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Original Article



ORIGINAL ARTICLE

# Incidence and prognosis of acute kidney injury versus acute kidney disease among 71 041 inpatients

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## ABSTRACT

**Background.** Acute kidney disease (AKD) defines patients with acute kidney injury (AKI) or subacute loss of kidney function lasting for >7 days. Little is known about the prognosis of AKD in hospitalized patients. The aim of this study was to investigate the risk factors and prognosis of AKD and to compare different types of acute/subacute renal impairment among Chinese inpatients.

**Methods.** Complete data were available for 71 041 patients for a range of 5–63 months. AKI and AKD were diagnosed based on the Acute Disease Quality Initiative criteria of 2017.

**Results.** Of 71 041 inpatients, 16 098 (22.7%) patients developed AKI or AKD; 5895 (8.3%) AKI patients recovered within 7 days, 5623 (7.9%) AKI patients developed AKD and 4580 (6.4%) patients developed AKD without AKI. Mortality was proportional to stages of AKI and AKD ($P < .05$), while AKI followed by AKD was associated with a higher risk of long-term mortality [hazard ratio (HR) 4.51] as compared with AKD without AKI (HR 2.25) and recovery from AKI (HR 1.18). The AKD criteria were robustly associated with overall survival [area under the receiver operating characteristic curve (AUROC) 0.71] and *de novo* CKD (AUROC 0.71), while the AKI criteria showed a relatively lower ability to fit the risk of overall survival (AUROC 0.65) and CKD (AUROC 0.63).

**Conclusions.** AKD and AKD stages are useful clinical definitions for clinical practice, as they predict unfortunate clinical outcomes such as overall long-term mortality and CKD. Research activities should focus on AKD.

**Keywords:** acute kidney disease, acute kidney injury, chronic kidney disease, diagnose, prognosis

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## INTRODUCTION

The incidence of acute kidney injury (AKI) among inpatients worldwide varies from 0.7% to 31%, with intensive care unit (ICU) patients exceeding 50% [1, 2]. The mortality rate related to AKI is 23%, which increases to 49.4% in those requiring renal replacement therapy [1]. Patients who survived AKI with complete kidney function recovery have a better long-term prognosis, but many patients experience significant irreversible nephron loss and subsequently develop chronic kidney disease (CKD) [3–7]. Indeed, 20–50% of AKI patients develop progressive CKD, while 3–15% reach end-stage kidney disease (ESKD) [8], all associated with increased mortality. The current AKI criteria from the Kidney Disease: Improving Global Outcomes (KDIGO) group are comprehensive to predict the need for dialysis and early mortality [9]. However, given the reversibility of pre- and post-renal AKI compared with acute tubular necrosis, the KDIGO matrix is less useful to predict long-term outcomes.

On 8 November 2015, the 16th Acute Disease Quality Initiative (ADQI) meeting defined acute kidney disease (AKD) as acute or subacute damage and/or loss of kidney function lasting 7–90 days following an AKI-initiating event [10]. However, there are limited reports available regarding AKD epidemiology. A first meta-analysis study involving 1 114 012 hospitalized adults suggested that the incidence of community-acquired AKD is 4.60% and the incidence of hospital-acquired AKD is 28.2%. The study also revealed a significant association between AKD and increased risks of CKD and mortality [11, 12]. The idea of AKD fills the gap between AKI and subsequent CKD, thus supporting the evaluation of CKD risk in patients after AKI [13–15].

Little is known about the risk and prognosis of AKD in inpatients, hence the aims of this study were to study the incidence of AKI and AKD in hospitalized patients and dissect risk factors for AKI compared with AKD, evaluate long-term outcomes of AKI and AKD and assess which of the AKI and AKD criteria best predict the long-term prognosis.

## MATERIALS AND METHODS

### Data collection

This retrospective study enrolled a total of 450 000 inpatients from all hospital admissions of five institutions admitted from 1 June 2012 to 31 March 2018. All subjects were treated with standard care without study interventions and followed up for 5–63 months (median 14) until 1 January 2019. Patients were excluded if they met one of the following criteria: age <18 years, hospitalization <24 hours, continuous dialysis, less than two serum creatinine (SCr) tests during hospitalization and missing data elements that needed further analysis.

This study was approved by the Institutional Review Board (IRB; QDFY WZ 2018-9-13) to screen out those patients with qualifying SCr levels. Clinical data were obtained via electronic medical records and a database review and were de-identified (patient names were replaced with the identification code and private patient information was deleted before analysis) to protect patient privacy. The IRB supervised the entire de-identification process and waived patient's informed consent.

Complete blood counts, blood chemistry analyses and urine tests were performed within 3 days of admission. Additionally, demographic characteristics such as gender, age and body mass index, as well as inpatient department (medical, surgical and intensive care unit) and hospitalization-related factors (length of stay, surgery and mortality) were documented. Comorbidities such as hypertension, diabetes mellitus and coronary heart disease were defined based on the International Classification of Diseases, 10th Revision. Variables for concomitant drugs such as non-steroidal anti-inflammatory drugs (NSAIDs) were also collected as comprehensively as possible, especially when these medications were used before kidney injury. The information was extracted from the electronic clinical letter via regular expression matching.

### Definitions of AKI recovery, AKD with AKI, AKD without AKI and CKD

The criteria for AKI were based on the 2012 KDIGO guideline as follows: an increase in SCr level >26.5 $\mu$mol/l (0.3 mg/dl) within 48 hours, an increase in SCr to >1.5 times the baseline-confirmed value or an increase presumed to have occurred within 7 days; or urine output <0.5 ml/kg/hour for >6 hours. According to the 2017 ADQI, AKD is defined as persistent renal damage and/or renal dysfunction for a duration of 7–90 days after exposure to an AKI-initiating event [10]. Based on the diagnostic criteria of AKI and AKD, patients were classified into the following groups: AKI recovery, if SCr returned to baseline within 7 days (renal impairment duration <7 days or rapid recovery within 7 days); AKD with AKI, if stage ≥1 AKI persisted for ≥7 days after an AKI-initiating event (continuous AKI progressing to AKD); AKD without AKI, if SCr levels increased slowly but lasted >7 days (subacute AKD without meeting the AKI criteria); CKD, if both the index estimated glomerular filtration rate (eGFR) and preceding eGFR were <60 ml/min/1.73 m$^2$ or if albuminuria was present for at least 3 months (AKD that persisted >90 days was considered CKD); and no kidney disease (NKD), if the eGFR was ≥60 ml/min/1.73 m$^2$, albuminuria was absent or not measured and neither the AKI nor the AKD criteria were met. The diagnosis of AKI and AKD was established once the participants first met the ADQI criteria. The final classification consisted of four categories: NKD, AKI recovery, AKD with AKI and AKD without AKI.

Baseline SCr was defined as the lowest SCr level measured within 1 month before and 1 week after admission. All patients underwent at least three SCr tests, including two during hospitalization and one at the first follow-up. If elevated SCr levels did not return to baseline, additional tests were conducted once a week during hospitalization or at the next follow-up. The baseline eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration formula [16].

### Statistical analysis

We choose an empirical threshold that indicators with >15% missing values were excluded. In addition, missing values warranted interpolation by multiple imputation using the MICE [17] package, and all model variables were considered simultaneously. We assumed that the data were missing at random [18]. Therefore we performed predictive mean matching [19] to generate five complete imputed data sets that fit the logistic models. Sample size calculation showed an estimated 35 222 CKD-free events would be needed to provide 90% power for detecting a minimum clinically meaningful hazard ratio (HR) of 1.32 for AKI stage 1 relative to NKD with a two-sided $\alpha$ of 0.05. The continuous variables were transformed into categorical variables based on recognized cut-off values.

To account for confounders, we performed 1:1 propensity score matching (PSM) based on selected covariates using logistic regression with a caliper of 0.2 of the standard deviation [20]. PSM was performed for the matched patients stratified by baseline characteristics and other variables related to hospitalization, such as the inpatient department, surgery and concomitant drugs [21]. Forward stepwise regression analyses were performed to select adjusted indicators for Cox models. The Kaplan–Meier method was used to depict differences in renal impairment among the inpatients, and the Mantel–Haenszel logrank test was performed to evaluate differences among the groups classified by the stage of renal impairment. For pairwise comparison, continuous variables were subjected to a t-test or Mann–Whitney U test for variables with a non-normal distribution, and categorical variables subjected to the chi-squared test or Fisher's exact test. For multiple comparisons, continuous variables were subjected to one-way analysis of variance followed by the Tukey post hoc test. The package timeROC [22] was used to estimate time-dependent receiver operating characteristics (ROC) curves for censored event times and compare the area under the ROC curve (AUROC) values. All analyses were performed using R version 3.4.2 (http://www.r-project.org/).

## RESULTS

### Incidence and risk factors of the different kidney injury entities

Fig. 1 describes the selection of patients for the cohort used in the final analysis. A total of 71 041 inpatients were enrolled this study. Of those, 11 518 (16.2%) patients met the diagnostic criteria for AKI and 10 203 (14.4%) met the AKD criteria. In total there were 16 098 (22.7%) patients who developed acute/subacute kidney dysfunction (AKI and/or AKD criteria), with 5623 (7.9%) who met both the AKI and AKD criteria, 4580 (6.4%) who developed AKD without AKI and 5895 (8.3%) who had AKI recovery (Table 1). Thus AKI and AKD are frequent complications in Chinese inpatients. Patients with acute/subacute kidney dysfunction had a lower eGFR and impaired liver function and abnormal urine (Supplementary Table 1) and blood tests on admission. Also, chronic comorbidities were more prevalent in these patients compared with NKD patients (Table 1). These findings suggest that patients with chronic illnesses and worse hepatic and kidney function are more vulnerable to AKI or AKD during hospitalization.

Next, we applied PSM to remove the bias arising from unbalanced baseline characteristics and generate a more comparable subgroup to determine whether there are specific risk factors for AKI and AKD, which were selected by stepwise regression. We found that cancer {odds ratio [OR] 1.26 [95% confidence interval (CI) 1.16–1.36], $P < .01$} and hypoproteinaemia [OR 1.09 (95% CI 1.02–1.17), $P < .05$] are risk factors for AKI progressing to AKD ($P < .05$; Fig. 2A) instead of AKI recovery. Furthermore, when comparing AKD with and without AKI, hypoproteinaemia [OR 1.12 (95% CI 1.04–1.20), $P < .05$] and cardiovascular events [OR 1.17 (95% CI 1.03–1.34), $P < .05$] were risk factors for AKD with AKI (Fig. 2B), while the use of NSAIDs [OR 0.75 (95% CI 0.68–0.82), $P < .05$] and cancer [OR 0.87 (95% CI 0.82–0.93), $P < .05$] were inclined to cause AKD without AKI. Therefore, patients with cancer and NSAIDs administration are more likely to experience long-term, slowly declining renal function without recovery, while hypoproteinaemia and cardiovascular events are key risk factors for AKD with AKI.

### Different clinical outcomes after AKI and AKD

AKI survivors have a worse long-term prognosis and a higher risk for CKD than the AKI-free patients, but little is known about how outcomes of AKD compare with those of AKI. In our cohort, any type of kidney function impairment had a higher hospital mortality rate (7.7% versus 1.3%, $P < .05$) and a higher incidence of *de novo* CKD (8.6% versus 3.3%, $P < .05$) than NKD (Table 2). Furthermore, AKI with AKD was also associated with advanced staging (stage 3) (19.9% versus 0.8% versus 4.7%, $P < .05$), higher hospital mortality (16.6% versus 2.1% versus 3.8%, $P < .05$) and incidence of *de novo* CKD (10.5% versus 6.6% versus 9.0%, $P < .05$) as compared with the AKI recovery or AKD without AKI group (Table 2). The three subtypes of renal impairments showed a close association with long-term survival ($P < .05$; Supplementary Fig. 2A), and *de novo* CKD was proportionally associated with the stage of kidney injury ($P < .05$; Supplementary Fig. 2B).

The regression analyses demonstrated a significantly higher overall mortality in patients with AKI and AKD [adjusted HR 4.51 (95% CI 4.32–4.71), $P < .05$] compared with those with AKD without AKI [adjusted HR 2.25 (95% CI 2.13–2.39), $P < .05$] or AKI recovery [adjusted HR 1.18 (95% CI 1.09–1.26), $P < .05$; Fig. 3A, Table 3]. On the other hand, AKI with AKD yielded a higher risk for *de novo* CKD [adjusted HR 2.49 (95% CI 2.37–2.62), $P < .05$] than AKI recovery [adjusted HR 1.64 (95% CI 1.54–1.73), $P < .05$) and AKD without AKI [adjusted HR 2.17 (95% CI 2.05–2.30), $P < .05$; Table 3]. More specifically, AKI and AKD patients with a small increase in SCr achieved significantly better results in terms of long-term survival [adjusted HR 2.14 (95% CI 2.09–2.19), $P < .05$] and *de novo* CKD [adjusted HR 2.05 (95% CI 1.99–2.11), $P < .05$] than those with larger increases in SCr, which means that for every doubling of SCr during hospitalization, the risk of death increases by 114% and the risk of developing CKD increases by 105% compared with NKD (Supplementary Table 2). AKI and AKD, especially AKI followed by AKD, exhibit significant associations with overall mortality and *de novo* CKD.

### Sensitivity analyses of the AKI and AKD criteria

Next, we compared the predictive ability of different kidney injury criteria for outcomes. First, AKI yielded a higher risk for overall survival and a lower risk for *de novo* CKD than AKD (Table 3). These data indicate that both criteria imply persistent kidney damage, but that a rapid decline in excretory kidney function implies higher mortality risks while a persistent decline may result in *de novo* CKD. Second, the AKD criteria were robustly associated with overall survival (AUROC 0.71, $P < .05$) and *de novo* CKD (AUROC 0.71, $P < .05$), whereas the AKI criteria demonstrated relatively lower predictive ability for overall survival (AUROC 0.65, $P < .05$) and CKD (AUROC 0.63, $P < .05$; Supplementary Fig. 1). Meanwhile, these associations between different kidney injury criteria and outcomes exhibited good generalizability and were constant across comorbidities and surgeries (Fig. 2). Therefore, we propose using the AKD criteria in clinical practice, which are far more accurate to predict prognosis, especially *de novo* CKD.

## DISCUSSION

The aims of this study were to investigate the incidence of AKI and AKD in hospitalized patients, dissect risk factors for AKI compared with AKD, evaluate long-term outcomes of AKI and AKD and assess which of the AKI and AKD definitions best

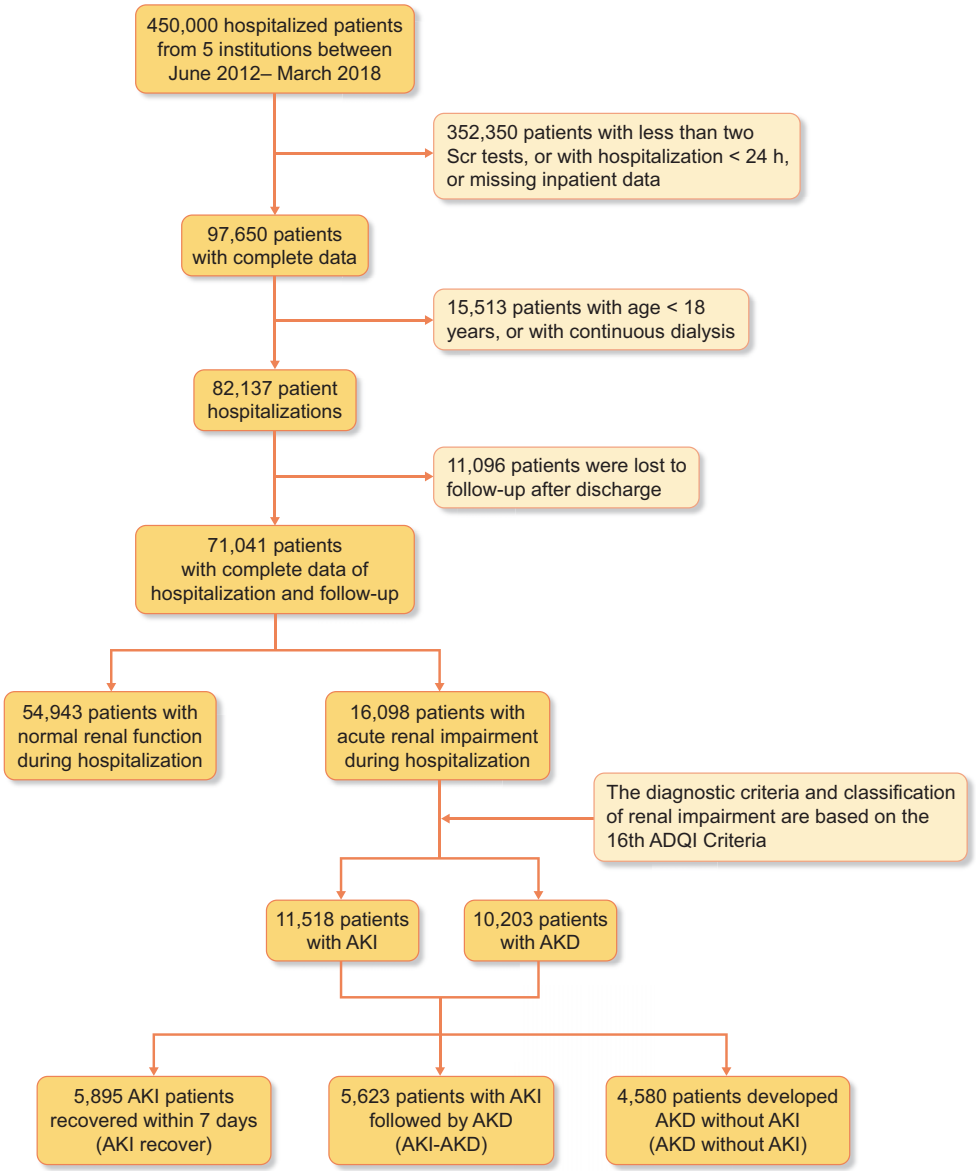


**Figure 1:** Flow diagram of patient selection.

predict the long-term prognosis. We found that among Chinese inpatients, 16.2% developed AKI and/or AKD, 7.9% developed AKD with AKI, 8.3% recovered from AKI and 6.4% developed AKD without AKI; cancer and administration of NSAIDs were more likely lead to long-term renal function decrease without recovery, while hypoproteinaemia and cardiovascular events were key risk factors for AKD with AKI; both AKI and AKD, particularly AKI followed by AKD, were strongly associated with overall mortality and *de novo* CKD; and the AKI criteria had a higher risk for overall survival compared with the AKD criteria, while the AKD criteria showed a higher risk for *de novo* CKD and had better accuracy in predicting prognosis for both mortality and *de novo* CKD than the AKI criteria.

The AKD criteria identified many patients who did not meet the AKI and CKD criteria, and the risk factors of AKI and AKD are different. In our study, 23% of patients had acute/subacute kidney dysfunction during hospitalization, aligning with previous research [23]. Among patients with kidney damage, 8.3% had AKI recovery, 7.9% had AKI followed by AKD and 6.4% had AKD without AKI, which did not meet the AKI and CKD criteria. Our

**Table 1: Baseline characteristics of inpatients**

| Clinical features | NKD ($n = 54\,943$) | Acute/subacute renal impairment | | | | |
|---|---|---|---|---|---|---|
| | | AKD with AKI ($n = 5623$) | AKD without AKI ($n = 4580$) | AKI recovery ($n = 5895$) | Total ($N = 16\,098$) | *P*-value[a] |
| Baseline characteristics | | | | | | |
| Male, *n* (%) | 32 111 (58) | 3226 (57) | 2619 (57) | 3364 (57) | 9209 (57) | <.05 |
| Age (years) | 59 ± 14 | 62 ± 15 | 61 ± 15 | 60 ± 16 | 61 ± 15 | <.05 |
| BMI (kg/m$^2$) | 24.4 ± 3.7 | 23.7 ± 3.8 | 23.9 ± 3.9 | 24.4 ± 4.0 | 24.0 ± 3.9 | <.05 |
| Hb (g/l) | 128 ± 22 | 114 ± 25 | 118 ± 24 | 122 ± 24 | 118 ± 25 | <.05 |
| WBC count ($\times 10^9$/l) | 6.9 ± 3.1 | 8.3 ± 4.4 | 7.6 ± 3.6 | 8.7 ± 4.2 | 8.3 ± 4.2 | <.05 |
| PLT count ($\times 10^9$/l) | 226 ± 83 | 207 ± 100 | 223 ± 96 | 207 ± 85 | 211 ± 94 | <.05 |
| LDL (mmol/l) | 2.8 ± 1.0 | 2.5 ± 1.3 | 2.7 ± 1.2 | 2.5 ± 1.1 | 2.6 ± 1.2 | <.05 |
| ALT (U/l) | 35 ± 72 | 59 ± 138 | 46 ± 106 | 49 ± 123 | 52 ± 124 | <.05 |
| AST (U/l) | 30 ± 58 | 59 ± 139 | 42 ± 98 | 53 ± 136 | 52 ± 127 | <.05 |
| HDL (mmol/l) | 1.29 ± 0.40 | 1.10 ± 0.43 | 1.17 ± 0.43 | 1.19 ± 0.42 | 1.15 ± 0.43 | <.05 |
| LDH (U/l) | 177 ± 79 | 226 ± 126 | 206 ± 103 | 215 ± 118 | 216 ± 117 | <.05 |
| ALB (g/l) | 37.4 ± 6.0 | 33.0 ± 6.5 | 34.4 ± 6.6 | 34.0 ± 6.5 | 33.7 ± 6.6 | <.05 |
| SCr ($\mu$mol/l) | 85 ± 42 | 113 ± 111 | 90 ± 68 | 109 ± 105 | 105 ± 99 | <.05 |
| eGFR (ml/min/1.73 m$^2$) | 103 ± 25 | 94 ± 38 | 103 ± 34 | 97 ± 41 | 98 ± 38 | <.05 |
| UA ($\mu$mol/l) | 297 ± 106 | 297 ± 150 | 292 ± 134 | 307 ± 141 | 299 ± 142 | <.05 |
| Comorbidities, *n* (%) | | | | | | |
| CKD | 798 (1.45) | 281 (5.00) | 203 (4.43) | 169 (2.87) | 653 (4.06) | <.05 |
| DM | 7801 (14.2) | 1347 (24.0) | 845 (18.0) | 1226 (20.8) | 3418 (21.2) | <.05 |
| HBP | 16 120 (29) | 2348 (41) | 1630 (36) | 2368 (40) | 6346 (39) | <.05 |
| CHD | 7592 (13) | 1532 (27) | 996 (22) | 1467 (25) | 3995 (25) | <.05 |
| Admission, *n* (%) | | | | | | |
| Surgical | 39 827 (72) | 2697 (48) | 2389 (52) | 3040 (52) | 8126 (50) | <.05 |
| Medical | 14 384 (26) | 2267 (40) | 2058 (45) | 2334 (39) | 6660 (42) | <.05 |
| ICU | 732 (1) | 659 (12) | 133 (3) | 521 (9) | 1313 (8) | <.05 |

Values are presented as mean ± SD unless stated otherwise.

BMI: body mass index; ALB: albumin; LOS: length of stay; WBC: white blood cell; Hb: haemoglobin; PLT: platelet; ALT: alanine transaminase; AST: aspartate aminotransferase; LDL: low-density lipoprotein; HDL: high-density lipoprotein; LDH: lactate dehydrogenase; UA: uric acid; DM: diabetes; HBP: hypertension; CHD: coronary heart disease.

[a]The *P*-value was calculated by analysis of variance or chi-squared test among NKD and three subtypes of acute/subacute kidney dysfunction.

findings also demonstrated a strong association between the severity and duration of AKI and the persistence of kidney injury and delayed recovery [24]. The proportion of patients with stage 2 and 3 among those with AKD and AKI was significantly higher than that among patients with AKI recovery or AKD without AKI, suggesting that patients with stage ≥2 AKI not only have a worse prognosis, but also have an increased incidence of AKD compared with patients with stage 1 AKI [25, 26]. Moreover, in elderly patients ≥65 years of age, CKD, hypertension, diabetes, heart disease and tumours are known factors leading to persistent AKI [27, 28]. However, little literature exists regarding the risk of AKD. Our study conducted additional research by employing PSM to match more comparable subgroups, aiming to identify specific risk factors for AKI and AKD. The results indicated that cancer was a significant risk factor for AKD, followed by NSAIDs and hypoproteinaemia. Moreover, cardiovascular events were found to be associated with AKI. Therefore, AKD exhibits distinct clinical features that are crucial in addressing the gap between AKI and CKD [29].

The long-term prognosis of patients with acute/subacute renal impairment has always been a topic of considerable interest in nephrology, and we showed the prognosis of AKI and AKD is different. First, acute/subacute renal dysfunction is associated with a high mortality rate [23]. AKD with AKI caused a hospital mortality rate of 16%, which is nearly five times higher than that in patients with AKD without AKI (3.8%), while the mortality was 2.12% in those with AKI recovery and 1.26% in non-kidney damage patients. Second, the severity of acute/subacute renal impairment is closely related to the occurrence and development of CKD. Patients with AKI and AKD had a higher proportion of *de novo* CKD (11%) and *de novo* ESKD (4.4%) than those with AKI or AKD alone, which is consistent with the findings of a Swedish multicentre cohort study [30]. Therefore, AKD is an extension between AKI and CKD to assess declining renal function and prognosis. Further investigation of AKD is necessary to develop and evaluate clinical intervention strategies.

Despite the initial publication of the AKD criteria in the 2012 KDIGO clinical practice guideline for AKI, there is limited information on the different abilities to fit the risk of prognosis between AKI and AKD. Clinical studies have shown that AKI is an independent risk factor for CKD [5] and death [31], while James *et al.* [32] compare the differences between AKD and AKI based on 1 109 099 adults cohort, which showed that AKD was associated with a higher risk of developing new CKD and ESKD, and AKI led to higher mortality compared with NKD. In our study, we showed AKI and AKD are related to both mortality and *de novo* CKD, and all types of acute renal impairment showed a close association with long-term survival, namely, the risk of *de novo* CKD proportionally changed with the stage of AKI and AKD. However, the AKD criteria exhibited a stronger association with overall survival and *de novo* CKD than the AKI criteria, with constant associations across different genders, surgeries

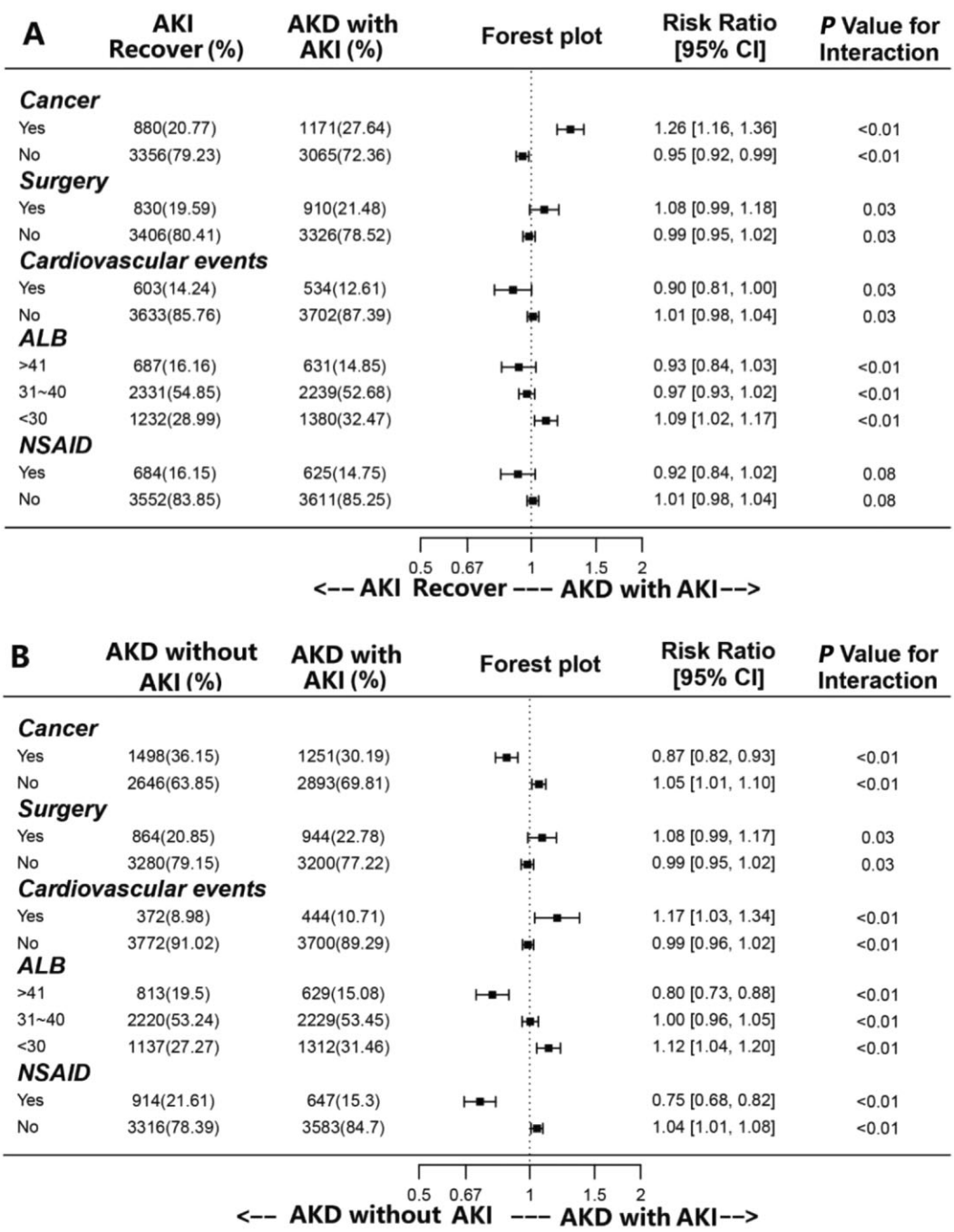


Figure 2: Forest plot of ORs of acute renal impairment for patients suffering from AKI or AKD after propensity score matching. Comparison of **(A)** AKI recovery and AKD with AKI, **(B)** AKD with AKI and AKD without AKI.

and comorbidities. Therefore, we propose using the AKD criteria in clinical practice, which is far more accurate to predict prognosis, especially CKD development.

Our study has several limitations. First, the analysis was conducted using data from only five institutions, thus further investigations on a larger scale are necessary to provide more robust and representative evidence. Second, our study is a retrospective investigation and we intend to conduct a randomized controlled trial in the future. Third, our study employed forward stepwise and Cox regression analyses to identify the risk factors associated with AKI and AKD. For future research, we intend to utilize diverse machine learning algorithms to enhance and optimize the predictive model. Despite these limitations, our study stands as the pioneering investigation that compares the long-term prognosis of three distinct renal functional trajectories following kidney injury. The criteria for both AKI and AKD demonstrated robust associations with overall mortality and *de novo* CKD. The AKD criteria provide a more

**Table 2: Comparison of AKI and AKD on clinical features and prognosis of patients**

| Risk factors and prognosis | NKD ($n = 54\,943$) | Acute/subacute renal impairment | | | | P-value[a] |
|---|---|---|---|---|---|---|
| | | AKD with AKI ($n = 5623$) | AKD without AKI ($n = 4580$) | AKI recovery ($n = 5895$) | Total ($N = 16\,098$) | |
| Surgery | 10 464 (19) | 1243 (22) | 952 (21) | 1056 (18) | 3251 (20) | <.05 |
| Cardiovascular events | 2839 (5.2) | 668 (11.9) | 376 (8.2) | 867 (14.7) | 1911 (11.9) | <.05 |
| Urologic procedures | 3502 (6.4) | 276 (4.9) | 335 (7.3) | 569 (9.7) | 1180 (7.3) | <.05 |
| Cancer | 12 465 (23) | 1565 (28) | 1812 (40) | 1162 (20) | 4539 (28) | <.05 |
| Drugs | | | | | | |
| ACEI | 2585 (4.7) | 749 (13.3) | 466 (10.2) | 687 (11.7) | 1902 (11.8) | <.05 |
| ARB | 5808 (11) | 1071 (19) | 758 (17) | 1041 (18) | 2870 (18) | <.05 |
| Antibiotic | 35 538 (65) | 4378 (78) | 3293 (72) | 4202 (71) | 11 873 (74) | <.05 |
| NSAID | 5729 (10) | 810 (14) | 969 (21) | 912 (15) | 2691 (17) | <.05 |
| Kidney injury level | | | | | | |
| Stage 1 | 0 (0) | 2921 (52) | 3591 (78) | 5649 (96) | 12 161 (76) | <.05 |
| Stage 2 | 0 (0) | 1586 (28.2) | 774 (16.9) | 198 (3.4) | 2558 (15.9) | <.05 |
| Stage 3 | 0 (0) | 1116 (19.9) | 215 (4.7) | 48 (0.8) | 1379 (8.6) | <.05 |
| Hospital mortality | 933 (1.3) | 821 (16.6) | 175 (3.8) | 125 (2.1) | 1233 (7.7) | <.05 |
| Length of stay (days) | $13 \pm 7$ | $20 \pm 11$ | $18 \pm 10$ | $14 \pm 9$ | $17 \pm 10$ | <.05 |
| Renal outcome | | | | | | |
| *de novo* CKD | 1788 (3.3) | 589 (10.5) | 410 (9.0) | 386 (6.6) | 1385 (8.6) | <.05 |
| *de novo* ESRD | 444 (0.81) | 246 (4.4) | 116 (2.5) | 105 (1.8) | 467 (2.9) | <.05 |

Values are presented as n (%) unless stated otherwise.
ACEI: angiotensin-converting-enzyme inhibitor; ARB: angiotensin II receptor blocker; CCB: calcium channel blocker.
[a]The P-value was calculated by analysis of variance or chi-squared test among NKD and three subtypes of acute/subacute kidney dysfunction.

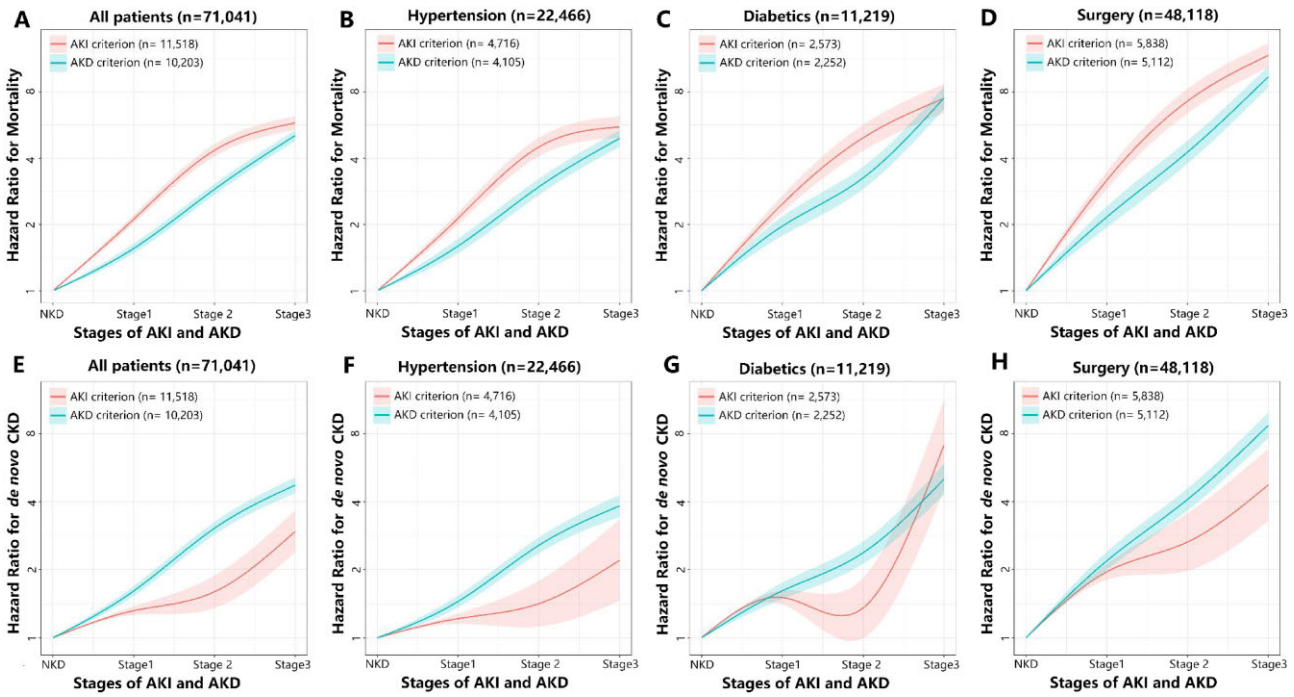


**Figure 3:** Distributions and HRs of AKI and AKD for **(A–D)** survival and **(E–H)** *de novo* CKD by using restricted cubic splines in different clinical settings.

accurate prediction of CKD than the AKI criteria. Therefore, this research holds significant relevance for clinicians in their clinical practice.

In conclusion, AKI and AKD are prevalent conditions among hospitalized patients. They have been demonstrated to be predictive of adverse clinical outcomes, including overall long-term survival and the development of CKD. Therefore, further investigation into the aetiology and pathogenesis of acute/subacute renal impairment is imperative to establish standardized diagnostic approaches, therapeutic interventions and strategies for

**Table 3: Cox regression model of the association between acute renal impairment and prognosis of patients**

| | | Mortality | | | | | | *de novo* CKD | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acute/subacute renal impairment | n | HR | *P*-value | AUROC | Adjusted HR[a] | *P*-value | AUROC | HR | *P*-value | AUROC | Adjusted HR[b] | *P*-value | AUROC |
| Categories | | | | 0.71 | | | 0.88 | | | 0.78 | | | 0.83 |
| NKD | 54 943 | 1.00 (Reference) | | | 1.00 (Reference) | | | 1.00 (Reference) | | | 1.00 (Reference) | | |
| AKI recovery | 5895 | 1.99 (1.85–2.14) | <.01 | | 1.18 (1.09–1.26) | .03 | | 2.84 (2.69–3.01) | <.01 | | 1.64 (1.54–1.73) | <.01 | |
| AKD without AKI | 4580 | 4.06 (3.84–4.29) | <.01 | | 2.25 (2.13–2.39) | <.01 | | 2.9 (2.73–3.07) | <.01 | | 2.17 (2.05–2.3) | <.01 | |
| AKD with AKI | 5623 | 10.9 (10.48–11.33) | <.01 | | 4.51 (4.32–4.71) | <.01 | | 4.67 (4.45–4.9) | <.01 | | 2.49 (2.37–2.62) | <.01 | |
| AKI criteria | 11 518 | | | 0.65 | | | 0.90 | | | 0.63 | | | 0.83 |
| Stage 1 | 9392 | 4.58 (4.4–4.77) | <.01 | | 2.11 (2.02–2.20) | <.01 | | 3.09 (2.97–3.22) | <.01 | | 1.32 (1.27–1.38) | <.01 | |
| Stage 2 | 1342 | 9.94 (9.09–10.88) | <.01 | | 4.35 (4.08–4.64) | <.01 | | 3.82 (3.33–4.4) | <.01 | | 1.59 (1.35–1.88) | <.01 | |
| Stage 3 | 784 | 17.55 (15.36–20.05) | <.01 | | 5.77 (5.38–6.2) | <.01 | | 8.25 (6.6–10.3) | <.01 | | 2.96 (2.39–3.66) | <.01 | |
| AKD criteria | 10 203 | | | 0.71 | | | 0.90 | | | 0.71 | | | 0.83 |
| Stage 1 | 6538 | 2.77 (2.64–2.91) | <.01 | | 1.55 (1.48–1.63) | <.01 | | 2.33 (2.21–2.45) | <.01 | | 1.61 (1.53–1.69) | <.01 | |
| Stage 2 | 2506 | 6.54 (6.2–6.91) | <.01 | | 2.89 (2.73–3.05) | <.01 | | 4.73 (4.44–5.05) | <.01 | | 3.06 (2.87–3.26) | <.01 | |
| Stage 3 | 1440 | 16.62 (15.8–17.49) | <.01 | | 5.05 (4.77–5.34) | <.01 | | 8.6 (7.93–9.34) | <.01 | | 4.73 (4.37–5.13) | <.01 | |
| AKI and AKD criteria | 16 098 | | | 0.71 | | | 0.90 | | | 0.72 | | | 0.84 |
| Stage 1 | 12 161 | 3.72 (3.56–3.88) | <.01 | | 1.84 (0.80–2.88) | <.01 | | 2.7 (2.58–2.82) | <.01 | | 1.71 (1.64–1.78) | <.01 | |
| Stage 2 | 2558 | 8.45 (8.01–8.92) | <.01 | | 3.24 (2.18–4.30) | <.01 | | 5.58 (5.25–5.94) | <.01 | | 3.09 (2.9–3.29) | <.01 | |
| Stage 3 | 1379 | 21.66 (20.56–22.82) | <.01 | | 5.42 (4.36–6.48) | <.01 | | 9.75 (9–10.57) | <.01 | | 5.1 (4.71–5.53) | <.01 | |

[a]The COX regression model was adjusted by surgical operation, serum albumin, ICU admission, age, haemoglobin, serum uric acid, aspartate aminotransferase and cancer.
[b]The COX regression model was adjusted by hypertension, red blood cell count, total bilirubin, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, serum uric acid, aspartate aminotransferase, NSAIDs, haemoglobin, age, and proton pump inhibitors.

reducing complications and CKD ultimately leading to improved survival rates.

## SUPPLEMENTARY DATA

Supplementary data are available at *ckj* online.

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## AUTHORS' CONTRIBUTIONS

L.X. and C.L. contributed equally to this work. All authors contributed to the study conception, design, analysis and interpretation of data. Each author contributed important intellectual content during manuscript revision and approved the final manuscript.

## DATA AVAILABILITY STATEMENT

The data underlying this article will be shared upon reasonable request to the corresponding author.

## CONFLICT OF INTEREST STATEMENT

None declared.

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