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ORIGINAL RESEARCH

Daily Improvement in APACHE II Score (APACHE/m) and Outcomes in ICU Trauma Patients

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Background: The Acute Physiology and Chronic Health Evaluation II (APACHE II) is a widely used intensive care unit (ICU) severity score; however, it provides only an admission snapshot. Therefore, we introduced a novel metric, APACHE/m (average daily decrease in APACHE II score during ICU stay), to examine whether faster physiological improvement was correlated with better outcomes in ICU trauma patients.

Methods: This retrospective cohort study was conducted at a level I trauma center. Participants comprised 1784 adult trauma patients admitted to the ICU (2016–2023) who survived ICU discharge were included in this study. The APACHE II scores at ICU admission and discharge were recorded. APACHE/m was calculated as the decrease in APACHE II divided by the length of stay in the ICU. We analyzed the ability of APACHE/m to predict post-ICU in-hospital mortality and compared outcomes between the high and low APACHE/m groups. Propensity score matching (1:1) was used to adjust for initial injury severity and comorbidities.

Results: Hospital mortality after ICU discharge was 2.3% (41/1784). APACHE/m alone showed poor discrimination for mortality (AUC = 0.57). In the unmatched cohort, mortality was 2.6% in high APACHE/m patients (>1.03 points/day) vs 2.0% in low APACHE/m patients (≤1.03), P = 0.523. After matching (199 pairs), high APACHE/m patients had longer hospital stays (median, 14 vs 12 days, P = 0.005) and higher mortality (3.5% vs 0%, P = 0.022) than matched low APACHE/m patients.

Conclusion: A rapid APACHE II score decline (high APACHE/m) did not predict improved survival in ICU trauma patients. Paradoxically, the patients with the fastest APACHE II improvements had similar or worse late outcomes, likely because they were initially more critically ill. Thus, initial severity remains an important predictor of outcomes than the ICU recovery rate.

Keywords: APACHE II, trauma, intensive care unit, mortality, prognosis

Introduction

Trauma is the leading cause of morbidity and mortality worldwide. Severe injuries often exhibit a trimodal distribution of death timing, with many late deaths due to complications such as multi-organ failure (MOF) and sepsis.[1] Objective scoring systems are essential for assessing injury severity and guiding prognosis in trauma care. Traditional trauma scoring methods include anatomical and physiological indices such as the Abbreviated Injury Scale and its derived Injury Severity Score (ISS), Glasgow Coma Scale (GCS), Revised Trauma Score (RTS), and combined metrics such as the Trauma and Injury Severity Score (TRISS), which integrates RTS, ISS, and patient age to estimate survival.[2] These trauma-focused scores are often used for initial triage and outcome prediction in the emergency or operative phases.

However, in intensive care unit (ICU) settings, general severity scoring systems are widely applied to critically ill patients with all etiologies. One of the most widely used scoring system is the Acute Physiology and Chronic Health

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Evaluation II (APACHE II), which comprises 12 acute physiological variables, patient age, and chronic health status to generate a severity-of-disease score.[3] The APACHE II (and its successors APACHE III and IV) were designed to stratify ICU patients by illness severity and predict hospital mortality.[4,5] Similarly, the Sequential Organ Failure Assessment (SOFA) score was introduced to track the degree of organ dysfunction over time in ICU patients and provide a general severity score.[6] Both APACHE II and SOFA have been evaluated specifically in trauma ICU populations.[7,8] These ICU scoring systems allow quantification of physiological derangement and are valuable for benchmarking and prognosis. Importantly, they are typically administered at admission (APACHE II, usually within the first 24 hours in the ICU) and provide an initial mortality risk estimate.[9]

As trauma involves unique variables (eg, injury severity), a robust physiology-based index such as the APACHE II remains highly relevant for ICU trauma prognosis.[10] Correlations between APACHE II severity and specific metabolite signatures were identified and underscored how metabolic reprogramming mirrors physiologic derangements captured by APACHE II.[11,12] In patients with trauma, APACHE II outperformed both ISS and TRISS as a predictor for mortality.[13,14] Wong et al found that APACHE II scores measured during ICU admission were practical for outcome prediction in ICU trauma patients, with reported specificity around 97% and an overall accuracy of 91%.[15] However, a limitation of the conventional APACHE II scoring is its static nature; it captures patient status at a single time point upon ICU admission.[16,17] The conditions of critically ill patients change during their ICU stay, and the trajectory of physiological improvement or deterioration may provide prognostic information. In non-trauma ICU populations, changes in organ failure scores over time have been shown to predict outcomes;[18] for instance, an increasing SOFA score in the first 48 hours is associated with high mortality.[19] In another study on older adults in the ICU, the delta-SOFA (ΔSOFA; change in SOFA over 3 days) was a stronger independent predictor of 45-day mortality than the APACHE II (during admission). In other words, patients whose SOFA decreased had higher survival, and ΔSOFA predicted mortality better than the static APACHE II.[20] A recent analysis identified the Day-3 APACHE II score as an optimal threshold-based prognostic marker in ICU patients, outperforming the admission APACHE II score in mortality prediction.[16] Currently, there is uncertainty regarding whether the daily improvement rate of APACHE II can predict the outcomes of ICU trauma patients. We hypothesized that for trauma patients, the rate of improvement in the APACHE II score during ICU stay could reflect recovery momentum and thus be related to outcomes. However, clinicians may want a dynamic APACHE metric beyond the admission scores to identify at-risk patients. Therefore, this study was designed to answer the following question: Does a faster daily improvement in APACHE II translate to better survival in ICU trauma patients, or are those who improve the fastest simply those who were initially most critically ill?

Methods

Study Design and Population

We conducted a retrospective cohort study using data from a single level I trauma center. As shown in Figure 1, trauma patients admitted to the ICU between 2016 and 2023 were screened using the hospital's Trauma Registry System. The APACHE score was determined by a full-time senior certified nurse when the patient was admitted to the ICU and before discharge. The attending physician confirmed registration of the data. Inclusion criteria were aged ≥20 years (adult trauma), admission to ICU within three days of arrival to emergency room (to capture acute injury cases), and surviving ICU discharge with transfer to a ward. In this study, we proposed a novel metric – "APACHE/m" – defined as the average daily change (specifically, decrease) in APACHE II score during the ICU admission. This is formulated as follows:

APACHE/m = [APACHE/a (eg, APACHE II on ICU admission) – APACHE/d (eg, APACHE II on ICU discharge)] ÷ (ICU length of stay in days).

This metric yields the average daily decrease in APACHE II (with a higher value indicating a faster improvement in physiological status per day). Conceptually, APACHE/m resembles a recovery "slope", where a larger value implies a more rapid resolution of physiologic derangements. It is important to note that only patients who survived ICU discharge were included in this study; therefore, a survival bias must be acknowledged in the interpretation of the results.

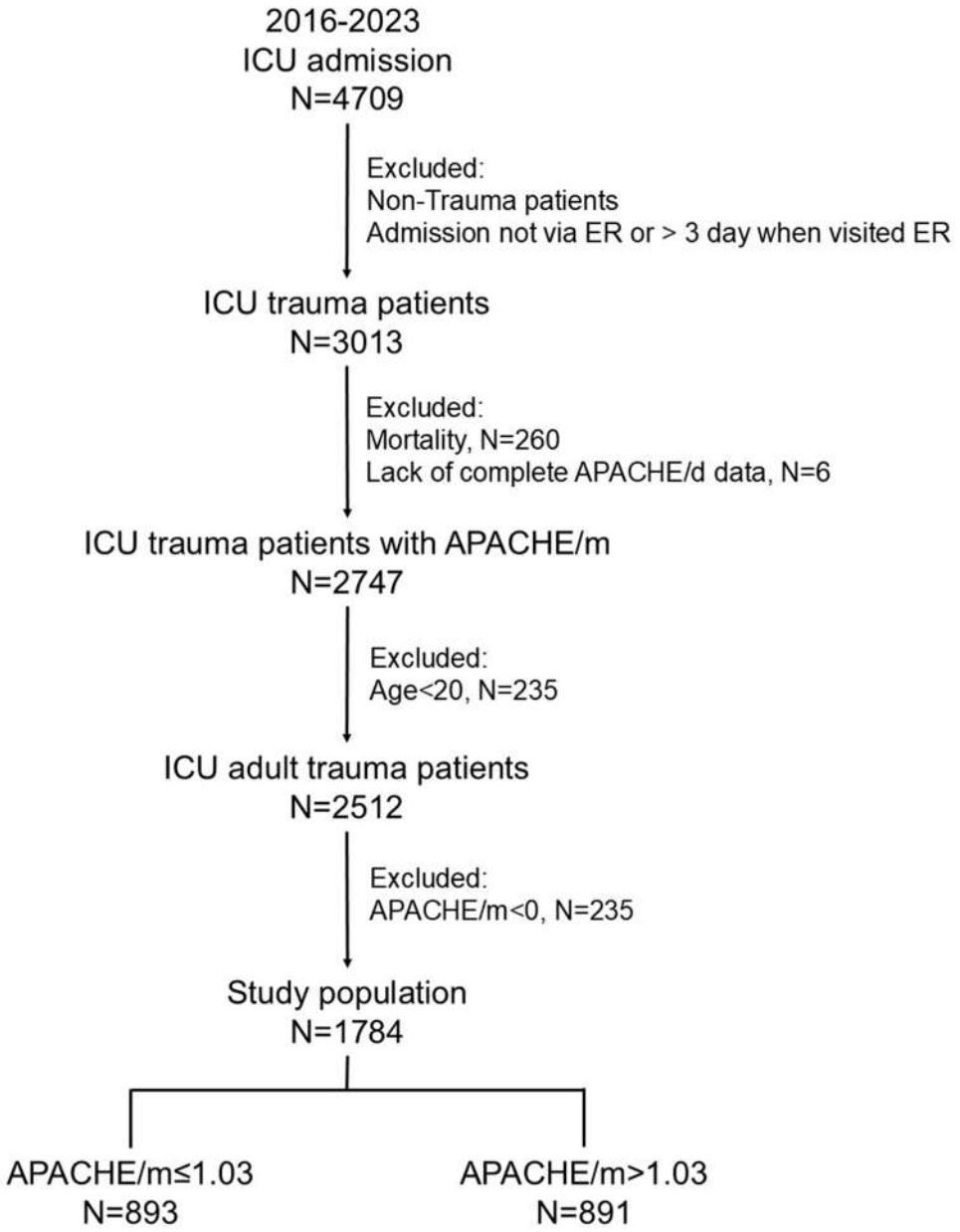

Figure 1 Flow diagram of patient screening and enrollment into the trauma ICU cohort (N = 1784).

We aimed to investigate whether the APACHE/m score is associated with patient outcomes after ICU discharge, particularly hospital mortality, in a cohort of patients with trauma. We also examined the characteristics of patients with high versus low APACHE-m scores to understand what this score represents.

For each included patient, we calculated the APACHE II score on ICU admission (APACHE/a) and discharge (APACHE/d) using the standard APACHE II methodology. The difference between these scores divided by the ICU length of stay (in days) was defined as APACHE/m. By definition, all included patients had APACHE/d ≤APACHE/a (since they survived to be discharged from the ICU); those who did not show any improvement (APACHE/d not lower than APACHE/a) or who worsened were very few and were excluded to focus on the effect of positive improvement (APACHE/m > 0). We excluded patients who died in the ICU or had incomplete APACHE II data.

Data Collection

In addition to the APACHE II scores, we collected patient demographics and clinical data, including sex, age, body mass index (BMI), preexisting comorbidities (eg, hypertension, diabetes, coronary artery disease, congestive heart failure, end-stage renal disease, and cerebrovascular accident history), and injury characteristics. Injury severity was quantified using the ISS for each patient. Key ICU course variables such as ICU length of stay and total hospital length of stay were recorded. The primary outcome of interest was hospital mortality (death before discharge from the hospital, including any death that occurred after ICU transfer to the ward).

Statistical Analysis

We first performed descriptive analyses comparing survivors and non-survivors in the cohort using appropriate statistical tests (chi-square or Fisher's exact test for categorical variables and the Mann–Whitney *U*-test for continuous variables with skewed distributions). Using a two-sided independent-samples *t* test ($d = 0.50$, $\alpha = 0.05$, power = 0.95) with equal allocation, the required sample was at least 105 patients per group (total n = 210; actual power = 0.950). We then examined APACHE/m score as a predictor of mortality, constructed a receiver operating characteristic (ROC) curve to assess discriminative ability, determined the optimal cutoff value of APACHE/m score for mortality prediction using the Youden index, and calculated the area under the ROC curve (AUC). We further explored the differences between patients with high and low APACHE/m scores. "High" vs "low" was defined by the median APACHE/m of the entire cohort (median split at APACHE/m = 1.03). We compared baseline characteristics and outcomes between the two groups. For comparison, the AUC of the APACHE/a and SOFA scores to predict mortality after ICU discharge was calculated. Because baseline differences were expected in patients with high APACHE/m scores compared to those with low APACHE/m, we performed a propensity score matching analysis. Analyses were conducted with NCSS 10 software (NCSS, LLC, Kaysville, UT), a propensity score for "high APACHE/m" group membership was calculated for each patient using logistic regression based on baseline covariates: age, sex, BMI, major comorbidities, ISS, and laboratory data. When there were missing data, the variable was imputed with a median value for the same attributes. We matched patients with high and low APACHE/m 1:1 using nearest-neighbor matching without replacement and achieved well balanced pairs (n = 199 per group) for outcome comparison. In the matched sample, we compared hospital mortality between the high and low APACHE/m groups using McNemar's test, and ICU/hospital length of stay using the Wilcoxon signed-rank test. Statistical significance was set at $P < 0.05$ (two-tailed).

Table 1 Baseline Characteristics of the ICU Trauma Patients (N = 1784), Comparing Survivors (N = 1743) to Those Who Died in-Hospital Post-ICU (N = 41). Data are Presented as Median [IQR] or Number (Percentage); p-values Compare the Mortality vs Survival Groups

Variables	Total	Mortality	Survival	P
	N = 1784	N = 41	N = 1743	
APACHE/m (median [IQR])	1.03 [0.47, 2.21]	1.50 [0.63, 2.44]	1.03 [0.47, 2.19]	0.134
APACHE/a (median [IQR])	14.62 [8.71, 23.49]	35.50 [23.49, 46.03]	12.89 [8.71, 23.49]	<0.001
APACHE/d (median [IQR])	6.65 [5.05, 9.95]	14.62 [9.95, 23.49]	6.65 [5.05, 9.95]	<0.001
Age, years (median [IQR])	59.00 [41.00, 71.00]	74.00 [61.00, 81.00]	58.00 [41.00, 71.00]	<0.001
Male, N (%)	1184 (66.4)	33 (80.5)	1151 (66.0)	0.077
BMI (median [IQR])	24.03 [21.59, 27.15]	23.52 [20.49, 25.95]	24.06 [21.62, 27.18]	0.131
CVA, N (%)	80 (4.5)	4 (9.8)	76 (4.4)	0.205
HTN, N (%)	622 (34.9)	25 (61.0)	597 (34.3)	0.001

(*Continued*)

Table 1 (Continued).

Variables	Total	Mortality	Survival	P
	N = 1784	N = 41	N = 1743	
CAD, N (%)	132 (7.4)	6 (14.6)	126 (7.2)	0.137
CHF, N (%)	11 (0.6)	0 (0.0)	11 (0.6)	>0.999
ESRD, N (%)	64 (3.6)	6 (14.6)	58 (3.3)	0.001
DM, N (%)	396 (22.2)	11 (26.8)	385 (22.1)	0.595
ISS (median [IQR])	17.00 [13.00, 25.00]	20.00 [16.00, 25.00]	17.00 [13.00, 25.00]	0.229
ISS stratification				0.144
ISS < 16	462 (25.9)	9 (22.0)	453 (26.0)	
16 ≤ ISS < 25	786 (44.1)	14 (34.1)	772 (44.3)	
ISS ≥ 25	536 (30.0)	18 (43.9)	518 (29.7)	
Transfusion of RBC, units (median [IQR])	0.00 [0.00, 4.00]	6.00 [0.00, 12.00]	0.00 [0.00, 4.00]	<0.001
Transfusion of FFP, units (median [IQR])	0.00 [0.00, 2.00]	2.00 [0.00, 6.00]	0.00 [0.00, 2.00]	<0.001
ICU stay, days (median [IQR])	4.00 [3.00, 10.00]	10.00 [5.00, 23.00]	4.00 [3.00, 9.00]	<0.001
Hospital stay, days (median [IQR])	16.00 [10.00, 27.25]	25.00 [19.00, 40.00]	16.00 [10.00, 27.00]	<0.001

Abbreviations: APACHE/a, APACHE II score on ICU admission; APACHE/d, APACHE II score on ICU discharge; APACHE/m, average daily decrease in APACHE II score during ICU stay; CVA, cerebrovascular accident; HTN, hypertension; CAD, coronary artery disease; CHF, congestive heart failure; ESRD, end-stage renal disease; DM, diabetes mellitus; ISS, Injury Severity Score; RBC, red blood cell transfusion units; FFP, fresh frozen plasma transfusion units; ICU, intensive care unit.

Results

Patient Characteristics: As shown in Table 1, 1784 ICU trauma patients met the inclusion criteria (median age, 59 years; 66% men). Most patients were discharged from the ICU to the ward. Of these, 41 patients (2.3%) died before hospital discharge (post-ICU and in-hospital mortality). The median ICU length of stay was 4 days (interquartile range [IQR], 3–10 days), and the median hospital length of stay was 16 days (IQR, 10–27). The median APACHE II score at ICU admission was 14.6 (IQR 8.7–23) and at discharge from ICU was 6.7 (IQR 5.1–10.0), with a median APACHE/m of 1.03 points per day (IQR 0.47–2.21). By design, all patients had an APACHE/m >0 (improvement); a small subset of patients with APACHE II not decreasing in the ICU was not included in this analysis.

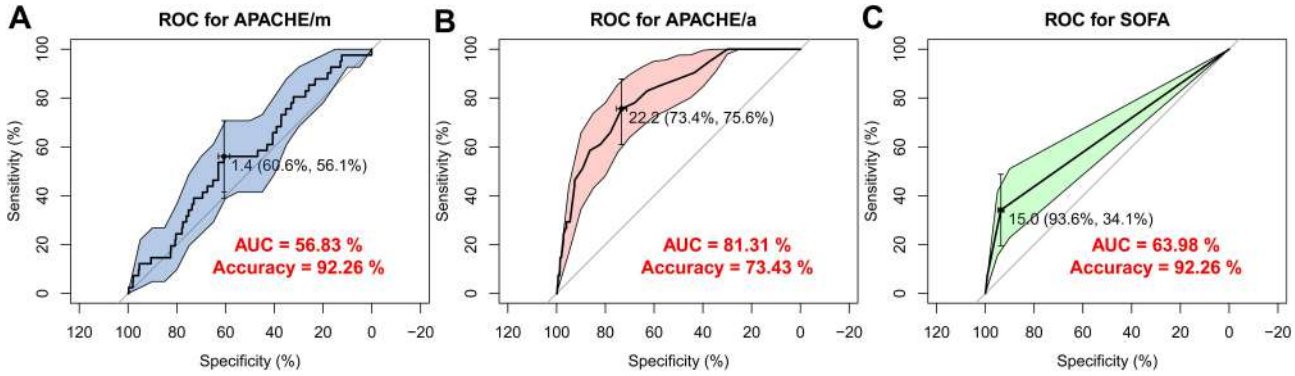

Figure 2 Receiver operating characteristic (ROC) curve for (**A**) APACHE/m; (**B**) APACHE/a; and (**C**) SOFA as a predictor of in-hospital mortality after leaving the ICU (N = 1784).

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Figure 2 shows the ROC curve for APACHE/m scores in predicting hospital mortality. The AUC was 56.83%, indicating poor discrimination. The optimal cutoff identified was APACHE/m ≈ 1.4 points/day, which yielded a sensitivity of about 57% and specificity of about 60%. In other words, a patient whose APACHE II score decreased by more than 1.4 points per day during ICU stay was classified as "predicted survivor" by this cutoff; however, this rule was not very reliable. Additionally, the AUC was 81.31% and 63.98% for APACHE/a and SOFA, respectively, both presenting significant differences from the AUC of APACHE/m (both $p < 0.001$). Rapid APACHE II decline was associated with worse late outcomes after ICU discharge, likely reflecting a higher initial severity. The accuracies for predicting mortality using APACHE/m, APACHE/a, and SOFA was 92.26, 73.43, and 92.26%, respectively.

We next compared patients in the high APACHE/m group (daily APACHE II improvement >1.03) versus the low APACHE/m group (≤1.03) (as shown in Table 2). The hospital mortality rate among high APACHE/m patients was 2.6% (23/891) compared to 2.0% (18/893) in low APACHE/m patients, a difference that was not statistically significant (P = 0.523). As anticipated, significant baseline differences were observed between the groups. High APACHE/m patients tended to be older (median age 61 vs 56 years, $P < 0.001$) and had a greater burden of chronic diseases; for example, the prevalence of cerebrovascular accident, hypertension, coronary artery disease, and end-stage renal disease. They also had higher injury severity on admission: the median initial APACHE II (admission) was about 18.7 in the high APACHE/m group vs 8.8 in the low APACHE/m group ($P < 0.001$). However, there was no significant difference in the ISS or the

Table 2 Comparison of High versus Low APACHE/m Groups in the Original Cohort and After Propensity Matching. Characteristics of Patients with High APACHE/m (>1.03 Points/Day) vs Low APACHE/m (≤1.03) are Shown for the Full Cohort (N = 1784) and for the Propensity Score–Matched Sub-Cohort (N = 398, 199 Pairs)

Variables	Original Cohort			Matched Cohort		
	APACHE/m > 1.03	APACHE/m ≤ 1.03	p	APACHE/m > 1.03	APACHE/m ≤ 1.03	P
	N = 891	N = 893		N = 199	N = 199	
APACHE/m, (median [IQR])	2.21 [1.50, 3.67]	0.47 [0.27, 0.69]	<0.001	2.19 [1.44, 3.54]	0.50 [0.31, 0.70]	<0.001
APACHE/a (median [IQR])	18.65 [12.89, 29.13]	8.80 [6.65, 14.62]	<0.001	14.62 [11.33, 23.49]	7.62 [5.80, 8.71]	<0.001
APACHE/d (median [IQR])	7.62 [5.05, 9.95]	6.65 [4.40, 9.95]	<0.001	5.80 [4.40, 8.17]	5.80 [3.82, 7.62]	0.054
Age (median [IQR])	61.00 [45.50, 73.00]	56.00 [39.00, 69.00]	<0.001	53.00 [35.50, 66.00]	51.00 [35.50, 66.00]	0.687
Male, N (%)	597 (67.0)	587 (65.7)	0.605	143 (71.9)	125 (62.8)	0.069
BMI (median [IQR])	23.89 [21.54, 26.69]	24.26 [21.73, 27.54]	0.012	24.45 [21.30, 26.36]	23.70 [21.09, 26.64]	0.474
CVA, N (%)	57 (6.4)	23 (2.6)	<0.001	23 (100.0)	23 (100.0)	>0.999
HTN, N (%)	335 (37.6)	287 (32.1)	0.018	39 (19.6)	39 (19.6)	>0.999
CAD, N (%)	88 (9.9)	44 (4.9)	<0.001	3 (1.5)	3 (1.5)	>0.999
CHF, N (%)	8 (0.9)	3 (0.3)	0.225	3 (100.0)	3 (100.0)	>0.999
ESRD, N (%)	54 (6.1)	10 (1.1)	<0.001	10 (100.0)	10 (100.0)	>0.999
DM, N (%)	214 (24.0)	182 (20.4)	0.073	22 (11.1)	22 (11.1)	>0.999
ISS (median [IQR])	17.00 [14.00, 25.00]	17.00 [13.00, 25.00]	0.597	16.00 [13.00, 20.00]	16.00 [13.00, 20.00]	>0.999
ISS stratification			0.929			>0.999
ISS < 16	231 (25.9)	231 (25.9)		57 (28.6)	57 (28.6)	
16 ≤ ISS < 25	389 (43.7)	397 (44.5)		104 (52.3)	104 (52.3)	
ISS ≥ 25	271 (30.4)	265 (29.7)		38 (19.1)	38 (19.1)	

(*Continued*)

Table 2 (Continued).

Variables	Original Cohort			Matched Cohort		
	APACHE/m > 1.03	**APACHE/m ≤ 1.03**	**p**	**APACHE/m > 1.03**	**APACHE/m ≤ 1.03**	**P**
	N = 891	**N = 893**		**N = 199**	**N = 199**	
Na, mEq/L (median [IQR])	138.00 [136.00, 140.00]	138.00 [136.00, 140.00]	0.78	138.00 [136.00, 140.00]	138.00 [136.00, 139.00]	0.773
K, mEq/L (median [IQR])	3.60 [3.30, 4.00]	3.70 [3.40, 4.00]	0.008	3.50 [3.30, 3.90]	3.60 [3.40, 4.00]	0.058
HbA1c, % (median [IQR])	6.20 [5.70, 7.10]	6.40 [5.70, 7.50]	0.059	5.90 [5.50, 7.05]	6.35 [5.77, 6.90]	0.252
BUN, mg/dL (median [IQR])	16.00 [12.00, 20.90]	14.20 [11.47, 18.92]	0.002	14.00 [11.00, 18.00]	14.00 [10.07, 17.00]	0.408
Cr, mg/dL (median [IQR])	1.00 [0.78, 1.33]	0.93 [0.75, 1.13]	<0.001	0.89 [0.73, 1.08]	0.84 [0.68, 1.01]	0.047
AST, U/L (median [IQR])	41.00 [29.00, 70.25]	40.00 [29.00, 72.50]	0.995	40.00 [30.00, 68.25]	35.50 [26.00, 69.25]	0.146
ALT, U/L (median [IQR])	29.00 [19.00, 49.00]	29.00 [20.00, 54.00]	0.104	29.00 [20.00, 50.50]	28.00 [19.00, 57.00]	0.920
Bilirubin, mg/dL (median [IQR])	0.80 [0.60, 1.20]	0.80 [0.60, 1.10]	0.956	0.80 [0.60, 1.20]	0.80 [0.60, 1.10]	0.565
Albumin, g/dL (median [IQR])	3.49 [3.09, 3.90]	3.50 [3.10, 3.86]	0.859	3.70 [3.28, 4.08]	3.70 [3.39, 4.10]	0.442
WBC, 10^9/L (median [IQR])	12.70 [8.80, 17.70]	13.20 [9.45, 17.60]	0.264	13.20 [9.28, 18.60]	12.80 [8.80, 17.20]	0.395
RBC, 10^{12}/L (median [IQR])	4.23 [3.61, 4.75]	4.40 [3.86, 4.87]	<0.001	4.27 [3.83, 4.80]	4.49 [3.95, 4.87]	0.068
Hemoglobin, g/dL (median [IQR])	12.50 [10.80, 14.20]	13.00 [11.50, 14.40]	<0.001	12.80 [11.47, 14.50]	13.20 [11.90, 14.40]	0.234
Hematocrit, % (median [IQR])	37.90 [32.60, 42.20]	39.05 [34.80, 43.10]	<0.001	39.00 [33.80, 42.92]	40.00 [36.10, 42.90]	0.105
Platelets, 10^9/L (median [IQR])	217.00 [168.00, 264.00]	216.00 [174.00, 267.00]	0.252	235.50 [178.75, 272.50]	229.00 [187.00, 283.00]	0.439
PT, seconds (median [IQR])	10.90 [10.40, 11.65]	10.90 [10.50, 11.40]	0.272	10.80 [10.30, 11.45]	10.80 [10.40, 11.10]	0.236
aPTT, seconds (median [IQR])	25.55 [23.90, 27.80]	25.40 [23.60, 27.20]	0.005	25.40 [24.20, 27.60]	25.40 [23.90, 27.10]	0.567
INR (median [IQR])	1.04 [0.99, 1.11]	1.03 [0.99, 1.09]	0.143	1.03 [0.98, 1.09]	1.02 [0.99, 1.06]	0.192
Outcomes comparison						
ICU stay, days (median [IQR])	4.00 [3.00, 7.00]	6.00 [3.00, 14.00]	<0.001	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	>0.999
Hospital stay, days (median [IQR])	16.00 [10.00, 26.00]	16.00 [10.00, 29.00]	0.191	14.00 [9.50, 21.50]	12.00 [8.00, 18.50]	0.005
Mortality, N(%)	23 (2.6)	18 (2.0)	0.523	7 (3.5)	0 (0.0)	0.022

Abbreviations: APACHE/m, average daily decrease in APACHE II score during ICU stay; APACHE/a, APACHE II score on ICU admission; APACHE/d, APACHE II score on ICU discharge; BMI, body mass index; CVA, cerebrovascular accident; HTN, hypertension; CAD, coronary artery disease; CHF, congestive heart failure; ESRD, end-stage renal disease; DM, diabetes mellitus; ISS, Injury Severity Score; Na, serum sodium; K, serum potassium; HbA1c, glycated hemoglobin; BUN, blood urea nitrogen; Cr, creatinine; GOT, glutamic-oxaloacetic transaminase (AST); GPT, glutamic-pyruvic transaminase (ALT); WBC, white blood cell count; RBC, red blood cell count; Hb, hemoglobin; Hct, hematocrit; PLT, platelet count; PT, prothrombin time; aPTT, activated partial thromboplastin time; INR, international normalized ratio.

proportion of ISS stratification between the high and low APACHE/m groups. In this study, a paradoxical finding (higher mortality in patients with high APACHE/m scores after matching) was observed. In essence, patients who showed the fastest daily improvement in the ICU were generally those who were more critically ill with higher physiological derangement, although the injury severity was not significantly different. In association with faster improvement, these patients also required shorter critical care; the ICU length of stay was significantly shorter in the high APACHE/m group (median 4 days vs 6 days for the low APACHE/m group, $P < 0.001$). Before matching, the length of hospital stay was slightly longer in the high APACHE/m group (median, 16 days vs 14 days), but this difference was not statistically significant ($P = 0.191$) in the unmatched comparison. Unadjusted post-ICU mortality was likewise similar between the groups, as noted above (2.6% vs 2.0%, $P = 0.523$).

After 1:1 propensity matching (n = 199 pairs), the baseline covariates were well balanced between the high and low APACHE/m groups. In this matched sample, the outcomes diverged more clearly. High APACHE/m patients had a significantly longer total hospital stay than low APACHE/m patients (median 14 days [IQR 10–22] vs 12 days [IQR 8–19], P = 0.005). Most importantly, hospital mortality was significantly higher in the high APACHE/m group; mortality in the matched high-APACHE/m group was 3.5% (7/199) versus 0% (0/199) in the low-APACHE/m group (P = 0.022). Thus, when patients were matched for initial condition and injury severity, those who improved more rapidly in the ICU paradoxically experienced greater late mortality in the ward than those who improved more slowly (none of the matched low APACHE/m patients died after ICU discharge). Interestingly, these findings suggest that a very high APACHE/m score (fast recovery in ICU) is not necessarily protective and may in fact be a marker for patients at risk of delayed decline after ICU admission, perhaps owing to the underlying injury burden or frailty that is not resolved by ICU care alone.

Discussion

In this study on ICU trauma patients, we considered APACHE/m, the average daily improvement in the APACHE II score during the ICU stay, as a potential prognostic indicator. Our results indicate that APACHE/m has a poor ability to predict hospital mortality in this population. For APACHE/m, the ROC AUC of ~0.57 is only slightly better than chance and far below the predictive performance of the established severity scores measured at admission. Prior studies report that the initial APACHE II score has an AUC of 0.85 for mortality in trauma ICU cohorts. In our study, knowing how quickly a patient's APACHE II score declined offered little additional insight into whether the patient survived. Even an optimal APACHE/m cutoff (approximately 1.4 points/day) misclassified a large proportion of patients. Thus, the hypothesis that faster physiological recovery implies a better outcome was not supported by the overall statistics. However, a rapid APACHE II score decline was associated with worse late outcomes after ICU admission, likely reflecting a higher initial severity.

One explanation for this is that APACHE/m is highly influenced by the initial APACHE II score. Indeed, we observed that patients with high APACHE/m scores were initially far more ill (higher APACHE II scores at admission and generally older with more comorbid conditions) than those with low APACHE/m scores. This makes intuitive sense: A patient who starts with a very high APACHE II score, which indicates more severe physiological derangement, has more room for improvement when there is a decline in scores and can drop faster in absolute terms than a patient who starts with a modest APACHE II score. Our high APACHE/m group comprised patients who were critically ill but stabilized; as such, their APACHE II scores dropped substantially during ICU care, whereas the low APACHE/m group had a less dramatic illness to begin with. Crucially, a high APACHE/m score did not indicate a better prognosis. Despite recovering faster in the ICU, patients with high APACHE/m scores had worse outcomes after leaving the ICU. After matching for baseline differences, their in-hospital mortality was significantly higher than that of matched low APACHE/m patients (3.5% vs 0%). Thus, a rapid decline in the APACHE II score is not necessarily indicative of a better outcome. In trauma, advanced age and preexisting conditions adversely affect outcomes independent of acute injury severity.[21,22] Our high APACHE/m score patients fit that profile—older and more comorbid—which likely contributed to their higher late mortality due to factors such as frailty or diminished physiological reserves. Patients who improve quickly in the ICU are often those who are at the brink initially; they survive the critical phase under intensive interventions but may still succumb to latent injuries or complications. Notably, these observations are contrary to reports that ICU patients with high SOFA scores at admission improved in 48 hours, showing significantly better 12- and 24-month survival than those whose scores remained elevated,[23] which emphasizes that rapid improvement, even from a severe state, can indicate good long-term prognosis.

Another way to interpret these findings is that APACHE/m serves as a marker of injury severity and physiological reserve rather than a simple "recovery speedometer". A very high APACHE/m value implies that the patient had a very high APACHE II score on admission (severe initial evaluation) and survived critical illness (hence, a large drop in score). While these patients demonstrate substantial recovery in the ICU, they might have survived against the odds with residual vulnerability that manifested after ICU discharge. Our high APACHE/m score patients could be viewed in a similar light; many would have been predicted to die based on their initial severity, yet they lived through the ICU

phase. Therefore, it is not entirely surprising that some of them died later in the hospital, perhaps due to complications such as organ failure, infections, or the inability to withstand additional surgeries. The continued significance of post-injury MOF as a cause of late death has been documented, even in modern trauma care.[24]

Our analysis underscores a key point: single metrics or improvements cannot wholly capture outcome trajectories in trauma. This aligns with the view of some investigators that prognostic scoring systems should be used only as an adjunct to clinical judgment and not as definitive predictors of individual outcomes.[25] APACHE II remains a useful tool for comparing groups and assessing severity, but its derived measure, APACHE/m, did not add to the prognostic power in our study. Once the initial severity is accounted for, the rate of improvement adds little new information about survival odds.

Other scoring paradigms have attempted to improve trauma outcome prediction by incorporating additional patient information or using different approaches. These innovations highlight that trauma outcome prediction is an evolving field, and perhaps a future direction could involve dynamic physiological measurements.[26,27] There is evidence that considering ICU day 3 scores or changes from admission can improve mortality prediction in critically ill patients.[28] While APACHE/m in its simple form was not predictive, one could explore more sophisticated uses of time-series data; for instance, machine learning models that consider the trend of multiple vital signs and lab values over time, rather than a single summary statistic. Studies have correlated the relationship between APACHE II severity and specific metabolite signatures, highlighting how metabolic reprogramming mirrors physiological derangements captured by APACHE II.[11,12] In our context, it remains possible that a more nuanced metric than a linear daily drop, such as distinguishing early improvement from late deterioration, could have a prognostic value.

This study has some limitations. First, by focusing on patients who survived ICU discharge (and those with APACHE/m >0), we introduced a selection bias that excluded the most severe trauma patients who died early. Therefore, our findings do not apply to predicting ICU mortality but only to post-ICU outcomes for ICU survivors. Second, this was a single-center retrospective study and the overall hospital mortality rate was relatively low (2.3%), which may limit statistical power for detecting differences. Our propensity matching helped adjust for confounders, but unmeasured factors (eg, variations in post-ICU care, unrecorded complications, and various managements by different surgeons) could have influenced the outcomes. Third, a key limitation was the potential survivorship bias introduced by excluding patients who died early in the ICU. By design, the APACHE/m score could only be calculated for patients who remained in the ICU long enough to show a trend; those who died soon after admission (often with high or worsening scores) were excluded. This exclusion may have overestimated the beneficial association between the APACHE/m score and survival. Additionally, low mortality rate may reduce the statistical power. Furthermore, the linearity assumption (steady daily improvement) may not hold in real ICU trajectories, which is a limitation of the interpretation of this study. Moreover, there may be a possible misclassification bias since APACHE II was documented solely at admission and discharge, rather than on a daily basis. Finally, we did not directly examine the causes of post-ICU fatalities; it is unclear if they were due to irreversible secondary injuries or systemic complications, such as sepsis or MOF. A detailed analysis of the causes might provide insights into why a patient who improves in the ICU may still succumb later.

Conclusion

In conclusion, this study suggests that the average daily improvement in APACHE II score (APACHE/m) during ICU hospitalization is not a reliable standalone predictor of the ultimate outcome in trauma patients. Rapid APACHE II decline was associated with worse late outcomes after ICU admission, likely reflecting a higher initial severity. These findings highlight that initial injury severity matters far more to trauma outcomes than the rate of score normalization. Further research is warranted in dynamic models or external validation to identify which aspects of a patient's ICU course (eg, persistent organ dysfunction, complications, and trajectory of improvement) can be combined with baseline severity to more accurately stratify risk in the post-ICU phase of trauma care.

Ethic Statement

Chang Gung Memorial Hospital's Institutional Review Board (IRB) accepted the investigation under permission number 202500994B0. The IRB waives the requirement for a consent form due to the retrospective evaluation of registration data as part of the study design.

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Disclosure

The authors declare no competing interests.

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