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Revised Acute Physiology and Chronic Health Evaluation score as a predictor of neurosurgery intensive care unit readmission: A case-controlled study

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Abstract

Purpose: Patients with neurologic system problems are among the most common patients readmitted to the intensive care unit (ICU). Readmission predictors for neurologic ICU patients have not been established. Previous research suggests that the Revised Acute Physiology and Chronic Health Evaluation (APACHE II) score is one indication of the critical status of ICU-admitted patients; however, the ability of the discharge APACHE II to predict readmission to the ICU requires further study. The purpose of this study was to investigate the ability of the APACHE II scoring system to predict ICU readmission of neurosurgical and ICU patients.

Materials and Methods: A retrospective case-controlled comparison study and a review of patient records for all patients admitted to 8 ICUs from January 2003 to June 2005 (N = 753) were conducted. Readmitted neurosurgery ICU patients were matched with 58 randomly selected nonreadmitted patients.

Results: Nine variables were significantly different between the readmission and case-controlled group. The APACHE II discharge score was the only significant predictor and was able to predict 18.6% of neurologic ICU readmissions. The risk of ICU readmission increased when the APACHE II score at the time of discharge exceeded 8.5 points.

Conclusions: The risk of ICU readmission of neurologic ICU patients can be predicted by determining APACHE II score upon ICU discharge.

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1. Introduction

Intensive care units (ICUs) account for approximately 5% to 10% of total hospital beds, but 20% to 34% of all acute care resources [1-2]. The high cost of caring for critically ill patients requires strategies to improve patient outcomes. Intensive care unit readmission is one indicator of quality care; mortality, cost, and length of stay (LOS) have been associated with ICU readmission rates [2-9]. Talbot and Hsueh [10] found that the medical cost of patients readmitted to the ICU was 2 times higher than those not readmitted. Intensive care unit readmission impacts the use of medical resources. The mortality rate of ICU-readmitted patients has been reported as 4 to 8 times higher than that of ICU patients not readmitted [11-13].

Unplanned ICU readmissions can be due to premature discharge from the ICU, worsening of the patient's disease, inappropriate level of care after transfer, or newly developed problems [2,9,13,14]. Eliminating unnecessary ICU stays can decrease the cost of hospitalization and the occurrence of ICU-related complications, but premature discharge from ICU can place patients in an inadequate care environment that results in readmission [15]. Reasons cited in the literature for ICU readmission include age, unstable vital signs, hypoxemia, fluid overload, increased P_{CO_2}, hematocrit less than 30%, and infection [2,11,12]. Respiratory, neurologic, and cardiovascular system problems [2,4,8-10,12,13] along with organ dysfunction are the bases for ICU readmission [2].

Intensive care unit readmission rates range from 5% to 12% [3,4,11,13]. Patients with neurologic diagnoses have readmission rates of 16% to 22%, with the rate showing signs of increasing [9,10,12]. Alban et al (2006) [9] found that the rate of ICU readmission of neurology patients had increased from 22% in 1996 to 27% in 2001; the reason for the increase is unknown. Talbot and Hsueh [15] investigated the frequency of surgical ICU readmissions and found that neurosurgical patients were ranked first and neurology patients were ranked third. However, the factors responsible for the readmission were not identified.

Since 1985, the Revised Acute Physiology and Chronic Health Evaluation (APACHE II) score has been frequently applied throughout the world to predict mortality. The APACHE II score includes 12 acute physiologic parameters, age, and chronic disease state. The APACHE II score is widely used in ICUs as a severity of illness index to predict patient outcomes, quality of care, and likelihood mortality within 24 hours [12,14,16]. The reliability of the APACHE II was established by Polderman and colleagues [17] in surgical ICU patients. Both intraobserver reliability and interobserver reliability were strong (0.84 and 0.83, respectively).

Research using the APACHE II has recorded APACHE scores within 24 to 48 hours of admission to ICU. Talbot and Hsueh (2001) suggested that an adequate APACHE score should be identified before discharge to avoid an ICU readmission. The growing neurosurgical and neurologic ICU readmission rate requires explanation. Therefore, the purpose of this study was to investigate the ability of APACHE II scoring system to predict ICU readmission of neurosurgical and ICU patients.

2. Materials and methods

A retrospective, case-controlled comparison study was conducted on patients who had been admitted to 1 of 8 ICUs (92 beds) in a medical center in southern Taiwan.

2.1. Setting and sample

After receiving approval from the hospital ethics committee, records of all patients with neurologic problems admitted to the ICU from January 2003 to July 2005 were reviewed. Patients with unrelated surgical procedures (eg, tracheotomy), brain tumor, or spinal diseases were excluded. Of the 753 neurologic ICU admissions, 58 (7.7%) patients were readmitted to the ICU. Fifty-eight patients not readmitted were randomly selected as case controls.

2.2. Procedures

The readmitted and case-control patient records were reviewed by 2 advanced-practice, master's-prepared nurses. In addition to collecting demographic information, admission APACHE II score, and ICU discharge vital signs, a discharge APACHE II score was calculated. Before data abstraction, 3 unselected patient records were chosen at random; and the discharge APACHE II score was independently calculated by each reviewer and compared. The calculated APACHE II discharge scores were identical.

2.3. Data analysis

After determining any group differences, significant independent variables were entered into a logistic regression to predict readmission. The odds ratio (OR) was calculated for significant variables with 95% conference interval (CI). Data analysis to compare case and control group means used SPSS version 16.0 (SPSS Inc, Chicago, Ill).

3. Results

3.1. Characteristics of the sample

The readmitted and case-control groups were similar on sex but not age (Table 1). The readmitted group was older and was more likely to have heart disease or end-stage renal disease (ESRD). Neurology patients were more likely to be readmitted than neurosurgical patients. Not unexpectedly, the readmission group had a higher mortality and greater hospital and initial ICU LOS.

Table 1 Characteristics of ICU-readmitted and nonreadmitted patients

	Readmitted (n = 58)	Nonreadmitted (n = 58)	*P*
Patient characteristics			
Age (y)	60.9 (19.4)	50.6 (16.9)	.003
Male, n (%)	42 (72.4)	37 (63.8)	.319
Chronic disease history	40 (69)	28 (48.3)	.024
Hypertension, n (%)	29 (50)	21 (36.2)	.134
Heart disease, n (%)	8 (13.8)	1 (1.7)	.032
COPD, n (%)	2 (3.4)	1 (1.7)	1.00
ESRD, n (%)	8 (13.8)	1 (1.7)	.032
Previous CVA, n (%)	6 (10.3)	11 (19.0)	.189
Diabetes, n (%)	15 (25.9)	10 (17.2)	.259
Vital signs on ICU discharge			
Temperature (°C)	37.0 (0.6)	36.8 (0.6)	.086
Heart rate (beats/min)	90.0 (19.9)	79.1 (16.3)	.002
Respiratory rate (times/min)	19.5 (5.5)	18.6 (4.9)	.328
Systolic blood pressure (mm Hg)	141.5 (23.7)	134.3 (20.2)	.083
Diastolic blood pressure (mm Hg)	72.9 (17.9)	73.5 (19.4)	.866
Required oxygen, n (%)	31 (53.4)	19 (32.8)	.024
APACHE II–initial admitted to ICU	15.0 (6.8)	10.1 (5.9)	<.001
APACHE II–discharge from ICU	12.1 (5.4)	7.3 (4.8)	<.001
GCS–initial admitted to ICU	10.3 (3.6)	11.4 (34)	.093
GCS–discharge from ICU	11.8 (2.8)	12.9 (2.4)	.029
Outcome variables			
ICU death upon readmission, n (%)	9 (15.5)	0	.003
Hospital LOS (d)	48.8 (29.8)	18.7 (11.8)	<.001
Initial ICU LOS (d)	7.6 (7.05)	5.2 (4.7)	.035

Values represent mean (SD), unless specified otherwise. COPD indicates chronic obstructive pulmonary disease. ESRD indicates end-stage renal disease. CVA indicates cerebro-vascular accident.

The reasons for readmission included respiratory problems or pneumonia (n = 25, or 43.1%); complications of hydrocephalus, seizures, or electrolyte imbalance (n = 12, or 20.7%); new hemorrhage (n = 10, or 17.2%); septic or wound infection (n = 5, or 8.6%); and other (n = 6, or 10.3%). Initial ICU admission and discharge APACHE II scores were significantly different between the groups. The ICU-readmitted patients had higher admission and discharge APACHE II scores. Discharge APACHE II scores were lower at discharge than at admission for both groups. There was no difference on the Glasgow Coma Score (GCS) between the groups on ICU admission; however, the readmission group had a significantly lower GCS upon initial ICU discharge, indicating poorer neurologic status. There was a significant difference ($P < .05$) between the initial and discharge scores for the 2 groups even if the difference was 1 point (GCS on readmission, 10.3 versus 11.8; nonreadmission, 11.4 versus 12.9).

3.2. Readmission predictors

In univariate analysis, a significant difference between the readmission and case-controlled group was found among 9 predictor variables. Three variables—age, heart rate, and chronic disease history—included in APACHE II score were not entered into the regression equation. Variables entered into the regression equation were APACHE II–initial admitted to ICU, APACHE II–discharge from ICU, disease history–heart disease, disease history–ESRD, required oxygen, GCS–initial admitted to ICU, and GCS–discharge from ICU. Table 2 showed the result from multiple logistic regression analysis. The score of APACHE II at discharge was the only significant predictor. The APACHE II discharge score was the only significant predictor and was able to predict 18.6% of neurologic ICU readmissions. A 1-point increase in the APACHE II discharge score was associated with a 21% increased probability of ICU readmission (OR, 1.21; 95% CI, 1.108-1.325; $P < .05$) according to the logistic regression model.

Receiver operating characteristic (ROC) analysis is used in biomedical research to examine the effectiveness of

Table 2 Multiple logistic regression analysis

Variables	OR	95% CI	*P*
Apache II–initial admitted to ICU	1.05	0.94-1.18	.372
Apache II–discharge from ICU	1.16	1.03-1.30	.013
Disease history–heart disease	7.57	0.82-69.85	.074
Disease history–ESRD	3.32	0.30-36.81	.328
Required oxygen	2.30	0.95-5.60	.067
GCS–initial admitted to ICU	1.00	0.82-1.21	1.000
GCS–discharge from ICU	1.07	0.86-1.34	.530

Table 3 APACHE II discharge cut score using YI

APACHE II score positive if ≥ [a]	Sensitivity	1 − Specificity	Sensitivity + (specificity − 1)
−1	1.000	1.000	0.000
0.5	1.000	0.948	0.052
1.5	1.000	0.914	0.086
2.5	0.983	0.793	0.190
3.5	0.966	0.741	0.224
4.5	0.966	0.672	0.293
5.5	0.931	0.552	0.379
6.5	0.845	0.517	0.328
7.5	0.810	0.448	0.362
8.5	0.793	0.414	0.379
9.5	0.655	0.362	0.293
10.5	0.586	0.293	0.293
11.5	0.448	0.155	0.293
12.5	0.379	0.121	0.259
13.5	0.345	0.121	0.224
14.5	0.276	0.103	0.172
15.5	0.224	0.069	0.155
16.5	0.190	0.034	0.155
17.5	0.172	0.034	0.138
19	0.121	0.000	0.121
21	0.069	0.000	0.069
22.5	0.052	0.000	0.052
26.5	0.017	0.000	0.017
31	0.000	0.000	0.000

[a] The smallest cutoff value is the minimum observed test value minus 1, and the largest cutoff value is the maximum observed test value plus 1. All the other cutoff values are the averages of 2 consecutive ordered observed test values.

biomarkers in distinguishing between 2 groups [19]. The ROC curve is a plot of the sensitivity versus 1 − specificity over all possible cutoff points of the marker. The greater the area under ROC curve is, the better is the scoring system. The Youden index (YI), a function of sensitivity and specificity (YI = max[sensitivity + {specificity − 1}]), provides a criterion for determining the optimal cutoff point. The index ranges between 0 and 1, with values close to 0 indicating the biomarker's limited effectiveness and values close to 1 indicating relatively large effectiveness [18,19].

The YI was calculated to determine the cutoff points for the APACHE II discharge score (Table 3). The higher the YI was, the better the readmission prediction was. At the time of patient discharge from ICU, an APACHE II cut score of 8.5 point was determined to have a sensitivity of 0.79 and a specificity of 0.59. The predicted readmission risk at an APACHE II score of 8.5 (Table 3) shows an area under the curve of 0.75 (95% CI, 0.66-0.833; P = .000; Fig. 1). The logistic regression model determined that the risk of readmission was 5.4 times higher if the APACHE II score was higher than 8.5 (95% CI, 2.386-12.362; P < .05).

4. Discussion

Similar to previous reports [9,11], neurologic patients readmitted to the ICU in this study were significantly older than those not readmitted. Residual organ dysfunction on the day of ICU discharge has been found to be a significant predictor of ICU readmission [2,11]. The findings indicate that the frequency of comorbid conditions, especially heart disease and ESRD, is higher among those readmitted to the ICU than the group of patients not readmitted. Researchers [4] have suggested that patients with heart disease or ESRD may require longer initial ICU stays to prevent ICU readmission and reduce mortality. The data from this study suggest that patients with neurologic problems combined with organ dysfunction, especially heart disease or ESRD, should be carefully evaluated before discharge from the ICU.

There were no significant sex differences between readmitted and not readmitted patients. This finding differs from the data of Chen et al [13], which concluded that the probability of ICU readmission was higher for men than for women. However, the men in the study of Chen et al were also older and had a higher illness severity than the women. The ICU readmission and the possible independent effects of sex require further study.

Respiratory problems, including pneumonia, were common reasons for readmission in this study. Previous studies have also indicated that these factors are common causes of death after discharge from intensive care [2,4,8-10,12-13].

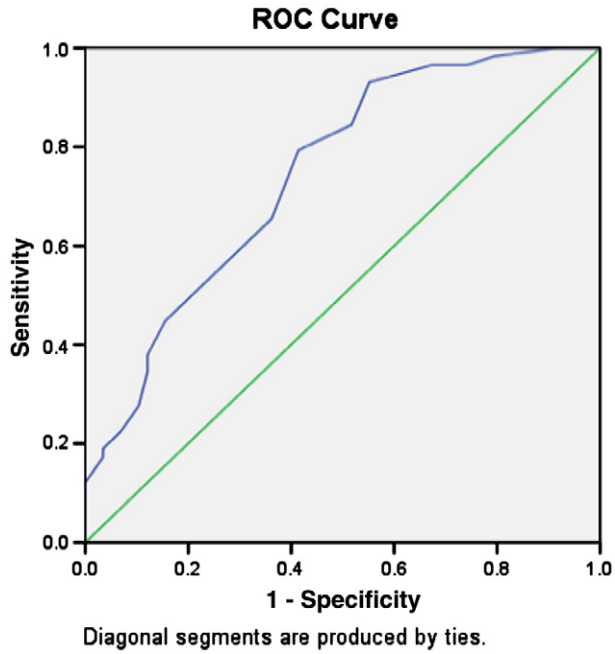

Fig. 1 Receiver operating characteristic curve of 116 ICU patients from January 1, 2003, to June 30, 2005. The area under the curve is 0.75 (95% CI, 0.66-0.833; P = .000).

Respiration system problems are important indicators for readmission, mortality, and medical cost [2,4,6,9]. Snow et al [4] suggested that care in a step-down unit may be necessary, as special attention must be paid to respiratory care for patients with neurologic problems discharged from ICU.

Interestingly, in the study of Alban et al [9], the readmission rate was lower (2.7%) than the rate in this study (7.7%), but the average APACHE II scores on admission and before discharge from ICU were higher. The patients in this study were transferred to a general ward. The availability of a step-down unit in the United States may be one reason for a lower readmission rate despite higher APACHE II scores.

Length of hospital stay, ICU stay, and mortality rate were significantly higher in the readmission group than the nonreadmission group. Chen et al [13] suggested that APACHE II scores at the time of discharge from ICU may be helpful in identifying patients in a medical ICU at high risk for post-ICU death. In the current study, the readmission group also had a higher mortality rate than did the nonreadmitted group as well as higher APACHE II scores at the time of ICU discharge. Regardless of the subjects' primary diagnosis, APACHE II scores at the time of discharge from ICU were significant higher in readmitted patients than nonreadmitted group. This finding seems to suggest that the condition of the readmission group was more severe than the nonreadmission group when they were discharged from ICU.

Two studies [9-10] have shown higher APACHE II scores at discharge for readmitted patients. An APACHE II cut point score has been suggested to guide clinical practice [10]. Talbot and Hsueh (2001) concluded that an acceptable low APACHE II score at ICU discharge should be identified. In this study, an APACHE II score of 8.5 or higher at discharge was a significant predictor of ICU readmission. This cut score of 8.5 may be a useful predictor for the neurosurgical and neurology patient population. Premature discharge from the ICU may expose patients to inadequate levels of care and place patients at risk of clinical deterioration and higher mortality [11]. The findings from this study suggest that (1) APACHE II scores should be routinely measured before ICU discharge for patients with neurologic diagnoses and (2) if patients' APACHE II score is 8.5 or higher, their discharge from the ICU need to be postponed. When necessary, a step-down unit may be an alternative to support respiratory care.

5. Conclusions

Intensive care unit readmission is an important indicator of quality and hospital costs. In patients admitted and discharged from the ICU for neurologic disorders, risk factors for readmission include age, admitting diagnosis, history of heart disease and ESRD, heart rate, oxygen requirements, GCS upon ICU discharge, and APACHE II score upon initial admission. The APACHE II score at the time of ICU discharge is a significant predictor of ICU readmission. By evaluating the patients' APACHE II score at the time of ICU discharge, readmission rates may decline and quality of care may be improved.

Further research is needed to evaluate the ability of the APACHE II scoring system to predict readmission of patients with cardiovascular and other major diagnoses. The role of additional risk factors to predict ICU readmission warrants additional investigation. The findings of this study cannot be generalized to facilities that transfer neurosurgical and neurologic ICU patients to intermediate care or step-down units. The impact of the nursing care provided by the nursing staff of these units may reduce ICU readmission risk.

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