Acute Physiology Score prediction in patients with traumatic brain injury

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Key words:
- Traumatic Brain Injury (TBI)
- APACHE-II
- Acute Physiology Score (APS)
- Regression

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SUMMARY. Background: APACHE-II is one of the severity-of-illness scoring systems. It describes in an arithmetical manner the severity of injury by calculating 12 variables, the Acute Physiology Score (APS), age and the chronic health status. **Objectives:** The aim of this study was to find a regression equation to predict the APS from a limited number of variables in patients with traumatic brain injury (TBI). **Population and Method:** The characteristics were studied of 74 subjects admitted to the Intensive Care Unit (ICU) of the University General Hospital of Alexandroupolis, Greece, during the decade 1994-2003 with the diagnosis of "TBI". The subjects had a mean age of 45.19±2.55 years, 65 were male (87.8%) and 9 female (12.2%) and their mean Glasgow Coma Scale (GCS) score was 6.39±0.55. Statistical analysis was made using stepwise regression, with APS as the dependent variable and the 12 physiological variables and age being the independent variables. The following selection criteria were also taken into consideration: Akaike, Amemiya, Mallows' and Schwarz. **Results:** The data analysis provided the following equation: APS = 148.843 – (1.074*GCS) – (16.878*pH) – (0.190*HCT) + (4.082*CR), where HCT is the haematocrit and CR is serum creatinine. The statistics of the equation were: F=116.304 (p=0.000), adjusted coefficient of determination (R'^2)=0.863 and standard error of the estimate=2.624. The corresponding values for Akaike, Amemiya, Mallows' and Schwarz selection criteria were: 147.575, 0.148, 3.053 and 159.095. **Conclusions:** These results suggest that it is possible to estimate the APS value based on four variables only, thus saving time in APACHE-II calculation. In this series, 86.3% of the APS change was due to the four aforementioned variables, while the remaining 13.7% was due to other factors which are not entered in the equation. ***Pneumon 2008; 21(4):374–379***

INTRODUCTION

The prediction of outcome in hospitalized patients is influenced not only by the type and the severity of disease, but also by the availability and the quality of medical interventions[1,2]. In this context, severity-of-illness scoring systems constitute a necessary tool, among others, for classifying the severity of disease[3].

The Acute Physiology, Age, and Chronic Health Evaluation – II (APACHE-II) scale[4] constitutes one of these scoring systems. Globally, it is one of the most prominent neurological scales, used especially in the assessment of neurosurgical patients[5,6]. It employs basic physiological variables, the Acute Physiology Score (APS) for defining the severity of disease and predicting the outcome (i.e., probability of death)[4]. This scale is the evolution of the initial APACHE system [based on 34 variables for 805 admissions in two US Intensive Care Units (ICUs)] and its development was based on data collected from 5,815 ICU admissions in 13 US hospitals[7].

This study investigated the possibility of constructing a regression equation to predict the APS value based on a limited number of physiological variables in patients with traumatic brain injury (TBI). The main advantage of such an equation would be the gain in time needed for calculating the APACHE-II score.

MATERIALS AND METHODS

Study population

The study population consisted of 74 subjects who were admitted to the ICU of the University General Hospital of Alexandroupolis, Greece, during the decade 1994-2003 with a diagnosis of "TBI". The treatment of all subjects was based on the same clinical protocols. Of the subjects, 65 were male (87.8%) and 9 female (12.2%) with a mean age of 45.19±2.555 years. The causes of TBI were: traffic accidents (76%), falls (23%) and assaults (1%). The mean Glasgow Coma Scale (GCS) score of the subjects was 6.39±0.55, the mean APS value was 13.77±0.825, the mean APACHE-II score was 15.91±0.890, and the mean length of stay in the ICU was 11.5±2.051 days. CT scan demonstrated that 13 patients had developed epidural haematoma (17.6%), 28 subdural haematoma (37.8%), 14 intracerebral haematoma (18.9%) και 32 subarachnoid haemorrhage (43.2%). Only 7 patients (11.7%) were transferred to the operating room.

The APACHE-II system

The APACHE-II system includes twelve physiological variables, the APS (temperature, mean arterial pressure, heart rate, respiratory rate, oxygenation, arterial pH, serum Na, serum K, serum creatinine, haematocrit, white blood cell count, GCS), age and chronic health status (immunocompromisation, respiratory, cardiac, renal or hepatic insufficiency)[4,8]. A score of 5 is assigned in the case of an emergency postoperative patient with an organ insufficiency or in the case of a patient with medical problems. Two points are assigned in elective postoperative patients. Each variable takes a value ranging from 0 to 4. The sum of all values gives the final score of the APACHE-II system. Even though the highest possible score is 71, in the article of Knaus et al no patient had a score >55 **(Table 1)**[4].

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) for Windows, version 16.00 (SPSS Inc, Chicago, Illinois) was used for data handling and analysis. Continuous variables were expressed as the mean ± standard deviation. Stepwise regression was employed in order to construct the best possible equation. APS was considered to be the dependent variable, while the twelve physiological variables and age the independent variables. In addition, the following selection criteria were used: Akaike, Amemiya, Mallows' and Schwarz[9].

These information criteria are used when comparing different models for the same data. For example, the Akaike and the similar Amemiya criteria are grounded in the concept of entropy, in effect offering a relative measure of the information lost when a given model is used to describe reality, and can be said to describe the tradeoff between bias and variance in model construction. On the other hand the Mallows' criterion is considered as a way of facilitating comparisons among many alternative subset regressions. Finally, the Schwarz criterion deals with the overtraining problem if the number of parameters is too large. The best model presents the lowest values of these information criteria.

Finally, the frequency histogram of the residuals of the equation, and the normal probability plot of the residuals were constructed. Probability (p) values of less than 0.05 were considered statistically significant.

RESULTS

Data analysis provided the following simple linear regression equation:

$$APS = 148.843 - (1.074*GCS) - (16.878*pH) - (0.190*HCT)$$

TABLE 1. The APACHE-II system.

Physiological Variable	High Abnormal Range					Low Abnormal Range				
	+4	+3	+2	+1	0	+1	+2	+3	+4	Points
Temperature	≥41°	39 to 40.9°		38.5 to 38.9°	36 to 38.4°	34 to 35.9°	32 to 33.9°	30 to 31.9°	≤29.9°	
Mean Arterial Pressure – mm Hg	≥160	130 to 159	110 to 129		70 to 109		50 to 69		≤49	
Heart Rate	≥180	140 to 179	110 to 139		70 to 109		55 to 69	40 to 54	≤39	
Respiratory Rate	≥50	35 to 49		25 to 34	12 to 24	10 to 11	6 to 9		≤5	
Oxygenation: A-aDO_2 **or** PaO_2 (mm Hg)	≥500	350 to 499	200 to 349		<200					
a. FIO_2 ≥0.5 record A-aDO2										
b. FIO_2 <0.5 record PaO2					PO2>70	PO2 61 to 70		PO2 55 to 60	PO2<55	
Arterial pH	≥7.7	7.6 to 7.69		7.5 to 7.59	7.33 to 7.49		7.25 to 7.32	7.15 to 7.24	<7.15	
Serum HCO_3 (venous mEq/l)	≥52	41 to 51.9		32 to 40.9	22 to 31.9		18 to 21.9	15 to 17.9	<15	
Serum Sodium (mEq/l)	≥180	160 to 179	155 to 159	150 to 154	130 to 149		120 to 129	111 to 119	≤110	
Serum Potassium (mEq/l)	≥7	6 to 6.9		5.5 to 5.9	3.5 to 5.4	3 to 3.4	2.5 to 2.9		<2.5	
Serum Creatinine (mg/dl)	≥3.5	2 to 3.4	1.5 to 1.9		0.6 to 1.4		<0.6			
Haematocrit (%)	≥60		50 to 59.9	46 to 49.9	30 to 45.9		20 to 29.9		<20	
White Blood Count (total/mm3)	≥40		20 to 39.9	15 to 19.9	3 to 14.9		1 to 2.9		<1	
Glasgow Coma Score (GCS)										
Score = 15 minus actual GCS										

A. Total Acute Physiology Score (APS) (sum of 12 above points)
B. Age points (years) ≤44=0; 45 to 54=2; 55 to 64=3; 65 to 74=5; ≥75=6
C. Chronic Health Points (see below)
Total APACHE II Score (add together the points from A+B+C)

+ (4.082*CR), where HCT is the haematocrit and CR is the serum creatinine. The statistics of the equation were: F=116.304 (p=0.000), adjusted coefficient of determination (R'^2)=0.863 and standard error of the estimate=2.624.

All regression coefficients were different from 0, since all p-values were equal to 0.000. The colinearity control showed variance inflation factor (VIF) values ranging from 1.105 to 1.181.

The corresponding values for Akaike, Amemiya, Mallows' and Schwarz selection criteria were: 147.575, 0.148, 3.053 and 159.095 (these were the smaller values for all equations studied) **(Table 2)**.

In **Figure 1** the frequency histogram of the residuals of the equation is presented. It can be seen that the residuals follow approximately the normal distribution with constant dispersion. In addition, **Figure 2** shows the normal probability plot of the residuals (the observed values are plotted against the expected values) which leads to the same conclusion as **Figure 1**, since almost all the data values are found in a straight line.

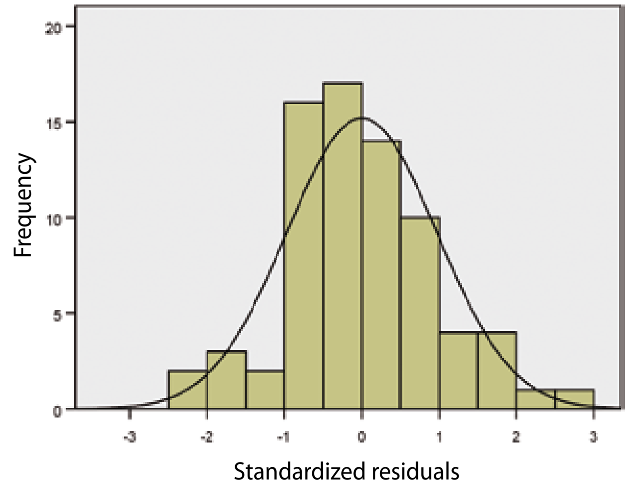

FIGURE 1. Histogram of the residuals of the equation.

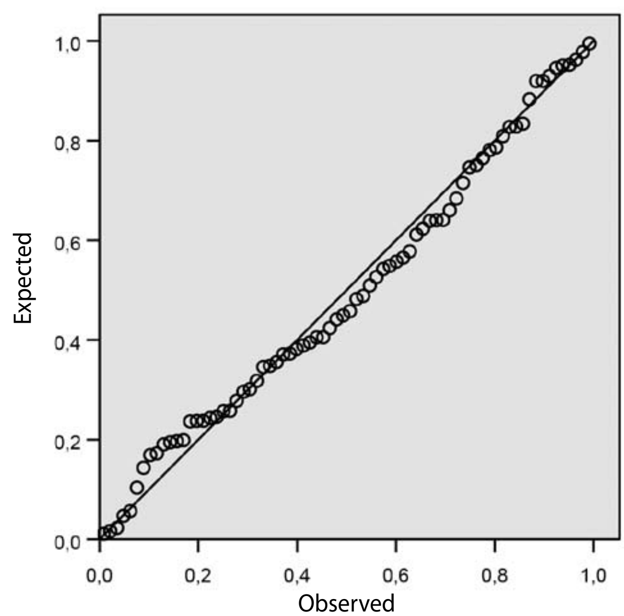

FIGURE 2. Residuals' normal probability plot.

DISCUSSION

Severity of disease systems are used in classifying the degree of injury severity, in predicting outcome, and in evaluating the course of disease[10]. Their role is also of major importance in quality control, in supporting therapeutic interventions in isolated cases, and in evaluating new treatment options through stratification of patients [11]. Finally, they are employed in the recording of nursing expenditure and the tracing of personnel shortages[12].

The APACHE-II system is one such system, which encompasses basic physiological variables for defining the severity of disease and predicting the probability of death[3,4,13]. It is a tool that is widely accepted not only in general[14], but also in neurosurgical ICUs[5,], although the recording and summating of all the component variables requires a significant amount of time.

In the present study it was attempted to limit the number of necessary variables for computing APACHE-II in patients with TBI, thus saving precious time. In the result-

TABLE 2. Selection criteria.

Independent variables	Akaike	Amemiya	Mallows'	Schwarz
Constant, GCS	195.770	0.284	69.470	200.378
Constant, GCS, pH	169.970	0.200	27.791	176.882
Constant, GCS, pH, HCT	159.308	0.173	14.727	168.525
Constant, GCS, pH, HCT, CR	147.575	0.148	3.053	159.095

GCS = Glasgow Coma Score, pH = arterial blood pH, HCT = haematocrit, CR = serum creatinine ing equation the four variables are presented in the order of significance provided by the SPSS stepwise regression analysis. This means that the GCS that influences the APS score to the greatest degree. GCS by itself explained 72.8% of APS change and the standard error of the estimate was 3.704. This finding is in line with other reports, suggesting that it is the neurological component (GCS) that confers on APACHE-II scale its prognostic potential[2,6].

With the addition of the second most significant independent variable, that is arterial blood pH, the adjusted coefficient of determination reached 0.810 and the standard error of the estimate was limited to 3.091. The third best independent variable was the haematocrit, which increased the adjusted coefficient of determination to 0.838, while reduced the standard error of the estimate to 2.858. In conclusion, it is possible to calculate the APS score based on only four variables, the GCS, arterial pH, haematocrit and serum creatinine. In this series of patients with TBI, 86.3% of APS change was due to these four variables, while the remaining 13.7% was due to other factors which are not shown in the equation.

However, it is imperative to test this equation in a larger number of ICU patients in order to confirm its validity. It should also be kept in mind that the experience of data collectors is of major importance, since it ultimately affects the scoring and the predicted probability of death[15,16]. The APACHE-II scale, as other scoring systems, presents differences in outcome prediction ability when applied in the ICUs of different countries. This could be because of differences in the admission criteria, organizational and treatment methods and therapeutic interventions prior to ICU admission (lead time bias), and to incorrect recording of the main reason for ICU admission (selection bias)[3,16-18].

It is thus obvious that the establishment of strict guidelines is urgently needed for dealing with the casemix problem, with improvement in personnel education and data collection[19-22]. Many reports also propose the extension of automated systems integration in ICUs, aimed at calculating the severity scores in less time and with greater reliability[23].

However, the use of scores obtained from systems of severity of disease alone should by no means justify medical decisions in intensive care, because in any individual patient outcome prediction carries a great degree of uncertainty[1,3,4,24].

Finally, predicting outcome after TBI based on admission characteristics could be made more accurate by implementing in current practice the conclusions drawn from international studies with large numbers of patients. The CRASH Trial[25] and the articles of Xu et al (2007)[26] and Steyerberg et al (2008)[27] are such examples. All these studies agree on the substantial role of parameters such as age, GCS, pupillary and motor reaction, CT findings, the presence of extracranial injury, hypotension, hypoxia and haemoglobin and blood glucose values[25-27]. It is certain that adding all the above parameters in the proposed equation would improve its prognostic capacity but, at the same time, would increase its complexity and the time required for calculation.

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