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Acute kidney injury in different time windows: a retrospective study of hospitalized elderly patients

Qinglin Li[a], Guanggang Li[b], Dawei Li[c], Yan Chen[d,*], Feihu Zhou[e,*]

Abstract

Background: To compare the differences between the Kidney Disease Improving Global Outcomes (KDIGO) criteria of the 48-hour window (early acute kidney injury [AKI], 3–5 day window [middle AKI], and 6–7 day window [late AKI]) in the diagnosis of AKI, as well as the relationship between the diagnosis time windows and 90-day mortality.

Methods: We conducted a retrospective cohort study. All elderly patients admitted to the Geriatric Department of the Chinese PLA General Hospital between 2007 and 2018 were evaluated for AKI during their hospital stay. Patients with AKI were divided into early, middle, and late AKI groups according to the time of diagnosis. Statistical analyses were performed using SPSS 21.0 statistical software. Continuous parametric variables are expressed as the means ± standard deviations (SDs), and continuous nonparametric variables are presented as the medians with interquartile ranges (25th and 75th percentiles). Categorical variables are presented as numbers (n) or percentages (%). Group comparisons were conducted using one-way analysis of variance or the Kruskal-Wallis *H* test for continuous variables and Pearson's chi-square or Fisher's exact test for categorical variables. Logistic regression analyses and a forward stepwise selection method were used to identify risk factors associated with AKI diagnosis time windows and 90-day mortality.

Results: During the follow-up period, 1847 patients were enrolled. Overall, 22.4% of the patients (413/1847) developed early AKI, 7.3% (134/1847) developed middle AKI, and 10.7% (197/1847) developed late AKI. Risk factors for early AKI included age, hypoalbuminemia, low prealbumin level, and the need for mechanical ventilation; middle AKI was significantly associated with age, low prealbumin, low hemoglobin, and the need for mechanical ventilation, whereas late AKI was closely associated with age, low baseline estimated glomerular filtration rate, low prealbumin, and low hemoglobin. In the multivariable-adjusted analysis, AKI time windows (early AKI, odds ratio [OR]: 6.069; $P < 0.001$; middle AKI, OR: 5.000; $P < 0.001$) and late AKI (OR: 2.847; $P < 0.001$) were more strongly associated with higher 90-day mortality than non-AKI.

Conclusion: Clinical differences and risk factors for AKI in elderly patients depend on the definition used. A better understanding of how AKI develops during different diagnostic windows may lead to improved outcomes.

Keywords: Acute kidney injury, Diagnosis time window, Early AKI, Late AKI, Risk factor

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Introduction

Acute kidney injury (AKI) is a common diagnosis that occurs in elderly patients, and is characterized by a sudden decline in renal function, from multiple causes.[1,2] An association between AKI and poor outcomes has been consistently shown in multiple patient populations.[3–5] Since 2004, there have been three main criteria used to define AKI: Risk, Injury, Failure, Loss, and End Stage Renal Disease (RIFLE),[6] Acute Kidney Injury Network (AKIN),[7] and Kidney Disease: Improving Global Outcome (KDIGO).[8] For example, with the use of the KDIGO guidelines, AKI was defined as an increase in serum creatinine (Scr) ≥0.3 mg/dL (26.5 μmol/L) within 2 days, or equivalent to a 50% rise in Scr within 7 days.[8] This creates a dilemma, where, for example, a patient whose Scr increases from 2.0 to 2.3 mg/dL within 2 days is viewed the same as a patient whose Scr increases from 2.0 to 3.0 mg/dL over a 3- to 5-day time window or from 2.0 to 3.0 mg/dL over a 6- to 7-day time window.[9]

A previous study examined AKI by adopting the KDIGO diagnostic criteria and showed that the clinical outcomes and risk factors for early AKI (occurring within the first 48 hours) were different from those of late AKI (occurring after 48 hours to 7 days) following major surgery.[10] The present study seeks to improve our understanding by evaluating the utility of separating the KDIGO AKI definition into 3 diagnostic windows based on Scr criteria: early AKI, an absolute increase in Scr of 0.3 mg/dL within 2 days; middle AKI, a 50% relative increase in Scr within 3 to 5 days; or late AKI, a 50% relative increase in Scr within 6 to 7 days.

Therefore, the aim of this study was to identify differences (including risk factors and prognosis) in different AKI timeframes in a single-center cohort of patients and to identify potentially modifiable risk factors that could be targeted in future studies.

Patients and methods

Study population

This was a retrospective cohort study. We analyzed the clinical data of 3861 patients admitted to the Geriatric Department of the Chinese PLA General Hospital in Beijing, China, from January 1, 2007, to December 31, 2018. We limited the current analysis to very elderly patients (≥75 years of age). All hospital admissions were screened, evaluated for AKI, and categorized according to the KDIGO criteria. Patients with AKI were divided into the early AKI group and the late AKI group. All participants were followed up for 90 days. The following patients were excluded: previously diagnosed chronic kidney disease (CKD), hospitalized for less than 48 hours, had fewer than two Scr measurements, and incomplete medical history.

This study was approved by the Ethics Committee of the Chinese PLA General Hospital (No. S2017-054-01, June 29, 2017). The requirement for written informed consent was waived because this was an observational, retrospective study. Patient information was anonymized and deidentified. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Definitions

Based on the AKI diagnosis time (ie, the time at which the AKI criteria were first met), we classified AKI manifesting within 48 hours as early AKI, AKI manifesting within 3–5 days as middle AKI, and AKI manifesting within 6–7 days as late AKI.[11] The baseline Scr was the value obtained in a stable state within 3 months of AKI onset.[12] The estimated glomerular filtration rate (eGFR) was determined using the 2009 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation.[13]

Data collection

General conditions (age, sex, and body mass index [BMI]), previous disease history, AKI diagnosis time, mechanical ventilation, mean arterial pressure, baseline Scr, eGFR, Scr at AKI diagnosis, peak Scr, blood urea nitrogen (BUN), uric acid, blood glucose, serum potassium, sodium, calcium, phosphate, magnesium, albumin, prealbumin, and hemoglobin were collected.

Statistical analysis

Statistical analyses were performed using SPSS software (version 21.0; SPSS Inc, Chicago, IL, USA). Continuous variables were expressed as the mean and standard deviation (SD) if normally distributed and as the median and interquartile range (IQR) if non-normally distributed. Categorical variables are presented as numbers (n) or percentages (%). Group comparisons were conducted using one-way analysis of variance or the Kruskal-Wallis *H* test for continuous variables and Pearson's chi-square or Fisher's exact test for categorical variables. Logistic regression analyses and a forward stepwise selection method were used to identify risk factors associated with AKI diagnosis time windows and 90-day mortality. Variables with $P < 0.05$ in the univariate logistic regression analysis were entered as independent variables in the multivariate logistic regression analysis. $P < 0.05$ was considered to be statistically significant.

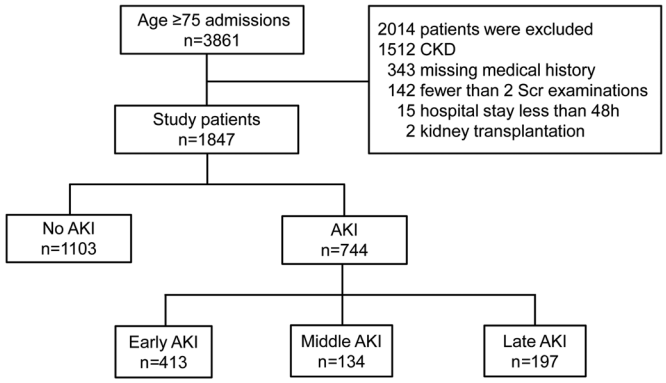

Figure 1. Flowchart of the inclusion and exclusion process of patients in this study. AKI, acute kidney injury; CKD, chronic kidney disease; Scr, serum creatinine.

Results

General characteristics of patients included in the study

In the period between 2007 and 2018, a total of 3861 very elderly patients (age, ≥75 years) were hospitalized at the Chinese PLA General Hospital National Clinical Research Center for Geriatric Diseases. Among these patients, 1512 were excluded due to CKD, 343 due to missing medical history, 142 due to having fewer than 2 Scr measurements, 15 due to hospital stay <48 hours, and 2 due to kidney transplantation, resulting in 1847 patients who were suitable for analysis. A flowchart of the study is shown in Fig. 1. The 1847 study patients had a median age of 83 (77–88) years, and most patients (1712, 92.7%) were male. Table 1 shows the main characteristics and outcomes of the included patients. The most common comorbid conditions were coronary disease (78.1%), hypertension (72.3%), chronic obstructive pulmonary disease (COPD) (62.8%), and diabetes mellitus (36.5%). According to our diagnostic criteria, 22.4% of the patients (413/1847) were diagnosed with early AKI, and AKI stage 3 (39.5%) was the most common followed by stage 1 (35.1%) and stage 2 (25.4%). Furthermore, 7.3% of patients (134/1847) were diagnosed with middle AKI, and AKI stage 1 (45.5%) was the most common followed by stage 2 (28.4%) and stage 3 (26.1%). Another 10.7% of patients (197/1847) were diagnosed with late AKI, and AKI stage 1 (59.4%) was the most common, followed by stage 2 (23.9%) and stage 3 (16.8%).

Characteristics associated with AKI and non-AKI

As shown in Table 1, significant differences were observed among the 4 groups in the following variables: age ($P < 0.001$), BMI ($P < 0.001$), COPD ($P < 0.001$), mechanical ventilation ($P < 0.001$), baseline Scr ($P < 0.001$), and baseline eGFR ($P < 0.001$). Indeed, Scr ($P < 0.001$) at the time of AKI diagnosis and peak Scr ($P < 0.001$) as well as BUN ($P < 0.001$), uric acid ($P < 0.001$), blood glucose ($P < 0.001$), potassium ($P < 0.001$), sodium ($P < 0.001$), calcium ($P < 0.001$), phosphate ($P < 0.001$), magnesium ($P < 0.001$), albumin ($P < 0.001$), prealbumin ($P < 0.001$), and hemoglobin ($P < 0.001$) differed significantly among the 4 groups. The all-cause 90-day mortality rate was 16.9%; the non-AKI group had a 4.8% mortality rate, whereas the AKI group had an average mortality rate of 34.9%.

Table 1

Characteristics of Patients With Early and Late AKI

Characteristics	Non–AKI Patients (n = 1103)	Early AKI (n = 413)	Middle AKI (n = 134)	Late AKI (n = 197)	P^a	P^b
Age (years)	79 (75–84)	87 (83–91)	88 (84–91)	88 (84–91)	<0.001	0.314
Male	1011 (91.7)	385 (93.2)	125 (93.3)	191 (97.0)	0.064	0.159
BMI (kg/m^2)	23.8 ± 3.2	22.9 ± 3.2	23.1 ± 3.1	23.0 ± 3.0	<0.001	0.878
Comorbidity						
Coronary disease	823 (74.6)	302 (73.1)	109 (81.3)	154 (78.2)	0.188	0.107
Hypertension	790 (71.6)	293 (70.9)	102 (76.1)	151 (76.6)	0.325	0.241
COPD	649 (58.8)	283 (68.5)	90 (67.2)	138 (70.1)	<0.001	0.852
Diabetes	392 (35.5)	164 (39.7)	56 (41.8)	63 (32.0)	0.131	0.113
Baseline Scr (μmol/L)	75.0 (62.0–84.0)	70.0 (57.0–80.0)	72.0 (60.0–81.3)	78.0 (68.0–86.0)	<0.001	<0.001
Baseline eGFR (mL/min/1.73 m^2)	81.9 (75.3–87.2)	80.7 (73.7–86.7)	79.0 (74.0–84.6)	76.3 (69.7–80.1)	<0.001	<0.001
Clinical conditions						
Oliguria	–	34 (8.2)	6 (4.5)	6 (3.0)	–	0.030
Mechanical ventilation	97 (8.8)	194 (47.0)	53 (39.6)	51 (25.9)	<0.001	<0.001
Laboratory parameters						
Scr (μmol/L)	84.0 (72.0–92.0)	128.0 (112.4–150.5)	126.0 (113.8–140.0)	130.0 (120.9–142.2)	<0.001	0.208
Peak Scr (μmol/L)	84.0 (72.0–92.0)	152.7 (123.5–232.0)	140.0 (125.7–183.0)	137.8 (123.9–175.0)	<0.001	0.018
BUN (mmol/L)	6.5 (5.6–8.1)	13.7 (9.3–22.0)	13.0 (8.8–21.0)	11.1 (8.6–17.7)	<0.001	0.008
Uric acid (mmol/L)	317.0 (254.3–380.6)	362.0 (292.8–461.0)	383.0 (283.3–506.3)	372.0 (285.0–461.0)	<0.001	0.214
Blood glucose (mmol/L)	5.9 (5.1–7.8)	8.1 (6.1–10.8)	7.5 (5.9–10.0)	6.4 (5.3–8.2)	<0.001	<0.001
Potassium (mmol/L)	4.0 (3.8–4.3)	4.2 (3.8–4.7)	4.1 (3.8–4.8)	4.1 (3.9–4.7)	<0.001	0.954
Sodium (mmol/L)	139.0 (136.0–143.0)	140.0 (135.0–147.0)	142.0 (137.0–149.0)	140.0 (136.0–145.0)	<0.001	0.058
Calcium (mmol/L)	2.2 (2.1–2.3)	2.2 (2.0–2.3)	2.2 (2.1–2.4)	2.3 (2.1–2.4)	<0.001	<0.001
Phosphate (mmol/L)	1.1 (1.0–1.2)	1.2 (0.9–1.4)	1.2 (1.0–1.4)	1.2 (1.0–1.4)	<0.001	0.350
Magnesium (mmol/L)	0.9 (0.8–1.0)	0.9 (0.8–1.0)	0.9 (0.8–1.0)	1.0 (0.8–1.1)	<0.001	<0.001
Albumin (g/L)	38.0 ± 4.4	33.4 ± 5.5	35.0 ± 5.5	35.8 ± 5.5	<0.001	<0.001
Prealbumin (g/L)	222.0 (213.0–269.0)	163.0 (126.0–210.0)	183.0 (140.0–242.0)	205.0 (159.0–266.0)	<0.001	<0.001
Hemoglobin (g/L)	125 ± 16	112 ± 23	107 ± 22	115 ± 21	<0.001	0.003
AKI stage					–	<0.001
1	–	145 (35.1)	61 (45.5)	117 (59.4)		
2	–	105 (25.4)	38 (28.4)	47 (23.9)		
3	–	163 (39.5)	35 (26.1)	33 (16.8)		
90-day mortality	53 (4.8)	173 (41.9)	48 (35.8)	39 (19.8)	<0.001	<0.001

Values are n (%), mean ± SD, or median (inter-quartile range).

AKI, acute kidney injury; BMI, body mass index; BUN, blood urea nitrogen; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; MAP, mean arterial pressure; Scr, serum creatinine.

[a]Overall *P* is for comparison among no AKI, early AKI, middle AKI, and late AKI.

[b]*P* is for comparison between early AKI, middle AKI, and late AKI.

Clinical characteristics associated with AKI diagnosis time windows

Table 1 also shows that baseline Scr ($P < 0.001$), baseline eGFR ($P < 0.001$), prevalence of mechanical ventilation ($P < 0.001$), and oliguria ($P = 0.030$) differed significantly among the three AKI groups.

In terms of laboratory findings, significant differences were observed in the following variables between the 3 groups at the time of AKI diagnosis: peak Scr ($P = 0.018$), BUN ($P = 0.008$), blood glucose ($P < 0.001$), calcium ($P < 0.001$), magnesium ($P < 0.001$), albumin ($P < 0.001$), prealbumin ($P < 0.001$), and hemoglobin ($P = 0.003$). Patients with early AKI exhibited stage 3 AKI more frequently ($P < 0.001$).

Factors associated with AKI diagnosis time windows

Multivariate logistic regression analysis revealed that early AKI was significantly associated with age (odds ratio [OR]: 1.182; 95% confidence interval [CI]: 1.148–1.217; $P < 0.001$), low albumin (OR: 0.916; 95% CI: 0.885–0.950; $P < 0.001$), low prealbumin (OR: 0.843; 95% CI: 0.815–0.873; $P < 0.001$), and a need for mechanical

Table 2

Risk Factors Associated With Different Diagnostic Windows AKI as Indicated by Logistic Regression

	Early AKI			Middle AKI			Late AKI		
Risk Factors	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Age	1.182	1.148–1.217	<0.001	1.244	1.190–1.300	<0.001	1.240	1.196–1.286	<0.001
Baseline eGFR	–	–	–	–	–	–	0.952	0.930–0.974	<0.001
Albumin	0.916	0.885–0.950	<0.001	–	–	–	–	–	–
Prealbumin	0.843	0.815–0.873	<0.001	0.907	0.867–0.949	<0.001	0.932	0.899–0.966	<0.001
Hemoglobin	–	–	–	0.959	0.946–0.973	<0.001	0.973	0.962–0.984	<0.001
Mechanical ventilation	3.879	2.689–5.595	<0.001	2.307	1.346–3.956	0.002	–	–	–

AKI, acute kidney injury; CI, confidence interval; eGFR, estimated glomerular filtration rate; OR, odds ratio.

ventilation (OR: 3.879; 95% CI: 2.689–5.595; $P < 0.001$; Table 2), whereas middle AKI was significantly associated with age (OR: 1.244; 95% CI: 1.190–1.300; $P < 0.001$), low prealbumin (OR: 0.907; 95% CI: 0.867–0.949; $P < 0.001$), low hemoglobin (OR: 0.959; 95% CI: 0.946–0.973; $P < 0.001$), a need for mechanical ventilation (OR: 2.307; 95% CI: 1.346–3.956; $P = 0.002$), and late AKI was significantly associated with age (OR: 1.240; 95% CI: 1.196–1.286; $P < 0.001$), low baseline eGFR (OR: 0.952; 95% CI: 0.930–0.974; $P < 0.001$), low prealbumin (OR: 0.932; 95% CI: 0.899–0.966; $P < 0.001$), and low hemoglobin (OR: 0.973; 95% CI: 0.962–0.984; $P < 0.001$; Table 2).

Influence of AKI on patient 90-day mortality

As shown in Table 1, the 90-day mortality rates were 41.9%, 35.8%, and 19.8% in patients with early, middle, and late AKI, respectively ($P < 0.001$). The multivariate analysis results showed that BMI (OR: 0.931; 95% CI: 0.887–0.977; $P = 0.003$), baseline eGFR (OR: 1.019; 95% CI: 1.003–1.035; $P = 0.021$), sodium (OR: 1.037; 95% CI: 1.019–1.055; $P < 0.001$), albumin (OR: 0.934; 95% CI: 0.901–0.967; $P < 0.001$), prealbumin (OR: 0.938; 95% CI: 0.911–0.966; $P < 0.001$), hemoglobin (OR: 0.990; 95% CI: 0.982–0.998; $P = 0.014$), and AKI time windows (early, OR: 6.069; 95% CI: 4.095–8.996; $P < 0.001$, middle, OR: 5.000; 95% CI: 2.989–8.365; $P < 0.001$, and late: OR: 2.847; 95% CI: 1.717–4.722; $P < 0.001$) were independent risk factors affecting 90-day mortality (Table 3).

Discussion

In this study, we demonstrated that AKI occurring within 48 hours and within 7 days was significantly different in terms of risk factors and outcomes. The results showed that the incidence of patients in the early AKI group compared with the middle and late AKI groups was 22.4%, 7.3%, and 10.7%, respectively. Overall, age, low baseline eGFR, low albumin, low prealbumin, low hemoglobin, and a need for mechanical ventilation are independent risk factors for AKI. AKI was an independent risk factor affecting the 3-month mortality of elderly patients.

AKI is a complex and severe kidney disease that has always been a search hotspot. Epidemiological research on AKI in China has made significant progress, including initial reports on the domestic incidence of AKI, geographical distribution, and risk factors; however, accompanying challenges such as AKI prevention and treatment have emerged.[14] Compared with the task of the "0 by 25" initiative, the status of AKI prevention and treatment in China is also very serious [14–17]: (1) clinicians pay little attention to AKI, the missed diagnosis rate is more than 75%, the rate of timely diagnosis is less than 20%, with substantial underdiagnosis and undertreatment; (2) the proportion of referral to a renal specialist of the patients with detected AKI is only 21%, and only 26.0% of the AKI patients saw a nephrologist within 90 days after AKI developed; (3) 68% of patients had not recovered their renal function when they were discharged, and this cohort of patients lacked follow-up nephrology care; and (4) more than half of patients were over 60 years old, with huge consumption of medical resources, but there are few studies on AKI in elderly individuals.

Table 3

Multivariable Logistic Models for Comparing Mortality Among AKI Diagnosed at Different Diagnostic Windows

Risk Factors	OR	95% CI	*P*
Body mass index	0.931	0.887–0.977	0.003
Baseline eGFR	1.019	1.003–1.035	0.021
Sodium	1.037	1.019–1.055	<0.001
Albumin	0.934	0.901–0.967	<0.001
Prealbumin	0.938	0.911–0.966	<0.001
Hemoglobin	0.990	0.982–0.998	0.014
AKI time windows			<0.001
Non–AKI	–	–	–
Early AKI	6.069	4.095–8.996	<0.001
Middle AKI	5.000	2.989–8.365	<0.001
Late AKI	2.847	1.717–4.722	<0.001

AKI, acute kidney injury; CI, confidence interval; eGFR, estimated glomerular filtration rate; OR, odds ratio.

The detection rate of AKI is largely based on the frequency of clinical detection of Scr. However, best practices for AKI, such as routine urinalysis and measurement of urine output, occur infrequently, and even repeat measurement of Scr throughout their hospital stay is not universal.[18] For early AKI, the time window of "abrupt decrease of renal function" is limited to 48 hours; therefore, in theory, only patients with more than two Scr measurements within a 48-hour period may be detected. This is very difficult in clinical practice.[19] For late AKI, the determination of baseline Scr values is important for diagnosis and staging. However, many patients did not have a baseline Scr recorded. In previous studies, the proportion of patients with ≥2 Scr tests during hospitalization in developed countries was 63.2%,[20] much higher than the figures reported in China (25%–30%).[14,21,22] Even among patients who had 2 Scr tests in 7 days, AKI was missed in 48% of patients.[21]

Our results showed that patients with early AKI differed from those with late AKI in terms of baseline characteristics and prognosis. Importantly, the differences in risk factors for early and late AKI allow us to speculate that they are in fact different phenotypes and that interventions developed for one may not be effective for the other. Furthermore, the present method for detecting AKI is largely based on laboratory measurements, and the frequency of Scr testing has a substantial impact on the detection rate. In a study by Yang et al., the detection rate of AKI (KDIGO criteria) in hospitalized adult patients in China was 0.99%. After adjusting for the frequency of Scr tests, the incidence of AKI increased to 11.6%.[14] Thus, early detection of AKI is also dependent on how often Scr is measured.

Although the concepts of early AKI or late AKI have been discussed previously in acute myocardial infarction, burns, and intensive care unit (ICU) patients, definitions and time boundaries vary among these studies. Moriyama et al. published a prospective study involving 760 patients with acute myocardial infarction and AKI using the AKIN criteria. The time boundary between early and late AKI was 48 hours after hospital admission. They reported that early AKI was an independent predictor of in-hospital mortality.[23] In a retrospective cohort study, Mosier et al. examined 221 adult burns patients, and early AKI was defined as AKI (RIFLE criteria) developed within 24 hours post hospital admission. The authors also found that patients with early AKI had higher mortality (36%) than those without AKI (13%).[24] Similarly, Li et al. retrospectively analyzed 3,499 patients who were admitted to the ICU following noncardiac major surgery, and early AKI was defined as AKI that developed within 48 hours or late AKI that developed within 48 hours to 7 days following surgery. In this study, 41.7% of patients had early AKI and 14.4% of patients had late AKI. Early AKI was associated with age, BMI, decreased eGFR, and anemia, whereas late AKI was related to postoperative complications such as sepsis, mechanical ventilation, positive fluid balance, blood transfusions, or drugs. The authors also found that both early AKI and late AKI were associated with higher 1-year mortality compared with patients without AKI.[10]

What factors contribute to AKI development? Multiple factors predispose elderly individuals to AKI. With advanced age, comorbidities, including hypertension, diabetes mellitus, and heart failure, can damage renal vasculature and compromise renal perfusion.

Comorbidities are often associated with the use of medications (such as angiotensin-converting enzyme inhibitors or angiotensin receptor blockers) that potentially increase the risk of AKI. However, nontraditional risk factors, particularly laboratory indicators, are often overlooked. In our study, we demonstrated that age and prealbumin were risk factors associated with early, middle, and late AKI. In contrast, albumin was only associated with early AKI, whereas baseline eGFR was associated with late AKI. Aging is associated with a decline in organ function and the emergence of chronic diseases resulting from accumulated damage to vulnerable organ systems. These changes make elderly patients more susceptible to malnutrition, with lower serum albumin and prealbumin. In addition, chronic diseases and comorbidities are prominent in elderly individuals, and multidrug combination therapy is required.

The results of this study showed that the 90-day survival was worse in patients with early AKI than in those with middle and late AKI. There are several possible explanations for this finding. First, AKI lacks a specific and effective treatment, as prevention may be more important than treatment. A randomized controlled study reported that increasing the diagnostic rate of AKI by using an electronic alert system did not show any meaningful benefit, which also supports our results. Second, early AKI does not mean that renal injury is at an early stage, as increased Scr alone is a relatively late, highly confounded, nonspecific biomarker of kidney function.[25] It may take as long as 72 hours postinjury to detect an increase in Scr, which can also lead to a delayed diagnosis, especially in the elderly population. When elderly patients meet the AKI diagnostic criteria, they may have entered the end-stage of renal failure based on histopathological findings, and may have missed the treatment window to improve outcomes.

Limitations

This study has some limitations. First, the elderly patients were recruited from a general ward. Although elderly patients are prone to developing severe AKI, they are not admitted to the ICU, and the risk factors for AKI in the general ward are different from those in the ICU. Second, our patient population consisted primarily of elderly men. Consequently, biased results were inevitable. Third, in the clinical work of the general ward, urine volume measurements were not performed, and the diagnostic criteria for AKI were based only on Scr. This may lead to a missed diagnosis of AKI, to a certain extent. Fourth, factors affecting the prognosis of AKI are complex, especially in an elderly cohort with a mean age of nearly 88 years. They had several underlying diseases and poor overall health. Therefore, many combined factors may affect the accuracy of the prognostic analysis.

Conclusion

The diagnosis time window of AKI in geriatric patients is independently associated with mortality and may provide prognostic information in addition to that provided by the magnitude of Scr alone. Early AKI was significantly different from middle- and late-stage AKI in terms of baseline characteristics, risk factors, and short-term outcomes.

Conflict of interest statement

The authors declare no conflict of interest.

Author contributions

Li Q contributed to conceptualization, data curation, formal analysis, methodology, and drafting of the initial manuscript. Li G contributed to software and methodology. Li D contributed to data collection and data management. Chen Y participated in investigation, project administration, and funding acquisition. Zhou F contributed to supervision, validation, and review and editing.

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Ethical approval of studies and informed consent

This study followed the principles of the Declaration of Helsinki as revised in 2013. This study was approved by the Ethics Committee of the Chinese PLA General Hospital (No. S2017-054-01, June 29, 2017). The requirement for written informed consent was waived by the ethics committee of the designated hospital because this was an observational, retrospective, and anonymous study. The data in this study does not involve issues related to patients' cognitive impairment.

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