Factors Associated with Non-Recovery of Renal Function in Patients with Septic Acute Kidney Injury

Pongpon Suttiruk, Anan Chuasuwan

Division of Nephrology, Department of Medicine, Bhumibol Adulyadej Hospital, Royal Thai Air Force, Bangkok, Thailand.

Abstract

Background: Acute kidney injury (AKI) is a common complication in patients with infection and septicemia, contributing to increased mortality and longer hospital stays. However, factors predicting renal recovery in patients with septic AKI remain unclear. This study investigated biochemical factors associated with renal recovery in septic AKI patients.

Methods: This was a retrospective, single-center study of patients admitted with infection-associated AKI between January 1st, 2015, and December 31st, 2020. Patients were categorized into full recovery and non-recovery groups, and factors associated with non-recovery of renal function within 90 days were analyzed.

Results: A total of 4,431 patients with septic AKI were included in the final analysis. Of these, 2,429 patients (54.82%) were in the full recovery group, and 2,002 patients (45.18%) were in the non-recovery group. Independent predictors of non-recovery included older age, male gender, AKI severity, the need for dialysis and assisted ventilation, thrombocytopenia, elevated serum phosphorus and magnesium levels, and lower serum albumin. There was no association between underlying conditions or the degree of chronic kidney disease and renal outcomes.

Conclusions: Older age, male gender, infection and AKI severity, the need for dialysis, thrombocytopenia, and lower serum albumin were associated with non-recovery of renal function in patients with septic AKI.

Keywords: acute renal failure; renal failure; sepsis; ARF

Corresponding author: *Anan Chuasuwan*
Email: *chuasuwan.md@gmail.com*

Received: 15 September 2024; Revised: 20 October 2024; Accepted: 1 November 2024

ปัจจัยที่มีความสัมพันธ์กับการไม่ฟื้นตัวของไต ในผู้ป่วยภาวะไตวายเฉียบพลันจากภาวะติดเชื้อ

พงศ์พล สุทธิรักษ์ และ อนันต์ เชื้อสุวรรณ

หน่วยโรคไต กองอายุรกรรม โรงพยาบาลภูมิพลอดุลยเดช กรมแพทย์ทหารอากาศ

บทคัดย่อ

บทนำ: ภาวะไตวายเฉียบพลันที่มีสาเหตุมาจากการติดเชื้อหรือการติดเชื้อในกระแสเลือด เป็นภาวะแทรกซ้อนที่พบได้บ่อยในผู้ป่วยที่นอนในโรงพยาบาล ส่งผลต่ออัตราการตายที่เพิ่มขึ้นรวมไปถึงอัตราการครองเตียง ปัจจุบันมีการศึกษาจำนวนน้อยที่สนใจปัจจัยที่ส่งผลต่อการฟื้นตัวของไตหลังการเกิดภาวะไตวายเฉียบพลัน

ระเบียบวิธีวิจัย: การศึกษานี้เป็นการเก็บข้อมูลย้อนหลังของผู้ป่วยที่เข้ารับการรักษาในโรงพยาบาลด้วยภาวะไตวายเฉียบพลันที่มีสาเหตุมากจากการติดเชื้อ ระหว่างวันที่ 1 มกราคม พ.ศ. 2558 ถึงวันที่ 31 ธันวาคม พ.ศ. 2563 โดยผู้ป่วยจะได้รับการแบ่งออกเป็น 2 กลุ่ม คือ กลุ่มที่มีการฟื้นตัวของไตอย่างสมบูรณ์ และกลุ่มที่ไม่มีการฟื้นตัวของไต จากนั้นจะทำการวิเคราะห์ปัจจัยที่มีความสัมพันธ์กับการไม่ฟื้นตัวของไตภายในระยะเวลา 90 วัน

ผลการวิจัย: มีผู้ป่วยที่ผ่านเกณฑ์การคัดเข้าและออกทั้งหมดจำนวน 4431 คน ในจำนวนนี้ผู้ป่วย 2,429 ราย (ร้อยละ 54.82) มีการฟื้นตัวของไตอย่างสมบูรณ์ และ 2,002 ราย (ร้อยละ 45.18) ไม่มีการฟื้นตัวของไต จากการวิเคราะห์แบบพหุตัวแปร ปัจจัยที่พบว่ามีความสัมพันธ์กับการไม่ฟื้นตัวของไต ได้แก่ อายุที่เพิ่มขึ้น เพศชาย ความรุนแรงของภาวะไตวายเฉียบพลัน การได้รับการบำบัดทดแทนไต การใช้เครื่องช่วยหายใจ ภาวะเกร็ดเลือดต่ำ ระดับฟอสฟอรัส และ แมกนีเซียม ที่เพิ่มขึ้น และระดับอัลบูมินในเลือดที่ลดลง ทั้งนี้ไม่พบความสัมพันธ์ระหว่างโรคประจำตัว และความรุนแรงของโรคไตเรื้อรังกับผลลัพธ์ทางไต

สรุป: ปัจจัยที่มีความสัมพันธ์กับการไม่ฟื้นตัวของไตหลังการเกิดภาวะไตวายเฉียบพลันที่มีสาเหตุจากการติดเชื้อ ได้แก่ อายุที่เพิ่มขึ้น เพศชาย ความรุนแรงของไตวายเฉียบพลัน การได้รับการบำบัดทดแทนไต การใช้เครื่องช่วยหายใจ เกร็ดเลือดและระดับอัลบูมินในเลือดต่ำ

คำสำคัญ: ไตวาย; ไตบาดเจ็บ; ฟอกเลือด; ล้างไต; ติดเชื้อ; ผู้ป่วยใน

Introduction

Acute kidney injury (AKI) is one of the most common complications in patients admitted to the intensive care unit. Infection and sepsis account for 10–20% of AKI cases in the ICU and are associated with increased mortality rates and longer hospital stays compared to patients without AKI[1,2,3]. Consequently, many studies have focused on early diagnosis using various biological markers to facilitate timely management and prevention[4,5]. However, long-term outcomes, particularly renal recovery, which are equally important, have often been overlooked[6].

AKI and chronic kidney disease (CKD) are now understood to be interconnected. Several factors, categorized as risk factors and disease modifiers, have been studied in relation to renal recovery[7]. Recently, the term “acute kidney disease” was introduced to emphasize that renal recovery can be anticipated if certain reversible factors are identified.

Various working groups have proposed recovery patterns to characterize renal outcomes, which are di-

ผู้ประพันธ์บรรณกิจ: *อนันต์ เชื้อสุวรรณ*
อีเมล: *chuasuwan.md@gmail.com*

รับบทความ: 15 กันยายน 2567; ปรับปรุงแก้ไข: 20 ตุลาคม 2567; รับตีพิมพ์: 1 พฤศจิกายน 2567

vided into three categories: full recovery, partial recovery, and non-recovery[8]. These recovery patterns are not only associated with renal outcomes but are also linked to long-term mortality and cardiovascular risks, which indirectly affect overall patient outcomes[9-11].

While several studies have identified risk factors for renal recovery in cases with non-specific causes of AKI, little attention has been given to specific causes[12-16]. This study aims to highlight the factors, including risk factors and disease modifiers, associated with non-recovery of renal function in patients with septic AKI.

Methods

This retrospective, single-center cohort study was conducted at Bhumibol Adulyadej Hospital, Bangkok, Thailand. The study was approved by the hospital's Institutional Review Board. The Ethics Committee of Bhumibol Adulyadej Hospital determined that the project qualified for exemption, as it involved the use of medical records collected for non-research purposes (e.g., routine care or diagnosis), and the data collection was completely anonymous. As a result, the requirement for informed consent was waived.

Study population

Patients with septic AKI admitted between January 1, 2015, and December 31, 2020, were identified using electronic medical records. The inclusion criteria were as follows: 1) age ≥ 18 years; 2) a diagnosis of AKI based on the KDIGO 2012 criteria[5] which defines AKI as an increase in serum creatinine ≥ 0.3 mg/dL within 48 hours or ≥ 1.5 times the baseline, known or presumed to have occurred within the prior 7 days; and 3) the presence of infection, identified using ICD codes for conditions such as pneumonia (J09–J18), other lung infections (J85–J86), central nervous system infections (G00–G07), cardiovascular infections (I301, I300, I400), gastrointestinal and hepatobiliary infections (K35, K57, K61, K75, K81, K83), musculoskeletal infections (M00, M01, M462–M465, M600, M726), genitourinary infections (N10, N300, N390, N41), and sepsis/septic shock (R572, R65). The exclusion criteria were: 1) a history of end-stage kidney disease prior to the infection; 2) a presence of glomerulonephritis; 3) readmission with a history of previous AKI or recurrent AKI within 90 days; and 4) kidney transplant recipients.

Definitions

AKI was defined and staged according to the KDIGO 2012 criteria[5]. The lowest serum creatinine level within 7 days before the development of AKI was used as the baseline serum creatinine in this study. Patients without a recorded baseline serum creatinine were excluded. A previous study defined sepsis-associated AKI, or septic AKI, as a sudden deterioration in kidney function associated with a documented infection[17]. In this study, septic AKI was defined as the presence of AKI occurring concurrently with an infection.

The ATN trial categorized renal recovery into three groups: full recovery, partial recovery, and non-recovery[18]. However, in the present study, renal recovery was categorized into two groups, with partial recovery grouped under non-recovery. The full recovery group included patients whose serum creatinine returned to ≤ 0.5 mg/dL above baseline within 90 days of the first AKI event. The non-recovery group consisted of patients whose serum creatinine remained > 0.5 mg/dL above baseline.

Outcomes

The primary outcome of the study was predictors of non-recovery of renal function in patients with septic AKI.

Data collection

Biochemical parameters were obtained from electronic medical records. Baseline demographic data included age, sex, and underlying conditions such as diabetes mellitus, hypertension, ischemic heart disease, chronic heart failure or dilated cardiomyopathy, and cerebrovascular disease. Laboratory data included serum creatinine, estimated glomerular filtration rate (eGFR), electrolytes, albumin, total protein, calcium, phosphate, magnesium, and complete blood counts. The use of assisted ventilation, duration of assisted ventilation, and the type and duration of renal replacement therapy were also collected.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, while categorical variables were

expressed as count and percentage. The relationship between two continuous variables was analyzed using Pearson's correlation, and differences between two continuous variables were assessed using the Student's t-test. Differences between two categorical variables were analyzed using the chi-square test. To identify factors associated with renal recovery, univariate and multivariate logistic regression analyses were conducted. Statistical analyses were performed using STATA version 15.1 (Stata Corp., USA). A p-value of < 0.05 was considered statistically significant.

Results

A total of 10,724 cases of AKI were identified. Three hundred fifty-four patients were excluded due to a diagnosis of glomerulonephritis or kidney transplant status. Infection-associated AKI was identified in 4,708 patients. An additional 277 patients were excluded due to preexisting CKD stage 5, as defined by the KDIGO 2020 criteria[19]. In total, 4,431 patients were included in the final analyses. Of these, 2,429 patients (54.82%) were in the full recovery group, and 2,002 patients (45.18%) were in the non-recovery group (**Figure 1**). Demographic and laboratory data for all patients are shown in **Table 1**.

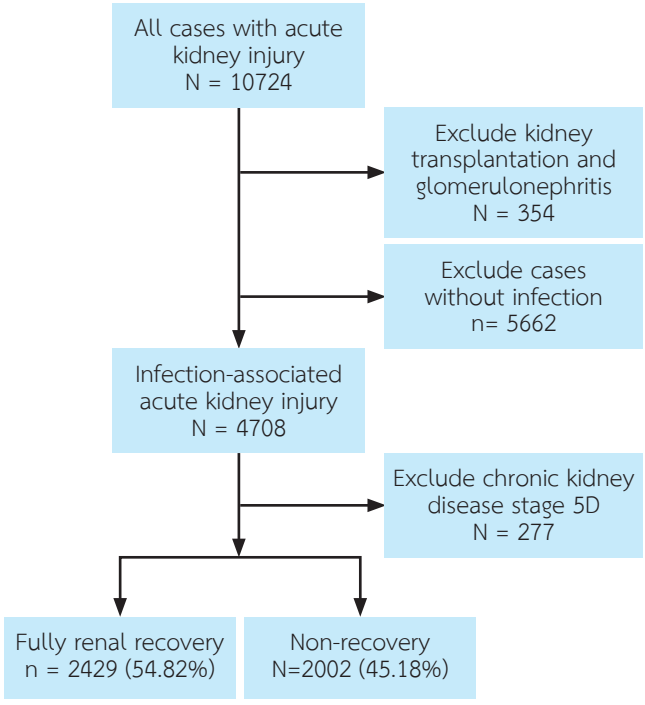

Figure 1 Study Flow Chart

Table 1 Demographic and laboratory data of all patients

Parameters	N=4,431
Male (N/%)	2,352 (53.08)
Age (years) (N/%)	66.61± 18.78
≤ 30	277 (6.25)
31-40	170 (3.84)
41-50	334 (7.54)
51-60	581 (13.11)
61-70	824 (18.6)
>70	2,245 (50.67)
Hypertension (N/%)	2,292 (51.13)
Diabetes Mellitus (N/%)	1,445 (32.61)
Cardiovascular disease (N/%)	3,567 (80.5)
eGFR (mL/min/1.73 m^2) (N/%)	
≥ 60	2,715 (61.27)
45 – 59	557 (12.57)
30 – 44	580 (13.09)
15 - 29	579 (13.07)
Acute kidney injury (N/%)	
Stage1	1,326 (29.93)
Stage2	798 (18.01)
Stage3	2,307 (52.06)
Acute hemodialysis (N/%)	
Intermittent hemodialysis	316 (7.13)
CRRT	243 (5.48)
Duration (days)	0.5 ± 1.87
Assisted Ventilation (hours) (N/%)	
≤ 96	657 (14.83)
> 96	2,630 (59.35)
Baseline laboratory data	
Hemoglobin (g/dL) (N/%)	10.28 ± 2.24
≥ 12	1,142 (25.77)
10-11	1,287 (29.05)
8-9	1,474 (33.27)
<8	528 (11.92)
Platelets (cells/μL)	229,000 ± 147.04
Platelets < 100,000 cells/μL (N/%)	735 (16.59)
Creatinine (mg/dL)	1.05 ± 0.67
eGFR (mL/min/1.73 m^2)	77.46 ± 41.82
Sodium (mmol/L)	137.68 ± 7.28
Potassium (mmol/L)	4.05 ± 0.76

Table 1 Demographic and laboratory data of all patients (continued)

Parameters	N=4,431
Chloride (mmol/L)	100.76 ± 7.94
Bicarbonate (mmol/L)	19.67 ± 5.87
Calcium (mg/dL)	8.27 ± 1.02
Phosphate (mg/dL)	3.94 ± 1.98
Magnesium (mg/dL)	2.13 ± 0.52
Total protein (g/dL)	6.1 ± 1.12
Albumin (g/dL)	2.65 ± 0.67

eGFR, estimated glomerular filtration rate; CRRT, continuous renal replacement therapy

Differences in biochemical parameters between the full recovery and non-recovery groups are shown in **Table 2**. The full recovery group had a lower proportion of male patients, older individuals, and those with CKD stage 3A or higher, thrombocytopenia, and anemia. Most patients in the full recovery group were in AKI stage 1 and were less likely to receive dialysis or assisted ventilation. Serum potassium, phosphate, and magnesium levels were lower, while serum bicarbonate, calcium, total protein, and albumin levels were higher in the full recovery group. There were no significant differences in the proportion of patients with diabetes, hypertension, or cardiovascular disease between the two groups.

Table 2 Demographic and laboratory data in full recovery vs. non-recovery groups

Parameters	Full Recovery N=2429	Non-Recovery N=2002	P-value
Male (N/%)	1,244 (51.21)	1,108 (55.34)	0.005
Age (years) (N/%)			< 0.001
≤ 30	199 (8.19)	78 (3.9)	
31-40	106 (4.36)	64 (3.2)	
41-50	178 (7.33)	156 (7.79)	
51-60	328 (13.5)	253 (12.64)	
61-70	462 (19.02)	362 (18.08)	
> 70	1,156 (47.59)	1,089 (54.4)	
Hypertension (N/%)	1,276 (52.53)	1,016 (50.75)	0.237
Diabetes Mellitus (N/%)	806 (33.18)	639 (31.92)	0.372
Cardiovascular Disease (N/%)	1,960 (80.69)	1,607 (80.27)	0.724
Chronic kidney disease (N/%)			0.001
Stage 2	1550 (63.81)	1,165 (58.19)	
Stage 3A	275 (11.32)	282 (14.09)	
Stage 3B	306 (12.6)	274 (13.69)	
Stage 4	298 (12.27)	281 (14.04)	
Acute dialysis (N/%)	179 (6.13)	380 (18.98)	< 0.001
Intermittent hemodialysis	101 (4.16)	215 (10.74)	

Table 2 Demographic and laboratory data in full recovery vs. non-recovery groups (continued)

Parameters	Full Recovery N=2429	Non-Recovery N=2002	P-value
CRRT	78 (3.21)	165 (8.24)	
Duration (days)	0.27 ± 1.30	0.78 ± 2.36	< 0.001
Assisted Ventilation (hours) (N/%)	1669 (68.71)	1618 (80.82)	< 0.001
≤ 96	322 (13.26)	335 (16.73)	
> 96	1,347 (55.45)	1,283 (64.09)	
Laboratory data			
Platelets < 100,000 cells/μL (N%)	316 (13.01)	419 (20.93)	< 0.001
Hemoglobin (g/dL) (N/%)			< 0.001
≥ 12	671 (27.62)	471 (23.53)	
10-11	761 (31.29)	527 (26.32)	
8-9	753 (31.00)	721 (36.01)	
< 8	245 (10.09)	283 (14.14)	
Acute kidney injury (N/%)			< 0.001
Stage 1	1,035 (42.61)	291 (14.54)	
Stage 2	392 (16.14)	406 (20.28)	
Stage 3	1,002 (41.25)	1,305 (65.18)	
Sodium (mmol/L)	137 ± 7	137.6 ± 7.6	0.56
Potassium (mmol/L)	4.0 ± 0.7	4.1 ± 0.8	< 0.001
Chloride (mmol/L)	100.5 ± 7.8	101.0 ± 8.1	0.07
Bicarbonate (mmol/L)	20.3 ± 5.8	18.8 ± 5.8	< 0.001
Calcium (mg/dL)	8.3 ± 0.9	8.1 ± 1.0	< 0.001
Phosphate (mg/dL)	3.7 ± 1.8	4.1 ± 2.1	< 0.001
Magnesium (mg/dL)	2.1 ± 0.5	2.2 ± 0.5	0.032
Total protein (g/dL)	6.3 ± 1.1	6.0 ± 1.1	< 0.001
Albumin (g/dL)	2.8 ± 0.7	2.5 ± 0.6	< 0.001

eGFR, estimated glomerular filtration rate; CRRT, continuous renal replacement therapy

Univariate and multivariate regression analyses are presented in **Table 3**. In the univariate analyses, factors associated with an increased risk of non-recovery included male gender, age over 40, the need for dialysis, longer duration of dialysis, the need for assisted ventilation, thrombocytopenia, worsening anemia, AKI stage 2 or higher, CKD stage 3A or higher, higher serum phosphate and magnesium levels, and lower serum albumin levels.

Underlying diseases, including hypertension, diabetes mellitus, cardiovascular disease, serum electrolytes and calcium, were not associated with the outcome. In the multivariate analysis, independent predictors of non-recovery included male gender, increasing age, the need for dialysis and assisted ventilation, thrombocytopenia, moderate to severe anemia (Hb <10 g/dL), higher AKI stages, elevated serum phosphate and magnesium levels, and lower serum albumin levels. A Forest plot of the odds ratios for predictors of non-recovery is shown in **Figure 2**.

Table 3 Univariate and multivariate logistic regression analyses of predictors for non-recovery of renal function

Parameters	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Male (vs. Female)	1.18 (1.04-1.32)	0.006	1.3 (1.1-1.53)	0.002
Age (10 years)			1.16 (1.1-1.23)	< 0.001
≤ 30 (reference)	1	-	-	-
31 - 40	1.54 (1.02-2.31)	0.037	-	-
41 - 50	2.23 (1.59-3.13)	< 0.001	-	-
51 - 60	1.96 (1.44-2.68)	< 0.001	-	-
61 - 70	1.99 (1.48-2.68)	< 0.001	-	-
> 70	2.40 (1.82-3.16)	< 0.001	-	-
Hypertension	0.93 (0.82-1.04)	0.237	-	-
Diabetes Mellitus	0.94 (0.83-1.07)	0.372	-	-
Cardiovascular disease	1.02 (0.88-1.19)	0.724	-	-
Dialysis (Yes vs. No)	2.94 (2.43-3.5)	< 0.001	1.60 (1.18-2.16)	0.003
CRRT (Yes vs. No)	0.99 (0.69-1.42)	0.973	-	-
Duration of dialysis (days)	1.19 (1.14-1.24)	< 0.001	1.03 (0.97-1.08)	0.338
Assisted ventilation				
Yes vs. No	1.91 (1.66-2.2)	< 0.001	1.51 (1.23-1.86)	< 0.001
> 96 hours (vs. ≤ 96 hours)	0.91 (0.77-1.08)	0.312	-	-
Thrombocytopenia (Yes vs. No)	1.76 (1.5-2.07)	< 0.001	1.44 (1.17-1.78)	0.001
Hemoglobin (g/dL)				
≥ 12 (reference)	1	-	-	-
10-11	0.98 (0.84-1.16)	0.883	-	-
8-9	1.36 (1.16-1.59)	< 0.001	-	-
< 8	1.64 (1.33-2.02)	< 0.001	-	-
≥ 10 (reference)	1	-	-	-
< 10	1.44 (1.28-1.62)	< 0.001	1.16 (0.98-1.36)	0.086
Stages of acute kidney injury			2.04 (1.85-2.25)	< 0.001
Stage 1 (reference)	1	-	-	-

Table 3 Univariate and multivariate logistic regression analyses of predictors for non-recovery of renal function (continued)

Parameters	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Stage 2	3.68 (3.04-4.45)	< 0.001	-	-
Stage 3	4.63 (3.97-5.4)	< 0.001	-	-
Stages of chronic kidney disease			0.95 (0.8-1.14)	0.608
Stage 2 (reference)	1	-	-	-
Stage 3A	1.36 (1.13-1.63)	0.001	-	-
Stage 3B	1.19 (0.99-1.42)	0.056	-	-
Stage 4	1.25 (1.04-1.5)	0.013	-	-
Blood Chemistry				
Sodium	1.00 (0.98-1.02)	0.809	-	-
Potassium	1.01 (0.89-1.13)	0.859	-	-
Chloride	0.99 (0.97-1.01)	0.699	-	-
Bicarbonate	0.98 (0.96-1)	0.072	-	-
Calcium	1.01 (0.92-1.11)	0.735	-	-
Phosphate	1.08 (1.03-1.13)	< 0.001	1.06 (1.02-1.11)	0.006
Magnesium	1.22 (1.03-1.45)	< 0.033	1.20 (1.03-1.42)	0.023
Albumin	0.53 (0.45-0.62)	< 0.001	0.56 (0.49-0.64)	< 0.001
Total Protein	0.98 (0.9-1.08)	0.797	-	-

CRRT, continuous renal replacement therapy

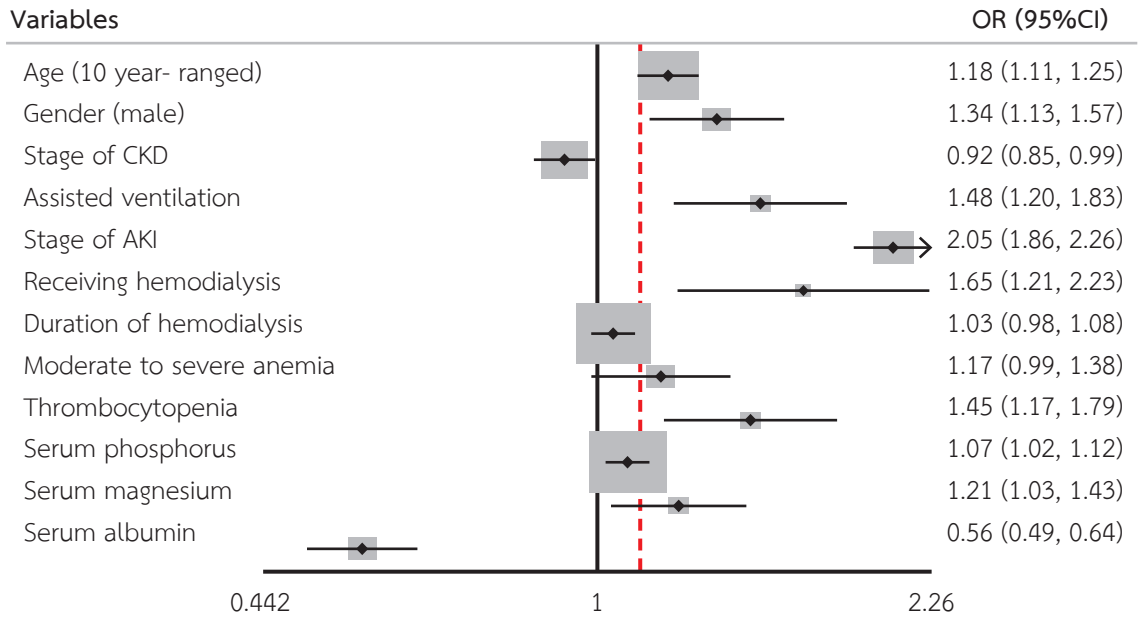

Figure 2 Forest plot of odds ratios for factors predicting non-recovery of renal function

Discussion

The main findings of the present study demonstrated that independent predictors of non-recovery of renal function in patients with septic AKI were male gender, increasing age, the need for dialysis and assisted ventilation, thrombocytopenia, higher AKI stages, elevated serum phosphate and magnesium levels, and lower serum albumin levels. Underlying conditions, including diabetes mellitus, hypertension, cardiovascular disease, and CKD stages, were not associated with the outcome.

The present study showed that increasing age raised the risk of non-recovery of renal function in patients with septic AKI. Similar findings have been reported in patients with non-infectious causes of AKI[12,14,20,21]. Decreased serum albumin, a traditional risk factor for predicting in-hospital mortality in both infectious and non-infectious causes, can also be used to predict non-recovery of renal function in septic AKI[22,23].

Parameters associated with infection severity, such as the need for assisted ventilation, were linked to an increased risk of non-recovery. Similarly, other studies have reported an association between higher APACHE II scores and the risk of non-recovery of renal function[12,14,16,20,23].

More advanced stages of AKI and the need for renal replacement therapy reflected the severity of kidney injury and significant organ failure[12,16,20,23,24]. The lack of an association between the duration of dialysis and non-recovery could result from the small number of patients that required dialysis. The associations between higher serum phosphate and magnesium levels with non-recovery were likely a result of the severity of AKI. Similarly, thrombocytopenia and anemia in the present study were likely consequences of infection severity and, therefore, predicted worse outcomes. These findings are consistent with those from the SEA-AKI study[16].

The association between male gender and non-recovery has never been reported previously. This may be explained by the link between male gender and increasing age in this study. Traditional underlying conditions, including CKD, diabetes mellitus, hypertension, and cardiovascular disease, were not associated with non-recovery in this study. While diabetes, hypertension, and cardiovascular disease have been shown to predict non-recovery of AKI from any cause[20], they did not predict renal outcomes in patients with septic AKI in this study, as well as in others[12,15]. It is plausible that the severity of the infection overshadowed any effects these underlying conditions might have caused. Previous research has shown that CKD is a risk factor for progression to end-stage kidney disease but not necessarily for renal recovery[12].

There are some limitations to this study. First, it is an observational retrospective cohort study that relies on diagnostic codes (ICD-9 and ICD-10). Certain variables influencing renal recovery, such as urine output and APACHE II scores, were not retrieved. Second, infection-associated AKI was defined by the presence of both infection and AKI at the same time; therefore, it did not preclude the possibility of other causes affecting AKI[17]. However, the large sample size likely mitigated this issue, allowing infection-associated AKI to be assumed in most patients. Finally, as this study was retrospective, there was no matching of parameters to prevent selection bias that could have influenced the outcomes. Nonetheless, a key strength of this study is the large sample size, which should have provided sufficient power to detect associations between each variable and renal recovery.

Conclusions

Aging, male gender, the severity of infection and AKI, and the need for dialysis were associated with non-recovery of renal function in patients with septic AKI.

References

1. Hoste EAJ, Bagshaw SM, Bellomo R, Cely CM, Colman R, Cruz DN, et al. Epidemiology of acute kidney injury in critically ill patients: the multinational AKI-EPI study. Intensive Care Med. 2015;41(8):1411–23.
2. Motzkus CA, Chrysanthopoulou SA, Luckmann R, Rincon TA, Lapane KL, Lilly CM. ICU Admission Source as a Predictor of Mortality for Patients With Sepsis. J Intensive Care Med. 2018;33(9):510–6.

3. Bagshaw SM, Uchino S, Bellomo R, Morimatsu H, Morgera S, Schetz M, et al. Septic Acute Kidney Injury in Critically Ill Patients: Clinical Characteristics and Outcomes. Clin J Am Soc Nephrol. 2007;2(3):431–9.
4. Palevsky PM, Molitoris BA, Okusa MD, Levin A, Waikar SS, Wald R, et al. Design of Clinical Trials in Acute Kidney Injury: Report from an NIDDK Workshop on Trial Methodology. Clin J Am Soc Nephrol. 2012;7(5):844–50.
5. Khwaja A. KDIGO Clinical Practice Guidelines for Acute Kidney Injury. Nephron. 2012;120(4):c179–84.
6. Goldstein SL, Chawla L, Ronco C, Kellum JA. Renal recovery. Crit Care. 2014;18(1):301. doi: 10.1186/cc13180.
7. Chawla LS, Eggers PW, Star RA, Kimmel PL. Acute Kidney Injury and Chronic Kidney Disease as Interconnected Syndromes. N Engl J Med. 2014;371(1):58–66.
8. Kellum JA. How Can We Define Recovery after Acute Kidney Injury? Considerations from Epidemiology and Clinical Trial Design. Nephron Clin Pract. 2014;127(1–4):81–8.
9. Hsu C, Hsu RK, Yang J, Ordonez JD, Zheng S, Go AS. Elevated BP after AKI. J Am Soc Nephrol. 2016;27(3):914–23.
10. Go AS, Hsu C, Yang J, Tan TC, Zheng S, Ordonez JD, et al. Acute Kidney Injury and Risk of Heart Failure and Atherosclerotic Events. Clin J Am Soc Nephrol. 2018;13(6):833–41.
11. Legrand M, Rossignol P. Cardiovascular Consequences of Acute Kidney Injury. Ingelfinger JR, editor. N Engl J Med. 2020;382(23):2238–47.
12. Fiorentino M, Tohme FA, Wang S, Murugan R, Angus DC, Kellum JA. Long-term survival in patients with septic acute kidney injury is strongly influenced by renal recovery. Ricci Z, editor. PLoS ONE. 2018;13(6):e0198269. doi: 10.1371/journal.pone.0198269.
13. Kellum JA, Chawla LS, Keener C, Singbartl K, Palevsky PM, Pike FL, et al. The Effects of Alternative Resuscitation Strategies on Acute Kidney Injury in Patients with Septic Shock. Am J Respir Crit Care Med. 2016;193(3):281–7.
14. Sood MM, Shafer LA, Ho J, Reslerova M, Martinka G, Keenan S, et al. Early reversible acute kidney injury is associated with improved survival in septic shock. J Crit Care. 2014;29(5):711–7.
15. Chen JCY, Hu B, Frank RD, Kashani KB. Inpatient Kidney Function Recovery among Septic Shock Patients Who Initiated Kidney Replacement Therapy in the Hospital. Nephron. 2020;144(8):363–71.
16. Sukmark T, Lumlertgul N, Praditpornsilpa K, Tungsanga K, Eiam-Ong S, Srisawat N. SEA-MAKE score as a tool for predicting major adverse kidney events in critically ill patients with acute kidney injury: results from the SEA-AKI study. Ann Intensive Care. 2020;10(1):42. doi: 10.1186/s13613-020-00657-9.
17. Alobaidi R, Basu RK, Goldstein SL, Bagshaw SM. Sepsis-Associated Acute Kidney Injury. Semin Nephrol. 2015;35(1):2–11.
18. Pannu N, James M, Hemmelgarn B, Klarenbach S, for the Alberta Kidney Disease Network. Association between AKI, Recovery of Renal Function, and Long-Term Outcomes after Hospital Discharge. Clin J Am Soc Nephrol. 2013;8(2):194–202.
19. de Boer IH, Caramori ML, Chan JCN, Heerspink HJL, Hurst C, Khunti K, et al. KDIGO 2020 Clinical Practice Guideline for Diabetes Management in Chronic Kidney Disease. Kidney Int. 2020;98(4):S1–115.
20. Kellum JA, Sileanu FE, Bihorac A, Hoste EAJ, Chawla LS. Recovery after Acute Kidney Injury. Am J Respir Crit Care Med. 2017;195(6):784–91.
21. Forni LG, Darmon M, Ostermann M, Oudemans-van Straaten HM, Pettilä V, Prowle JR, et al. Renal recovery after acute kidney injury. Intensive Care Med. 2017;43(6):855–66.
22. Herrmann FR. Serum Albumin Level on Admission as a Predictor of Death, Length of Stay, and Readmission. Arch Intern Med. 1992;152(1):125-30.
23. Lee C-W, Kou H, Chou H-S, Chou H, Huang S-F, Chang C-H, et al. A combination of SOFA score and biomarkers gives a better prediction of septic AKI and in-hospital mortality in critically ill surgical patients: a pilot study. World J Emerg Surg. 2018;13(1):41. doi: 10.1186/s13017-018-0202-5.