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Comparison of Acute Physiology and Chronic Health Evaluation (APACHE) II Scoring System and Inflammation-Nutrition-Consciousness-Neurologic Function-Systemic Condition (INCNS) as Predictors of Mortality in Neurosurgical Patients in the Intensive Care Unit: A Multicenter Study

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Abstract

Introduction: We aimed to determine the prognostic significance of INCNS compared to APACHE II in predicting mortality for neurocritically ill patients. Methods: The study involved neurosurgical ICU patients, and data collection followed a prospective cross-sectional approach. The collected data underwent editing, coding, processing, and cleaning before statistical analysis using SPSS. The primary outcome of current study is mortality. Mortality was defined as the condition of patients who passed away while still under ICU care. Results: A total of 77 patients who met the inclusion criteria for this study. The average age of the patients in this study was 50.87 years. Of this total, 37 (48.1%) were male and 40 (51.9%) were female. The APACHE II score yielded a cut-off point of 22.5, with a sensitivity of 66.7%, specificity of 64.7%, positive predictive value of 80%, and negative predictive value of 93.6%. The INCNS score resulted in a cut-off point of 16, with a sensitivity of 77.8%, specificity of 97.1%, positive predictive value of 97.1%, and negative predictive value of 77.8%. Both assessment systems showed goodness-of-fit statistical tests with p > 0.05, with INCNS (Hosmer-Lemeshow statistic = 45.207, p < 0.001) demonstrating better fit compared to APACHE II (Hosmer-Lemeshow statistic = 3.753, p = 0.053). Conclusion: The research results suggest that the INCNS score is a valuable tool for predicting patient outcomes and optimizing patient management strategies in neurosurgical ICU settings. Further validation studies are warranted to establish the reliability and widespread adoption of the INCNS score in neurocritical care practice.

Keywords: *INCNS, APACHE II, mortality, outcome, neurocritical patients.*

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Introduction

The INCNS score is a novel risk prediction score developed to predict the 3-month functional outcome of neurocritical individuals. It integrates measurements from five aspects: inflammation, nutrition, consciousness, neurological function, and systemic condition. The INCNS score was found to have significantly stronger predictive power than the APACHE II and SAPS II scores at both 24 hours and 72 hours in the neurointensive care unit (N-ICU).(Gürsoy et al., 2020; Yuan et al., 2023; Zhao et al., 2020)

The APACHE II and SAPS II scores are widely used scores for critical illness. The major measurements of the INCNS score were derived from APACHE II and SAPS II, which have been validated in abundant cohorts worldwide. However, the INCNS score outperformed both APACHE II and SAPS II in terms of discriminative power, sensitivity, negative predictive value (NPV), and concordance correlation (CC).(Zhao et al., 2020) The INCNS score had a higher rate of false positives compared to APACHE II, indicating that more patients with a favorable outcome were predicted wrongly as having an unfavorable outcome. Additionally, the INCNS score performed better at 72 hours compared to 24 hours, possibly due to the progressive worsening of neurocritical illness beyond 24 hours after admission to the ICU.(Gao et al., 2020; Gürsoy et al., 2020; Yuan et al., 2023; Zhao et al., 2020)

The INCNS score includes measurements from five aspects: inflammation (I), nutrition (N), consciousness (C), neurological function (N), and systemic condition (S). These aspects are used to assess the patient's overall condition and predict their functional outcome.(Broessner et al., 2007; Kiphuth et al., 2010) The specific variables included in each aspect are not mentioned in the available sources.(Gao et al., 2020; Zhao et al., 2020) However, it is mentioned that the major measurements of the INCNS score were derived from the APACHE II and SAPS II scores, which are widely used scores for critical illness. These scores include various physiological and laboratory measurements to assess the severity of illness and predict patient outcomes.(Fischer et al., 2010) Therefore, it can be inferred that the INCNS score incorporates similar variables related to inflammation, nutrition, consciousness, neurological function, and systemic condition. Here, we aimed to develop the prognostic significance of a novel score, called the INCNS score, for predicting the functional outcome of neurocritically ill patients and to compare its predictive power with the APACHE II and SAPS II scores in a cohort of neurocritically ill patients. Here, we aimed to determine the prognostic significance of INCNS compared to APACHE II in predicting mortality for neurocritically ill patients.

Methods

We conducted a retrospective analysis in two institution (Siloam Hospital Lippo Village and Hasan Sasdikin General Hospital) from 2018 – 2023. The IRB was granted by both institution in order to gather study sample data from medical record and was conducted in accordance to the STROBE guideline. All methods were performed in accordance with the relevant guidelines and regulations. The research subjects for current study were neurosurgical patients treated in the ICU. The selection of research subjects was based on the following criteria: all neurosurgical patients who underwent surgery or received non-operative treatment, aged above 17 years, and were admitted to the ICU. Exclusion criteria include neurosurgical patients who underwent surgery or received non-operative treatment and passed away within 24 hours. Patients with incomplete medical data were also excluded from the study.

The research method encompasses the type and design of the study, conceptual and operational definitions, data collection procedures, and data analysis plan. This study adopted a descriptive analytical design with a prospective cross-sectional method, using medical records of ICU-admitted patients. Data collection was conducted prospectively by retrieving medical records of patients who met the inclusion and exclusion criteria. We collected the following variables such as body temperature, mean blood pressure, systolic blood pressure, respiratory rate, heart rate, GCS, sodium level, potassium level, hematocrit, creatinine, leukocytes, blood glucose, albumin, total bilirubin, pH, PaO2, HCO3, PaO2/FiO2 ratio, age, chronic disease history, arousal, awareness, pupil light reflex, corneal reflex, verbal response, motor response, motor strength, swallowing function, APACHE II scoring system, and INCNS scoring system in a formatted excel sheet.

We used APACHE II and INCNS scoring system for this retrospective analysis. APACHE II is a scoring system that measures 12 physiological variables, age, and chronic disease history.(Haq et al., 2014) On the other hand, the INCNS score is a scoring system that measures 19 physiological variables, including inflammation, nutrition, consciousness, neurological function, and systemic parameters. Mortality was defined as the condition of patients who passed away while still under ICU care.(Zhao et al., 2020) Hospitalization was defined as the total number of days a patient was admitted to the ICU.

After the data is collected, it undergoes editing, coding, processing, and cleaning. The activities involved in the data processing are as follows. Firstly, editing, which is the stage where the collected data is reviewed to ensure that it meets the predetermined criteria based on the research needs (variables under investigation). In the coding stage, data is assigned specific codes based on the variables being studied to facilitate data processing. Processing entails inputting the data into a computer software package for data processing. During the cleaning phase, researchers check the data again for any errors. Once the data has been collected, it is then analyzed statistically.

The data was processed using statistical software (Microsoft® Excel 2016 and SPSS 24.0) and presented in the form of tables. The subsequent analysis aimed to describe the variables. For numerical data, the analysis involved calculating the mean, minimum and maximum values, standard deviation, range, and median. For continuous data, the T-test was used for variables with a normal distribution, and the Mann-Whitney test for variables with a non-normal distribution. Categorical data were analyzed using the Chi-square test or Fisher's exact test. A p-value less than 0.05 was considered statistically significant.(Barceló, 2018)

To assess discrimination and distinguish between surviving and deceased patients, the data were analyzed using the ROC curve. The closer the value of AUC (Area Under the Curve) is to 1, the better the model can predict patient mortality outcomes.(Myerson et al., 2001) Calibration, which measures the ability of the prediction results to approximate the truth, was analyzed using the Hosmer-Lemeshow test. A p-value greater than 0.05 indicates that the scoring system has good calibration. Sensitivity and specificity tests were conducted based on the optimal cut-off values obtained from the Youden index.(Fluss et al., 2005)

Results

A total of 77 patients who met the inclusion criteria for this study. The average age of the patients in this study was 50.87 years. Of this total, 37 (48.1%) were male and 40 (51.9%) were female. The average APACHE II and INCNS scores were 21.987 and 9.883, respectively (Table 1). The APACHE II and INCNS scores were significantly higher in patients who died. Table 2 shows the distribution of APACHE II and INCNS scores between death and survival. The patients treated in the ICU suffered from the following conditions: tumors (n = 51), trauma (n = 3), spinal cord (n = 6), blood vessels (n = 10), infection (n = 1), non-hemorrhagic cerebrovascular disease (n = 4), and other (n = 1). The overall mortality rate was 11.7% (9/77).

Table 1. Characteristics of Study Patients

Variable	Frequency (n)	Mean (SD)
Sex, n (%)		
Male	37	
Female	40	
Age (years)		50.87 (65)
ICU stay (days)		2.66 (11)
APACHE II score		
Mean (SD)	21.987 (20)	
Median	22	
Maximum	41	
Minimum	7	
INCNS score		
Mean (SD)	9.883 (34)	
Median	9	
Maximum	23	
Minimum	3	
Mortality		
Alive	69	

APACHE II: Acute Phsyiology and Chronic Health Evaluation; INCNS: Inflammation-Nutrition-Consciousness-Neurologic Function-Systemic Condition; SD: Standard Deviation.

Table 2. Discriminant Analysis on Patient Mortality using Acute Physiology and Chronic Health Evaluation (APACHE) II and Inflammation-Nutrition-Consciousness-Neurologic Function-Systemic Condition (INCNS) Scores.

Variable	Results
APACHE II score	
Area under the ROC	0.74
Standard Deviation	0.111
Confidence Interval	0.523 to 0.957
p-value	0.019
INCNS score	
Area under the ROC	0.977
Standard Deviation	0.015
Confidence Interval	0.947 to 1
p-value	< 0.001

APACHE II: Acute Phsyiology and Chronic Health Evaluation; INCNS: Inflammation-Nutrition-Consciousness-Neurologic Function-Systemic Condition; ROC: Time receiver operating characteristic curve.

There is a statistically significant difference between the APACHE II and INCNS scores based on mortality (p = 0.019 and p < 0.001). Therefore, the researchers decided to calculate the cutoff points for the APACHE II and INCNS scores based on mortality using receiver operating characteristic analysis. The area under the curve was 0.74 with a standard error of 0.11 for APACHE II and 0.977 with a standard error of 0.015 for INCNS (Table 2 and Figure 1). The INCNS scoring system shows a significantly higher AUROC compared to APACHE II.

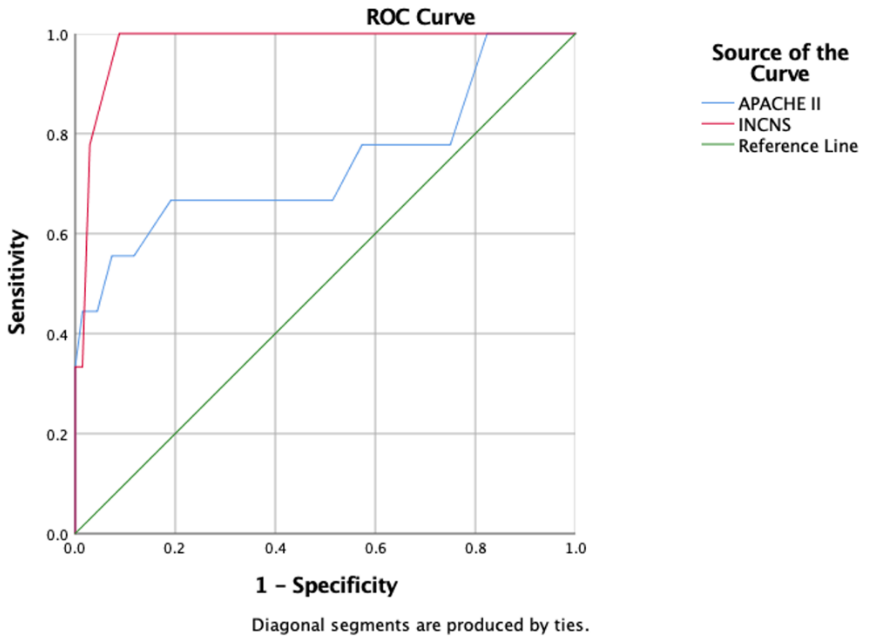

Figure 1. Receiver Operating Characteristic (ROC) curve for INCNS and APACHE II scoring systems in neurosurgical patients treated in the ICU.

The APACHE II score yielded a cut-off point of 22.5, with a sensitivity of 66.7%, specificity of 64.7%, positive predictive value of 80%, and negative predictive value of 93.6%. The INCNS score resulted in a cut-off point of 16, with a sensitivity of 77.8%, specificity of 97.1%, positive predictive value of 97.1%, and negative predictive value of 77.8% (Table 3).

Table 3 Calibration analysis towards mortality according to the APACHE II and INCNS

	p value	Hosmer Lemeshow
Skor APACHE II	0.084	0.319 (0.086 -1.18)
Skor INCNS	< 0.001	4.749 (2.64 - 6.858)

APACHE II: Acute Phsyiology and Chronic Health Evaluation; INCNS: Inflammation-Nutrition-Consciousness-Neurologic Function-Systemic Condition; CI: Confidence Interval.

Both assessment systems showed goodness-of-fit statistical tests with p > 0.05, with INCNS (Hosmer-Lemeshow statistic = 45.207, p < 0.001) demonstrating better fit compared to APACHE II (Hosmer-Lemeshow statistic = 3.753, p = 0.053).

According to the logistic regression analysis, INCNS showed a statistically significant correlation in predicting mortality (RR 4.749 [95% CI 2.64 - 6.858]; p < 0.001), while

APACHE II did not show a significant statistical correlation (RR 0.319 [95% CI 0.086 - 1.18]; p = 0.084).

Discussion

In this retrospective study, we compared the performance of APACHE II and INCNS scores in predicting the mortality of surgical patients treated in the ICU. APACHE II is a validated scoring system designed to predict ICU mortality based on physiological parameters, age, and chronic disease history.(Kondziella et al., 2020) The neurological status of patients can only be evaluated using the Glasgow Coma Scale (GCS); however, the verbal component of GCS cannot be tested in intubated patients. Additionally, brainstem reflexes and respiratory patterns cannot be evaluated with GCS.(Bodart et al., 2013) APACHE II showed good predictive ability for mortality in surgical neurosurgery patients in this study (AUROC = 0.74).

In the INCNS score, we utilized tests for eye opening, behavioral responses, and non-reflex movements to evaluate the level of arousal and consciousness. The INCNS score also includes an assessment of brainstem reflexes and swallowing function.(Gürsoy et al., 2020) A comprehensive examination of neurological function and consciousness provides a clearer understanding of the severity of surgical neurosurgery patients. In addition to APACHE II, the nutritional status is also examined in INCNS. Nutritional status can influence neurological recovery in surgical ICU patients.(Bodart et al., 2013; Zhao et al., 2020) The brain requires sufficient nutrition to support nerve function, synaptic plasticity, and neurotransmitter synthesis. Appropriate nutrition can help optimize brain metabolism, improve cognitive function, and enhance neurological outcomes after surgical procedures.(Nardi et al., 2012; Su et al., 2009)

Pupil light reflex and corneal reflex are routine neurological assessments used in the ICU and are an easy approach to assess brainstem function, which plays a crucial role in maintaining basic functions such as consciousness, respiration, heart rate, and sleep.(Kondziella et al., 2020) The INCNS scoring system is different from other assessment systems because it includes parameters that evaluate brainstem reflexes.(Gao et al., 2020) Our research results indicate that the INCNS score has significantly stronger predictive abilities in terms of discrimination, sensitivity, and specificity compared to the APACHE II scoring system. Therefore, the use of INCNS in surgical neurosurgery patients in the ICU would be highly beneficial.

In the analysis of mortality rates among the cohort under study, a significant observation arose regarding the causes of death related to vascular complications. Remarkably, out of 10 patients who required ICU admission, 6 patients succumbed to these complications. This finding underscores the potential clinical relevance and importance of utilizing the INCNS scoring system. By accurately evaluating and predicting the severity of neurological issues, this scoring system can assist in identifying individuals facing an elevated risk of mortality stemming from vascular complications. Several cohort studies explored the impact of vascular complications on mortality rates in critically ill patients admitted to ICUs.(Bui et al., 2011; Mi et al., 2018; Westendorp et al., 2011) The studies observed a higher mortality rate among patients with vascular complications, corroborating the heightened vulnerability of this subgroup. Furthermore, a separate investigation by Jeng et al. (2008) delved into the prognostic implications of vascular surgery in critically ill individuals. Their study revealed a noteworthy association between post-surgical mortality and underlying vascular comorbidities, suggesting a potential avenue for further research into the mechanisms underlying vascular-related fatalities in ICU settings.(Jeng et al., 2008)

In terms of limitation, due to the nature of retrospective multicenter study, while offering valuable insights, we could not control the risk of bias and confounding due to nonrandom participant selection and unaccounted variables, potential inaccuracies in data quality and availability across institutions, susceptibility to recall bias from participants, absence of randomization leading to inherent group differences, limited generalizability, and the inability to definitively determine causal relationships.

Conclusion

In conclusion, the INCNS score, a novel risk prediction score that integrates measurements from five aspects (inflammation, nutrition, consciousness, neurological function, and systemic condition), was found to outperform the widely used APACHE II and SAPS II scores in predicting the 3-month functional outcome of neurocritically ill patients. The INCNS score demonstrated significantly stronger predictive power, discrimination, sensitivity, and specificity compared to APACHE II and SAPS II at both 24 and 72 hours in the neurointensive care unit (N-ICU).

The INCNS score's comprehensive evaluation of neurological function, including brainstem reflexes and swallowing function, offers a clearer understanding of the severity of surgical neurosurgery patients. By considering nutritional status, the INCNS score also takes into account the influence of proper nutrition on neurological recovery in surgical ICU patients. This score's incorporation of routine neurological assessments like pupil light reflex and corneal reflex, essential for assessing brainstem function, further enhances its predictive abilities.

List of abbreviations

ICU: Intensive care unit

APACHE: Acute Physiology and Chronic Health Evaluation

INACNS: Inflammation-Nutrition-Consciousness-Neurologic Function-Systemic Condition

SAPS: Simplified Acute Physiology Score

ROC: Receiver operating characteristic

GCS: Glasgow coma scale

NPV: Negative predictive value

CC: Concordance correlation

n: Number

AUROC: Area under the receiver operating characteristic

Statements and Declarations

Ethics approval and informed consent

All subjects, or parents of subjects younger than 18 years old, signed a written informed consent. The ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia and Siloam Hospital Lippo Village.

Consent for publication

Handwritten consent was gained from the patients for publication.

Data Availability

The genetic analysis data used to support the findings of this study are included in the article.

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None

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this article.

Authors' contributions

Study conception and design: MW, DY, IA

Acquisition of data: MW, DY, IA

Analysis and interpretation of data: MW, DY, IA

Draft of manuscript: MW, DY, IA

Critical revision of manuscript: MW, DY, IA

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