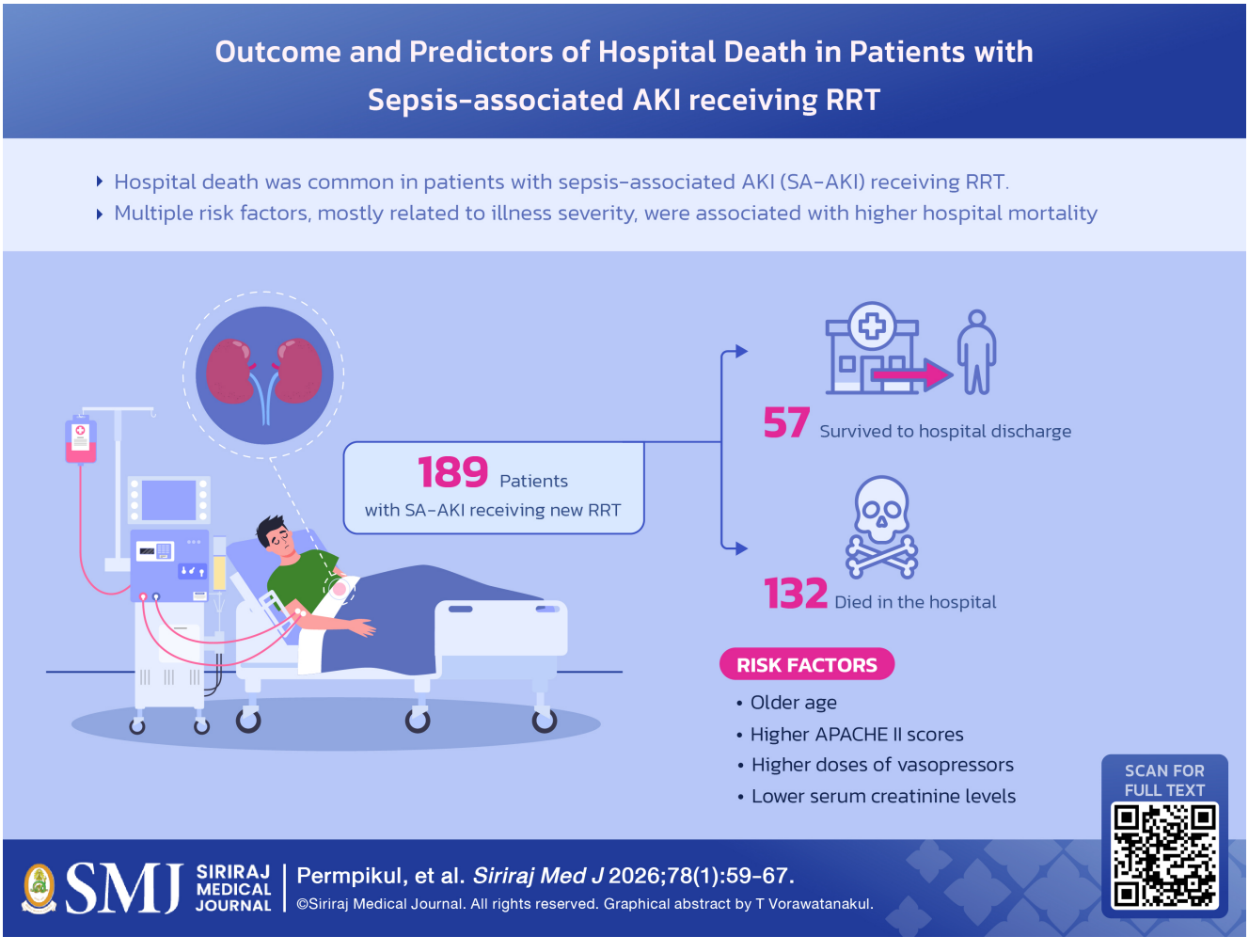
Hospital Mortality and Predicting Factors in Patients with Sepsis-associated Acute Kidney Injury Requiring Renal Replacement Therapy

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ABSTRACT

Objective: To investigate the clinical predictors for hospital mortality in patients with sepsis-associated acute kidney injury who required renal replacement therapy.

Materials and Methods: A retrospective cohort study enrolling adult patients hospitalized in medical wards at Siriraj Hospital between 2018-2021, who were concurrently diagnosed with sepsis and acute kidney injury. Patients who previously received long-term renal replacement therapy were excluded. We compared clinical characteristics and treatment strategies, then analyzed the predictors of mortality according to hospital mortality.

Results: Among 189 patients with acute kidney injury requiring renal replacement therapy, 132 (69.8%) died during hospitalization. A receiver operating characteristic curve analysis for predictors of hospital mortality revealed cutoff values for age > 60 years, SOFA score > 10, APACHE II score > 20, total colloid in 72 hr > 1,500 mL, maximum vasopressor > 0.3 mcg/kg/min, white blood cell count < 12 cells/μL, serum creatinine < 4 mg/dL, and serum albumin < 2.5 g/dL. Multivariate analysis identified age > 60 (OR 2.8, 1.27-6.38), APACHE II score > 20 (OR 2.57, 1.23-5.42), and maximum vasopressor dose > 0.3 μg/kg/min (OR 4.26, 1.94-9.86) as independent mortality predictors, while creatinine > 4 mg/dL was protective (OR 0.36, 0.17-0.75).

Conclusion: Patients with sepsis-associated acute kidney injury who underwent renal replacement therapy had high hospital mortality. Age > 60 years, APACHE II score > 20, maximum vasopressor dose > 0.3 mcg/kg/min, and serum creatinine ≤ 4 mg/dL were predictors for hospital mortality.

Keywords: Acute kidney injury; sepsis; septic shock; renal replacement therapy; mortality (Siriraj Med J 2026;78(1): 59-67)

INTRODUCTION

Sepsis and septic shock are among the most common causes of admission to intensive care units worldwide.[1-5] They are associated with multiple organ dysfunction, including the kidney, resulting in acute kidney injury (AKI). The complication develops in up to 50% of patients with sepsis[6-9], leading to worse outcomes like longer ICU stay and higher short-term mortality.[1,6,7,10] In clinical practice, sepsis-associated AKI (SA-AKI) is defined as AKI in the presence of sepsis without other significant contributing factors explaining AKI.[11]

Although most cases of SA-AKI could be conservatively managed with medications while allowing time for renal recovery, initiation of renal replacement therapy (RRT) was warranted in 45-72% of these patients.[5,6,12] Few clinical studies have focused on the presentation, patient profile, and outcome of SA-AKI[5,12,13], particularly those undergoing RRT. A prospective cohort study of sepsis and septic shock patients who developed AKI across intensive care units (ICU) in European countries reported an overall mortality rate of 41%.[14] Whereas for the subgroup of patients who received RRT, the mortality was reported to be as high as 69%[12] Because of the scarcity of data, clinical predictors for death in patients with SA-AKI who required RRT are not fully elucidated.

To address this knowledge gap, the aim of this study was twofold. The primary objective was to determine the prognoses of the subgroup of patients with sepsis-associated acute kidney injury who received renal replacement therapy in terms of hospital death. The secondary objective was to determine clinical and biochemical predictors for hospital mortality in this subgroup of patients.

MATERIALS AND METHODS

Design and setting

This was a single-center, retrospective observational cohort study. It was conducted at the Faculty of Medicine Siriraj Hospital, Mahidol University – a tertiary referral center in Thailand, consisting of 10 general medical units. Anonymized charts of patients admitted in these wards from January 1st, 2018 to December 31st, 2021 were reviewed for retrieval of the data.

The study protocol was approved by the Institutional Review Board of Siriraj Hospital (approval number COA no. Si 119/2022). The IRB allowed the study to waive the requirement to obtain informed consent. This study received no external funding.

Participants

The following inclusion criteria were used to identify eligible patients.

1. Adult patients 18 years or older
2. Patients were diagnosed with either sepsis or septic shock according to either the 2012 Surviving Sepsis Campaign guidelines[15]
3. Patients were diagnosed with acute kidney injury

according to the Kidney Disease Improving Global Outcomes 2012 guideline, using serum creatinine and urine output criteria[16]

4. Patients were treated with renal replacement therapy

Patients who satisfied the following exclusion criteria were excluded from the study.

1. Patients who had do-not-resuscitate orders
2. Patients who received surgical intervention in this hospital visit prior to ICU admission
3. Patients who were pregnant
4. Patients with end-stage malignancy
5. Patients with renal diseases who were previously receiving RRT
6. Patients with the following concurrent illnesses: acute stroke, acute coronary syndrome, acute pulmonary edema, status asthmaticus, active gastrointestinal bleeding, status epilepticus, severe trauma, fatal drug overdose

All participants were resuscitated according to current international guidelines for septic shock[15], which included fluid resuscitation, vasopressor therapy, antimicrobial therapy, appropriate source control, and organ support.

The decisions to initiate RRT in each patient were made by consulting nephrologists together with attending intensivists. Standard indications for RRT initiation included uremic symptoms, fluid overload, metabolic acidosis, and other electrolyte abnormalities. The initial modes of RRT utilized were also up to the discretion of the nephrologists. Either intermittent hemodialysis, sustained low-efficiency dialysis, or continuous renal replacement therapy was used.

Data collection

We performed an electronic medical records review from which we collected and recorded patient baseline characteristics at the time of AKI diagnosis: age, sex, underlying conditions, severity score, vital signs, body mass index, site of infection, and laboratory investigations. Treatment data were also recorded, specifically to the amount of fluid resuscitation in the following three days after the diagnosis, as well as vasopressor type and dosage, organ support requirements, modes of RRT, indications of RRT, and treatment outcomes of the index hospitalization. The primary outcome of this study was hospital mortality.

Statistical analysis

Participants were classified as survivors and non-survivors, according to their status upon hospital discharge. Baseline characteristics at the time of enrollment – i.e., at the time of initiation of renal replacement therapy – were compared between the two groups.

Baseline characteristics were reported as percentages, means and standard deviations, and median and interquartile ranges as appropriate. Comparisons of these parameters between survivors and non-survivors were performed using independent t-tests, Mann-Whitney U-tests, or chi-square tests where appropriate.

Receiver operating characteristic (ROC) curve analyses were performed to identify cutoff values for continuous variables that differed significantly between survivors and non-survivors. Each optimal cutoff value, along with its sensitivity and specificity, was determined using Youden's index. The largest area under the ROC curve (AUROC) was used to identify variables best predicting hospital mortality. Variables were reclassified into two groups using the ROC curve–identified cutoff values. A comparative analysis was performed between each group using univariate analyses. Risk is expressed as an unadjusted OR with a 95% CI. Factors with *p-value* ≤ 0.1 and other factors of interest were included in multivariate analyses. The results of the multivariate analysis with stepwise forward variable selection are shown as adjusted OR with the 95% CI and *p-value*. Independent predictive factors associated with hospital mortality are those with a *p-value* ≤ 0.05.

All statistical analyses were performed using SPSS ver. 18 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 356 sepsis and septic shock patients were screened. 167 patients were excluded, resulting in a total of 189 patients enrolled (Fig 1). Among these, 57 patients (30.16%) survived to hospital discharge, and 132 patients (69.84%) died in hospital. In the survivor group: 35 patients were discharged with RRT-free status, and 22 patients needed RRT after discharge.

The patients' baseline characteristics are shown in Table 1. Compared to survivors, non-survivors had significantly higher SOFA and APACHE II scores, but lower white blood cell count, serum creatinine, and serum albumin.

Concurrent treatments and interventions used are shown in Table 2. Compared to survivors, non-survivors received a higher volume of intravenous colloids in 72 hours, including human albumin solutions, gelatins, and plasmas. They were treated with more vasopressors, especially epinephrine and dopamine. They received more mechanical ventilation, and were more likely treated with continuous renal replacement therapy as their first mode of RRT. These are likely reflective of more severe disease.

To identify the optimal cutoff values for continuous variables predicting hospital mortality, ROC curve analyses

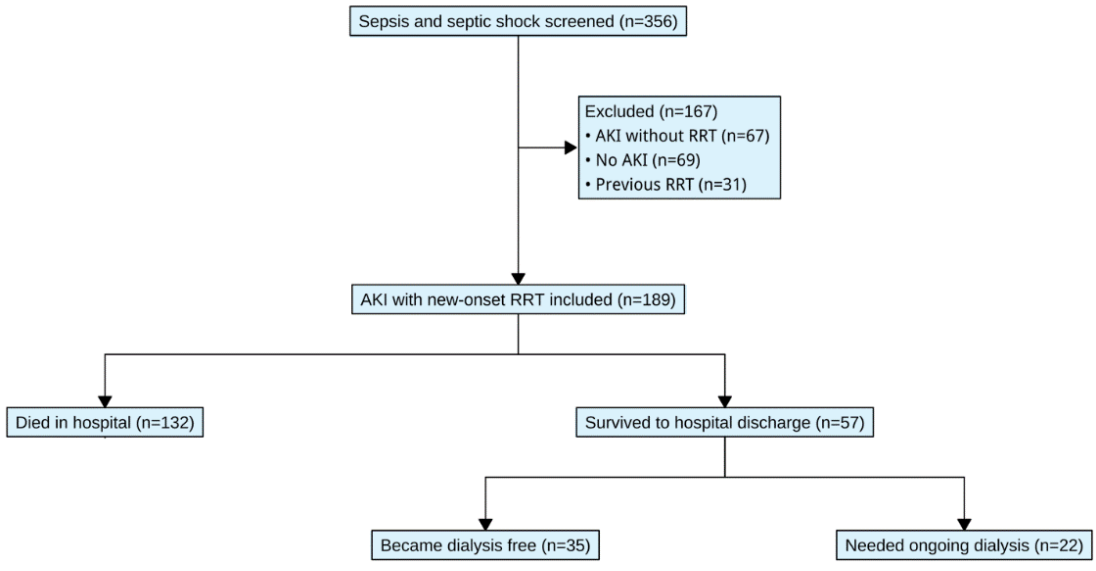


Fig 1. Flow diagram illustrating screening, inclusion, and outcome of patients.

were performed. The ROC curves and corresponding area under the curve are shown in Fig 2 and Table 3, respectively. Optimal cutoff values for each parameter are shown in Table 3, including SOFA score > 10, APACHE II score > 20, total colloid received in 72 hours > 1,500 mL, and maximum vasopressor dose > 0.3 mcg/kg/min were identified to be associated with hospital mortality. Conversely, WBC count > 12 cell/μL, serum creatinine > 4 mg/dL, and serum albumin > 2.5 g/dL were shown to be inversely associated with hospital mortality.

Table 4 shows the independent predictive factors for hospital mortality among septic-AKI patients requiring RRT. Variables with significant differences between survivors and non-survivors (identified from baseline characteristics and categorized using optimal AUC cutoffs) were included. Eight parameters were significant in univariate analyses. The multivariate model identified four independent predictors: age > 60 years, APACHE II score > 20, maximum vasopressor dose > 0.3 mcg/kg/min (all higher in non-survivors), and serum creatinine ≤ 4 mg/dL (lower levels associated with higher mortality).

DISCUSSION

In this single-center, retrospective observational cohort study, we found that (1) in patients with sepsis-associated acute kidney injury, the need to receive RRT was associated with poor prognoses, with 69.84% hospital mortality rate, and (2) multiple clinical and biochemical factors were associated with higher hospital mortality in these patients, namely age > 60 years, APACHE II score > 20, maximum vasopressor dose > 0.3 mcg/kg/min, and serum creatinine ≤ 4 mg/dL.

The impact of sepsis-associated acute kidney injury on patients' prognoses was previously thought not to be substantial, as these patients usually have concurrent critical illnesses that are more directly linked to mortality, for instance, sepsis and circulatory shock. However, the receipt of renal replacement therapy is more strongly associated with worse outcomes, including mortality. Previous studies reported a mortality rate of 40-75% among patients with sepsis-associated AKI who were treated with RRT.[6,12] These data were consistent with our cohort, which demonstrated 69.84% hospital mortality.

Various predictors have been reported to be associated with mortality in patients with sepsis-associated AKI receiving RRT. The most consistently reported are markers of severity of illness, such as the APACHE II and SOFA scores.[6,13] As these tools reflect global organ failure in the patients, including renal function, they are more likely to be predictive of poor outcomes. Our study also concurred with these previous findings.

Similarly, higher vasopressor dose suggests more severe systemic complications. Vasopressor doses higher than that equivalent with 0.25 mcg/kg/min is generally considered as a threshold of severe shock, warranting the use of adjunct treatments[15], while our cohort suggested similar cutoff value of 0.3. This aligned with previous reports showing that, in sepsis and septic shock, extra-renal organ failures are associated with increased mortality in patients who underwent RRT.[18,19]

One interesting finding from our study was that having serum creatinine less than 4 mg/dL at the time of RRT initiation was associated with higher survival at hospital discharge. This finding could be explained in two ways. First, serum creatinine could also be falsely low, or only minimally elevated, in patients who are also fluid

TABLE 1. Baseline characteristics, compared between patients who survived to hospital discharge and patients who died in hospital.

Patient characteristic	Survivors (57)[1]	Non-survivors (132)[1]	*P*[2]
Age, years	63 (49, 77)	68 (58, 77)	0.143
Sex	25 (44%)	57 (43%)	0.931
Body mass index, kg/m²	23.6 (20.8, 26.2)	22.8 (20.0, 25.4)	0.293
SOFA score[3]	10 (8, 13)	12 (9, 15)	0.005*
APACHE II score[4]	20 (6)	26 (9)	<0.001*
Underlying conditions			
Hypertension	37 (65%)	84 (64%)	0.867
Diabetes mellitus	29 (51%)	58 (44%)	0.380
Chronic kidney disease	24 (43%)	53 (40%)	0.730
Ischemic heart disease	11 (19%)	20 (15%)	0.480
Cerebrovascular disease	6 (11%)	13 (9.8%)	0.887
Malignancy	4 (7.0%)	17 (13%)	0.239
Cirrhosis	3 (5.3%)	14 (11%)	0.239
Site of infection			0.372
Pneumonia	16 (28%)	56 (42%)	
Urinary tract infection	6 (11%)	9 (6.8%)	
Intra-abdominal infection	12 (21%)	25 (19%)	
Skin and soft tissue infection	4 (7.0%)	3 (2.3%)	
Catheter-related infection	4 (7.0%)	6 (4.5%)	
Primary bacteremia	12 (21%)	24 (18%)	
Other	3 (5.3%)	9 (6.8%)	
Vital signs			
Temperature, °C	38.1 (1.4)	37.9 (1.8)	0.315
Heart rate, beats/minute	110 (96, 125)	110 (90, 130)	0.611
Respiratory rate, times/minute	26 (24, 34)	28 (24, 32)	0.528
Mean arterial blood pressure, mmHg	62 (56, 68)	60 (55, 66)	0.274
Central venous pressure, mmHg	13 (10, 18)	12 (9, 17)	0.329
Laboratory investigations			
White blood cell, cells/µL	13.2 (10.2, 18.7)	12.2 (3.9, 17.0)	0.042*
Hemoglobin, g/dL	9.4 (7.8, 11.0)	9.0 (7.6, 10.9)	0.308
Platelet, cells/µL	133 (69, 235)	123 (45, 196)	0.289
Blood urea nitrogen, mg/dL	45 (32, 58)	42 (28, 71)	0.999
Creatinine, mg/dL	3.92 (2.30, 5.76)	2.86 (1.99, 4.71)	0.038*
Sodium, mmol/L	136 (134, 139)	137 (133, 141)	0.534
Potassium, mmol/L	4.2 (3.7, 4.7)	4.2 (3.7, 4.9)	0.541
Chloride, mmol/L	97 (94, 102)	98 (93, 103)	0.629
Bicarbonate, mmol/L	13 (11, 19)	14 (9, 19)	0.694
Serum lactate, mmol/L	4.4 (2.5, 9.2)	5.2 (2.8, 11.2)	0.333
Albumin, g/dL	2.9 (0.6)	2.6 (0.7)	0.002*
Serum pH	7.34 (7.25, 7.39)	7.30 (7.19, 7.40)	0.314
Partial pressure of carbon dioxide, mmHg	26 (22, 33)	27 (20, 35)	0.754
Partial pressure of oxygen, mmHg	127 (75, 197)	122 (84, 173)	0.786

[1]Data are summarized in mean (SD), median (Q1, Q3), or n (%), as appropriate. For variables with missing data, summary data are based on available number
[2]Wilcoxon rank sum test; Pearson's Chi-squared test; Welch Two Sample t-test; Fisher's exact test
[3]Sequential Organ Failure Assessment (SOFA) score ranges from 0-24, with higher scores indicates greater organ failure and disease severity
[4]Acute Physiology and Chronic Health Evaluation II (APACHE II) score ranges from 0-71, with higher scores indicate greater organ failure and disease severity
*$p < 0.05$ when compared with survival to hospital discharge

TABLE 2. Detailed treatment strategies, compared between patients who survived to hospital discharge and patients who died in hospital.

Treatment	Survivors (57)[1]	Non-survivors (132)[1]	*p*[2]
Fluid resuscitation			
Crystalloid volume on day 1, mL	2,800 (1,700, 4,400)	3,190 (1,850, 5,260)	0.333
Crystalloid volume on day 2, mL	750 (100, 1,770)	450 (0, 1,920)	0.437
Crystalloid volume on day 3, mL	3,850 (2,500, 7,100)	5,040 (2,150, 8,755)	0.428
Total crystalloid in 72 hours, mL	7,520 (4,400, 12,900)	9,605 (4,300, 15,960)	0.360
Colloid volume on day 1, mL	400 (0, 1,250)	745 (50, 1,500)	0.109
Colloid volume on day 2, mL	0 (0, 346)	0 (0, 992)	0.087
Colloid volume on day 3, mL	0 (0, 250)	0 (0, 632)	0.042*
Total colloid in 72 hours, mL	840 (0, 2,020)	1,534 (548, 3,064)	0.005*
Human albumin solutions use	23 (40%)	82 (62%)	0.006*
Gelofusine use	1 (1.8%)	18 (14%)	0.013*
Packed red cell use	22 (39%)	73 (55%)	0.035*
Fresh frozen plasma use	27 (47%)	66 (50%)	0.740
Vasopressors use			
Norepinephrine	50 (88%)	118 (89%)	0.737
Epinephrine	17 (30%)	87 (66%)	<0.001*
Dobutamine	2 (3.5%)	1 (0.8%)	0.217
Dopamine	5 (8.8%)	2 (1.5%)	0.028*
Maximum vasopressor dose, mcg/kg/min[3]	0.12 (0.04, 0.36)	0.51 (0.14, 1.00)	<0.001*
Mechanical ventilator use	49 (86%)	128 (97%)	0.008*
Hydrocortisone use	41 (72%)	115 (87%)	0.012*
Indication for renal replacement therapy			0.255
Metabolic acidosis	30 (53%)	86 (65%)	
Volume overload	18 (32%)	25 (19%)	
Uremia	6 (11%)	12 (9.1%)	
Other	3 (5.3%)	9 (6.8%)	
Initial mode of renal replacement therapy			0.013*
Intermittent hemodialysis	10 (18%)	7 (5.3%)	
Sustained low-efficiency dialysis	9 (16%)	15 (11%)	
Continuous renal replacement therapy	38 (67%)	110 (83%)	

[1]Data are summarized in mean (SD), median (Q1, Q3), or n (%), as appropriate. For variables with missing data, summary data are based on available number

[2]Wilcoxon rank sum test; Pearson's Chi-squared test; Welch Two Sample t-test; Fisher's exact test

[3]The maximum vasopressor dose was defined as the highest cumulative vasopressor exposure (in mcg/kg/min) within 72 hours after AKI diagnosis, calculated as:

(Norepinephrine + Epinephrine + [Dopamine ÷ 100] + [Dobutamine ÷ 100])

where all doses were converted to norepinephrine-equivalent units.

*$p < 0.05$ when compared with survival to hospital discharge

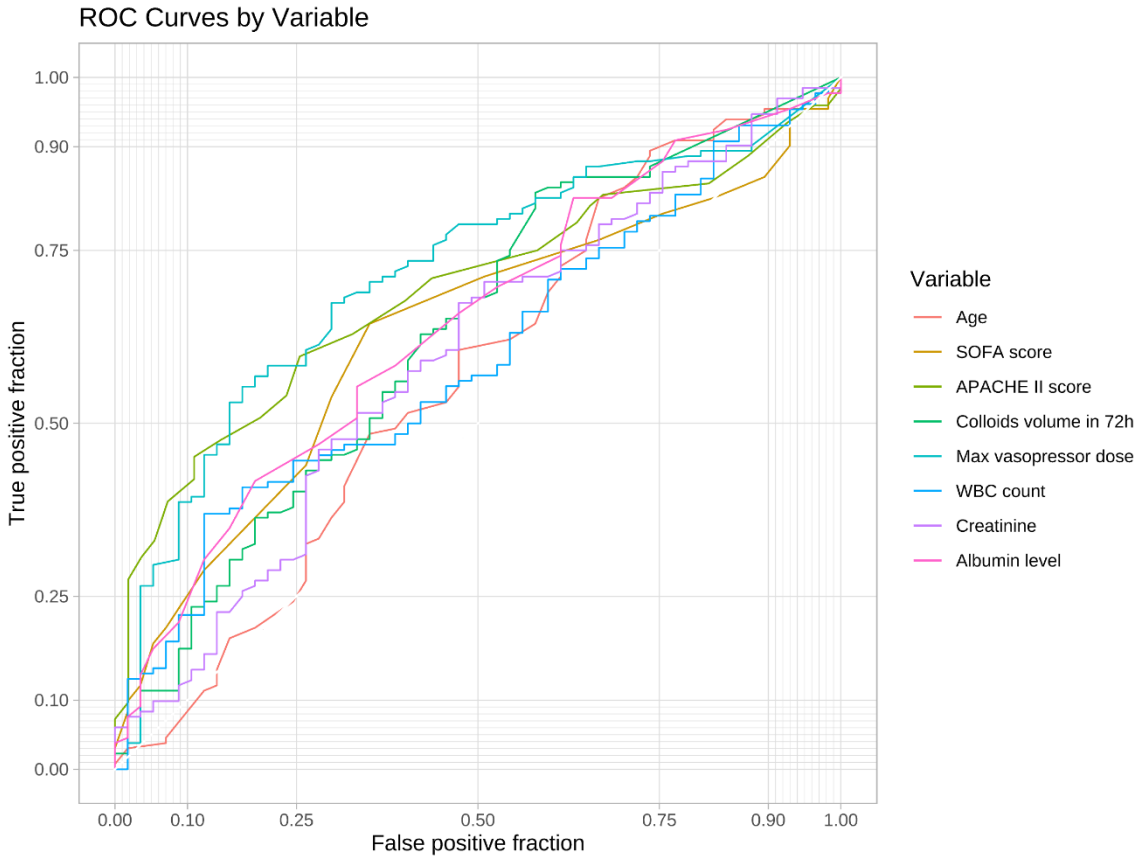


Fig 2. Receiver operating characteristic (ROC) curve analysis to identify the variable cutoff value predicting hospital mortality and table of area under the curve (AUC).

TABLE 3. Receiver operating characteristic (ROC) analysis to identify the cutoff values predicting hospital mortality and table of area under the curve (AUC). The *p* values are from tests comparing survivors and non-survivors.

Clinical Parameters	AUC (95% CI) [1]	Cutoff	*p* [2]
Age	0.567 (0.474 - 0.661)	60 years	0.215
SOFA	0.628 (0.545 - 0.711)	10	<0.001*
APACHE II	0.69 (0.613 - 0.768)	20	<0.001*
Total colloid in 72 hours	0.63 (0.542 - 0.718)	1,500 mL	0.078
Maximum vasopressor dose	0.714 (0.637 - 0.791)	0.3 mcg/kg/min	<0.001*
White blood cell	0.594 (0.508 - 0.679)	12 cell/μL	0.262
Creatinine	0.595 (0.506 - 0.685)	4 mg/dL	0.018*
Albumin	0.641 (0.557 - 0.725)	2.5 g/dL	0.027*

[1]Area Under the Receiver Operating Characteristic (ROC) Curve

[2]Pearson's Chi-squared test

TABLE 4. Univariate analyses and multivariate analyses to identify variables independently associated with hospital mortality in septic-acute kidney injury patients who required renal replacement therapy.

Clinical Parameters	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Age > 60 years	1.5 (0.78 - 2.86)	0.217	2.8 (1.27 - 6.38)	0.012*
SOFA score > 10	3.35 (1.76 - 6.5)	<0.001*	—	—
APACHE II score > 20	3.16 (1.64 - 6.16)	<0.001*	2.57 (1.23 - 5.42)	0.012*
Total colloid in 72 hours > 1,500 mL	1.77 (0.94 - 3.38)	0.08	—	—
Maximum vasopressor dose > 0.3 mcg/kg/min	4.07 (2.1 - 8.18)	<0.001*	4.26 (1.94 - 9.86)	<0.001*
WBC > 12 cell/μL	0.7 (0.37 - 1.31)	0.263	—	—
Creatinine > 4 mg/dL	0.47 (0.25 - 0.88)	0.019*	0.36 (0.17 - 0.75)	0.007*
Albumin > 2.5 g/dL	0.49 (0.25 - 0.92)	0.029*	—	—
Mechanical ventilator use	5.22 (1.57 - 20.31)	0.009*	—	—
Hydrocortisone use	2.64 (1.22 - 5.73)	0.013*	—	—
Continuous renal replacement therapy	1.97 (1.23 - 3.19)	0.005*	—	—

overloaded due to dilutional effect.[22] Having markedly positive cumulative fluid balance has been consistently demonstrated to be associated with worse outcomes in the intensive care units.[23] Thus, patients with lower serum creatinine at the time of RRT initiation could have poorer outcomes if the low levels were caused by dilution. Secondly, the use of serum creatinine to determine the glomerular filtration rate generally assumes a steady state.[20] In patients with acute kidney injury, measured serum creatinine may not reflect the real-time decline in kidney function[21]; elevation of serum creatinine may lag behind the deterioration up to 48-72 hours. Therefore, lower serum creatinine level at the time of RRT initiation may suggest rapidly worsening kidney function such that the abnormalities in electrolytes and acid-base statuses preceded the elevation of serum creatinine.[20] These patients would predictably have worse outcomes than patients with a more gradual progression of AKI.

The strength of our study is that this is a large retrospective cohort study in a specific population, which is sepsis-associated AKI who require RRT. Previous studies in Thailand and other countries all focused on acute kidney injury in critical settings or overall causes of AKI. Therefore, the predictors of mortality in this study are more specific in severe groups in sepsis-associated AKI (need RRT). In addition, we enrolled patients for a long period of time (2018-2020). The data we collected contained various parameters based on real treatment strategies for sepsis, which were more objective.

The limitations of this study should be mentioned. First, we did not collect and analyze the difference in timing of diagnosis of sepsis, AKI, and initiation of RRT, which could be predictors or confounding factors in mortality. Second, we did not follow long-term outcomes, such as 28-day or 90-day mortality, or incidence of long-term RRT. Future studies are needed to examine these outcomes. Third, the data from this study came from a single center which is a national tertiary referral center. As a result, the findings of this study might not be generalizable to other healthcare settings.

CONCLUSION

Among patients with sepsis, the mortality rate of patients who developed AKI requiring RRT is high. Older age, higher APACHE II scores, higher dose of vasopressor, and lower serum creatinine levels were also associated with higher hospital mortality.

Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due participant confidentiality, according to the REB, but are available from the corresponding author on reasonable request.

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Not applicable.

DECLARATIONS

Grants and Funding Information

No external funding was received for this study.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Registration Number of Clinical Trial

Not applicable.

Author Contributions

C.P.: Conceptualization, Methodology, Writing – Review & Editing, Supervision, Project Administration
N.W.: Methodology, Investigation, Data Curation, Formal Analysis, Validation, Writing – Original Draft, Writing – Review & Editing, Visualization
S.T.: Conceptualization, Methodology, Data Curation, Formal Analysis, Validation, Writing – Review & Editing, Supervision, Project Administration
M.K.: Methodology, Resources, Investigation, Data Curation, Formal Analysis, Validation, Writing – Original Draft, Writing – Review & Editing
T.N.: Conceptualization, Methodology, Resources, Investigation, Writing – Review & Editing

Use of Artificial Intelligence

Not applicable.

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