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Prognostic scoring systems for mortality in intensive care units — The APACHE model

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Abstract

The APACHE (Acute Physiology and Chronic Health Evaluation) scoring system is time consuming. The mean time for introducing a patient's data to APACHE IV is 37.3 min. Nevertheless, statisticians have known for years that the higher the number of variables the mathematical model describes, the more accurate the model. Because of the necessity of gathering data over a 24-hour period and of determining one cause for ICU admission, the system is troublesome and prone to mistakes.

The evolution of the APACHE scoring system is an example of unfulfilled hopes for accurately estimating the risk of death for patients admitted to the ICU; satisfactory prognostic effects resulting from the use of APACHE II and III have been recently studied in patients undergoing liver transplantations. Because no increase in the predictive properties of successive versions has been observed, the search for other solutions continues. The APACHE IV scoring system is helpful; however, its use without prepared spreadsheets is almost impractical. Therefore, although many years have passed since its original publication, APACHE II or its extension APACHE III is currently used in clinical practice.

Key words: intensive therapy; mortality risk, prediction; intensive therapy, prognostic scoring systems, APACHE

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Intensive care advances observed in the 1960s and 1970s involved searching for methods that evaluated therapeutic procedures used in critically ill patients [1, 2]. The Acute Physiology and Chronic Health Evaluation (APACHE) scoring system has been the gold standard in intensive therapy for years; subsequent versions have been developed every few years. The first version, which evaluated the severity of disease based on 34 physiological parameters, was presented by Knaus in 1981 [3]. The next version, APACHE II, was published in 1985 and calculated the risk of hospital death [4].

The APACHE II score consisted of three parts: a) 12 acute physiological parameters (acute physiology score [APS]), b) patient's age and c) chronic diseases and surgical procedures. Short computer programs (calculation sheets) that facilitated the use of APACHE II and automatically calculated both the APACHE II score and the risk of death are available on the Internet [5].

POINT SCORING OF PHYSIOLOGICAL PARAMETERS

This process constitutes an extensive, hence time-consuming, component of APACHE. The APS final score is the sum of the scores of 12 physiological parameters: consciousness; body temperature; mean arterial pressure; heart rate; respiratory rate; alveolar-capillary gradient; pH; serum concentrations of HCO_3^-, Na^+, K^+ and creatinine; and leukocyte and haematocrit counts. The data for measurements are gathered within the first 24 h of intensive care unit (ICU) stay; the results farthest from the baseline (normal) are chosen for the final calculations [6]. The parameters that were not measured are assigned 0; the sum of all 12 elements yields the final APS score.

POINT SCORING OF PATIENT'S AGE

The APACHE score evaluates individuals >16 years of age.

POINT SCORING OF CHRONIC DISEASES AND SURGICAL PROCEDURES

The chronic diseases included in the third part of APACHE II include liver cirrhosis, heart failure (NYHA IV), chronic obstructive pulmonary disease (COPD), chronic renal failure requiring dialysis therapy, and immune deficiency. Organ failure or immunocompromised state is presumably diagnosed and documented before hospital admission. An additional 2 points are given to patients who have one of the chronic diseases listed above, who are immunocompromised or who have undergone elective surgical procedures before admission to the ICU. Non-operative patients or emergency postoperative patients receive 5 points.

It was initially assumed that the APACHE II score will not be used to evaluate patients <16 years of age, those who are hospitalised in the ICU < 8 h, those who have burns or those who underwent coronary bypass grafting. Moreover, database cohorts did not include patients who were re-admitted to the ICU during the same hospitalisation [6].

A study conducted using 5815 ICU patients (Table 1) demonstrated a correlation between the APACHE II score and the mortality rate [4].

The predicted probability of death [5] was expressed using the formula:

$$e^{logit}/(1 + e^{logit}),$$

where

$$\text{logit} = -3.517 + (\text{APACHE II}) * 0.146.$$

Notably, logit is the function used in statistics (logistic regression) for transforming the probability into the logarithm of odds ratio:

$$\text{logit}(p) = \ln \frac{p}{1-p} = \ln(p) - \ln(1-p)$$

$$p = \frac{e^{\text{logit}(p)}}{1 + e^{\text{logit}(p)}} = \frac{1}{1 + e^{-\text{logit}(p)}}$$

The effect of surgery on the likelihood of survival has the following points of interest: a) surgery increases the likelihood of survival when the APACHE score is <29, b) surgery does not affect prognosis when the score ranges from 30 to 35, and c) surgery reduces the likelihood of survival when the score is > 35.

The APACHE II score did not always correlate well with the observed mortality; therefore, the variable of the diagnosis for ICU admission was included. Previously, patients were divided into post-operative and non-operative individuals. The post-operative causes for ICU admission included 16 detailed diagnoses and 5 general diagnoses, whereas in the group of non-operative patients, 24 detailed diagnoses and 5 general diagnoses were distinguished. First, the physician decided whether the patient was admitted because of post-operative organ failure or otherwise and selected the detailed diagnosis; if none of the diagnoses described the patient's condition, the physician chose one of five general diagnoses. The coefficient assigned to the admission diagnosis was found and placed into the following formula: the adjusted predicted risk of death according to APACHE II = $e^{logit}/(1+e^{logit})$, where logit = –3.517 + (APACHE II) * 0.146 + coefficient of admission diagnosis [5].

Several years of experience using the APACHE II scoring system exposed its flaws. The most important flaws include the following: a) no possibility for correcting the results distorted by therapeutic interventions, such as the administration of catecholamines or ventilatory treatment, b) too much value given to patient's age, e.g., age > 65 years was evaluated to be higher than A-a PO_2 > 500 mm Hg (6 and 4 points, respectively), and c) no scores for coronary bypass grafting.

In 1991, the APACHE III score was presented with the following changes: a) the number of parameters used to calculate APS was increased to 17, similarly for their score (0–52 points); b) the the value given to chronically ill patients was reduced from 16 to 7, and HIV infection and haematological malignancies were included; c) the number of disease entities was increased from 56 to 78; d) the place of hospitalisation preceding admission was scored; e) surgeries were scored; and f) the GCS score was increased. The APACHE III score does not evaluate patients who are < 16 years of age, who are hospitalised in the ICU for less than 4 h, who have burns or who underwent transplantations [7]. Concerning the calculation, the modules enabling the prediction of ICU mortality, the duration of intensive care and hospital treatment, ventilatory

Table 1. Correlation between the APACHE II score and the mortality rate in intensive care units [4]

APACHE II score (points)	Hospital mortality rate (%)	
	Postoperative patients	Non-operative patients
0–4	4	1
5–9	6	3
10–14	12	6
15–19	22	11
20–24	40	29
25–29	51	37
30–34	71	71
≥ 35	82	87

treatment and TISS calculations were introduced. The APACHE III score is the sum of its components: APS (0–52 points), concomitant chronic diseases (0–23 points) and age (0–24 points). The total range of scores is 0–299 points. The predicting formula uses the APS score, place of stay before ICU admission and detailed initial diagnosis [8].

From 1991 to 1998, the subsequent versions of APACHE III score were presented, which enabled calculating hospital mortality and mortality in terms of successive days of ICU hospitalisation [9]. Moreover, the scale was widened, and coronary bypass grafting patients were included. In 1998, the "i" version of APACHE III was published, in which APS calculations were remodelled by increasing the number of disease entities to 9, and the model calculating all types of predicted mortality was updated. Another version of APACHE III published in 2001 was marked with the letter "j". [10]. The algorithm for calculating the predicted ICU stay and the duration of ventilatory treatment was corrected. The method for calculating the predicted duration of hospitalisation was improved by introducing fractional values. Moreover, the PaO_2/F_IO_2 ratio was added. Unfortunately, the above changes did not result in the expected outcomes. To evaluate the correctness of mortality calculations, the standardised mortality ratio (SMR) was introduced, which is the quotient of expected and observed mortality. When SMR differs significantly from 1.000, the mathematical model should be revalidated. Such a situation was observed in 2002 and 2003 when the actual number of deaths was 13.5%, whereas the mathematical model predicted a 14.6% mortality. The SMR values reached 0.981 and 0.890, respectively, which confirmed the necessity of revalidating the formulas.

In 2002–2003, APACHE IV was developed. A large patient database was created that included the data of 132 618 patients hospitalised in 104 ICUs of 45 hospitals. Attention was paid to the representativeness of the data gathered. The data concerned patients hospitalised in various departments of university hospitals and of small hospitals. Approximately 65% of patients were treated in multi-profile wards, 38% in cardiology and cardiosurgery wards and fewer than 10% in neurosurgery and trauma departments. Male patients constituted 56% of the population, 1/3 of patients were admitted to ICUs directly from the emergency department, 1/3 of patients underwent surgeries, and the remaining patients were from various hospital wards. Patients readmitted to the ICU constituted 6.1% of the population [10]. The mortality among patients included in the database for APACHE IV was 13.6% (excluding patients after aorto-coronary bypass grafting) and was markedly lower than that in the database for APACHE III (17.3%) [7]. Moreover, the duration of intensive care was substantially shorter, 4.7 days for APACHE III and 3.3 days for APACHE IV. The magnitude of changes introduced to APACHE IV is demonstrated by the fact that 42 of 77 equations in APACHE III (55%) required remodelling, 24 (31%) remained unaltered, and 11 (14%) were excluded because of lack of correlation with clinical practice. Furthermore, several problems were solved. In the new APACHE IV, in cases where the laboratory data were lacking, the data from "the day nearest to the moment of ICU admission" could be used. Additionally, a new method for measuring hospitalisation time was introduced, which was defined as "the number of days the patient spent in hospital" (previously, it was the square root of the number of days between hospital admission and ICU admission). The method for neurologically evaluating analgosedated patients was established, which allowed introducing data to cover the 12-h period before providing analgosedation or using the Glasgow Verbal Score when the verbal response could not be evaluated (e.g., because of intubation) [11].

The essential change was the introduction of new categories. For patients without coronary bypass grafting, the number of categories increased from 94 to 116. Another 27 entities were devoted exclusively to cardiac surgical patients. Patients admitted to ICUs from other ICUs were excluded because the therapeutic methods supporting the functions of systems (e.g., respiratory, circulatory) implemented in other ICUs might "falsify" the evaluation of the patients' general state at the subsequent ICU admission.

Not surprisingly, calculations evaluating patients' conditions according to APACHE IV are more intricate. In addition to extensive evaluations of physiological parameters, age and chronic diseases, which were already included, a complex procedure of choosing one of 426 primary causes of ICU admission was added. The primary causes of admission were divided into 10 groups: cardio-vascular, urinary-genital, gastrointestinal, haematological, metabolic and endocrinological, skeleto-musculo-dermal, neurological, respiratory, transplantation-related and trauma-related. The division of patients into non-operative and post-operative was left unchanged (aorto-coronary bypass grafting was separated). Each diagnosis was assigned a letter code, which in turn was assigned to one of 115 coded groups of disease entities that were assigned an index used for additional calculations.

When calculating the probability of hospital and ICU death (hospital and ICU mortality rate (MR)), the index of oxygenation should be given and several questions should be answered concerning ventilatory treatment during the first day of ICU stay, thrombolytic therapy used in patients with myocardial infarction, the previous place of stay, scheduled or emergent hospitalisation, duration of hospitalisation thus far, etc. Subsequently, each of the 11 parameters mentioned is assigned the index that was then transformed into the indirect index. From the sum of indirect indices, natural antilogarithm = x is extracted, which placed into

the formula gives the probability of death (MR) value [12]. As a result, MR APACHE IV = x/(1 + x), where x is a natural antilogarithm from the sum of 11 indirect indices.

A unique asset of the APACHE score is its predictive capacity; its flaws include a high degree of complexity and a large number of variables required.

SUMMARY

The APACHE scoring system is work consuming. The mean time of introducing patient's data to APACHE IV is 37.3 min [13]. Nevertheless, statisticians have known for years that the higher the number of variables the mathematical model describes, the more accurate the model is. Due to necessity of gathering data covering 24 hours and of determining one cause of ICU admissions, the system is troublesome and exposed to mistakes.

The evolution of APACHE scoring system is an example of unfulfilled hopes for more accurate estimation of the risk of death of patients admitted to ICU; satisfactory prognostic effects resulting from its use have been recently studied for version II and III in patients undergoing liver transplantations [14, 15]. Since no evident increase in predictive properties of successive versions has been observed, the search for other solutions is continued. The APACHE IV scoring system is extremely helpful yet its use without ready calculative sheets is almost infeasible. Therefore, even though many years have passed since its publication, it is the APACHE II [16, 17] or its extension APACHE III [17, 18] that is still used in practice.

References:

1. *Reis Miranda D, Ryan DW, Schaufeli WB, Fidler V, eds.:* Organization and management of intensive care: a prospective study in 12 European countries. Springer-Verlag, Berlin Heidelberg 1997, vol. 29.
2. *Moreno R, Miranda DR, Matos R, FevereiroT:* Mortality after discharge from intensive care: the impact of organ system failure and nursing workload use at discharge. Intensive Care Med 2001; 27: 999–1004.
3. *Knaus WA, Zimmerman JE, Wagner DP, Draper EA, Lawrence DE:* APACHE — acute physiology and chronic health evaluation: a physiologically based classification system. Crit Care Med 1981; 9: 591–597.
4. *Knaus WA, Draper EA, Wagner DP, Zimmerman JE:* APACHE II: a severity of disease classification system. Crit Care Med 1985; 13: 818–829.
5. www.sfar.org/scores2/apache22.html
6. *Le Gall JR:* Modeling the severity of illness of ICU patients. A systems update. JAMA 1994; 272: 1049–1055.
7. *Knaus WA, Wagner DP, Draper EA, et al.:* The APACHE III prognostic system. Risk prediction of hospital mortality for critically ill hospitalized adults. Chest 1991; 100: 1619–1636.
8. *Dyk D:* APACHE III prognostic system for prediction of outcome from intensive care. Anaesthesiol Intensive Ther 2001; 33: 9–13.
9. *Zimmerman JE, Wagner DP, Draper EA, et al.:* Evaluation of acute physiology and chronic health evaluation III predictions of hospital mortality in an independent database. Crit Care Med 1998; 26: 1317–1326.
10. https://apachefoundations.cernerworks.com/apachefoundations/
11. *Marion DW, Carlier PM:* Problems with initial Glasgow Coma Score assessment caused by prehospital treatment of patients with head injuries: results of a national survey. J Trauma 1994; 36: 89–95.
12. www.cernercare.com/public/filedownload.asp?LibraryID=40394.
13. *Kuzniewicz MW, Vasilevskis EE, Lane R, et al.:* Variation in ICU risk-adjusted mortality, impact of methods of assessment and potential confounders. Chest 2008; 133: 1319–1327.
14. *Chung IS, Park M, Ko JS, et al.:* Which score system can best predict recipient outcomes after living donor liver transplantation? Transplant Proc 2012; 44: 393–395.
15. *Fikatas P, Lee JE, Sauer IM, et al.:* APACHE III score is superior to King's College Hospital criteria, MELD score and APACHE II score to predict outcomes after liver transplantation for acute liver failure. Transplant Proc 2013; 45: 2295–2301.
16. *Hwang SY, Lee JH, Lee YH, Hong CK, Sung AJ, Choi YC:* Comparison of the sequential organ failure assessment, Acute Physiology and Chronic Health Evaluation II scoring system, and Trauma and Injury Severity Score method for predicting the outcomes of intensive care unit trauma patients. Am J Emerg Med 2012; 30: 749–753.
17. *Iyegha UP, Asghar JI, Habermann EB, et al.:* Intensivists improve outcomes and compliance with process measures in critically ill patients. J Am Coll Surg 2013; 216: 363–372.
18. *Bohensky MA, Jolley D, Pilcher DV, Sundararajan V, Evans S, Brand CA:* Progostic models based on administrative data alone inadequately predict the survival outcomes for critically ill patients at 180 days post-hospital discharge. J Crit Care 2012; 27: 422.e11–422.e21.

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