SCORING SYSTEMS FOR PREDICTING OUTCOMES OF CRITICALLY ILL PATIENTS IN NORTHEASTERN THAILAND

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Abstract. The Acute Physiology and Chronic Health Evaluation System (APACHE) III, the APACHE II, the Simplified Acute Physiology Score (SAPS), and the Therapeutic Intervention Scoring System (TISS), calculated within the first 24 hours of admission, were compared in 209 critically ill patients admitted to the regional hospital in northeastern Thailand. Eighty-five (40.7%) patients subsequently died. The nonsurvivors had significantly higher APACHE III, APACHE II, SAPS, and TISS scores than the survivors. ROC curves drawn for each severity index were in a discriminating position. There were no significant differences either among the areas under the ROC curves drawn for APACHE III, APACHE II, SAPS, and TISS, or among the overall accuracies of these indices. All four scoring system correlated well with the short-term prognosis, *ie* the mortality outcome, of critically ill patients. APACHE III, APACHE II, SAPS, and TISS appeared to be comparable predictors of severity of critical illness. Selection of a severity indicator will depend on the resources available.

INTRODUCTION

Assessment of patient's outcome as an index of the quality of care has become commonplace (Knaus and Nash, 1988). Many investigators have compared mortality among hospitals and have considered relative mortality as a surrogate indicator for the quality of care rendered by a hospital (Dubois and Brook, 1988). Various prognostic scoring systems have been proposed to fulfill this role (Sirio and Knaus, 1990). A widely reported system is the modified Acute Physiology and Chronic Health Evaluation System (APACHE II), the Simplified Acute Physiology Score (SAPS), and the Therapeutic Intervention Scoring System (TISS). Recently APACHE III was also developed (Knaus *et al*, 1991). To our knowledge, the use of APACHE III, and comparison of APACHE III, APACHE II, SAPS, and TISS in Asian institutions have not been reported. This study was performed to determine the validity of the APACHE III, APACHE II, SAPS, and TISS in a regional hospital in northeastern Thailand and to compare those scores in assessment of the prognosis in the critically ill patients.

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MATERIAL AND METHODS

Study area and patients

All critically ill patients who were admitted to medical and surgical intensive care units (ICUs) at Maharat Hospital from November 15, 1993 to January 7, 1994 were entered to the study. Maharat Hospital at Nakhon Ratchasima is a referral center and teaching hospital with 1,005 beds and two specialized ICUs (medical and surgical).

The indications of critical illness were a basis for monitoring or failure of one or more of the seven major organ systems (Knaus *et al*, 1982), *ie* gastrointestinal, cardiovascular, respiratory, renal, metabolic, neurologic, and hematologic. Patients excluded from the study were children < 15 years of age. Those patients who died within 24 hours of admission; those persons whose the scores could not be derived because of an incomplete set of physiologic variables were also excluded from the study.

APACHE III, APACHE II, SAPS, and TISS were calculated at the end of the first 24 hours of ICU admission. The patients were followed up when they were discharged from the ICUs until death or discharge from the hospital.

Mortality prediction scores

APACHE III was calculated from 16 physiologic measurements: body temperature, heart rate, respiratory rate, blood pressure, hematocrit (Hct), white blood cell (WBC) count, serum sodium, albumin, bilirubin, glucose, blood urea nitrogen (BUN), creatinine, urine output, PaO_2, $pH/PaCO_2$ (combined in a single acid/base variable; PaO_2 = partial arterial oxygenation, $PaCO_2$ = partial arterial carbon dioxide concentration) and the Glasgow coma scale. The chronic health component consisted of six questions regarding the presence or absence of acquired immune deficiency syndrome (AIDS), hematologic malignancies, metastatic cancer, immune suppression, hepatic failure and cirrhosis (Knaus *et al,* 1991).

APACHE II was obtained from 12 physiologic measurements. In addition, APACHE II took into account age and chronic health status among the following other variables: mean arterial pressure, spontaneous respiratory rate, oxygenation (fractional inspired oxygenation (FiO_2) > 0.5 record alveoloarterial oxygenation pressure difference or FiO_2, > 0.5 record PaO_2), arterial pH (pH_a), serum sodium, potassium, and creatinine, Hct, WBC count, body temperature, heart rate, and Glasgow coma scale (Knaus *et al,* 1985).

SAPS was obtained from 14 physiologic measurements: heart rate; systolic blood pressure; body temperature; mechanical ventilation, or continuous positive airway pressure; urine output; BUN; Hct; WBC count; serum sodium; serum potassium; serum glucose; serum bicarbonate; Glasgow coma scale; and the age of the patient (Le Gall, 1984).

TISS assigned a score of 1 to 4 for 73 therapies commonly recieved by critically ill patients. Total TISS points provided a measure of intensive care resources utilization and of type and amount of intensive care as previously described (Cullen *et al,* 1974).

Statistical analysis

Sensitivity (Se), specificity (Sp), and accuracy (Ac) were calculated for each severity index. Se is the proportion of the true positives, *ie* the ratio of the correctly predicted number of nonsurvivors to the number of survivors. Sp is the proportion of the true negatives, *ie* the ratio of the correctly predicted number of survivors to the number of survivors. Ac is the total correct classification rate, *ie* the ratio of the correctly predicted number of nonsurvivors and of survivors to the number of nonsurvivors and survivors. Se, Sp, and Ac were calculated at the cutoff point giving the best Youden index (Youden, 1950). A Receiver Operation Characteristic (ROC) curve was drawn for each severity index (Hanley and McNeil, 1983). An ROC curve depicts the relationship between the proportion of true-positives, *ie* Se, and the proportion of false-positives (which is equal to 1-Sp). The area under the ROC curve is a measurement of the overall discriminatory power of the prognostic variable, with a value of 0.5 indicating that the variable performs no better than chance and a value of 1.0 indicating perfect discrimination.

Results are expressed as mean ± SD. Discrete variables were tested against the chi-square distribution, using Yates correction when appropriate. Observed mortality rates were calculated within each index interval of growing values. Comparisons between these mortality rates observed for each severity index were made by means of the chi-square test for trend. The Student's *t* for unpaired data was used. The differences between Ac obtained with each severity index were studied by means of the McNemar's test. Areas under the ROC curves were measured by means of the Wilcoxon statistic and the SE of the area was calculated as described by Hanley and McNeil (1982). Comparisons between area under the curves were based on the calculation of a critical ratio, "z" (Hanley and McNeil, 1983). Correlations were assessed by means of Pearson's coefficient. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographic data

During the period studied, 209 patients fulfilled the inclusion criteria as critically ill cases. Table 1 shows the characteristic of the patients. Most of them (56%) were referral cases. The mortality rate of

Table 1

Demographic features of the patients.

	Survivors (n = 124)	Nonsurvivors (n = 85)	Total (n = 209)
Age (years)	55.2 ± 16.5	55.6 ± 18.8	55.36 ± 17.44
Male/female ratio	63/61	49/36	112/97
Hospital ward:			
Medical ICU	2 (1.6%)	4 (4.7%)	6 (2.9%)
Surgical ICU	48 (38.7%)	21 (24.7%)	69 (33%)
Medical non-ICU	74 (59.7%)	60 (70.6%)	134 (64.1%)
No. of referral cases	65 (52.4%)	51 (60%)	116 (55.5%)
Prior treatment location:			
Emergency room	38 (30.6%)	21 (24.7%)	59 (28.2%)
OPD	3 (2.4%)	1 (1.2%)	4 (1.9%)
Operating room	43 (34.7%)	21 (24.7%)	64 (30.6%)
Other hospital	34 (27.5%)	37 (43.5%)	71 (34%)
Ward floor	6 (4.8%)	5 (5.9%)	11 (5.3%)
Hospital stay (days)	12.2 ± 8.9	8.4 ± 6.5	10.7 ± 7.9

ICU = intensive care unit; OPD = out-patient department

referral cases was not significantly different from non-referral cases.

Main diagnostic categories of the patients are shown in Table 2. The most frequent diagnoses were shock (n = 46; 22%), emergency operative cases (n = 44; 21.1%), and cardiovascular diseases (n = 41; 19.6%). The highest mortality was found in sepsis (n = 21; 24.7% of fatal patients). Most of nonsurvivors had associated underlying diseases: 3 with cirrhosis, 2 with chronic renal failure, 3 with diabetes mellitus, 3 with cardiovascular accident (CVA), 1 with carcinoma, and 1 with chronic obstructive pulmonary disease (COPD).

Table 2

Main diagnostic categories of the patients (n = 209).

Diagnostic category of admissions	No. (%)
Shock	46 (22)
Cardiovascular diseases	41 (19.6)
Respiratory diseases	27 (12.9)
Gastrointestinal diseases	17 (8.1)
Neurologic diseases	4 (1.9)
Nephrologic diseases	2 (1)
Poisoning	8 (3.8)
Postoperative patients	64 (30.6)

The age of the patients ranged from 16 to 93 years. The mean ± SD ages between survivors and nonsurvivors were not significant different (Table 1). The mean duration of hospital stay was significantly longer for survivors than nonsurvivors. The highest mortality rate (43.5%) was found in those who were transfered from other hospitals; nonsurvivors from emergency room and operating room had higher APACHE III, APACHE II, SAPS, and TISS scores than survivors ($p < 0.01$).

Regarding to presenting diagnoses, septic shock and post-operation for APACHE III, organophosphate poisoning and emergency operation for APACHE II, septic shock and emergency operation for TISS showed significantly higher scores in nonsurvivors than in survivors; while SAPS did not differ significantly between survivors and nonsurvivors in all presenting diagnoses.

APACHE III, APACHE II, SAPS, and TISS values according to hospital mortality are shown in Table 3. Nonsurvivors had significantly higher APACHE III, APACHE II, SAPS, and TISS scores than survivors.

Table 3

Values of APACHE III, APACHE II, SAPS, and TISS in the patients (mean ± SD).

	Survivors (n = 124)	Nonsurvivors (n = 85)	All patients (n = 209)
APACHE III	46.52 ± 22.13	70.57 ± 28.84	55.57 ± 27.92
APACHE II	14.01 ± 6.32	20.01 ± 7.55	16.48 ± 7.44
SAPS	10.65 ± 4.65	14.86 ± 4.47	12.83 ± 5.00
TISS	15.63 ± 7.03	20.99 ± 5.69	17.84 ± 6.99

Table 4

Sensitivity, specificity, and accuracy calculated for APACHE III, APACHE II, SAPS, and TISS in the patients (means ± SD).

	APACHE III	APACHE II	SAPS	TISS
Cutoff point[a]	60	19	14	20
Se	79.8	77.4	74.2	74.2
Sp	65.9	61.1	60.0	60.0
Ac[b]	74.2	70.8	68.4	68.4

[a]Giving the best Youden index.
[b]There was no significant difference between the accuracies.

Se, Sp, and Ac values obtained with each severity index are shown in Table 4. There was no significant difference between the Acs obtained with APACHE III, APACHE II, SAPS, and TISS.

ROC curves of each severity index are shown in Fig 1. The area under the curve was equal to 0.694 ± 0.053 for APACHE III, 0.723 ± 0.039 for APACHE II, 0.71 ± 0.078 for SAPS, and 0.70 ± 0.036 for TISS. The area under the curve for each score was not significantly different from that of the other scores ($z > 0.05$). Observed mortality rates calculated within index of intervals of growing values are shown in Table 5 (APACHE III), Table 6 (APACHE II), Table 7 (SAPS), and Table 8 (TISS). There were significant differences between the mortality rates observed when APACHE III, APACHE II, SAPS, and TISS increased (chi-square = 47.90, 32.83, 30.38, and 27.11 respectively, $p < 0.001$). APACHE III was significantly correlated with APACHE II ($r = 0.85$, $p < 0.001$), SAPS ($r = 0.73$, $p < 0.001$), and TISS ($r = 0.37$, $p = 0.001$). APACHE II was significantly correlated with SAPS

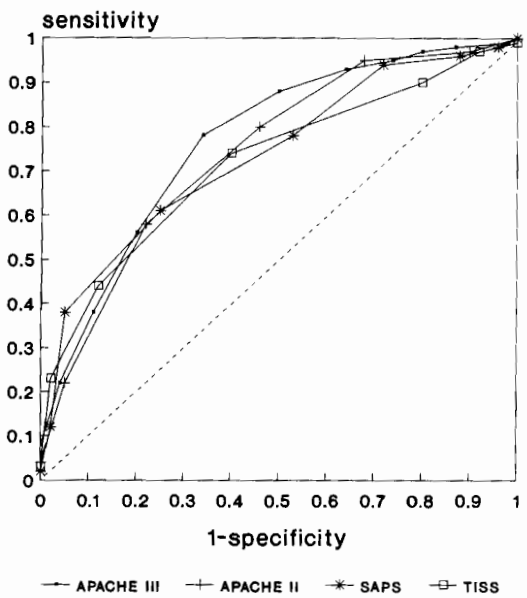

Fig 1–ROC curves for APACHE III, APACHE II, SAPS, and TISS. The curves are above the dash-line drawn by chance (sensitivity = 1-specificity). There were no differences between the areas under the curves for all four scores (see Results).

Table 5

Relationship between APACHE III and observed mortality rates in the patients.

APACHE III	No. patients	Observed mortality rates[a]
1 - 25	22	0.045[b]
26 - 50	76	0.237
51 - 75	65	0.462
76 - 100	28	0.750
> 100	18	0.833

[a]Proportions of the number of patients who died to the total number of patients within each index interval.
[b]Difference between the observed mortality rates is significant (see Results).

Table 6

Relationship between APACHE II and observed mortality rates in the patients.

APACHE II	No. patients	Observed mortality rates[a]
1 - 10	49	0.122[b]
11 - 20	99	0.374
21 - 30	54	0.685
> 30	8	0.625

[a]Proportions of the number of patients who died to the total number of patients within each index interval.
[b]Difference between the observed mortality rates is significant (see Results).

Table 7

Relationship between SAPS and observed mortality rates in the patients.

SAPS	No. patients	Observed mortality rates[a]
1 - 8	52	0.096[b]
9 - 16	117	0.453
17 - 22	34	0.676
> 22	6	0.667

[a]Proportions of the number of patients who died to the total number of patients within each index interval.
[b]Difference between the observed mortality rates is significant (see Results).

($r = 0.81$, $p < 0.001$), and TISS ($r = 0.38$, $p < 0.001$). SAPS was also significantly correlated with TISS ($r = 0.45$, $p < 0.001$).

DISCUSSION

Nakhon Ratchasima is the largest province in northeastern Thailand in terms of population size. The province has a population of 2.23 million, including many small villages. The people in this area are poor, rural, subsistence-farmers. Most of them live in extended families, often without running water or adequate facilities for disposal of sewage. Maharat Hospital is a teaching hospital in Nakhon Ratchasima

Table 8

Relationship between TISS and observed mortality rates in the patients.

TISS	No. patients	Observed mortality rates[a]
1 - 10	36	0.056[b]
11 - 20	101	0.386
21 - 30	63	0.619
> 30	9	0.556

[a]Proportions of the number of patients who died to the total number of patients within each index interval.
[b]Difference between the observed mortality rates is significant (see Results).

and serves patients from northeastern Thailand. The hospital is also a referral center, thus it is not surprising to see more severe cases in this hospital. The overall mortality rate in this study (40.7%) was higher than in United States, New Zealand, France, Saudi Arabia and Hong Kong which ranged from 8.9% to 38.3% (Knaus *et al,* 1986; Zimmerman *et al,* 1988; French multicenter group of ICU research, 1989; Chang *et al,* 1988; Oh *et al,* 1993). The higher mortality rate in this study may be due to the well established clinical deterioration of the patients' conditions, late referral for further management from other hospitals, high sepsis rate, the large number of accident cases in that area, inadequate availability of physicians and nurses for proper care.

Location of the patients to intensive care treatment was the important factors on outcome prediction. Knaus *et al* (1991) demonstrated that among non-operative patients, those who are ICU readmissions, transferred from other units, and admitted from the hospital wards had marginally increased risks of death relative to patients admitted directly from the emergency room. Our study showed that the patients admitted from other hospitals and from the emergency room carried significantly higher mortality. Le Gall *et al,* (1984) reported that age was an important factor for survival. On the contrary, our study showed that there was no significant difference in age between survivors and nonsurvivors.

Individually, APACHE III, APACHE II, SAPS, and TISS described accurately the severity of critical illness. Their respective values were higher in nonsurvivors than in survivors. The Se, Sp, and overall Ac obtained with these indices were those expected for a good severity index (Le Gall *et al,* 1984), and their respective ROC curves were in a discriminating position. In addition, the information provided by APACHE III, APACHE II, SAPS, and TISS was comparable. There were no significant differences between the overall accuracies and the areas measured under the ROC curves. Thus, all four scoring systems appeared to be prognostic indicators which accurately reflected the short-term prognosis of the critically ill patients. However, APACHE III, APACHE II, and SAPS are simpler and less time-consuming method than TISS as they require fewer parameters to culculate the scores.

The observed mortality rate rose significantly when the score values increased (Tables 5 to 8). The increased scores of APACHE II, SAPS, and TISS were significantly associated with the increased risk of death in previous reports (Knaus *et al,* 1985; Le Gall, 1984) because higher scores indicated more severe illness. Our study also confirmed this finding. Apart from the previous 3 scores, we also found that nonsurvivors had significantly higher APACHE III scores than survivors. Oh *et al* (1993) reported that survivors has a shorter stay in ICU than nonsurvivors, however Zimmerman *et al* (1988) reported that survivors had a longer length of ICU stay. Similar to the latter report, the present study shows that survivors stayed longer in ICU than nonsurvivors. This may be due to the critically severe illness of nonsurvivors.

Although our findings revealed a rather high mortality rate (40.7%) of the critically ill patients, the fatal outcome of the patients with high scores might be reduced if ward resussitation had been performed better, or if the patients were transfered earlier to ICU before clinical deterioration. More appropriate referral of the patients to ICU and adequate number of ICU beds might also reduce the fatal outcome (Oh *et al,* 1993).

In conclusion, we have shown the APACHE III, APACHE II, SAPS, and TISS to be the comparably accurate predictors of group outcome in critically ill patients in northeastern Thailand. The scores are applicable in health systems and ethnic groups other than those groups previously studied. Selection of a severity indicator will depend on the resources available. However, the predictive scores are insufficiently accurate to predict individual patient's outcome but may contribute to clinical decision making for a clinician who is handling the patient. A more effective provision of intensive care services can be achieved with more ICU beds.

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