calculating the SAPS II and NISS indices for identifying the NAS. This fact made it impossible to create new models with the inclusion of other variables in these institutions.

In addition, all the hospitals in the study were centres that provide a high level of care for trauma victims, which may limit applying the results in non-specialized hospitals for the care of trauma patients.

## 6 | CONCLUSION

The SAPS II and NISS variables that composed the original model did not always explain the patients' NAS at ICU discharge, and the adjustment of the equation's coefficients did not attain sufficient improvement in the model performance in all institutions. The authors propose that institutions should validate the original model and (if necessary) adjust the coefficients or create and validate their own model with the inclusion of other variables that best explain the nursing workload at the ICU discharge.

## 7 | IMPLICATIONS FOR NURSING MANAGEMENT

Early estimation of the NAS value upon patient discharge from the ICU can contribute to organising the unit, which will follow up the patient's treatment. In addition, knowing the expectation of discharge from ICU patients is important for nurses to plan and organise care in the intensive care unit and to establish criteria to discharge ICU patients, which is essential for a more rational use of beds and to avoid exposing patients to unnecessary risks through reducing or increasing their time in the unit.




Being that client characteristics, service structure and the regional trauma care system are key determinants for estimating nursing care needs, the results of this study showed that institutions should evaluate, adjust or create models that propose to estimate nursing workload of severe trauma victims before applying them for nursing management.

## ETHICAL APPROVAL

The research ethics committees of the institutions approved this study (Opinion numbers 1220/09; 464.035; 601.359-0; and 601.353-0), and written consent form to participate in the study was obtained from the patients or their legal guardians. The research was approved by the Research Ethics Committee of the Nursing School of the University of São Paulo (protocol no. 464.035).

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