Good Mortality Prediction by Glasgow Coma Scale for Neurosurgical Patients

Hsien-Wei Ting[1,4], Ming-Shung Chen[2], Yueh-Chun Hsieh[3], Chien-Lung Chan[4]*

[1]Department of Neurosurgery, Taipei Hospital, Department of Health, [2]Department of Neurosurgery, Taipei Veterans General Hospital, Taipei, [3]Genomics Laboratory, Phalanx Biotech Inc., Hsinchu, and [4]Department of Information Management, Yuan Ze University, Taoyuan, Taiwan, R.O.C.

Background: How to effectively use the finite resources of an intensive care unit (ICU) for neurosurgical patients is a critical decision-making process. Mortality prediction models are effective tools for allocating facilities. This study intended to distinguish the prediction power of the Acute Physiology and Chronic Health Evaluation II (APACHE II), the Simplified Acute Physiology Score II (SAPS II), and the Glasgow Coma Scale (GCS) for neurosurgical patients.

Methods: According to the definitions of the APACHE II, this study recorded both APACHE II and SAPS II scores of 154 neurosurgical patients in the ICU of a 600-bed general hospital. Linear regression models of GCS (GCS-mr) were constructed. The *t* test, receiver operating characteristic (ROC) curve and Wilcoxon signed rank test were used as the statistical evaluation methods.

Results: There were 50 (32.5%) females and 104 (67.5%) males in this study. Among them, 108 patients survived and 46 patients died. The areas under the ROC curves (AUC) of SAPS II and APACHE II were 0.872 and 0.846, respectively. The AUC of GCS-mr was 0.866, and the R^2 was 0.389. The evaluation powers of SAPS II, GCS-mr and APACHE II were the same ($p > 0.05$). Patients with GCS ≤ 5 or motor component of GCS (GCS-M) ≤ 3 had a higher probability of mortality than patients with GCS > 5 or GCS-M > 3 ($p < 0.01$).

Conclusion: The predictive powers of SAPS II, APACHE II and GCS-mr were the same. The GCS-mr is more convenient for predicting mortality in neurosurgical patients. Both GCS ≤ 5 and GCS-M ≤ 3 are good indicators of mortality in these patients. [*J Chin Med Assoc* 2010;73(3):139–143]

Key Words: APACHE II, Glasgow Coma Scale, linear regression model, mortality prediction model, SAPS II

Introduction

Neurosurgical conditions such as head injury, intracranial hemorrhage (ICH), brain neoplasm, stroke and so on usually require intensive care. Due to advances in the modern critical care system, decision-making in how intensive care facilities should be used is necessary.[1] Mortality prediction models can evaluate the severity of disease and allow for proper allocation of resources.[2] The 2 most popular mortality prediction models are the Acute Physiology and Chronic Health Evaluation II (APACHE II) proposed by Knaus et al in 1985,[3] and the Simplified Acute Physiology Score II (SAPS II) proposed by Le Gall et al in 1993.[4] For many diseases, both models can predict the probability of mortality.[5–7]

Some research has indicated that SAPS II performs better than APACHE II for certain diseases,[8,9] while other research has demonstrated that APACHE II is better than SAPS II for other diseases.[2,10,11] Alvarez et al[12] reported that SAPS II and APACHE II show a less than satisfactory calibration in head injury patients. Another report shows poor prediction in patients with low risk and patients who have lower tendency to mortality, even though the models were calibrated.[13] Capuzzo et al[14] reported that SAPS II overestimated mortality in patients at high risk for mortality, whereas APACHE II underestimated mortality in such patients.

The Glasgow Coma Scale (GCS) is one of the most important evaluation systems used to assess patient consciousness.[15] Some research has demonstrated that the

*Correspondence to: Dr Chien-Lung Chan, Department of Information Management, Yuan Ze University, 135, Yuan-Tung Road, Chung-Li 320, Taiwan, R.O.C.
E-mail: clchan@im.yzu.edu.tw • Received: March 27, 2009 • Accepted: January 19, 2010

GCS can be a good indicator for the outcome of diseases, especially neurosurgical diseases.[16–18] Many mortality prediction models include the component of GCS.[3,4] Recently, GCS was used for prognostic factor evaluation of patients with acute community-acquired bacterial meningitis.[17] However, the GCS cannot predict the probability of mortality. Instead, it only scores patients' degree of disease severity.

Some studies have evaluated the mortality rates of head injury patients using mortality prediction systems.[12,19] However, there is no report that focuses on mortality prediction for neurosurgical diseases. In this study, we demonstrated the power of probabilistic prediction models of APACHE II, SAPS II and GCS in neurosurgical patients.

Methods

We recorded 161 patients' data with neurosurgical diseases in the intensive care unit (ICU) of a 600-bed general hospital from January 2000 to August 2001. Seven patients were excluded from this study because they were younger than 18 years old. Both APACHE II and SAPS II scores in these 154 patients were analyzed. The GCS data of patients were included in both mortality models. A multiple linear regression model of GCS (GCS-mr) was built using the eye component of GCS (GCS-E), the verbal component of GCS (GCS-V) and the motor component of GCS (GCS-M) as the independent variables, and the probability of mortality was the dependent variable. The patients' probabilities of mortality were also analyzed. Patients were classified as dead if they died in hospital or within 24 hours of being discharged, and the probability of mortality of these patients was defined as 1. Patients were classified as alive if they were still alive at least 3 months after their ICU admission, and the probability of mortality of these patients was defined as 0.

There are 3 admission types according to the SAPS II definition: medical problems, scheduled surgery and emergency surgery. The definition of medical problems is when patients are admitted to the ICU due to their medical problems. The definition of scheduled surgery is when patients are admitted to the ICU with scheduled surgery but their conditions are ones of high risk. The definition of emergency surgery is when patients have undergone high-risk emergent surgery and need further intensive care.

This study used the disease classification system in APACHE II. Diseases were classified into 7 groups (Table 1). These included patients admitted to the ICU due to ICH, subdural hemorrhage (SDH) and subarachnoid hemorrhage (SAH) with or without surgery. Some patients could not be accurately diagnosed before discharge or death and were therefore classified as "non-classified neurological disease". Patients with brain tumors were also classified into this group if they did not receive craniotomy. Some patients were found to have neurological organ failure with unstable vital signs, and were often classified into the "neurological organ failure" group. Some patients suffered head injury but no ICH, SDH or SAH were found. Thus, they were classified into the "head trauma" group. Patients with more than 2 injured organs and a major head injury were classified into the "multiple trauma" group.

The predicted percentages of mortality using the APACHE II and SAPS II scoring systems were calculated. The coefficients of correlations of these 2 prediction models with GCS were also calculated. The receiver operating characteristic (ROC) curve was used to evaluate the accuracy of prediction, which is defined as good or excellent if the area under the ROC curve (AUC) is >0.8.[20] The ROC curve, multiple linear regression and coefficient of correlation were calculated using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA).

Results

The demographic characteristics of the 154 patients (50 female, 104 male) are shown in Table 1; 108 patients survived (53.11 ± 21.65 years old) and 46 patients died (59.59 ± 19.73 years old). The majority of patients were admitted to the ICU for medical problems (54.89 ± 20.77 years old), followed by admission for scheduled surgery (57.41 ± 20.95 years old) and then emergency surgery (52.00 ± 23.13 years old). Almost half of the patients were admitted to the ICU due to ICH, SDH and SAH without surgery (58.98 ± 16.66 years old) or with surgery (54.05 ± 21.56 years old). Twenty-seven patients were classified into the "non-classified neurological disease" group (65.00 ± 22.90 years old), and 6 patients were classified into the "neurological organ failure" group (68.00 ± 16.65 years old). Almost a third of patients had head trauma (42.47 ± 22.10 years old) or multiple trauma (47.00 ± 23.78 years old). Only 7 patients were admitted to the ICU because of surgery for brain tumor (53.57 ± 17.89 years old).

The AUCs of SAPS II and APACHE II were 0.872 and 0.846, respectively. There was no significant difference in performance between SAPS II and APACHE II ($p = 0.537$). To find a better scoring system, we also used GCS-E, GCS-V and GCS-M together as independent factors to build a multiple linear

Table 1. Demographic characteristics of patients ($n = 154$)

	Female	Male	Total
Sex (%)	32.5	67.5	100
Mean age (yr)	57.7	56.2	56.7 ± 20.4
Alive/dead (*n*)			
Alive	34	74	108
Dead	17	29	46
Admission type (*n*)			
Medical problem	30	50	80
Scheduled surgery	12	32	44
Emergency surgery	9	21	30
Disease type (*n*)			
ICH/SDH/SAH without surgery	17	32	49
Craniotomy for ICH/SDH/SAH	11	10	21
Head trauma	11	23	34
Multiple trauma	3	7	10
Craniotomy for neoplasm	3	4	7
Neurological organ failure	1	5	6
Non-classified neurological disease	6	21	27

ICH = intracranial hemorrhage; SDH = subdural hemorrhage; SAH = subarachnoid hemorrhage.

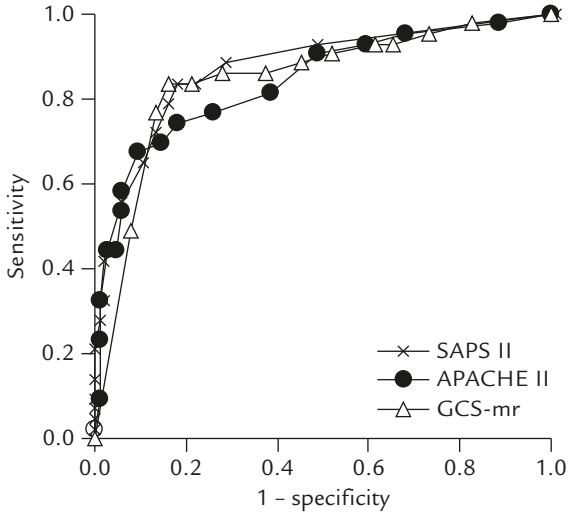

Figure 1. Receiver operating characteristic (ROC) curves of Acute Physiology and Chronic Health Evaluation II (APACHE II), Simplified Acute Physiology Score II (SAPS II), and the multiple regression model of the Glasgow Coma Scale (GCS-mr). The area under the ROC curve (AUC) of APACHE II is 0.846 and of SAPS II is 0.872. The AUC of GCS-mr is 0.866 ($R^2 = 0.389$).

regression model of GCS (GCS-mr). The AUC of GCS-mr was 0.866 ($R^2 = 0.389$). The prediction power of GCS-mr was the same as that of SAPS II ($p = 0.883$) and APACHE II ($p = 0.657$) (Figure 1). The functions of GCS-mr are:

$$\text{GCS-mr} = 0.873 - 0.0721 \times (\text{GCS-E}) + 0.0546 \times (\text{GCS-V}) - 0.137 \times (\text{GCS-M})$$

GCS is an important factor in most mortality prediction models. We thus evaluated the performance of SAPS II and APACHE II with GCS. The GCS score was calculated as an independent variable using linear regression. The R^2 of SAPS II was 0.560, and that of APACHE II was 0.484 ($p < 0.01$), indicating that GCS can replace more than half the data for SAPS II and almost half the data for APACHE II.

The total mean mortality ratio was 29.87%. The mortality rate was > 50% if the patient's GCS was < 5 (Figure 2). Patients with GCS ≤ 5 had a higher probability of mortality than patients with GCS > 5 ($p < 0.01$). We also found that patients with GCS-M ≤ 3 had a higher probability of mortality than patients with GCS-M > 3 ($p < 0.01$). But for GCS-E and GCS-V, patients with scores of 1 had a higher probability of mortality than patients with scores > 1 ($p < 0.01$) (Figure 3). Patients had a higher probability of mortality if GCS was E1V1M3 (GCS-E = 1, GCS-V = 1, and GCS-M = 3) or less ($p < 0.01$).

Discussion

There are many reports discussing the differences between APACHE II and SAPS II because one or the other have greater popularity and perceived accuracy depending on the patient group they are being used in. Many studies have demonstrated that there is no significant difference in accuracy between the 2 models.[21,22]

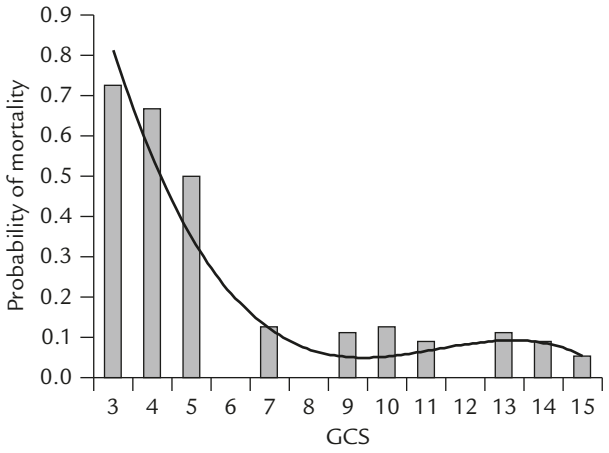

Figure 2. Mortality ratio by Glasgow Coma Scale (GCS). The R^2 of the tendency line is 0.8461. The total mortality rate is 29.87%.

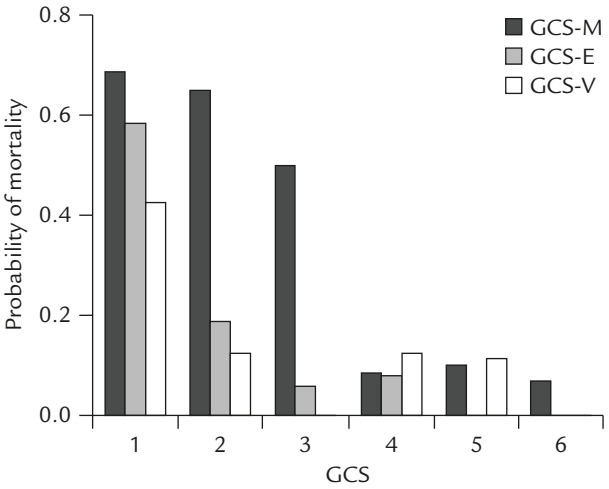

Figure 3. Mortality ratio by the motor component (GCS-M), eye component (GCS-E) and verbal component (GCS-V) of the Glasgow Coma Scale (GCS). The mortality rate is > 50% if GCS-M is ≤ 3. The mortality rate = 58.46% if GCS-E = 1. The mortality rate = 42.55% if GCS-V = 1.

But neither mortality prediction model can be applied to a single patient with good accuracy. Some studies have suggested that SAPS II performs better than APACHE II for certain diseases.[8,9] Other reports have the opposite conclusion for other diseases.[2,10,11] One of the most important differences between SAPS II and APACHE II is that the APACHE II has special disease calibrations and thus has better mortality prediction power within different disease groups. This study found that SAPS II and APACHE II had the same predictive power in clinical use.

SAPS II has 15 attributes and APACHE II has 12 attributes. APACHE II and SAPS II both contain the attribute of GCS. Le Gall et al reported that the weights of the GCS are 17% in APACHE II and 19% in APACHE III, without disease specificity.[4] In the current study, the GCS score was calculated as an independent variable using linear regression. The R^2 of SAPS II was 0.560 and that of APACHE II was 0.484 ($p < 0.01$), clearly indicating that GCS played an important role in mortality prediction for the neurological patients in this study.

APACHE II, III and IV are all good mortality prediction models, but they each have their advantages and disadvantages.[23] There is no significant difference in prediction power between APACHE II and APACHE IV. In addition, APACHE IV has more than 40 attributes and computer aids for prediction.[24] Thus, compared with APACHE II and SAPS II, data on many more attributes need to be collected for APACHE IV. This study showed that the power of GCS-mr was the same as that of APACHE II and SAPS II for mortality prediction. The GCS has only 3 attributes; the GCS-mr is therefore the most convenient for use in predicting the mortality of neurosurgical patients.

Elf et al reported that improved treatment for head injury patients with GCS-M ≥ 4 could increase the survival rate in the ICU.[25] In our study, neurological patients with GCS ≤ 5 had a high probability of mortality ($p < 0.01$). We also found that neurological patients with GCS-M ≤ 3 had a high probability of mortality ($p < 0.01$). Neurological or neurosurgical patients had a high probability of mortality if GCS was E1V1M3 or less ($p < 0.01$). This may be because brain stem injury was progressing and patients would be in a state of pathological postural decerebrate and decorticated rigidity or none. So both GCS ≤ 5 and GCS-M ≤ 3 are good indicators for the mortality of neurological patients.

In conclusion, SAPS II, APACHE II and GCS-mr have the same predictive power for the mortality of neurosurgical patients. But the GCS-mr is more convenient to use in such patients. If only for quick reference, both GCS ≤ 5 and GCS-M ≤ 3 are good indicators for the disease severity of neurological patients. We suggest that the GCS-mr can serve as a good mortality prediction model for neurosurgical patients.

Acknowledgments

We thank Dr Ying Wu (COO, Vice-President of Vita Genomics, Inc., Taipei, Taiwan) for critical reading and Miss Karen Chen (English Teacher, Cheng-Gong Elementary School, Tainan, Taiwan) for grammar and spelling correction of the manuscript. This work was supported by an internal research grant from

Taoyuan General Hospital, Department of Health, Taiwan, R.O.C.

References

1. Lemeshow S, Teres D, Pastides H, Avrunin JS, Steingrub JS. A method for predicting survival and mortality. *Crit Care Med* 1985;13:519–25.
2. Katsaragakis S, Papadimitropoulos K, Antonakis P, Strergiopoulos S, Konstadoulakis MM, Androulakis G. Comparison of Acute Physiology and Chronic Health Evaluation II (APACHE II) and Simplified Acute Physiology Score II (SAPS II) scoring systems in a single Greek intensive care unit. *Crit Care Med* 2000;28:426–32.
3. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985;13:818–29.
4. Le Gall JR, Lemeshow S, Saulnier F. A new simplified acute physiology score (SAPS II) based on a European/North American multicenter study. *JAMA* 1993;270:2957–63.
5. Schuster HP, Schuster FP, Ritschel P, Wilts S, Bodmann KF. The ability of the Simplified Acute Physiology Score (SAPS II) to predict outcome in coronary care patients. *Intensive Care Med* 1997;23:1056–61.
6. Moran JL, Solomon PJ, Fox V, Salagaras M, Williams PJ, Quinlan K, Bersten AD. Modeling thirty-day mortality in the acute respiratory distress syndrome (ARDS) in an adult ICU. *Anaesth Intensive Care* 2004;32:317–29.
7. Kroschinsky F, Weise M, Illmer T, Haenel M, Bornhaeuser M, Hoeffken G, Ehninger G, et al. Outcome and prognostic features of intensive care unit treatment in patients with hematological malignancies. *Intensive Care Med* 2002;28:1294–300.
8. Tan IKS. APACHE II and SAPS II are poorly calibrated in a Hong Kong intensive care unit. *Ann Acad Med* Singapore 1998;27:318–22.
9. Schellongowski P, Benesch M, Lang T, Traunmuller F, Zauner C, Laczika K, Locker GJ, et al. Comparison of three severity scores for critically ill cancer patients. *Intensive Care Med* 2004; 30:430–6.
10. O'Dair GN, Leaper DJ. Sequential physiology scoring facilitates objective assessment of resuscitation in patients with an intra-abdominal emergency. *Br J Surg* 2003;90:1445–50.
11. Markgraf R, Deutschinoff G, Pientka L, Scholten T. Comparison of Acute Physiology and Chronic Health Evaluations II and III and Simplified Acute Physiology Score II: a prospective cohort study evaluating these methods to predict outcome in a German interdisciplinary intensive care unit. *Crit Care Med* 2000;28: 26–33.
12. Alvarez M, Nava JM, Rue M, Quintana S. Mortality prediction in head trauma patients: performance of Glasgow Coma Score and general severity systems. *Crit Care Med* 1998;26:142–8.
13. Beck DH, Smith GB, Taylor BL. The impact of low-risk intensive care unit admissions on mortality probabilities by SAPS II, APACHE II and APACHE III. *Anaesthesia* 2002;57:21–6.
14. Capuzzo M, Valpondi V, Sgarbi A, Bortolazzi S, Pavoni V, Gilli G, Candini G, et al. Validation of severity scoring systems SAPS II and APACHE II in a single-center population. *Intensive Care Med* 2000;26:1779–85.
15. Jennet B, Teasdale G, Braakman R, Minderhoud J, Heiden J, Kurze T. Prognosis of patients with severe head injury. *Neurosurgery* 1979;4:283–9.
16. Gerlach R, Dittrich S, Schneider W, Ackermann H, Seifert V, Kieslich M. Traumatic epidural hematomas in children and adolescents: outcome analysis in 39 consecutive unselected cases. *Pediatr Emerg Care* 2009;25:164–9.
17. Ishihara M, Kamei S, Taira N, Morita A, Miki K, Naganuma T, Minami M, et al. Hospital-based study of the prognostic factors in adult patients with acute community-acquired bacterial meningitis in Tokyo, Japan. *Intern Med* 2009;48:295–300.
18. Demetriades D, Kuncir E, Murray J, Velmahos GC, Rhee P, Chan L. Mortality prediction of head Abbreviated Injury Score and Glasgow Coma Scale: analysis of 7,764 head injuries. *J Am Coll Surg* 2004;199:216–22.
19. Cho DY, Wang YC. Comparison of the APACHE III, APACHE II and Glasgow Coma Scale in acute head injury for prediction of mortality and functional outcome. *Intensive Care Med* 1997;23:77–84.
20. Swets JA. Enhancing diagnostic decisions. In: Connolly T, Arkes HR, Hammond KR, eds. *Judgment and Decision Making: An Interdisciplinary Reader*, 2nd version (66–81). Cambridge: Cambridge Press, 2003.
21. Nouira S, Belghith M, Elatrous S, Jaafoura M, Ellouzi M, Boujdaria R, Gahbiche M, et al. Predictive value of severity scoring systems: comparison of four models in Tunisian adult intensive care units. *Crit Care Med* 1998;26:852–9.
22. Beck DH, Smith GB, Pappachan JV, Millar B. External validation of the SAPS II, APACHE II and APACHE III prognostic models in South England: a multicentre study. *Intensive Care Med* 2003;29:249–56.
23. Wheeler MM. APACHE: an evaluation. *Crit Care Nurs Q* 2009;32:46–8.
24. Zimmerman JE, Kramer AA. Outcome prediction in critical care: the Acute Physiology and Chronic Health Evaluation models. *Curr Opin Crit Care* 2008;14:491–7.
25. Elf K, Nilsson P, Enblad P. Outcome after traumatic brain injury improved by an organized secondary insult program and standardized neurointensive care. *Crit Care Med* 2002;30: 2129–34.