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# SCORING SYSTEMS FOR PREDICTION OF MORTALITY IN PATIENTS WITH INTENSIVE CARE UNIT–ACQUIRED SEPSIS: A COMPARISON OF THE PITT BACTEREMIA SCORE AND THE ACUTE PHYSIOLOGY AND CHRONIC HEALTH EVALUATION II SCORING SYSTEMS

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ABSTRACT—This study compares the effectiveness of the Pitt bacteremia score, the Charlson weighted index of comorbidity, and the Acute Physiology and Chronic Health Evaluation II (APACHE II) scoring systems for the prediction of mortality in intensive care unit (ICU) patients with sepsis using the retrospective observational method on 134 patients with ICU-acquired sepsis. The statistical analyses show several important findings. First, Pitt bacteremia score is significantly correlated with the APACHE II scoring system (correlation coefficient = 0.738, $P < 0.001$). Second, the APACHE II scoring system, the Pitt bacteremia score, and the Charlson weighted index of comorbidity are independently correlated with mortality. Third, the Pitt bacteremia score and the APACHE II scores are positively related to mortality in patients with ICU-acquired sepsis. As the result of the analyses, the mortality rate in patients with sepsis in the ICU is better predicted with the Pitt bacteremia score because it provides better estimation of sensitivity and specificity than the APACHE II scoring system and the Charlson weighted index of comorbidity.

KEYWORDS—Pitt bacteremia score, Charlson weighted index of comorbidity, APACHE II scoring system, sepsis, mortality, intensive care unit

## INTRODUCTION

The Acute Physiology and Chronic Health Evaluation II (APACHE II) scoring system (Table 1) is an efficient index to determine the severity of sepsis in critically ill patients, to compare patient outcomes between centers, and more importantly, to predict clinical outcomes and guide physicians in the management of patients (1). However, it is difficult to clinically apply the system because of its requirement of numerous blood laboratory data and its complex calculation procedure. The Pitt bacteremia score is an alternative to the acute physiology score of the APACHE II scoring system, and the Charlson weighted index of comorbidity (3) is an alternative to the chronic health points used in the APACHE II system. Even though the Pitt bacteremia score is validated by a couple of studies on the severity of illness in bacteremia (2, 4, 5), the score has not been empirically compared with the APACHE II scoring system in the prediction of mortality. Even though many clinical institutions currently use the APACHE II variables to predict the outcomes of intensive care unit (ICU)–acquired sepsis, they often do not properly measure all the individual variables to estimate the APACHE II scores. Furthermore, as the APACHE II scoring system is based on numerous laboratory data including arterial blood gas analysis (ABGA) requiring invasive arterial puncture, this system is applied to retrospective studies only when laboratory data are available. The ideal system might use variables without laboratory data and simplify the prediction procedure of the severity of illness. Because the Pitt bacteremia score and the Charlson weighted index of comorbidity are simpler than the APACHE II scoring system and do not require laboratory data, they are good alternatives to APACHE II scoring system in estimating mortality in the ICU. The purpose of this study was to evaluate the Pitt bacteremia score and Charlson weighted index of comorbidity as the possible alternatives to the APACHE II scoring system, concerning the prediction of patient outcomes and the mortality rates of patients with ICU-acquired sepsis.

## MATERIALS AND METHODS

A retrospective review of medical records was conducted with the clinical data of Korean patients with ICU-acquired sepsis from January 2003 to December 2005. All the patients in the database acquired sepsis 48 h after being placed in the ICU. They are prospectively screened by infection control nurses based on the definition by the Centers for Disease Control. The definition of ICU-acquired sepsis is the sepsis with onset after 72 h of admission to ICU. For patients with multiple episodes of ICU-acquired sepsis, only first episode was included. For all patients, necessary information was collected to calculate the complete Pitt bacteremia score, the Charlson weighted index of comorbidity, and the chronic health point of APACHE II. Twenty-seven episodes were excluded because no ABGA data or bicarbonate data were available for calculating an APACHE II score. The end point of each datum is set at the time of death or discharge from the ICU.

### *Statistics*

Descriptive statistics are expressed as the mean ± SE. Student $t$ test is used to compare the means of the continuous variables with assured normality. Otherwise, the Mann-Whitney $U$ test is used. Categorical data are tested using chi-square analysis. Risk factors are assessed using univariate analysis. The

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TABLE 1. **Components of the APACHE II scoring system**

| Acute physiology score | High abnormal range | | | | | | Low abnormal range | | |
|---|---|---|---|---|---|---|---|---|---|
| Physiological variable | +4 | +3 | +2 | +1 | 0 | +1 | +2 | +3 | +4 |
| Temperature, °C | >41 | 39–40.9 | | 38.5–38.9 | 36–38.4 | 34–35.9 | 32–33.9 | 30–31.9 | <29.9 |
| MAP, mmHg | >160 | 130–159 | 110–129 | | 70–109 | | 50–69 | | <49 |
| Heart rate, beats per min | >180 | 140–179 | 110–139 | | 70–109 | | 55–69 | 40–54 | <39 |
| Respiratory rate, rpm | >50 | 35–49 | | 25–34 | 12–24 | 10–11 | 6–9 | | <5 |
| Oxygenation: $FiO_2$ >0.5, | >500 | 350–499 | 200–349 | | <200 | | | | |
| record $AaDO_2$; $FiO_2$ <0.50, | | | | | $PaO_2$ | $PaO_2$ | | $PaO_2$ | $PaO_2$ |
| record $PaO_2$ | | | | | >70 | 61–70 | | 55–60 | <55 |
| Arterial pH | >7.7 | 7.6–7.69 | | 7.5–7.59 | 7.33–7.49 | | 7.25–7.32 | 7.15–7.24 | <7.15 |
| Serum sodium, mmol/L | >180 | 160–179 | 155–159 | 150–154 | 130–149 | | 120–129 | 111–119 | <110 |
| Serum potassium, mmol/L | >7 | 6–6.9 | | 5.5–5.9 | 3.5–5.4 | 3–3.4 | 2.5–2.9 | | <2.5 |
| Serum creatinine level, mg/dL | >3.5 | 2–3.4 | 1.5–1.9 | | 0.6–1.4 | | <0.6 | | |
| Hematocrit, % | >60 | | 50–59.9 | 46–49.9 | 30–45.9 | | 20–29.9 | | <20 |
| WBC count, $10^3/\mu L$ | >40 | | 20–39.9 | 15–19.9 | 3–14.9 | | 1–2.9 | | <1 |
| Glasgow coma score: score = 15 - actual Glasgow coma score | | | | | | | | | |
| Serum $HCO_3$* | >52 | 41–51.9 | | 32–40.9 | 22–31.9 | | 18–21.9 | 15–17.9 | <15 |
| Age points | | | | | | | | | |
| Age, yrs | <44 | 45–54 | | 55–64 | | 65–74 | | >75 | |
| Score | 0 | 2 | | 3 | | 5 | | 6 | |

Acute Physiology Score: sum of the following 12 individual variable points.
rpm, rates per minute.
*Not preferred, use if no ABGAs.
From Knaus et al. (1).
Chronic Health Points:
1. Assigned if the patient has a history of severe organ system insufficiency or is immunocompromised.
2. For nonoperative or emergency postoperative patients, 5 points; and for elective postoperative patients, 2 points.
3. Organ insufficiency or an immunocompromised state must have been evident before hospital admission, and must conform to the following criteria:
Liver: biopsy-proven cirrhosis and documented portal hypertension, episodes of past upper gastrointestinal bleeding attributed to portal hypertension, or prior episodes of hepatic failure/encephalopathy/coma.
Cardiovascular: New York Heart Association Class IV (i.e., symptoms of angina or cardiac insufficiency at rest or during minimal exertion).
Respiratory: chronic restrictive, obstructive, or vascular disease resulting in severe exercise restriction, that is, unable to climb stairs or perform household duties, or documented chronic hypoxia, hypercapnia, secondary polycythemia, severe pulmonary hypertension (>40 mmHg), or dependency on a respirator.
Renal: receiving chronic dialysis.
Immunocompromised: the patient has received therapy that suppresses resistance to infection, for example, immunosuppression, chemotherapy, radiation, long-term or recent high-dose steroids, or has a disease that is sufficiently advanced to suppression of resistance to infection, for example, leukemia lymphoma, acquired immunodeficiency syndrome.

variables in which the statistical significances ($P < 0.05$) are found through univariate analyses are included in multivariate analysis. The correlation of paired variables within groups is assessed using the linear regression analysis and Pearson analysis.

Discrimination (i.e., ability of a model to distinguish between dead and surviving patients) is tested using the area under a receiver operating characteristic (ROC) curve. When the performance of a model resembles that of coin flipping, the area under the ROC curve approaches 0.5, but as the area approaches 1.0, the model approaches 100% sensitivity and specificity regardless of the cutoff point (6). Another ROC analysis is performed to calculate the cutoff values, sensitivity, specificity, overall correctness, positive predictive value (PPV), and negative predictive value (NPV) for the prediction of hospital mortality. The best cutoff point is determined when the point yielded the best specificity and sensitivity in the ROC analysis. Moreover, the best Youden index (sensitivity + specificity - 1) is also used to determine the best cutoff point (7). The Youden index is used to compare the proportions of cases that are correctly classified. A high Youden index indicates an accurate prediction. Spearman rank correlations are measured to compare the scores of each evaluation system with sepsis-related mortality. All statistical tests are two-tailed. A value of $P < 0.05$ indicated statistical significance. SPSS 11.0 for Windows 2000 (SPSS Inc, Chicago, Ill) is used for the analyses. MedCalc version 9.2 via the Internet is used for the ROC analyses of the scoring systems to access the statistical discrimination in terms of the prediction of mortality.

## RESULTS

One hundred sixty-one episodes (134 patients) of ICU-acquired sepsis were recorded in total. Twenty-seven episodes were excluded because their ABGA data were unavailable for the calculation of an APACHE II score. The median age of the 134 patients was 61 years, ranging from 16 to 88 years. The male-to-female ratio was 2.12 (91:43). The median duration of the follow-up was 22 days. Eighty-four of the patients (62.7%)

Table 2. **Correlation coefficients between the scoring systems**

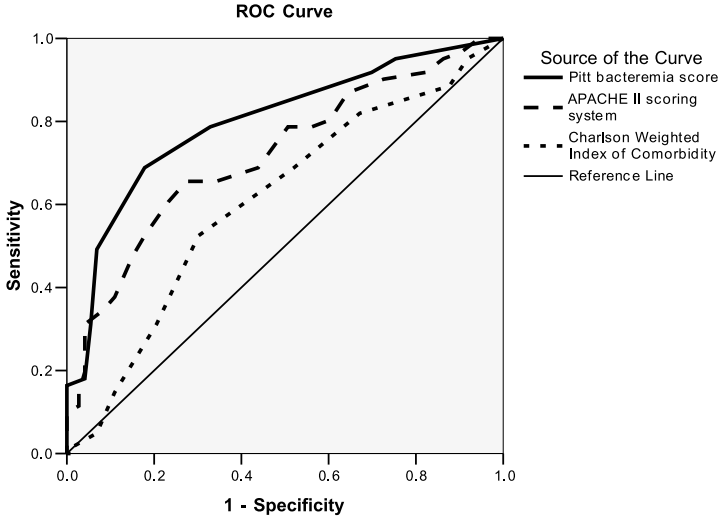
| | Acute physiology score of APACHE II scoring system | Chronic health points of APACHE II scoring system | APACHE II score | Pitt bacteremia score | Charlson weighted index of comorbidity |
|---|---|---|---|---|---|
| Acute physiology score of APACHE II scoring system | 1.000 (−) | | | | |
| Chronic health points of APACHE II scoring system | 0.106 (0.221) | 1.000 (−) | | | |
| APACHE II score | 0.920 (<0.001) | 0.356 (<0.001) | 1.000 (−) | | |
| Pitt bacteremia score | 0.709 (<0.001) | 0.325 (<0.001) | 0.738 (<0.001) | 1.000 (−) | |
| Charlson weighted index of comorbidity | 0.094 (0.280) | 0.240 (0.005) | 0.149 (0.086) | 0.073 (0.400) | 1.000 (−) |

Data are expressed as the correlation coefficient (*P* value) between each scoring system.
Correlation is significant at the 0.01 level (two-tailed).

were in the medical ICU, and 50 patients were in the surgical ICU. Thirty-two patients died of ICU-acquired sepsis. Sixty-one patients (45.5%) who have experienced ICU-acquired sepsis died.

The Spearman correlation coefficient between the acute physiology score of the APACHE II scoring system and the Pitt bacteremia score was 0.709 ($P < 0.001$). The Spearman correlation coefficient between the chronic health point of the APACHE II system and the Charlson weighted index of comorbidity was 0.240 ($P = 0.005$). The Pitt bacteremia score was significantly correlated with the APACHE II scoring system (correlation coefficient, 0.738; $P < 0.001$; Table 2).

The model ROC curve displayed the true-positive and false-positive rates on the vertical and horizontal axes, respectively. In mortality prediction, the area under the ROC curve of the Pitt bacteremia score (area, 0.799 ± 0.039; 95% confidence interval, 0.722–0.876) was not different from area under the ROC curve of the APACHE II system (area, 0.720 ± 0.045; 95% confidence interval, 0.632–0.807). But the area under the ROC curve of the Pitt bacteremia score was larger than the

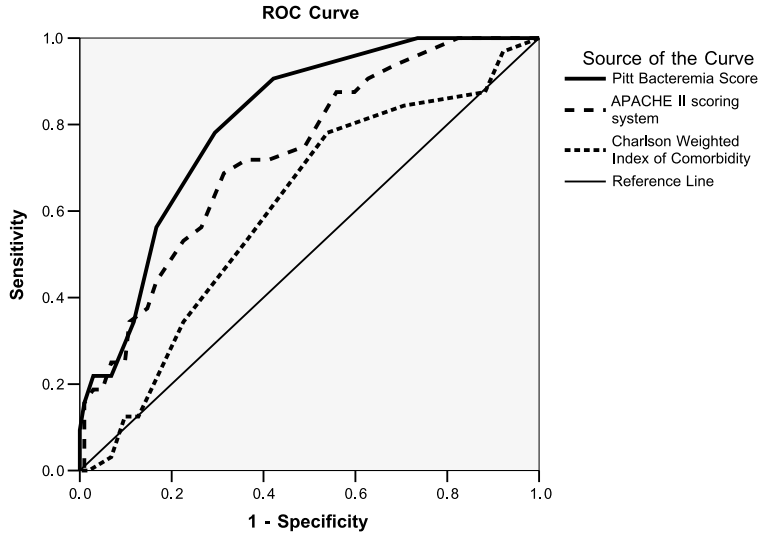



Diagonal segments are produced by ties.

**Area Under the Curve**

| Test Result Variable(s) | Area | Standard Error(a) | Asymptotic Sig.(b) | Asymptotic 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Pitt bacteremia score | 0.799 | 0.039 | 0.000 | 0.722 | 0.876 |
| APACHE II scoring system | 0.720 | 0.045 | 0.000 | 0.632 | 0.807 |
| Charlson weighted index of comorbidity | 0.608 | 0.049 | 0.032 | 0.511 | 0.704 |

Fig. 1. **The ROC plot of mortality predictions by all causes of death using the organ failure system**. The area under the ROC curve of the Pitt bacteremia score achieved equivalent result with area under the ROC curve of the APACHE II system. The area under the ROC curve of the Pitt bacteremia score was larger than the area under the ROC curve of Charlson weighted index of comorbidity.




Diagonal segments are produced by ties.

**Area Under the Curve**

| Test Result Variable(s) | Area | Standard Error(a) | Asymptotic Sig.(b) | Asymptotic 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Pitt bacteremia score | 0.806 | 0.039 | 0.000 | 0.729 | 0.883 |
| APACHE II scoring system | 0.731 | 0.048 | 0.000 | 0.637 | 0.826 |
| Charlson weighted index of comorbidity | 0.606 | 0.056 | 0.071 | 0.497 | 0.715 |

FIG. 2. **The ROC plot of predictions of mortality by sepsis using the organ failure systems**. The ROC curve of the Pitt bacteremia score showed a greater value in sepsis-related morality than in crude mortality.

area under the ROC curve of Charlson weighted index of comorbidity (area, 0.608 ± 0.049; 95% confidence interval, 0.511–0.704; Fig. 1). In addition, the ROC curve of the Pitt bacteremia score showed a greater value in sepsis-related morality than in crude mortality (area, 0.806 vs. area, 0.799; Fig. 2). However, no statistically significant difference was detected between the Pitt bacteremia score and the APACHE II scoring system when comparing the prediction of mortality ($P = 0.058$).

The sensitivity, specificity, PPV, and NPV of selected cutoff points for predicting hospital mortality, determined by the ROC analyses, were summarized in Table 3. Hospital mortality rates were significantly different ($P < 0.001$) between the patients with scores equal to or higher than the selected cutoff and the patients with scores lower than the selected cutoff: 4 points for the Pitt bacteremia score, 21 points for the APACHE II scoring system, and 5 points for the Charlson weighted index of comorbidity (Fig. 3).

TABLE 3. **Sensitivity and specificity of the scoring systems to predict mortality by using ROC**

| Scoring system | Cutoff value | Sensitivity, % | Specificity, % | PPV, % | NPV, % |
|---|---|---|---|---|---|
| APACHE II scoring system | 21 | 67.2 | 74.1 | 68.8 | 74.7 |
| Pitt bacteremia score | 4 | 68.9 | 82.1 | 76.3 | 75.9 |
| Charlson weighted index of comorbidity | 5 | 54.1 | 72.1 | 59.3 | 63.8 |

Regression analysis was performed to calculate the predicted mortality using the Pitt bacteremia score (Fig. 4). The regression coefficient of this variable was used to calculate a likelihood of death for each patient as:

The predicted mortality rate (%) = (0.123 + Pitt bacteremia score × 0.101) × 100.

## DISCUSSION

The overall mortality in this study was 45.5%, and the sepsis-related mortality was 23.9%. In patients with ICU-acquired sepsis, the data indicate that the Pitt bacteremia score and

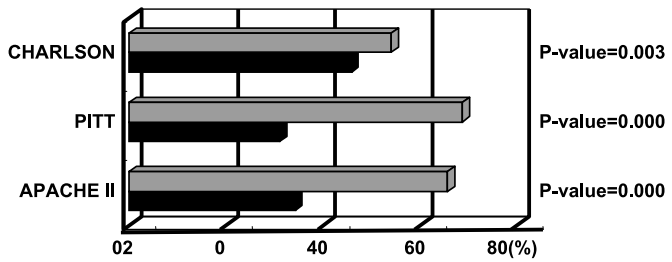



FIG. 3. **Mortality rates at the cutoff point giving the best Youden index for the Charlson weighted index of comorbidity, Pitt bacteremia score, and APACHE II**. Hospital mortality rates were significantly different ($P < 0.05$) between the patients with scores equal to or higher than the selected cutoff and the patients with scores lower than the selected cutoff: 4 points for the Pitt bacteremia score, 21 points for the APACHE II scoring system, and 5 points for the Charlson weighted index of comorbidity.

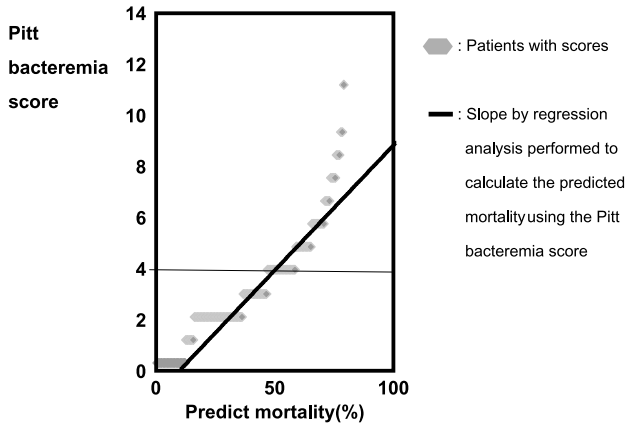



FIG. 4. **Predictive mortality (%) using the Pitt bacteremia score.**

APACHE II score were correlated with each other, and both were effective prognostic indices to predict mortality. The variables included in the APACHE II system have been widely used to have prognostic implications in critically ill patients, but it requires the use of blood laboratory data and very complicated calculation procedures. Furthermore, the APACHE II system is difficult to use in retrospective studies because of missing laboratory data. Even though the Charlson weighted index of comorbidity is a good predictor of mortality in studies of *Staphylococcus aureus* bacteremia and suspected infection (2, 8), the Charlson weighted index of comorbidity and the chronic health points of the APACHE II system are not found to be very effective predictors of mortality in this study. An ideal prognostic predictor would contain variables that could be calculated without laboratory data, and should predict patient severity in an easy and simple manner. In this regard, the Pitt bacteremia score, using an easy and simple method, is an ideal system to predict the mortality of patients with ICU-acquired sepsis. The data suggest that the Pitt bacteremia score could replace the APACHE II system for the prediction of mortality. Furthermore, the predicted mortality rate (%) in the patients with ICU-acquired sepsis is calculated using the equation based on the Pitt bacteremia score. According to that equation, if the Pitt bacteremia score is higher than 9, the patient is not likely to survive.

This study attempts to validate the Pitt bacteremia score by comparing it with the APACHE II system. The analytical results indicate a significant ($P < 0.05$) linear correlation between paired Pitt bacteremia scores and APACHE II scores. The overall predictive accuracy (PPV) of the Pitt bacteremia score was 8% greater than that of the APACHE II scores (Table 5). The results of this investigation suggest that the Pitt bacteremia score is an excellent tool for assessing not only crude mortality, but also mortality that is attributed to sepsis in ICU-admitted patients (Figs. 1 and 2). The Pitt bacteremia score ignores diagnosis, age, laboratory data, and conditions of comorbidity. The Pitt bacteremia score probably reflects the unique characteristics of the patient group, whose prognosis could be predicted without considering age and diagnosis. The regression analysis for mortality suggests that variables in the APACHE II scoring system, including factors in chronic health points (nonoperative or emergency postoperative patients, episodes of past upper gastrointestinal bleeding caused by portal hypertension), age, and blood laboratory data (white blood cell count, serum potassium), are not significant risk factors for mortality. However, all variables included in the Pitt bacteremia score are meaningful risk factors for mortality. This finding leads the Pitt bacteremia score to have better sensitivity and specificity than the APACHE II scoring system.

Despite the encouraging results of this study, several limitations should be noted. First, this investigation involves only 134 patients and is conducted in a single center, so the results may not be directly extrapolated to other patient populations. Second, this analysis is performed retrospectively, which may cause statistical biases. As a matter of fact, 27 (16.7%) of 161 episodes are excluded because of missing laboratory data. However, ICU-acquired sepsis is screened prospectively, and the patients are enrolled over time. Therefore, the probability of missing patients is quite low.

In conclusion, the data demonstrate that the Pitt bacteremia score and APACHE II scoring system have good discriminatory powers for predicting mortality in patients with ICU-acquired sepsis. Moreover, the relationship between the Pitt bacteremia score and the APACHE II scores for patients is linear, and is significantly correlated in all subgroups. The Pitt bacteremia score is found to be an efficient alternative method to simply and easily predict mortality in patients with ICU-acquired sepsis. The Pitt bacteremia score as a predictor of mortality should be further validated in large prospective studies.

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