

Original Article

Characteristics and predictors of acute kidney injury among patients attending ICU: a prospective study

Chun-Xue Wu¹, Yu Han², Long Yang¹, Fu-Qiang Jin¹, Yu-Chao Shen¹, Ying Cui³

¹Department of Emergency ICU, The Brain Science Hospital of Cangzhou Central Hospital, Cangzhou 061014, Hebei, P.R. China; ²Department of Intensive Care Unit, Cangzhou Central Hospital, Cangzhou 061014, Hebei, P.R. China; ³Department of Emergency, Cangzhou Central Hospital, Cangzhou 061014, Hebei, P.R. China

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Abstract: Background: The incidence and characteristics of AKI in ICU vary widely in previous investigations. In this context, we performed a prospective study to evaluate AKI among ICU patients. Methodology: We prospectively studied patients admitted to ICU over a period of six months. Demographics, clinico-laboratory data were extracted by using standardized case report form. AKI was stratified by using AKIN classification. Results: The incidence of AKI was 51.8%; with AKIN-I in 18.4% AKIN-II in 33.8% AKIN-III in 47.7% patients. The higher incidence of AKI was observed among patients with sepsis (75.3%) and cardiovascular causes (75.7%) of ICU admission. Patient with AKI had significantly longer hospital stay and mortality ($P=0.001$). Similarly, patients with old age ($OR: 2.1$), multiple organ failures ($OR: 3.3$), high APACHE II ($OR: 4.7$) and high SOFA ($OR: 5.4$) scores were more likely to develop AKI. Whereas, in addition to risk factors of AKI, non-renal MOF ($HR: 1.645$), need of dialysis ($HR: 1.924$), vasopressors ($HR: 2.124$), mechanical ventilation ($HR: 1.762$) and presence of AKI ($HR: 4.562$) was found to be significant predictors of mortality. Approximately, more than 50% surviving patients with AKI had mild to moderate renal insufficiencies on their discharge from ICU. Discussion: We found AKI in more than 50% of patients attending ICU. Patients with AKI had longer ICU stay and higher mortality. We identified eight and ten risk factors of AKI and ICU-mortality, respectively. Assessment of patients for these risk factors with vigorous therapeutic support could be beneficial to reduced AKI associated morbidity and mortality.

Keywords: Acute kidney injury, renal failure, intensive care unit, emergency

Introduction

Acute kidney injury (AKI) is commonly occurred presentation in intensive care unit (ICU) and is always a challenge for intensivists due to its high morbidity and mortality [1]. Previously a term, acute renal failure (ARF), was used to describe AKI and subjected to complete loss of kidney function. Recently several consensus groups made concordance that ARF is not a single disease related to complete kidney failure and accompanied by spectrum of illness-ranges from subclinical injury to organ failure. Therefore nomenclature shifts to AKI that accurately describes disease course based on severity [2]. Currently, AKIN (acute kidney injury network) and RIFLE (risk, injury, failure, loss of function and end stages renal disease) criteria are well accepted to stratify AKI in several settings. Epidemiological data comparing AKIN

and RIFLE criteria have showed agreement among critically ill patients [3].

The incidence of AKI is about 7% among total hospitalized patients and up to 36% to 67% among patients attending ICU, depending upon definition used [4, 5]. About 4% to 25% patients have severe AKI on ICU admission and 5% to 6% patients with AKI require renal replacement therapy (RRT) during their ICU stay [6, 7]. Reported mortality due to AKI in ICU varies considerably between studies depending on definition of AKI and its etiology (e.g. sepsis, trauma, cardiothoracic surgery or contrast nephropathy). It has been proposed that mortality increases proportionately with increasing severity of AKI where need of RRT in ICU is well recognized independent predictor of mortality accompanied by 50% to 70% fatality rate. Despite adjustment for co-morbidities and severity of disease,

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AKI with cardiopulmonary bypass, sepsis, major trauma and burn injury have consistently demonstrated significant association with increased risk of death [8]. Morbidity associated with AKI in ICU is less appreciated and resulted in increased cost, hospital stay and incidence of chronic kidney disease (CKD) [9]. The true incidence of CKD after AKI is unknown because of lack of consistency in reported rates of renal recovery and great disparity of reported incidence of AKI [10].

Besides of considerable morbidity and mortality associated with AKI in ICU, there is still scarcity of data demonstrating incidence, characteristics and risk factors of AKI among critically ill Chinese patients. Only limited number of studies demonstrated epidemiological features of AKI in ICU in China [11-14]. Therefore, a prospective observational study on patients admitted to ICU was performed in order to determine incidence, characteristics and risk factors of AKI.

Methodology

A prospective observational study on patients admitted to ICU of Brain Science Hospital of Cangzhou Central hospital over the period of six months (January to June 2013) was performed. A total 7380 were admitted to ICU during study period and all the patients were screened for inclusion. Patients younger than 14 years and with incomplete data (demographics, clinical, laboratory), chronic kidney disease and were on renal replacement therapy, and those whose ICU stay was <48 hours were excluded from current study. A total 1331 patients were included in final analysis.

Demographic, clinical and laboratory data were extracted by using computerized record database and patient's files. Demographics included age, gender and other baseline standard characteristics. Clinical data included presentation on hospital admission, co-morbidities and need of mechanical ventilation. Laboratory data included complete blood count, arterial blood gases, kidney and liver function tests. Kidney functions were assessed by serum creatinine (SCr), urine output and urea while severity of illness was assessed using SOFA score. Demographics and clinical data were recorded on the day of admission. Laboratory data were recorded until discharge or death, whichever

occurred earlier. All the data was collected by trained researcher by using electronic case report form (CRF). All the completed CRFs were sent to the principle investigator on daily basis via email to check the integrity of data collection. Current study was approved by institutional review board of Brain Science Hospital of Cangzhou Central hospital China (Reference no.: RRB/GW/2012-32). Board specifically approved the informed consent waiver due to the anonymous and non-interventional nature of the study.

Definitions

The primary diagnosis of patients was subjected to cause of ICU admission, recorded by treating clinician on ICU admission. Septic and septic shock as primary reason for admission was diagnosed if sepsis related diagnosis was present (sepsis due to infections, pneumonia and gastrointestinal disease or unknown cause of sepsis). The cardiac diagnosis subjected to presence of cardiogenic shock (systolic blood pressure <90 mmHg, absence of hypervolemia and clinical signs of poor tissue perfusion i.e. oliguria, cyanosis, cool extremities, altered mentation), congestive heart failure (bilateral basal crackles, cardiomegaly, elevated jugular venous pressure), cardiac arrest, and acute myocardial infarction (rise in troponin and either ischemic chest pain, new ST-T wave changes or pathological Q waves on ECG) on ICU admission. Respiratory reasons of ICU admission were presence of aspiration syndrome, exacerbation of chronic obstructive pulmonary disease (COPD) or asthma, pulmonary embolism, non-cardiogenic pulmonary edema, primary respiratory arrest and aspiration syndrome. Bleeding due to peptic ulcer, varices and diverticulosis were termed as gastrointestinal hemorrhage while all other non-surgical gastrointestinal diagnosis was termed as "others". The presence of epidural hematoma, stroke, intra-cerebral hemorrhage, subarachnoid hemorrhage and other neurological causes for coma were termed as neurological reasons of ICU admission. Lastly, non-operative causes of metabolic coma, diabetic ketoacidosis, drug overdose and other endocrinopathies were defined as metabolic or poisoning causes [15].

AKI was stratified by using AKIN criteria as shown in **Table 1** [16]. For the purpose of AKIN

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Table 1. AKIN criteria to diagnose AKI

	Serum Creatinine	Urine Output
AKI (regardless of stage)	Increase in serum creatinine ≥ 26.2 $\mu\text{mol/L}$ or increase to ≥ 150 - 199% (1.5- to 1.9-fold) from baseline	< 0.5 mL/kg/h for ≥ 6 h
AKIN-I	Increase in serum creatinine ≥ 26.2 $\mu\text{mol/L}$ or increase to ≥ 150 - 199% (1.5- to 1.9-fold) from baseline	< 0.5 mL/kg/h for ≥ 6 h
AKIN-II	Increase in serum creatinine to 200-299% (> 2 - 2.9 fold) from baseline	< 0.5 mL/kg/h for ≥ 12 h
AKIN-III	Increase in serum creatinine to $\geq 300\%$ (≥ 3 -fold) from baseline or serum creatinine ≥ 354 $\mu\text{mol/L}$ with an acute rise of at least 44 $\mu\text{mol/L}$ or initiation of RRT	< 0.3 mL/kg/h ≥ 24 h or anuria ≥ 12 h

criteria, SCr levels were measured at least once daily for every patient as part of the clinical routine. In addition, hourly urine output (UO) was checked and recorded by the study coordinator, and categorized according to UO criteria based on either actual or estimated body weight [17]. Patients without baseline SCr and having no history of chronic renal insufficiency (CRI), baseline SCr was estimated with Modification of Diet in Renal Disease (MDRD) equation by assuming glomerular filtration rate as 75 ml/min/1.73 m². Patients with CRI but not on chronic dialysis, SCr levels on hospital admission were served as baseline. For patients admitted to hospital and then ICU or vice versa, baseline SCr level was determined as the lowest value among both admissions. Patients were stratified into AKI by using either SCr or UO, whichever led to worst classification of AKI [11]. We recorded most severe stage of AKI in our study. For example, if patient with AKIN-II progressed to AKIN-III then this patient was classified with AKIN-III. Similarly, if patient with AKIN-III progressed to AKIN-I then we classified AKIN-III in this case. Approximately 41% of studied participants had no baseline value on hospital or ICU admission in our study.

Statistical analysis

The statistical package SPSS (version 20.0) was used for all statistical analyses. All the data were presented as mean \pm standard deviation and 95% confidence intervals or median and range depending upon data distribution. Continuous and categorical variables were compared by using Student's *t*-test, chi-square test, Fisher's exact test, and Mann-Whitney, where appropriate. Logistic regression was used to evaluate statistical significance ($P < 0.05$) and significant predictors from univariate analysis were subjected to multivariate logistic regression analysis to identify independent predictors AKI (enter method). Odds ratios were estimated from the beta coefficients obtained,

with respective 95% confidence intervals. Cox proportional hazards regression analysis were performed to determine hazard ratios and 95% confidence for mortality. Receiver operating characteristic (ROC) curve was used to determine the area under the curve for regression model of AKI. We considered $P < 0.05$ to be statistically significant.

Results

A total 7380 patients were admitted to ICU during study period and 1455 patients were included in final analysis after applying exclusion. Patients with incomplete data (1478), ICU stay shorter than 48 hours (2944), age < 14 years (789), chronic kidney disease (633), hemodialysis treatment (78) and renal transplant (3) were excluded from the study. Out of 1455 studied participants, males were predominant (58.3%) and mean age was 44.4 ± 13.3 years. Most of the patients had sepsis as primary diagnosis (52.4%) followed by cardiac (17.1%) and respiratory causes (13.7%). Mechanical ventilation was needed by 80.1% patients in current study. Study protocol flow chart is shown in **Figure 1**.

Based on AKIN criteria, 754 (51.8%) patients had AKI and among them AKIN-I, AKIN-II and AKIN-III was observed in 139 (18.4%), 255 (33.8%) and 360 (47.7%) patients respectively. Out of 139 patients with AKIN-I, abrupt increase in serum creatinine within 48 hours was observed in 56 (7.4%) patients. Initially, 88 patients with no evidence of kidney injury later developed AKI. On the other hand, some of the patients with AKI progressed to severe stage but we classified severe stages of AKI during ICU stay (**Figure 2**). Among the 789 patients with no evidence of AKI on ICU admission, 88 (11.1%) patients developed AKI during their ICU stay, including 41 (5.2%) patients with AKIN-I, 31 (3.9%) patients with AKIN-II and 16 (2%) patients with AKIN-III. Among 666 patients having AKI on ICU admission, 189 (28.4%) patients

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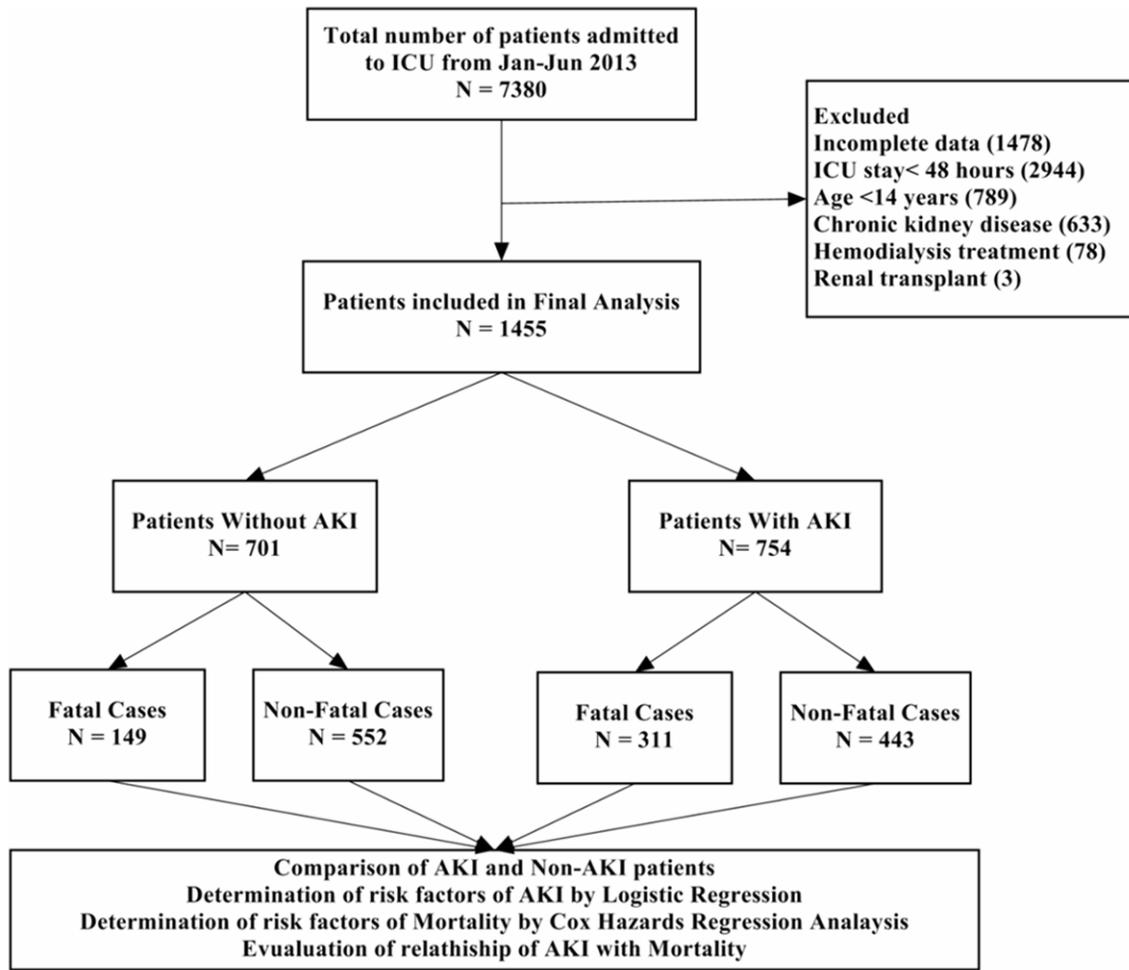


Figure 1. Study methodology flow.

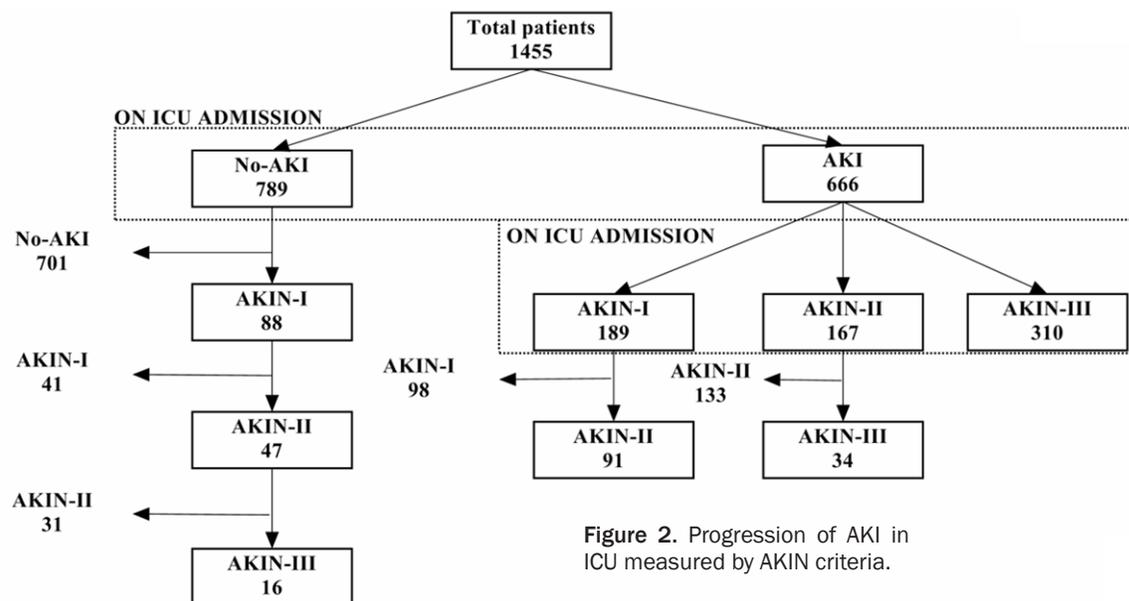


Figure 2. Progression of AKI in ICU measured by AKIN criteria.

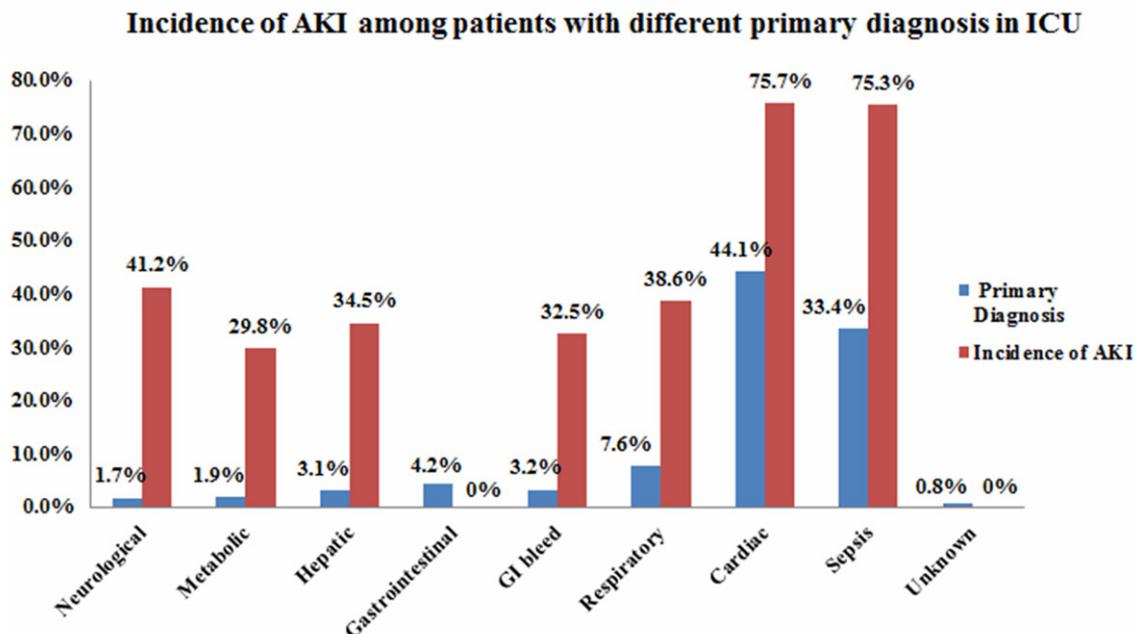


Figure 3. Incidence of AKI among patients with different primary diagnosis in ICU.

had AKIN-I and approximately half of these patients (48.1%) later progressed to AKIN-II during ICU stay. Likewise, out of 88 patients having AKIN-I during ICU stay, who had no-AKI on ICU admission, 53.4% progressed to AKIN-II and among them further 16 (18.2%) patients were progressed to AKIN-III in our study. Similarly, out of 167 patients with AKIN-II on ICU admission, 34 (20.4%) patients progressed to AKIN-III during their ICU stay. Fortunately, no patients with AKIN-I on ICU admission progressed to AKIN-III during their stay. The progression of AKI in ICU has been demonstrated in **Figure 2**. The risk of stage progression was higher in patients with AKIN-II [OR (95% CI): 4.3 (2.1-5.7), $P < 0.01$] as compared to AKIN-I [OR (95% CI): 1.5 (1.1-7.8), $P = 0.03$] in our study. Out of 360 patients with AKIN-III, dialysis was needed among 56.1% patients and among them 95.1% patients received intermittent hemodialysis while peritoneal dialysis was needed by 10 4.9% patients.

Patients with sepsis and cardiovascular causes of ICU admission had highest likelihood of developing AKI in our study i.e. 75.3% and 75.7% respectively. Incidence of AKI in patients with other primary diagnosis is shown in **Figure 3**.

The mean duration of ICU stay was 12 ± 5 days and this duration was significantly longer

among patients with AKI than without AKI ($P = 0.001$). More than half of the studied participants had co-morbidities and among them hypertension (26.2%) was commonest followed by diabetes mellitus (21.9%) and ischemic heart disease (20.5%). Of the co-morbidities, presence of diabetes mellitus was associated with the development AKI ($P = 0.024$) in our study. Patients with AKI had worse clinical presentations and poor prognosis during ICU stays compared to the patients with non-AKI. We found abnormal recordings of renal functions tests, hepatic function tests, complete blood count, arterial blood gasses and urinalysis were significantly higher in AKI patients than non-AKI. Similarly, need of CRRT, IHD, mechanical ventilation (both invasive and non-invasive), vasodilators, vasopressors and inotropes was more profound among patients with AKI compared to non-AKI. Multiple organ failures (more than two organ failures) were also more prominent among AKI cases. APACHE II and SOFA scores were calculated within 24 hours of ICU admission. Approximately, half of the study participants had SOFA score > 9 and AKI was more likely to occur in such patients (OR: 4.6, $P < 0.001$). Higher APACHE-II and SOFA scores were observed in patients with AKI ($P < 0.05$) as compared to non-AKI (**Table 2**).

Binary logistic regression analysis revealed that old age (> 60 years), multiple organ fail-

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Table 2. Baseline characteristics of total population, patients with and without AKI

Parameters	Total patients N=1455	Non-AKI N=701	AKI N=754	P value*
Age (years) Mean ± SD	44.4 ± 13.3	52.2 ± 13.1	65.7 ± 15.5	<0.001
Gender				0.123
Male [n (%)]	848 (58.3%)	373 (53.2%)	475 (63%)	
Female [n (%)]	607 (41.7%)	328 (46.8%)	279 (37%)	
Diabetes Mellitus [n (%)]	318 (21.9%)	95 (13.5%)	318 (29.6%)	0.024
Hypertension [n (%)]	381 (26.2%)	155 (22.1%)	381 (30%)	0.346
Ischemic Heart Disease [n (%)]	298 (20.5%)	161 (22.9%)	137 (18.2%)	0.442
Multiple organ failures [n (%)]	112 (7.7%)	24 (3.4%)	88 (11.7%)	0.033
Treatments				
CRRT [n (%)]	139 (9.6%)	41 (5.8%)	98 (13%)	0.040
IHD [n (%)]	30 (2.1%)	9 (1.3%)	21 (2.8%)	0.041
Mechanical Ventilation [n (%)]	1165 (80.1%)	514 (73.3%)	651 (86.3%)	0.032
Vasodilators [n (%)]	262 (18%)	109 (15.6%)	153 (20.3%)	0.031
Vasopressors [n (%)]	597 (41%)	201 (28.7%)	396 (52.5%)	<0.001
Inotropes [n (%)]	306 (21%)	111 (15.8%)	195 (25.9%)	0.013
ICU stay (days) mean ± SD	12 ± 5	6 ± 3	16 ± 4	0.001
Mortality [n (%)]	460 (31.6%)	149 (21.3%)	311 (41.3%)	<0.001
APACHE II Score on ICU admission Mean ± SD	44 ± 5	39 ± 6	51 ± 8	0.003
SOFA Score on ICU admission Mean ± SD	14 ± 2	16 ± 4	21 ± 4	0.045
SOFA score >9 [n (%)]	761 (52.3%)	266 (38%)	495 (65.7%)	0.001

*P-value is difference between AKI and Non-AKI patients and determined by student-t-test or Pearson Chi-square test, where appropriate. CRRT: continuous renal replacement therapy, IHD: ischemic heart disease, ICU: intensive care unit, SD: standard deviation, APACHE II: Acute Physiology and Chronic Health Evaluation II, SOFA: Sequential Organ Failure Assessment.

Table 3. Multivariate logistic regression analysis of risk factors of AKI among ICU patients

Risk Factors	Odds ratio	95% confidence interval	P-value
Old age (>60 years)	2.1	0.8-3.1	0.024
Multiple organ failures (MOFs)	3.3	2.9-5.7	<0.001
Severe sepsis/septic shock	2.9	1.8-4.1	<0.001
Use of inotropes	1.8	1.2-6.7	0.042
High APACHE-II	4.7	3.9-7.8	<0.001
High SOFA scores	5.4	2.2-8.4	<0.001
Diabetes mellitus	2.7	1.6-5.3	0.001
Nephrotoxic drugs	4.1	3.7-6.8	<0.001

ures, use of inotropes, higher APACHE-II and SOFA scores, presence of diabetes mellitus and use of nephrotoxic drugs were significantly associated with development of AKI in our study (Table 3). Presence of hypertension [OR (95% CI): 1.4 (1.0-7.1), P=0.412] and use of vasopressors [OR (95% CI): 2.3 (0.8-4.6), P=0.336] failed to demonstrate significant prediction of AKI in univariate analysis (Table 3).

For the patients who had no AKI on ICU admission but later developed during ICU stay, presence of multiple organ failures [OR (95% CI): 5.5 (3.7-9.4), P<0.001] and use of nephrotoxic drugs [OR (95% CI): 2.2 (1.3-4.9), P=0.002] were found to be risk factors of AKI in our study. While the presence of diabetes mellitus [OR (95% CI): 3.8 (2.8-5.7), P=0.001], SOFA score >9 [OR (95% CI): 5.1 (4.3-11.5), P<0.001] and use of inotropes [OR (95% CI): 1.9 (1.1-5.8), P=0.013] were found to be significant predictors of worst stage of AKI i.e. AKIN-III. ROC curve analysis demonstrated excellent prediction (area-under-curve: 0.947, 95% CI: 0.922-0.972, P<0.001) accuracy of regression model for AKI (Figure 4).

Overall mortality in our study was 31.6%. Patients with AKI had significantly higher mortality rate than patients without AKI (41.3% vs. 21.2% respectively, P<0.001). We found statistical significant association between presence of AKI and ICU mortality [OR (95% CI): 5.3 (2.1-

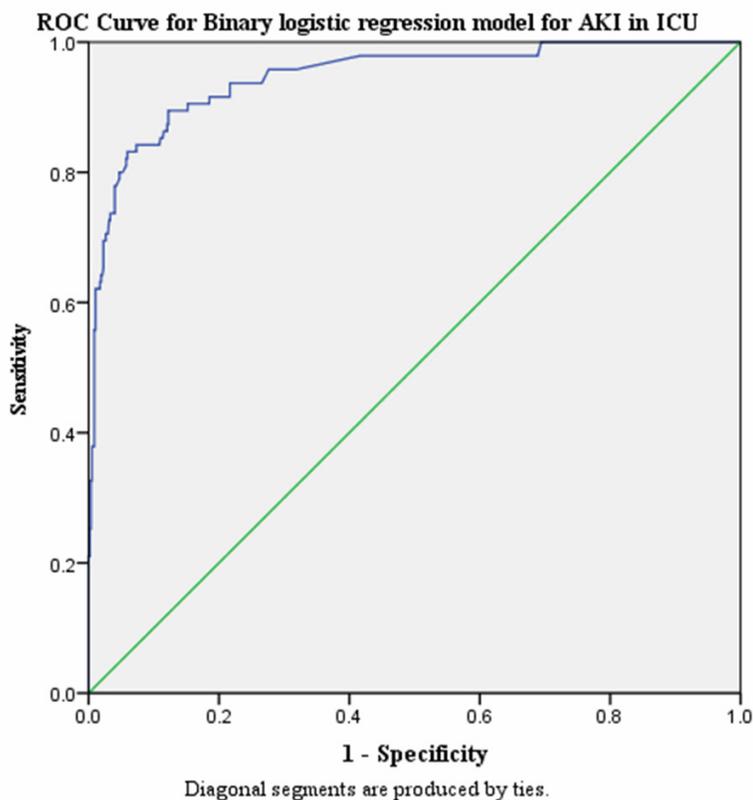


Figure 4. ROC curve analysis of prediction model of AKI in ICU.

Table 4. Independent risk factors of ICU mortality by Cox hazard regression analysis

Parameters	HR	95% CI	P-values
Old age (>60 years)	1.330	1.102-2.192	0.024
non-renal multiple organ failures	1.645	1.100-2.542	0.020
Malignancies	2.134	1.459-3.114	0.003
High APACHE II score	2.891	1.127-3.678	0.002
SOFA score greater than 9	2.624	2.134-4.567	0.013
Mechanical ventilation	1.762	2.145-2.953	0.026
Need of dialysis	1.924	1.139-3.672	0.012
Use of vasopressors	2.124	2.012-5.341	0.001
AKI	4.562	2.314-8.568	<0.001
Neurological reasons of ICU admission	3.678	2.778-7.301	<0.001

HR: Hazards ratio, CI: Confidence interval.

6.7), $P < 0.001$). Increasing AKI severity associated with significantly higher ICU mortality, 18.3% in the AKIN-I, 35.7% in the AKIN-II and 46% in the AKIN-III. The adjusted ICU mortality odds ratio were 1.3 (95% CI: 0.7-2.8, $P = 0.022$) for AKIN-I, 2.5 (95% CI: 2.0-5.4, $P = 0.001$) for AKIN-II and 3.2 (95% CI: 1.8-4.7, $P < 0.001$) for AKIN-III. Other risk factors of mortality were

analyzed by Cox proportional hazards regression analysis and we found that old age, non-renal multiple organ failures, acute kidney injury, malignancies, neurological reasons of ICU admission, high APACHE II score, SOFA score greater than 9, mechanical ventilation, need of dialysis and use of vasopressors were significantly associated with ICU mortality (Table 4). Surprisingly, mortality rate was higher among patients with progressive AKI (patients with AKI on admission and progressed to next stage, $n = 125$) than patients with non-progressive AKI ($n = 541$) (90.4% vs. 29% respectively, $P < 0.001$). Moreover, patients having no evidence of AKI on ICU admission but later developed had mortality rate of 23.6% compared to 43.5% among patients with AKI on ICU admission. These findings suggested that risk of AKI was higher among patients with AKI [OR (95% CI): 3.3 (2.4-5.6, $P < 0.001$)] on ICU admission and with progressive AKI [OR (95% CI): 4.1 (2.8-7.7), $P < 0.001$].

Unfortunately, none of the patient was followed up in our study after discharge.

Discussion

Acute Kidney Injury (AKI) is commonly occurred complication in ICU with heterogeneous etiologies that lead to renal dysfunction with different prognostic outcomes. The term acute renal failure was first used by Homer Smith in 1951 and term was replaced with AKI in 2004 [18]. The prevalence of AKI in ICU varied across different studies, depending of criteria used. Additionally, study design, population heterogeneity, differentiation of SCr versus UO criteria and determination of baseline creatinine levels

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are some other factors that lead to great disparity in incidence of AKI in ICU [19]. On the other hand, there is limited information on whether the epidemiology of AKI in critically ill patients in different regions of world has changed over time and there is a controversy on whether its outcome has improved [10]. Therefore, we sought to estimate the incidence of AKI in ICU and assess risk factors of AKI and mortality in our patient's cohort.

AKI has been stratified by several definitions therefore comparison of different studies is difficult and sometimes impossible. Therefore acute dialysis quality initiative (ADQI) came up with RIFLE criteria (Risk, Injury, Failure, Loss of function and end stage renal disease), that was modified by AKIN criteria in order to improve its sensitivity and reproducibility. AKIN definition allows earlier recognition of AKI rather than RIFLE and thus might constitute the preferred criteria in the ICU [20]. Therefore we stratify our patients by using AKIN criteria and found AKI in 51.8% patients. Our findings show a significant difference in clinical and laboratory characteristics between AKI and non-AKI cases. Likewise, risk of death was also significantly associated with the development of AKI. Whether this increased risk of death is due to complications resulting from AKI per se cannot be determined from our study. Similarly, patients with AKI had longer ICU stay, resulting in a significant burden in terms of cost of care. This is of particular importance in a resource limited settings, as ICU beds are limited and in great demand.

In recent years, there is gradual increase in incidence of AKI in ICU and it might be due to the use of aggressive diagnostic and therapeutic interventions [21]. The incidence of AKI reported by Hoste et al (i.e. 67%) in a retrospective single center study was higher that reported by us [2]. Two prospective studies conducted in Italy and Greece demonstrated incidence as 10.8% and 16% respectively [22, 23]. The difference in incidence of these studies might be contributed by some factors. First they used RIFLE criteria and some investigators used only SCr or glomerular filtration rate criteria to determine RIFLE category due to lack of 6 or 12 hour UO data. Secondly, Hoste et al only defined cases with early AKI, due to laboratory results seen beyond the first 24 or 48 hours of ICU admission. Besides this, Hoste et al conducted study in seven ICUs including surgical, neurological, trauma and solid organ transplant

patients and these patients are expected to have high risks of developing AKI. Thirdly, Cruz et al and Uchino et al included patients with an ICU stay of less than 24 hours, while they were excluded in our study. Wen et al reported incidence of AKI in ICU as 31.6%, lower than our findings [11]. It can be explained by the reason that Wen et al used RIFLE criteria that ignore patients with abrupt increase in serum creatinine (26.4 $\mu\text{mol/L}$) within 48 hours, which accounts 18.4% cases in our study. Moreover, ICU mortality due to AKI reported by Wen et al (35.9%) is comparable with ours (41.3%). Mortality due to AKI has shown some evidence of decline over the years, especially in certain subgroups such as trauma, hematological malignancy and cardiovascular surgery, but still it is one the most important causes of death in ICU patients [21, 24].

It appeared very difficult to determine exact etiology of AKI, even in prospective studies. It is due to complex nature AKI in ICU and numerous contributing factors among patients [25]. We found higher incidence of AKI among patients with sepsis and cardiac primary diagnosis and these findings are concordance with previously published literatures [11, 15]. Similarly old age, MOFs, use of inotropes/nephrotoxic drugs and presence of diabetes mellitus were found to be significantly associated with development of AKI in our study and these findings are also consistent with results of Piccinni et al [26]. As expected, sicker patients with high APACHE II and SOFA scores were more likely to develop AKI and these patients also had high mortality. The incidence of mortality was found to be 4 to 5 times higher among patients with AKI in our study.

Regarding the progression of AKI during ICU stay, higher mortality was observed in patients with progressive AKI. Similarly, patients having AKI on ICU admission had two times more chances of death as compared to patients with no AKI during admission, but later acquired during ICU stay. It can be explained by the reason that patients having no evidence of AKI on ICU admission, but later developed, had mild form of disease that was vigorously managed with fluid and electrolyte balance. On the other hand, patients having AKI on ICU admission were severe cases and risks of progression were also higher in them, which in turn caused high mortality.

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Understanding individual risk factors may help in preventing AKI and associated deaths. By this way patient's susceptibility to develop AKI can be assessed before certain exposures i.e. surgery or use of nephrotoxic agents [27]. We determined various risk factors of AKI and mortality in our cohort and these are also consistent with previous findings [11, 15, 24, 29, 30]. Risk assessment and management of patients according to their susceptibilities and exposures to reduce the hazards of AKI are some crucial measures in ICU.

We stratified patients by using both UO and SCr criteria and found that use of UO criteria leads to less mortality rate compared to SCr criteria. These findings suggest that UO criteria had better predictive values than SCr criteria and these results are agreements with findings of Fouad & Ismail [28]. In contrary to our study, Bagshaw et al reported where high mortality rate was observed with UO criteria [3]. This difference can be explained by the reason that Bagshaw et al used modified RIFLE criteria and defined AKI with SCr > 133 $\mu\text{mol/L}$ or 24-hours UO < 410 ml while we used values of RIFLE criteria for SCr and UO.

There are no specific treatments for AKI apart from adequate fluid resuscitation and avoidance of exposure i.e. nephrotoxic drugs and intravenous contrasts. In our study, inotrope support provided a benefit by regulating the blood pressure and noradrenalin was also found to be a preferred agent. On the other hand, dialysis provided to severe AKIN classification found to be promising measure but produced a significant burden on patients and health care system in terms of cost of care.

Limitations

Our study has several limitations. First, baseline SCr levels were not available for all patients; therefore, in such cases SCr-MDRD or lowest values of SCr during hospital stay were used as baseline. Second, we did not compare RIFLE criteria with AKIN, as RIFLE criteria has been found to be sensitive and robust. Third, sample size in our study is small as compared to studies conducted by other countries. Fourth, we did not follow-up patients after discharge to evaluate renal outcomes and to assess likelihood of AKI progression to chronic kidney disease.

Conclusion

In summary, our study demonstrated that incidence of ICU associated AKI is high among Chinese patients. In comparison of non-AKI patients, patients with AKI has poor prognosis during ICU stay as well as associated with high mortality. Several risk factors of AKI and mortality have been identified in our study and assessment of patients for these risk factors could not only reduce morbidity but also decrease associated mortality. On the other hand, understanding and predicting AKI in ICU can also lessen ICU stay which will reduce the cost that burdens patients and health care system.

Disclosure of conflict of interest

None.

Authors' contribution

Study design and conceptual: CW, YC. Data collection and statistical analysis: LY, FJ. Preparing draft and proof reading: YS, YC. Final approval of draft: CW, YC.

Address correspondence to: Ying Cui, Department of Emergency, The Brain Science Hospital of Cangzhou Central Hospital, No. 16, Xinhua Road, Cangzhou 061014, Hebei, P.R. China. Tel: 0086-317-2175221; Fax: 0086-317-2175221; E-mail: cuiyingccyy@hotmail.com

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