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RESEARCH ARTICLE

Risk factors of prognosis after acute kidney injury in hospitalized patients

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Abstract **The risk factors, especially laboratory indicators, of prognosis after acute kidney injury (AKI) remain unclear. We conducted a retrospective survey of Chinese People's Liberation Army General Hospital from January 1, 2012 to December 31, 2012 according to the AKI diagnosis standard issued by Kidney Disease Improving Global Outcomes. The epidemiological features and factors influencing hospital mortality and renal function recovery were evaluated through logistic regression analysis. Among 77 662 cases of hospitalized patients, 1387 suffered from AKI. The incidence rate and mortality of AKI were 1.79% and 14.56%, respectively. Multivariate logistic regression analysis revealed that high AKI stage, age greater than 80 years, neoplastic disease, low cardiac output, increased white blood cell count, and decreased platelet count and serum albumin levels were the risk factors affecting the mortality of AKI patients. Conversely, body mass index between 28 and 34.9 was a protective factor. Increased AKI stage, tumor disease, post-cardiopulmonary resuscitation, and RRT were the risk factors of renal function recovery upon discharge. In addition to traditional risk factors, white blood cell count, platelet count, albumin, and BMI were the predictors of the mortality of AKI patients. No laboratory indicators were found to be the risk factors of renal function recovery in AKI patients.**

Keywords acute kidney injury; risk factors; prognosis

Introduction

Acute kidney injury (AKI) is a set of clinical syndromes, including the entire spectrum of diseases exhibiting slight functional changes and requiring renal replacement therapy [1]. AKI is prevalent worldwide [2]. Its morbidity and mortality are high, and a mild decline in renal function negatively influences short- and long-term prognosis [3,4]. For instance, the risks of chronic kidney disease (CKD) and end-stage renal disease (ESRD) increase by 8- and 3-fold, respectively [5,6]. AKI largely contributes to economic burden, but effective treatments for AKI have yet to be developed. However, AKI is potentially reversible and its outcomes can be improved with early detection and treatment. Therefore, the risk factors influencing prognosis should be fully understood. Studies have mostly focused on traditional risk factors including age, underlying diseases (e.g., hypertension and CKD), and injury factors [6], but laboratory indicators have been rarely considered. Therefore, we conducted a large population-based study on AKI in accordance with Kidney Disease: Improving Global Outcomes (KDIGO) guidelines. We collected detailed information to investigate the risk factors, especially laboratory indicators and various exposure, influencing the in-hospital prognosis of AKI patients.

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Materials and methods

Subjects

This retrospective and observational study on AKI was performed at the People's Liberation Army (PLA) General Hospital, in Beijing, China. Patients aged over 12 years were screened from January 1, 2012 to December 31, 2012 for AKI in accordance with the KDIGO Clinical Practice Guideline for AKI released in March 2012. The

patients who satisfied the diagnostic criteria of KDIGO, stayed in the hospital for more than 24 h, and underwent initial diagnosis and original treatment were included. The patients with maintenance hemodialysis, CKD stage 5, kidney transplantation, or nephrectomy were excluded.

Survey design

The survey for AKI was divided into three steps. First, the characteristics of inpatients (age ⩾ 12 years) who were admitted to the PLA General Hospital in 2012 were obtained from the hospital's computer network system. The patients with suspected AKI were screened, based on the changes in their serum creatinine (SCr) reported by the HIS System, which is a computer application system that can provide Patient Care Information. The patients who did not satisfy the screening criteria were excluded on the basis of discharge records. Second, the hospital medical records of the patients with suspected AKI were further verified through case analysis to confirm the diagnosis. In this stage, the patients who did not satisfy the criteria for screening were excluded. Third, the following medical records of the patients who were confirmed to have AKI by our survey or the patients with detected AKI were collected: demographic data, diagnosis and underlying diseases, laboratory examinations, inclusion criteria, AKI classification, injury factors, etiology, Acute Physiology and Chronic Health Evaluation II (APACHE II) results, Sequential Organ Failure Assessment (SOFA) results, and estimated glomerular filtration rate (eGFR, based on the Modification of Diet in Renal Disease [MDRD] formula) and therapeutic regimen. APACHE II and SOFA scores were calculated on the basis of clinical indicators within 24 h of AKI diagnosis. To facilitate further statistical analysis, these data were then inputted into an online database system of AKI epidemiology (http://pd.cnrds.net:6780/aki/user.do?action = firstpage) established by computer professionals in accordance with the case report form.

Diagnostic criteria and related definition

Diagnosis and classification of AKI

AKI was defined as an increase in SCr by 26.5 μmol/L (0.3 mg/dl) within 48 h or a 50% increase in SCr from the baseline, which is known or presumed to have occurred within 7 days according to the KDIGO criteria. The staging of AKI is shown in Table 1. For patients receiving renal replacement therapy (RRT), SCr was taken before replacement. The earliest SCr change that satisfied the KDIGO criteria was defined as the SCr of AKI onset. The highest SCr was defined as the peak SCr.

Determination of underlying diseases

Underlying diseases were determined according to the codes of diagnosis of the International Classification of Diseases (ICD)-10 upon admission. CKD was defined as kidney damage caused by various factors or was indicated by the highest eGFR of 60 ml/(min·1.73 m^2) for more than 3 months [9].

Definition of related causes

AKI secondary to surgery was defined by a change in SCr, which was compared with the preoperative measurement upon admission to the hospital, during the first 7 days after surgery and the need for RRT [10]. This AKI is caused by renal ischemia-reperfusion injury because of an operation, and this condition was diagnosed according to the judgment of attending clinicians. A decreased cardiac output was defined as any structure or functional cardiac diseases, such as myocardial infarction, congestive heart failure, severe arrhythmia, and cardiac tamponade, causing impaired ventricular filling and/or ejection capacity yielding a cardiac index of < 2.2 L/(min·m^2) [11]. According to the judgment of clinicians [12], systemic vascular dilatation was defined as systemic arteriolar or

Table 1 Staging of AKI

Stage	Serum creatinine	Urine output[a]
1	1.5−1.9 times baseline[b] or⩾0.3 mg/dl (⩾26.5 μmol/L) increase	<0.5 ml/(kg·h) for 6−12h
2	2.0−2.9 times baseline	<0.5 ml/(kg·h) for⩾12 h
3	3.0 times baseline or increase in serum creatinine to⩾4.0 mg/dl (⩾353.6 μmol/L) or decrease in eGFR to <35 ml/(min·1.73 m^2) in patients <18 years	<0.3 ml/(kg·h) for⩾24 h or anuria for⩾12 h

[a]For patients without a urinary catheter, we modified the standard: 24 h urine volume was determined in the nursing record to calculate the average per hour urine volume per kilogram. If the urine volume decreased, the duration was identified; otherwise, the urine standard was not reached. [b]Baseline SCr was the lowest creatinine level that could be obtained from the patients in our hospital before they were admitted within the last 6 months (15.9%) [7], and kidney function had no progression with clinical evaluation; otherwise, the lowest SCr during hospitalization (82.3%) was chosen. If data were still unavailable, it could be estimated by using the MDRD equation, assuming that the baseline eGFR is 75 ml/(min·1.73 m^2) (1.7%) [8].

capillary expansion that induced the low perfusion of the renal artery because of sepsis, hepatic failure, allergic reaction, hypotensive drugs, or other causes. Drug-related AKI [13] was diagnosed as follows: the renal biopsy was diagnosed with drug-related; nephrotoxic agents administered for at least 3 days prior to AKI and/or detection of high plasma levels of these agents, causing renal hypoperfusion, interstitial nephritis, renal tubular necrosis, and other conditions. Infection-related AKI [13] was categorized as renal parenchymal infection and systemic infection. The diagnosis of the latter required at least one of the following conditions: documented bacteremia, a known focus of infection, or immune suppression with neutropenia. The latter was also diagnosed when at least two of the following clinical criteria were documented at the same time: rigors, abrupt increase in temperature to more than 38 °C, unexplained blood white cell count of more than 15×10^9/L, or unexplained sudden decrease in blood pressure. Histological confirmation was required in glomerular AKI [13]. Urethral obstruction-associated AKI was described as the acute urinary tract obstruction of various etiologies, such as stones, tumors, and prostatic hyperplasia, without cortical atrophy [14].

Definition of injury factors before AKI occurred

According to the clinician's judgment, hypovolemia was diagnosed as the decline of effective blood volume because of various factors, including massive hemorrhage and nephrotic syndrome, such that the blood volume was insufficient to maintain normal blood and oxygen supplies to tissue. Systolic blood pressure was lower than 90 mmHg for 1 h [8]. Low cardiac output was defined by the following symptoms: inadequate systolic function, hypotension, and signs of tissue hypoxia [8]. Post-cardiopulmonary resuscitation (CPR) was diagnosed according to the following factors: hemodynamic collapse and loss of autonomic circulation and pulse; need for CPR; and defibrillation or epinephrine administration but remained alive for more than 24 h [8]. Creatine kinase $>$ 5000 U/L or myoglobin $>$ 5000 μg/L was regarded as rhabdomyolysis [8]. The transfusion of more than ten red blood cell units within 72 h was considered massive transfusion [8].

Definition of prognosis

The primary outcome of AKI was in-hospital mortality, and the secondary outcome was the status of renal function which was divided into recovery and nonrecovery, at discharge. We considered an AKI case to have renal recovery for survival if the SCr at discharge was decreased to a level within 1.5 times the baseline in the absence of RRT; otherwise, a nonrecovery was defined [7].

Statistical analysis

The characteristics of the patients with AKI were determined and stratified in terms of survival status at discharge. The continuous data of normal distribution were shown as mean ± SD, and two groups were compared with *t*-tests. Continuous variables with an abnormal distribution were reported as median (Q_U, Q_L) and analyzed using Wilcoxon rank sum test. Categorical variables were shown as *n* (%), and χ^2 test or Mann−Whitney U test was used as appropriate. The cumulative rates of the in-hospital survival of different AKI stages were presented with Kaplan−Meier plot. Univariate logistic regression analysis was performed to evaluate whether age, gender, AKI stage, body mass index (BMI), underlying diseases, exposures, laboratory examination, or RRT affected the short-term outcome. If *P*-value was < 0.05, additional multivariate logistic regression analysis was conducted to estimate odds ratios (ORs).

Data were statistically analyzed with SPSS 17.0 (SPSS Inc., Chicago, Illinois, USA). *P*-values were two sided, and a $P < 0.05$ was considered significant.

Results

Demographic and clinical characteristics of hospitalized AKI patients

In 2012, 77 662 patients (age ⩾ 12 years) were treated in the Chinese PLA General Hospital. Of these patients, 1758 were suspected to have AKI. Medical records were reviewed, and 371 patients were excluded. The final cohort consisted of 1387 patients (Fig. 1), and the calculated overall detection rate of AKI was 1.79%. The age of more than 70% of the patients diagnosed with AKI was between 40 and 79 years (Table 2). The male-to-female ratio was 2.26:1. Nearly 50% of the patients in the final cohort reached stage 1. Furthermore, 55.0%, 41.4%, and 3.6% of the causes were pre-renal, renal parenchymal, and post-renal. Surgery, nephrotoxic drug use, and reduced cardiac output were the three most common causes of AKI (Table 3). The most common underlying disease was hypertension (661, 47.7%), followed by malignancy (408, 29.4%), coronary heart disease (397, 28.6%), diabetes (328, 23.7%), and pre-existing CKD (260, 18.8%). Among the injury factors that might be involved in AKI development, infection, antibiotics, and diuretics were the three most common. Of these AKI patients, 11.6% received RRT. Of the 1387 patients, 166 (12%) were diagnosed with AKI by their attending physicians during their hospital stay. The

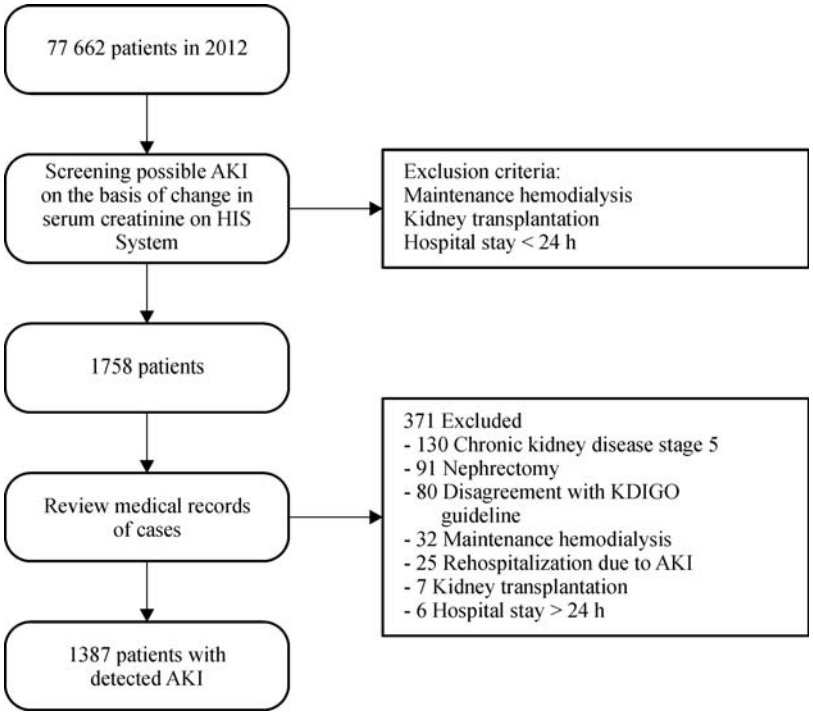

Fig. 1 Study profile AKI: acute kidney injury.

Table 2 Characteristics of patients with AKI according to survival condition

	Survival condition at discharge		Total (n = 1387)	P value
	Survival (n = 1185)	Death (n = 202)		
Age (year)	61 (48,73)	74 (59,82)	63 (49,74)	<0.001[a]
Age group				<0.001[a]
12–19 years	32 (2.7%)	2 (1.0%)	34 (2.5%)	
20–39 years	142 (12.0%)	13 (6.4%)	155 (11.2%)	
40–59 years	387 (32.7%)	40 (19.8%)	427 (30.8%)	
60–79 years	505 (42.6%)	74 (36.6%)	579 (41.7%)	
⩾80 years	119 (10.0%)	73 (36.1%)	192 (13.8%)	
Men	814 (68.7%)	148 (73.3%)	962 (69.4%)	0.192
AKI stage				<0.001[a]
1	618 (52.2%)	51 (25.3%)	669 (48.2%)	
2	283 (23.9%)	48 (23.8%)	331 (23.9%)	
3	284 (24.0%)	103 (51.0%)	387 (27.9%)	
BMI	24.3±4.2	22.3±4.0	24.0±4.2	<0.001[a]
<18.5	80 (6.8%)	33 (16.9%)	113 (8.2%)	
18.5–23.9	493 (41.9%)	97 (49.7%)	590 (43.0%)	
24–27.9	407 (34.6%)	53 (27.2%)	460 (33.6%)	
28–34.9	183 (15.6%)	11 (5.6%)	194 (14.2%)	
⩾35	13 (1.1%)	1 (0.5%)	14 (1.0%)	
AKI classification				0.151
Pre-renal	641 (54.1%)	122 (60.4%)	763 (55.0%)	
Intrinsic-renal	498 (42.0%)	76 (37.6%)	574 (41.4%)	
Post-renal	46 (3.9%)	4 (2.0%)	50 (3.6%)	
Underlying disease				
Hypertension	550 (46.4%)	111 (55.0%)	661 (47.7%)	0.025[a]
Malignancy	326 (27.5%)	82 (40.6%)	408 (29.4%)	<0.001[a]

(*Continued*)

	Survival condition at discharge		Total (n = 1387)	P value
	Survival (n = 1185)	Death (n = 202)		
CHD	317 (26.8%)	80 (39.6%)	397 (28.6%)	<0.001[a]
Diabetes	276 (23.3%)	52 (25.7%)	328 (23.7%)	0.449
CKD	222 (18.7%)	38 (18.8%)	260 (18.8%)	0.979
Cirrhosis	55 (4.6%)	8 (4.0%)	63 (4.5%)	0.667
MODS	41 (3.5%)	15 (7.4%)	56 (4.0%)	0.008[a]
COPD	32 (2.7%)	14 (6.9%)	46 (3.3%)	0.002[a]
Sepsis	22 (1.9%)	8 (4.0%)	30 (2.2%)	0.101
Number[b]	1 (0,1)	2 (1,2)	2 (1,2)	<0.001[a]
Injury factors				
Infection	690 (58.2%)	155 (76.7%)	845 (60.9%)	<0.001[a]
Antibiotics	683 (57.6%)	124 (61.4%)	807 (58.2%)	0.318
Diuretics	539 (45.5%)	120 (59.4%)	659 (47.5%)	<0.001[a]
Colloid infusion	439 (37.1%)	86 (42.6%)	525 (37.9%)	0.134
NSAID	305 (23.9%)	51 (25.1%)	356 (24.1%)	0.089
Low cardiac output	151 (12.7%)	53 (26.2%)	204 (14.7%)	<0.001[a]
Post-CPR	26 (2.2%)	8 (4.0%)	34 (2.5%)	0.210
Number[b]	3 (1,5)	4 (2,5)	3 (1,5)	0.139
APACHE II	10.6±6.0	19.5±8.9	11.9±7.2	<0.001[a]
SOFA	4 (2,7)	9 (5,14)	4 (2,8)	<0.001[a]
Laboratory examination[a]				
Hb (g/L)	108.9±26.0	100.7±30.0	107.7±26.7	<0.001[a]
WBC ($\times 10^9$/L)	10.0 (6.9,14.0)	11.8 (7.6,18.4)	10.3 (7.1,14.4)	<0.001[a]
PLT ($\times 10^9$/L)	168.5 (107.0,230.0)	126.0 (66.0,203.0)	163.0 (100.0,228.0)	<0.001[a]
ALB (g/L)	32.5±6.8	30.0±6.4	32.1±6.8	<0.001[a]
TBil (μmol/L)	11.2 (6.8,20.9)	16.6 (8.5,43.0)	11.8 (7.0,22.1)	<0.001[a]
Baseline SCr (μmol/L)	85.2 (68.6,115.7)	79.0 (58.7,102.2)	84.1 (67.2,114.7)	<0.001[a]
SCr on diagnosis (μmol/L)	157.9 (125.8,229.5)	157.9 (119.6,224.2)	157.9 (125.4,227.7)	0.184
Peak SCr (μmol/L)	166.2 (131.2,244.9)	196.7 (145.8,279.3)	170.0 (132.7,254.6)	0.004[a]
SUA (μmol/L)	418.9 (315.9,540.8)	434.4 (325.0,596.1)	422.3 (317.3,548.5)	0.063
LDH[c] (U/L)	235.7 (177.6,380.3)	485.0 (261.5,1033.0)	248.5 (181.6,443.2)	<0.001[a]
RRT	121 (10.2%)	40 (19.8%)	161 (11.6%)	<0.001[a]
Hospital stay (day)	18.0 (10.5,29.0)	18.5 (9.0,35.5)	18.0 (10.0,30.0)	0.597
Hospital cost[cd] (CNY)	77 889 (36 756, 131 609)	95 394 (48 949, 181 141)	79 475 (37 784, 135 837)	<0.001[a]

Data were expressed as mean ± SD, median (Q_U, Q_L), or n (%).
BMI, body mass index; CHD, coronary heart disease; CKD, chronic kidney disease; MODS, multiple organ dysfunction syndrome; COPD, chronic obstructive pulmonary disease; NSAID, non-steroidal anti-inflammatory drug; Post-CPR, post-cardiopulmonary resuscitation; APACHE II, Acute Physiology and Chronic Health Evaluation II; SOFA, Sequential Organ Failure Assessment; Hb, hemoglobin; WBC, white blood cell; PLT, platelet count; ALB, albumin; TBil, total bilirubin; SCr, serum creatinine; SUA, serum uric acid; LDH, lactate dehydrogenase; RRT, renal replacement therapy.
[a]$P<0.05$ with statistical differences. [b]Defined as cumulative number. [c]Missing data of hospital cost in two cases. [d]Defined as total hospitalization cost.

deceased group was older than the survival group. Half of the deceased patients were at stage 3, while, only a quarter of the survival were at this stage. Laboratory results were analyzed to determine the possible predictors of AKI prognosis for patients diagnosed with AKI for no more than 24 h. Our findings revealed that the hemoglobin concentration, platelet count, and serum albumin concentration of the deceased group decreased and their white blood cell count, total bilirubin, peak creatinine, and lactate dehydrogenase concentration increased (Table 2). No significant difference was found in their uric acid

Table 3 Etiology distribution of AKI

Causes	Patients, n (%)
Surgery-related AKI	226 (16.29%)
Decreased cardiac output	179 (12.91%)
Systemic vascular dilatation	147 (10.60%)
Drug-related AKI	197 (14.20%)
Infection-related AKI	145 (10.45%)
Renal ischemia-related AKI	110 (7.93%)
Glomerular AKI	62 (4.47%)
Urethral obstruction-related AKI	50 (3.60%)

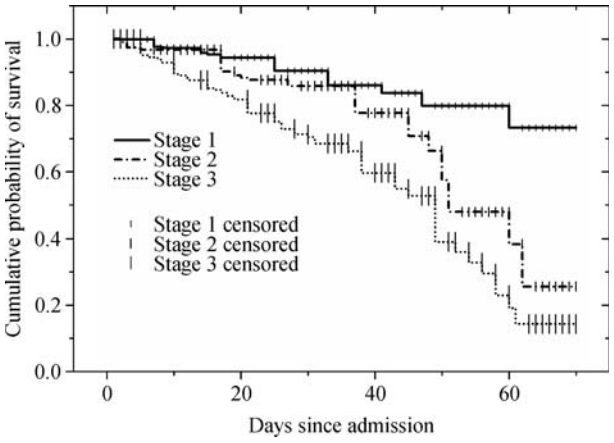

Fig. 2 Kaplan–Meier plot of cumulative rates of in-hospital survival by AKI stage.

concentration. The hospitalization expenses incurred by the deceased group were higher than those of the survival group. The hospitalization time of the two groups did not significantly differ. The clinical features of the patients stratified in terms of different living states at discharge are shown in Table 2.

Risk factors of the in-hospital mortality of patients with AKI

The all-cause in-hospital mortality of AKI was 14.56% (202/1387). With the severity of AKI, the cumulative survival rate decreased gradually (Fig. 2). The obtained data were assessed through univariate logistic regression analysis to estimate *P*-values. If a *P*-value was < 0.05, the variable was analyzed with the final multifactor regression model. Multivariate logistic analysis revealed that the ORs (95% confidence intervals) of in-hospital death of stages 2 and 3 AKI were 1.78 (1.06 to 3.00) and 4.21 (2.44 to 7.24), respectively, compared with those of stage 1 AKI (Table 4). The mortality risk of the patients aged more than 80 years was 7.14 times as high as that of the patients aged 12–19 years. Compared with that of the patients with BMI < 18.5, the mortality risk of the patients with BMI between 28 and 34.9 was decreased by 81%. These findings indicated that high BMI was an independent protective factor against the mortality risk of AKI. The independent mortality risk factors of AKI included the presence of a preexisting tumor, low cardiac output, high white blood count, low platelet counts, and low serum albumin concentration. The calibration and discrimination for the regression model shown in Table 4 were 6.961 ($P = 0.541$) and 0.871, respectively.

Table 4 Multivariate logistic regression analysis for the factors associated with all-cause in-hospital mortality of AKI

Variables	*P* value	OR (95% CI)
AKI stage		
1	–	1[a]
2	0.03[b]	1.78 (1.06,3.00)
3	<0.001[b]	4.21 (2.44,7.24)
Age		
12–19 years	–	1[a]
20–39 years	0.54	1.68 (0.32,8.77)
40–59 years	0.71	1.35 (0.28,6.53)
60–79 years	0.42	1.90 (0.39,9.12)
⩾80 years	0.02[b]	7.14 (1.43,35.53)
BMI		
<18.5	–	1[a]
18.5–23.9	0.39	0.77 (0.42,1.40)
24–27.9	0.08	0.56 (0.29,1.08)
28–34.9	<0.001[b]	0.19 (0.07,0.50)
⩾35	0.26	0.27 (0.03,2.73)
Underlying disease		
Number of underlying disease (yes vs. no)	0.38	1.19 (0.81,1.74)
Hypertension	0.56	1.19 (0.66,2.14)
CHD	0.25	1.46 (0.77,2.77)
Tumor	0.01[b]	2.19 (1.23,3.90)
MODS	0.57	1.31 (0.52,3.25)
CKD	0.94	1.03 (0.53,1.98)
COPD	0.62	1.26 (0.50,3.16)
Injury factors (yes vs. no)		
DIC	0.07	4.06 (0.88,18.66)
Hypovolemia	0.61	1.14 (0.68,1.92)
Low cardiac output	<0.001[b]	2.62 (1.55,4.42)
Contrast medium	0.17	0.51 (0.20,1.34)
ACEI/ARBs	0.16	0.54 (0.23,1.28)
Diuretic	0.55	1.13 (0.76,1.68)
Laboratory indexes		
Hb (1 g/L)	0.91	1.00 (0.99,1.01)
WBC (1×10^9/L)	<0.001[b]	1.04 (1.01,1.06)
PLT (1×10^9/L)	0.01[b]	1.00 (1.00,1.00)
ALB (1 g/L)	0.03[b]	0.96 (0.93,1.00)
TBil (1 μmol/L)	0.08	1.00 (1.00,1.00)
Peak SCr (1 μmol/L)	0.14	1.00 (1.00,1.00)
LDH (1 U/L)	0.17	1.00 (1.00,1.00)
RRT (yes vs. no)	0.48	1.23 (0.69,2.21)

All of the variables listed in this table were included in the regression analysis model. BMI, body mass index; CHD, coronary heart disease; MODS, multiple organ dysfunction syndrome; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DIC, disseminated intravascular coagulation; ACEI/ARBs, angiotensin-converting enzyme inhibitors/angiotensin receptor blockers; Hb, hemoglobin; WBC, white blood cell; PLT, platelet count; ALB, albumin; TBil, total bilirubin; SCr, serum creatinine; LDH, lactate dehydrogenase; RRT, renal replacement therapy.
[a]Reference value. [b]$P<0.05$ with statistical differences.

Risk factors of renal function recovery in patients with AKI

Of the 1179 patients with AKI in the study (202 died, 6 provided insufficient information regarding the status of RRT after the patients were discharged), 346 (29.4%) did not achieve full renal recovery at discharge. Approximately 60% of the patients who received RRT during hospitalization required RRT after they were discharged.

A high AKI stage was associated with poor renal outcomes. Stages 2 and 3 AKI corresponded to 85% and 178% poorer restoration than stage 1 AKI after adjustment was performed for demographic characteristics, underlying diseases, exposures, laboratory indicators, and RRT. Suffering from tumor, experiencing resuscitation, and RRT were adverse to renal recovery (Table 5). The calibration and discrimination for the regression model shown in Table 5 were 6.595 (P = 0.581) and 0.762, respectively.

Table 5 Multivariate logistic regression analysis for the factors associated with renal function recovery at discharge in AKI

Variables	*P* value	OR (95% CI)
AKI stage	<0.001[a]	
1	–	1[b]
2	<0.001[a]	1.85 (1.30,2.63)
3	<0.001[a]	2.78 (1.82,4.23)
Underlying disease (yes vs. no)		
Hypertension	0.16	0.80 (0.59,1.09)
Sepsis	0.10	2.46 (0.84,7.17)
CHD	0.40	1.17 (0.81,1.71)
Tumor	0.01[a]	1.63 (1.16,2.28)
MODS	0.55	0.79 (0.35,1.74)
CKD	0.17	0.74 (0.49,1.13)
Injury factors (yes vs. no)		
Post-CPR	0.03[a]	2.66 (1.11,6.35)
Hypovolemia	0.25	1.27 (0.85,1.90)
Antibiotics	0.39	1.16 (0.83,1.63)
Colloid	0.41	1.15 (0.82,1.62)
Antineoplastic drug	0.10	1.52 (0.92,2.51)
Laboratory index		
Hb (1 g/L)	0.57	1.00 (0.99,1.00)
PLT (1×10^9/L)	0.94	1.00 (1.00,1.00)
ALB (1 g/L)	0.29	0.99 (0.97,1.01)
Peak SCr (1 μmol/L)	0.88	1.00 (1.00,1.00)
LDH (1 U/L)	0.36	1.00 (1.00,1.00)
RRT (yes vs. no)	<0.001[a]	5.18 (3.00,8.95)

All of the variables listed in this table were included in the regression analysis model. CHD, coronary heart disease; MODS, multiple organ dysfunction syndrome; CKD, chronic kidney disease; Post-CPR, post-cardiopulmonary resuscitation; Hb, hemoglobin; PLT, platelet count; ALB, albumin; SCr, serum creatinine; LDH, lactate dehydrogenase; RRT, renal replacement therapy.
[a]$P<0.05$ with statistical differences. [b]Reference value.

Discussion

Since the establishment of a classification of AKI in accordance with the KDIGO Clinical Practice Guidelines for AKI published in 2012, the epidemiological characteristics of AKI across countries and populations have been accurately recognized. Poor prognosis, such as high mortality rate, poor renal recovery, and high risk of progression to CKD, ESRD, and cardiovascular events, have also been observed in patients with AKI [15]. However, effective approaches have yet to be developed to reverse AKI. As such, factors influencing patient prognosis should be investigated to identify and treat AKI in early stages and to reduce the occurrence of adverse outcomes. In this study, an AKI epidemiological survey among hospitalized patients aged ⩾ 12 years was performed in 2012 in a tertiary metropolitan hospital in China according to the KDIGO guideline to explore the risk factors affecting the prognosis of AKI patients. In addition to basic risk factors, laboratory indicators were considered to evaluate the prognosis comprehensively.

Our survey determined that the rate of AKI in the hospitalized patients was 1.79%, which is similar to the previously reported range of 0.99%–3.14% [16] in Chinese hospitalized adults but is lower than the rates reported in studies conducted in developed countries [2]. AKI does not manifest specific symptoms and is primarily diagnosed by observing the changes in serum creatinine over a short period. The lack of awareness on AKI in China may result in a low frequency of serum creatinine measurements. The data reported in developed countries reveals that a repeated serum creatinine assay for patients admitted to a hospital is 63.2% [17]. By comparison, a separate repeated serum creatinine assay yields 24.76% to 30% [16] in Chinese studies. Therefore, the prevalence of AKI in China is undoubtedly underestimated. The accurate measurement of urine volume is difficult for ordinary patients. As such, most studies are based on creatinine standards. The factors that negatively affect AKI reporting suggest that the documented incidence of AKI is lower than the actual value. These findings are consistent with the rate of missed AKI diagnoses of up to 70%.

Consistent with those in previous reports [16], the in-hospital mortality of the AKI patients in our study was 14.56%, nearly two-thirds of the survival fully recovered their renal function, and 60% of those receiving RRT must continue RRT post-discharge.

Multi-factor regression analysis revealed that, six factors, namely, AKI stage, BMI, low cardiac output, leukocyte count, platelet count, and serum albumin, in addition to age and tumor, were associated with hospital

mortality in patients with AKI. Our study confirmed that AKI stage was an independent risk factor of the in-hospital mortality of stage 1 patients serving as the internal control group; however, conventional controls are patients without AKI [18]. Although the peak SCr is a factor influencing mortality, as indicated by univariate analysis, no statistical significance was found after data were adjusted for potential confounding factors. Univariate analysis suggested that AKI stage might account for the effect of peak SCr. Therefore, peak SCr was a dependent risk factor of hospital mortality.

Obese patients with BMI $\geqslant$ 28 likely survive, but this finding contradicts our conceptions about obesity-related glomerulopathy. Druml *et al.* [19] showed that hospital mortality rates follow a U-shaped pattern, and the lowest mortality is observed in obese patients ($30 \leqslant$ BMI $\leqslant 35$). BMI $\geqslant$ 28 is considered obese in China, because the BMIs of Chinese are lower than those of Europeans and Americans. Nevertheless, the health industry standard of the People's Republic of China does not subdivide obese patients according to various adult weights. Instead, we further divided BMI $\geqslant$ 28 into mild obesity (28−34.9) and severe obesity (BMI = 35) in accordance with the obesity classification of WHO. Compared with that of the reference group, the OR of the patients with severe obesity (0.27) was higher than that of the patients with mild obesity (0.19), but this difference was not significant. An extensive sample size should be considered for further statistical analysis because mild obesity rather than normal weight yields the lowest mortality; this phenomenon has been termed "obesity paradox," and it has been confirmed in various diseases, such as chronic obstructive pulmonary disease, congestive heart failure, cirrhosis, and AKI [20]. In another study, the generation and distribution of uremic toxins in patients with chronic renal disease [19] are likely unsatisfactory.

Low cardiac output, caused by coronary heart disease, heart failure, and other cardiac conditions, induces peripheral vasoconstriction and tissue hypoperfusion. Hypokinemia could also be an independent predictor of the mortality of AKI patients. These findings are similar to observed by Abelha *et al.* [21], who reported that ischemic heart disease and congestive heart disease are preoperative determinants of death in the postoperative period. In addition to these known risk factors, laboratory indicators, namely, increased white blood cell count, decreased platelet count, and low serum albumin levels, were independent predictors of the mortality of AKI patients. De Labry *et al.* confirmed that increased leukocytes count contributed to mortality [22], and this phenomenon may be attributed to an increase in the concentrations of inflammatory cells and inflammatory factors in the serum [23]. Kertai *et al*. indicated the association between platelet count and short-term mortality risk in patients who underwent coronary artery bypass graft surgery [24]. Our study also obtained the same conclusion, but the causality should be further confirmed. A decrease in platelet count may be related to the consumption of platelets *in vivo* because of extensive coagulation [25], and this observation may indicate the tendency of bleeding and poor prognosis in patients with AKI. A low serum albumin level, which is often detected in some diseases with adverse outcomes, such as malnutrition and liver function injury, is related to the increased risk of mortality. Albumin is also implicated in antioxidation and repair [26]. The protective effects of serum albumin on patients with AKI were largely reduced when serum albumin content decreased. These patients were prone to cancer, lung diseases, and other diseases and hence increase the risk of death. However, the optimal concentration range of serum albumin has yet to be provided [27]. On the basis of normal albumin concentration, we divided the patients into two groups: $\geqslant 30$ and < 30 g/L. We found that the latter was at a higher risk of in-hospital death than the former. This finding could help clinicians manage their patients.

Multivariate regression analysis revealed that renal function recovery in patients with AKI was related to AKI stage, presence of a tumor, and receiving CPR and RRT, but it was not correlated with laboratory indicators. A high AKI stage corresponded to poor renal function recovery [28]. If the correct diagnosis and staging of AKI is provided, the progression of AKI can be prevented timely and the prognosis of AKI patients can be improved. Cardiac arrest and CPR result in warm renal ischemia and ischemia-reperfusion injury. These clinical cases of CPR and ischemia-reperfusion are similar to animal models used to investigate ischemic acute kidney injury [29]. Therefore, renal recovery is possibly impaired by ischemia reperfusion injury.

In this study, complete, detailed, and reliable epidemiological data were collected from hospitalized patients with AKI, and the factors influencing the prognosis of AKI were analyzed. However, some limitations should be considered. First, this study is a single-center retrospective study, which could only represent the same level of hospitals in China rather than those at the national level. Second, the lack of data of hospitalized patients without AKI limited our analysis of the control group. Third, further follow-up information was unavailable. As such, we were unable to analyze the long-term prognosis of patients with AKI. Fourth, not all cases were evaluated because of missing data. Finally, our study determined AKI on the basis of the changes in SCr and excluded urinary output. Therefore, some patients with AKI were not considered. The lack of repeated creatinine measurements probably underestimated the incidence of AKI. The serum creatinine of some malnourished patients did not also evidently change. Consequently, AKI was misdiagnosed.

A concurrent national multicenter prospective

epidemiological study on AKI is underway.

In conclusion, hospitalized patients with AKI yield a high mortality rate. Basic risk factors and some laboratory indicators can predict the death of patients with AKI. Basic risk factors are suggested to affect renal function recovery adversely. Government authorities, health care professionals, and civilians should increase their awareness on AKI. The incidence of AKI and adverse prognosis can be reduced by early prevention, early diagnosis, and individualized treatment.

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Compliance with ethics guidelines

Sasa Nie, Zhe Feng, Lihua Xia, Jiuxu Bai, Fenglin Xiao, Jian Liu, Li Tang, and Xiangmei Chen declare that they have no conflict of interest. This study was approved by the Ethics Committee of PLA General Hospital and was performed in accordance with the ethical standards and the *Helsinki Declaration* of 1975, as revised in 2000 (5).

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