# Duration of acute kidney injury, 90-day mortality, and chronic kidney disease progression in very elderly patients

**Qinglin Li**
Chinese PLA general Hospital
**Liang Pan**
Chinese PLA General Hospital
**Zhi Mao**
Chinese PLA General Hospital
**Hongjun Kang**
Chinese PLA General Hospital
**Feihu Zhou** ( feihuzhou301@126.com )
Chinese PLA General Hospital https://orcid.org/0000-0001-6154-013X

**Research**

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# Abstract

Background: This study evaluated the prognostic impact of AKI duration on 90-day mortality and new-onset chronic kidney disease (CKD) progression in very elderly patients.

Methods: We retrospectively enrolled very elderly patients (≥75 years) with normal RF from the hospital information system of the National Clinical Research Center for Geriatric Diseases of Chinese PLA General Hospital January 1, 2007 and December 31, 2018. AKI was diagnosed using the Kidney Disease: Improving Global Outcomes criteria. AKI patients were divided into T-AKI and P-AKI groups based on whether serum creatinine level returned to baseline within 48 h post-AKI.

Results: In total, 760 geriatric patients developed AKI, and 693 were suitable for the final evaluation. Among them, 62 (8.9%) patients had T-AKI (1–2 days), 104 (15.0%) had short-duration AKI (3–4 days), 140 (20.2%) had medium-duration AKI (5–7 days), and 387 (55.8%) had long-duration AKI (>7 days). In total, 209 (30.2%) of 693 patients died within 90 days, including 5 (8.1%) with T-AKI and 204 (32.3%) with P-AKI. Of the 484 survivors with AKI, 122 (25.2%) developed CKD. After adjusting for multiple covariates, duration of AKI (3–4 days: hazard ratio [HR] = 2.512; 95% confidence interval [CI]: 1.021–6.181; 5–7 days: HR = 3.154; 95% CI: 1.250–7.960; >7 days: HR = 6.212; 95% CI: 2.383–16.192;), more advanced AKI stages (stage 2: HR = 7.365; 95% CI: 4.114–13.183; stage 3: HR = 28.414; 95% CI: 16.360–49.350); and low body mass index (HR = 0.910; 95% CI: 0.870–0.953) were significantly associated with a higher 90-day mortality and longer AKI duration (3–4 days: odds ratio [OR] = 0.982; 95% CI: 0.247–3.900; 5–7 days: HR = 1.322; 95% CI: 0.381–4.592; > 7days: HR = 7.007; 95% CI: 2.417–20.311), and baseline eGFR (OR = 0.928; 95% CI: 0.901–0.956) was significantly associated with new-onset CKD of the survivors.

Conclusion: AKI duration is a useful parameter to predict of worse clinical outcomes in very elderly patients, emphasizing the importance of identifying an appropriate treatment window for early intervention.


# Background

Acute kidney injury (AKI) consists of a group of clinical syndromes associated with compromised patient survival, development of chronic kidney disease (CKD) or poor renal function (RF) recovery.[1–3] The recent recommendation from the international Kidney Disease Improving Global Outcomes (KDIGO) guidelines defined AKI and classified the stages of AKI severity into three grades, based on the increase and/or decrease in serum creatinine (Scr) and urine output, and a more advanced AKI stage has been associated with adverse outcomes.[2, 4] In fact, AKI duration recently has been viewed as another independent risk factor for a poorer outcome: longer duration of AKI (also called persistent AKI or P-AKI), typically defined as more than 48–72 h after onset, has been associated with a higher risk for CKD and death compared to short-duration AKI (also called transient AKI or T-AKI).[5–9] However, a recent intensive care unit patient-based retrospective study showed that although P-AKI is associated with poorer hospital survival, this association was attenuated after accounting for AKI severity.[10]

Limited information is available on the association between the duration of the increase in Scr and clinical outcomes in very elderly patients.[11] We have previously shown that patients with P-AKI (elevated Scr level over 3 days) are more likely to experience more severe AKI and have a higher 90-day mortality than patients with T-AKI (in whom Scr returned to baseline levels within 3 days).[8] In this study, however, the diagnoses of T-AKI and P-AKI were not made based on the 2017 Acute Disease Quality Initiative (ADQI) criteria, and RF recovery was not assessed 90 days post-AKI.[12] The aim of the current study was to evaluate the prognostic impact of AKI duration on 90-day mortality and progression of new-onset CKD in very elderly patients after AKI development.

# Materials And Methods

This was a retrospective observational study conducted at Chinese PLA General Hospital National Clinical Research Center for Geriatric Diseases (Beijing, China). The patient in this center was mainly retired people, and nearly all the patients were retired elderly males and fewer females are treated in this center. All patients aged ≥ 75 years with normal RF who were admitted between January 2007 and December 2018 were enrolled. The study design was approved by the Clinical Ethics Committee of the Chinese PLA General Hospital. All admissions were screened and evaluated for AKI and categorized according to the KDIGO criteria. AKI patients were divided into T-AKI or P-AKI groups based on their rate of Scr decline to the baseline level within 48 h post-AKI.

Demographic and basic data were noted from the medical records. Other laboratory data of interest included baseline Scr, Scr at AKI diagnosis, peak Scr, blood urea nitrogen (BUN), peak BUN, uric acid, blood glucose (BG), electrolytes (K, Na, Ca, P, and Mg), C-reactive protein (CRP), albumin, serum prealbumin, and hemoglobin.

The exclusion criteria were as follows: patients who had been previously diagnosed with CKD, hospital stay < 48 h, patients with no Scr or only one Scr examination, patients with insufficient medical records, and patients who died within 48 h of admission.

### Definitions

The 2012 KDIGO defined Scr criteria were used to identify and classify AKI. The CKD Epidemiology Collaboration was used to calculate baseline estimated glomerular filtration rate (eGFR).[13] The baseline Scr level was the most recent measure taken in the 1–3 months before admission for AKI.[14] Peak Scr was the highest Scr level reached during the episode. “T-AKI” was defined as Scr that returned to baseline within 48 h post-AKI (duration 1–2 days); “P-AKI” was defined as renal dysfunction without recovery within 48 h.[12] We further classified P-AKI into three categories based on AKI duration: (1) short duration: resolving AKI lasting 3–4 days, (2) medium duration: resolving AKI lasting 5–7 days, and (3) long duration: AKI lasting > 7 days. The outcome of RF 90 days post-AKI as indicated by eGFR was characterized as non-CKD (eGFR ≥60 mL/min per 1.73 $m^2$) or new-onset CKD (eGFR < 60 mL/min per 1.73 $m^2$).[15] Sepsis was defined according to the Surviving Sepsis Campaign Bundle: 2018 update.[16]

### Statistical analysis

Continuous variables of parametric data are presented as mean ± standard, deviation or as median with interquartile range (with $25^{th}$ and $75^{th}$ percentiles) for nonparametric variables. Categorical variables are presented as numbers (n) or percentages (%). Between-group comparisons were conducted using Student's *t*-test or the Mann–Whitney *U*-test for continuous variables and Pearson's chi-square or Fisher's exact test for categorical variables. Multivariate logistic regression analyses were performed to identify covariates associated with new-onset CKD from AKI. Prognostic survival factors were identified using the Cox proportional hazards regression model. Survival probability was estimated using the Kaplan–Meier method, and curves were compared among groups using the log-rank test. A *P*-value < 0.05 was considered significant. Statistical analyses were performed using SPSS version 21.0 for Windows software (SPSS Inc., Chicago, IL, USA).

## Results

### Study population

A total of 3861 very elderly patients (aged ≥ 75 years) were hospitalized between January 1, 2007 and December 31, 2018 at the National Clinical Research Center for Geriatric Diseases, and 760 developed AKI during hospitalization. Among these patients, 10 were excluded for hospital stays < 48 h, and 3 were excluded due to missing data. Therefore, 747 AKI patients were suitable for the subsequent analysis, including 685 (91.7%) patients with P-AKI and 62 (8.3%) patients with T-AKI. Of the 747 patients, we further excluded 54 patients due to death within 48 h post-AKI because the duration of AKI could not be determined. Consequently, 693 AKI patients were included in the final evaluation.

### AKI

As shown in Table 1, the median age of the 693 participants was 88 years, and the majority (656, 94.7%) were male. Of these, T-AKI was documented in 62 (9.0%), and P-AKI in 631 (91.0%) according to our definitions, including 104 (15.0%) with AKI duration of 3–4 days, 140 (20.2%) with AKI duration of 5–7 days, and 387 (55.8%) with persistent AKI > 7 days. Among the 693 patients, 319 (46.0%) had KDIGO stage 1 AKI, 172 (24.8%) had stage 2 AKI, 202 (29.1%) had stage 3 AKI, and 4 (0.6%) needed dialysis. Among all patients, 209 (30.2%) died within 90 days, including 5 (8.1%) with T-AKI and 204 (32.3%) with P-AKI. Of the 484 survivors with AKI in whom eGFR recovery could be assessed, 362 (74.8%) recovered to the baseline level and 122 (25.2%) developed CKD. The study flow chart is presented in Fig. 1.

### Clinical characteristics associated with T-AKI or P-AKI

The P-AKI group had a lower percentage of hypertension (71.8% vs. 83.9%, *P*=0.041), cardiovascular events (14.4% vs. 24.2%, *P* = 0.041), or surgical therapy compared with the T-AKI group (6.2% vs. 14.5%, *P* = 0.027; Table 2). Similarly, the P-AKI group more frequently required mechanical ventilation support (39.9% vs. 12.9%, *P* < 0.001). Laboratory results, such as Scr (129.0 vs. 116.1 μmol/L, *P* < 0.001) levels,

peak Scr (146.3 vs. 117.9 μmol/L, $P < 0.001$) levels, BUN (12.7 vs. 9.3 mmol/L, $P < 0.001$) levels, peak BUN (18.5 vs. 10.8 mmol/L, $P < 0.001$) levels, uric acid (364.8 vs. 338.3 μmol/L, $P = 0.017$) levels, Na (140 vs 138 mmol/L, $P=0.001$) levels, Mg (0.9 vs. 0.9 mmol/L, $P = 0.003$) levels, albumin (34.3 ± 5.5 vs. 36.1 ± 5.3 g/L, $P = 0.013$) levels, and hemoglobin (112 ± 22 vs. 119 ± 20 g/L, $P = 0.010$) differed significantly between the two groups. More patients with P-AKI were evaluated by nephrologists than those with T-AKI (27.4% vs. 11.3%, $P = 0.006$). No significant differences were observed in age, gender, BMI, pre-existing comorbidities (coronary disease, COPD and diabetes) or baseline Scr and eGFR, mean arterial pressure, oliguria, BG, K, Ca, P, CRP, prealbumin, as well as the need for renal replacement therapy between the two groups.

### Ninety-day mortality and new-CKD progression according to AKI duration and KDIGO stage

A total of 209 patients died within 90 days. Among the survivors, 25.2% experienced CKD progression and 74.8% did not. The 90-day mortality was 8.1% in patients with T-AKI and 32.3% in those with P-AKI ($P < 0.001$; Table 2). Accordingly, as shown in Table 3, the prevalence of P-AKI was significantly higher in the non-surviving group (97.6% vs. 88.2%, $P < 0.001$); AKI of medium or longer duration occurred more frequently among non-survivors than survivors (22.0% vs. 19.4% and 62.7% vs. 52.9%, respectively; $P<0.001$). The Kaplan–Meier survival plot demonstrated that 90-day survival was higher in the T-AKI group than in the P-AKI group. Furthermore, within the AKI groups, higher mortality was found in patients with a longer duration of AKI than those with a shorter AKI duration (log rank $P = 0.002$; Fig. 2).

Table 3 shows that the 90-day mortality rates were: 7.2%, 23.9%, and 68.9% for AKI stages 1, 2, and 3, respectively ($P < 0.001$). The Kaplan–Meier curves showed that 90-day mortality increased steadily with AKI severity ($P<0.001$, log-rank test; Fig. 3). Fig. 4 shows the 90-day mortality curves in the different AKI groups for each AKI stage. The 90-day mortality rates among the AKI groups for each AKI stage were significantly different (all $P < 0.001$, log-rank test), but there was no difference in T-AKI (duration 1–2 days) among the different AKI stage group (log-rank test: $P = 0.104$).

As shown in Table 3, the incidence rates of P-AKI were 96.7% in patients with new-onset CKD vs. 85.4% in the non-CKD group. Long-duration (> 7 days) AKI was more likely to be seen in new-onset CKD than in the non-CKD group (85.2% vs. 42.0%, $P < 0.001$). Fig. 5 shows the significant differences in new-onset CKD among the four groups ($P < 0.001$). Table 3 shows the relationship between the AKI stage and CKD progression. Surprisingly, AKI severity was not significantly associated with progression of new-onset CKD (63.9% vs. 62.4% for stage 1 patients, 23.0% vs. 26.0% for stage 2, and 13.1% vs. 11.6% for stage 3; $P = 0.765$ for the three stages).

### Influence of AKI duration and KDIGO stage on 90-day patient mortality and new-onset CKD progression

When AKI duration was considered a binary variable (T-AKI and P-AKI), P-AKI was associated with 90-day mortality (hazard ratio [HR] = 2.522; 95% confidence interval [CI]: 1.028–6.186; $P = 0.043$) and the progression of new-onset CKD (odds ratio [OR] = 3.907; 95% CI: 1.331–11.463; $P = 0.013$) in a multivariate regression analysis (data not shown).

When AKI duration was considered an ordinal variable (1–2, 3–4, 5–7, and > 7 days), the independent risk factors for 90-day mortality were the following: duration of AKI (3–4 days: HR = 2.512; 95% CI: 1.021–6.181; *P* = 0.045, 5–7 days: HR = 3.154; 95% CI: 1.250–7.960; *P* = 0.015; > 7days: HR = 6.212; 95% CI: 2.383–16.192; *P* < 0.001), more advanced AKI stage (stage 2: HR = 7.365; 95% CI: 4.114–13.183; *P* < 0.001; stage 3: HR = 28.414; 95% CI: 16.360–49.350; *P* < 0.001), and low BMI (HR = 0.910; 95% CI: 0.870–0.953; *P* < 0.001) (Table 4). The independent risk factors for the progression of new-onset CKD were duration of AKI (3–4 days: OR = 0.982; 95% CI: 0.247–3.900; *P* = 0.980; 5–7 days: HR = 1.322; 95% CI: 0.381–4.592; *P* = 0.661; > 7 days: HR = 7.007; 95% CI: 2.417–20.311; *P* < 0.001) and baseline eGFR (OR = 0.928; 95% CI: 0.901–0.956; *P* < 0.001) (Table 4).

# Discussion

In the present study, approximately 91% of geriatric patients with normal RF upon inclusion had AKI lasting more than 48 h during hospitalization, demonstrating a high incidence of P-AKI in this patient population. Furthermore, P-AKI in geriatric patients was independently associated with a higher 90-day mortality. Among patients who survived more than 90 days, AKI duration of more than 7 days was associated with a progression to CKD 90 days after the occurrence of AKI.

With wider recognition of the pathogenesis of AKI along with the greater economic and social burden it brings, the International Society of Nephrology (ISN) launched a global target of “0by25”, i.e., no one should die of untreated AKI in low-resource regions by 2025, to improve the diagnosis and treatment of AKI.[17] Early identification of P-AKI is vital to initiate an extended evaluation and management protocol to avoid further kidney damage and reduce mortality. However, only 21%–44% of patients receive a timely diagnosis of AKI in China, the largest developing country in the world with approximately 20% of the global population. Furthermore, the rate of missed diagnosis is 53%–74%.[18-20] One possible reason for these results may be the obscure definition in the KDIGO AKI criteria (48-h and 7-day time windows), which is neither widely recognized nor accepted by physicians.[21] Other potential reasons include insufficient recognition of AKI severity, insufficient RF surveillance during hospital stay, untimely Scr measurements among patients at higher risk, as well as the often ignored importance of a slight increase in Scr and subsequent reexaminations.[18-20,22-24] Therefore, vital treatment windows are often missed. In addition, some patients with T-AKI may progress to P-AKI, leading to a delayed or no nephrology referral.[21]

To the best of our knowledge, this is the first study to demonstrate an association between geriatric P-AKI, 90-day mortality, and CKD progression in patients using the ADQI 16 Workgroup definitions. Several studies have examined the prognostic impact of AKI duration using different diagnostic criteria as follows: transient azotemia (≤ 3 days) and acute tubular necrosis (≥ 4 days or needs renal replacement therapy [RRT]);[25] short (≤ 2 days), medium (3–6 days), and long (≥ 7 days or needs RRT) using the AKIN criteria;[6, 26] T-AKI (≤ 7 days) and P-AKI (> 7 days) using the KDIGO criteria;[15, 27] T-AKI (Scr ≤ 115 μmol/L at discharge) and P-AKI (Scr > 115 μmol/L at discharge) using the KDIGO criteria;[28] short (≤ 2 days),

medium (3–5 days), and long (≥ 6 days) using the KDIGO criteria;[9] T-AKI (≤3 days) and P-AKI (> 3 days) using the AKIN criteria;[10] and short (≤ 2 days), medium (3–7 days), and long (> 7 days) using the KDIGO criteria;[7] In the present study, no independent associations were observed between T-AKI and poor outcomes. The discrepancies between these studies might reflect the substantial variety in the duration of recovery from AKI according to the various definitions of AKI, T-AKI, or P-AKI according to different study populations, patient ages, and etiologies of AKI.

Clinical studies have indicated that the duration of AKI is associated with a higher risk of adverse outcomes, but ignore a potentially important factor after AKI develops: early and prolonged nephrology follow-up. Delayed or absent nephrology referrals are associated with higher mortality and a requirement for dialysis.[19] Interestingly, we found in this study that only 26% of AKI patients were evaluated by nephrologists. Thus, increasing the likelihood of a timely AKI diagnosis and identifying patients who are indicated for a nephrologist consultation remains a challenge. Clearly, the high likelihood of a missed diagnosis is mainly attributed to the uniformly known KDIGO AKI criteria in which routine daily Scr measurements are not warranted.[18, 21] The ISN 0by25 initiative recommends more frequent Scr monitoring in high-risk populations, electronic alerting systems for AKI, and timely nephrology referral and follow-up to document RF recovery.[17, 29] Although the exact pathophysiology has not been clearly elucidated, experimental models have shown that even with apparent RF recovery from AKI, histological and physiological changes may persist after AKI and can predispose patients to long-term CKD risk. However, our findings indicate that only patients with P-AKI for > 7 days had greater CKD progression, whereas those with ≤ 7 days of P-AKI did not. One possible explanation for this association with CKD progression is that many patients with P-AKI have structural kidney injury, the duration of AKI increases, and CKD increses.

Another important issue is the timing of the recovery assessment; i.e., some studies determined “recovery” after 3–7 days to make the distinction between T-AKI and P-AKI while most studies report recovery at hospital discharge, or after 1 year.[30-32] In the present study, RF outcome was evaluated 90 days after an AKI episode based on the KDIGO AKI guidelines. However, 74% of patients who survive an AKI episode do not see a nephrologist at all. Findings of studies from the USA and the UK show that within 1 year, only 60% of patients are seen by any physician and only 10–15% are seen by a nephrologist, even though involvement by nephrologists improves recovery rates.[33, 34] This practice may represent a missed treatment window to improve outcomes after an episode of severe AKI. Of course, there are not nearly enough nephrologists to see all very elderly patients with P-AKI.[35]

Effective treatment for AKI is strongly dependent on timely recognition and early nephrological care. Based on the results of this study and the experience from developed countries, an electronic alerting system for AKI and timing of a nephrology consultation may be suitable and needed.[18] Nephrologists need to take responsibility for organizing the battle against AKI, including education and training. Non-nephrologists should also fully understand the pathophysiological features of aging kidneys; be aware of drug nephrotoxicity, drug dose, and intervals based on RF when controlling an infection; hypotension

management with suitable vasoactive drugs to increase blood pressure; principles of perioperative AKI prevention and treatment; rational adjustment of ventilator parameters during ventilation treatment; raise the level of understanding and awareness of AKI; be familiar with the definition and diagnostic criteria of AKI; and invite a nephrologist to intervene in a timely manner, which is important for improving the prognosis of elderly AKI patients.[36]

### Strengths and limitations

The strengths of this study include the advanced age of the sample, the use of a consensus definition for the AKI/CKD diagnosis, the KDIGO/ADQI guidelines and stages, and the availability of baseline Scr for the entire sample of patients. However, there were several limitations in this study to be noted. (1) This was a single-center retrospective study, which was a 90-day follow-up; however, data were insufficient to analyze a long-term follow-up. (2) We did not have data on urine output, which is a component of the KDIGO definition; therefore, the incidence of AKI in our study may have been underestimated. (3) The patients at this center were mainly retired, and nearly all patients were male. Hence, we could not generalize the results to other hospitals in which diagnostic or practice patterns may vary across older populations. (4) The factors influencing the AKI prognosis are complicated, such as the Acute Physiologic and Chronic Health Evaluation II score and the sequential organ failure assessment score, which can also be used to predict AKI patient outcomes.

## Conclusion

AKI duration is an additional parameter for predicting worse clinical outcomes in very elderly patients, emphasizing the importance of identifying a treatment window and who may benefit from an early intervention.

## Declarations

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### Availability of data and material

All data generated and/or analyzed during this study are included in this published article.

### Authors' contributions

QL participated in the conception and design of the study, did the statistical analyses, reviewed the literature, analyzed and interpreted the data, and drafted the manuscript. LP and ZM participated in the conception and design of the study, acquisition of data, analyzed and interpreted the data. HK was involved in design and in acquisition of data and helped to revise the manuscript critically for important content. FZ conceived of the study, participated in its design, and helped to revise manuscript. All authors read and approved the final manuscript.

### Ethical approval

The study design was approved by the Clinical Ethics Committee of the Chinese PLA General Hospital.

### Informed consent

For this type of study, formal consent is not required.

### Consent for publication

The manuscript has been read and its submission approved by all coauthors.

### Competing interests

The authors declare that they have no competing interests.

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# Tables

**Table 1** Summary of participant characteristics

| Characteristic | Values |
|---|---|
| Age (years) | 88 (84–91) |
| Male | 656 (94.7) |
| BMI (kg/m$^2$) | 23.0 ± 3.1 |
| Comorbidity | |
| Coronary disease | 527 (76.0) |
| Hypertension | 505 (72.9) |
| COPD | 477 (68.8) |
| Diabetes | 266 (38.4) |
| Baseline Scr (μmol/L) | 72.0 (60.0–83.0) |
| Baseline eGFR (mL/min/1.73m$^2$) | 78.4 (71.7–84.9) |
| Etiology of AKI | |
| Sepsis | 285 (41.1) |
| Hypovolemia | 143 (20.6) |
| Cardiovascular events | 106 (15.3) |
| Nephrotoxicity | 88 (12.7) |
| Surgery | 48 (6.9) |
| Others | 23 (3.3) |
| Clinical conditions | |
| Oliguria | 35 (5.1) |
| MV | 260 (37.5) |
| AKI Stage | |
| 1 | 319 (46.0) |
| 2 | 172 (24.8) |
| 3 | 202 (29.1) |
| Duration of AKI | |
| Transient (1–2 days) | 62 (9.0) |
| Short (3–4 days) | 104 (15.0) |
| Medium (5–7 days) | 140 (20.2) |
| Long (>7 days) | 387 (55.8) |
| 90-day outcomes | |
| RRT | 4 (0.6) |
| Renal function recovery at 90 days | 362/484 (74.8) |
| 90-day mortality | 209/693 (30.2) |
| Nephrology consultation | 180 (26.0) |

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

**Abbreviations:** *AKI* acute kidney injury, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *Scr* serum creatinine, *eGFR* estimated glomerular fitration rate, *MV* mechanical ventilation, *RRT* renal replacement therapy

**Table 2** Characteristics of patients with transient and persistent AKI

| Characteristic | AKI patients (n = 693) | Transient AKI (62, 9.0) | Persistent AKI (631, 91.0) | *P*-value |
|---|---|---|---|---|
| Age (years) | 88 (84–91) | 87 (84–91) | 88 (84–91) | 0.343 |
| Age (years) | | | | 0.578 |
| 75–79 | 82 (11.8) | 10 (16.1) | 72 (11.4) | |
| 80–85 | 154 (22.2) | 10 (16.1) | 144 (22.8) | |
| 86–90 | 255 (36.8) | 25 (40.3) | 230 (36.5) | |
| 91–95 | 155 (22.4) | 12 (19.4) | 143 (22.7) | |
| ≥ 96 | 47 (6.8) | 5 (8.1) | 42 (6.7) | |
| Male sex | 656 (94.7) | 57 (91.9) | 599 (94.9) | 0.347 |
| BMI (kg/m$^2$) | 23.0 ± 3.1 | 22.6 ± 4.1 | 23.1 ± 3.0 | 0.363 |
| Comorbidity | | | | |
| Coronary disease | 527 (76.0) | 51 (82.3) | 476 (75.4) | 0.230 |
| Hypertension | 505 (72.9) | 52 (83.9) | 453 (71.8) | 0.041 |
| COPD | 477 (68.8) | 43 (69.4) | 434 (68.8) | 0.926 |
| Diabetes | 266 (38.4) | 26 (41.9) | 240 (38.0) | 0.547 |
| Baseline Scr (μmol/L) | 72.0 (60.0–83.0) | 70.0 (60.0–80.0) | 72.0 (60.0–83.0) | 0.236 |
| Baseline eGFR (mL/min/1.73 m$^2$) | 78.4 (71.7–84.9) | 80.2 (75.0–85.5) | 78.2 (71.6–84.8) | 0.171 |
| Baseline eGFR (mL/min/1.73 m$^2$) | | | | 0.054 |
| 60–69 | 141 (20.3) | 9 (14.5) | 132 (20.9) | |
| 70–79 | 258 (37.2) | 20 (32.3) | 238 (37.7) | |
| 80–89 | 209 (30.2) | 28 (45.2) | 181 (28.7) | |
| >90 | 85 (12.3) | 5 (8.1) | 80 (12.7) | |
| Etiology of AKI | | | | |
| Sepsis | 285 (41.1) | 19 (30.6) | 266 (42.2) | 0.079 |
| Hypovolemia | 143 (20.6) | 12 (19.4) | 131 (20.8) | 0.794 |
| Cardiovascular events | 106 (15.3) | 15 (24.2) | 91 (14.4) | 0.041 |
| Nephrotoxicity | 88 (12.7) | 4 (6.5) | 84 (13.3) | 0.122 |
| Surgery | 48 (6.9) | 9 (14.5) | 39 (6.2) | 0.027 |
| Others | 23 (3.3) | 3 (4.8) | 20 (3.2) | 0.509 |
| Clinical conditions | | | | |
| MAP (mmHg) | 79 ± 14 | 81 ± 14 | 79 ± 14 | 0.279 |
| Oliguria | 35 (5.1) | 2 (3.2) | 33 (5.2) | 0.465 |
| MV | 260 (37.5) | 8 (12.9) | 252 (39.9) | <0.001 |
| Laboratory parameters | | | | |
| Scr (μmol/L) | 128.0 (115.0–143.6) | 116.1 (107.0–134.9) | 129.0 (116.0–144.0) | <0.001 |
| Peak Scr (μmol/L) | 142.0 (123.2–204.5) | 117.9 (109.8–136.2) | 146.3 (125.9–212.3) | <0.001 |
| BUN (mmol/L) | 12.3 (8.8–20.1) | 9.3 (7.2–12.8) | 12.7 (9.0–20.5) | <0.001 |
| Peak BUN (mmol/L) | 16.8 (10.4–32.2) | 10.8 (8.1–15.6) | 18.5 (10.8–34.2) | <0.001 |
| Uric acid (μmol/L) | 363.0 (285.8–461.0) | 338.3 (268.9–419.4) | 364.8 (288.6–465.0) | 0.017 |
| BG (mmol/L) | 7.3 (5.8–10.0) | 7.6 (6.2–9.8) | 7.3 (5.7–10.1) | 0.518 |
| K (mmol/L) | 4.1 (3.8–4.6) | 4.1 (3.8–4.3) | 4.1 (3.8–4.7) | 0.130 |
| Na (mmol/L) | 140.0 (136.0–146.0) | 138.0 (132.0–142.0) | 140.0 (136.0–147.0) | 0.001 |
| Ca (mmol/L) | 2.2 (2.1–2.4) | 2.2 (2.0–2.3) | 2.2 (2.1–2.4) | 0.143 |
| P (mmol/L) | 1.2 (0.9–1.4) | 1.1 (0.9–1.5) | 1.2 (0.9–1.4) | 0.565 |
| Mg (mmol/L) | 0.9 (0.8–1.0) | 0.9 (0.7–1.0) | 0.9 (0.8–1.0) | 0.003 |
| CRP (mmol/L) | 3.7 (1.8–9.1) | 3.5 (1.6–8.4) | 3.8 (1.8–9.1) | 0.283 |
| Albumin (g/L) | 34.5 ± 5.5 | 36.1 ± 5.3 | 34.3 ± 5.5 | 0.013 |
| Prealbumin (g/L) | 180.0 (139.0–232.0) | 187 (143–235) | 179 (139–230) | 0.403 |
| Hemoglobin (g/L) | 112 ± 22 | 119 ± 20 | 112 ± 22 | 0.010 |
| AKI Stage | | | | 0.001 |
| 1 | 319 (46.0) | 39 (62.9) | 280 (44.4) | |
| 2 | 172 (24.8) | 18 (29.0) | 154 (24.4) | |
| 3 | 202 (29.1) | 5 (8.1) | 197 (31.2) | |
| Nephrology consultation | 180 (26.0) | 7 (11.3) | 173 (27.4) | 0.006 |
| 90-day outcome | | | | |
| RRT | 4 (0.6) | 0 | 4 (0.6) | 0.386 |
| Mortality | 209 (30.2) | 5 (8.1) | 204 (32.3) | <0.001 |

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

**Abbreviations:** *AKI* acute kidney injury, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *Scr* serum creatinine, *eGFR* estimated glomerular fitration rate, *MAP* mean aortic pressure; 1mmHg, 0.133 kPa. *MV* mechanical ventilation, *BUN* blood urea nitrogen, BG blood glucose, *CRP* C-reactive protein, *RRT* renal replacement therapy

**Table 3** Prevalence of AKI duration and KDIGO stage relative to mortality and renal function outcomes

| Characteristic | Non-survivors n = 209 (30.2) | Survivors n = 484 (69.8) | *P* | New-onset CKD n = 122 (25.2) | Non-CKD n = 362 (74.8) | *P* |
|---|---|---|---|---|---|---|
| Duration of AKI | | | <0.001 | | | <0.001 |
| Transient (1–2 days) | 5 (2.4) | 57 (11.8) | | 4 (3.3) | 53 (14.6) | |
| Short (3–4 days) | 27 (12.9) | 77 (15.9) | | 5 (4.1) | 72 (19.9) | |
| Medium (5–7 days) | 46 (22.0) | 94 (19.4) | | 9 (7.4) | 85 (23.5) | |
| Long (>7 days) | 131 (62.7) | 256 (52.9) | | 104 (85.2) | 152 (42.0) | |
| AKI stage | | | <0.001 | | | 0.765 |
| 1 | 15 (7.2) | 304 (62.8) | | 78 (63.9) | 226 (62.4) | |
| 2 | 50 (23.9) | 122 (25.2) | | 28 (23.0) | 94 (26.0) | |
| 3 | 144 (68.9) | 58 (12.0) | | 16 (13.1) | 42 (11.6) | |

Note: Values are n (%)

**Abbreviations:** *AKI* acute kidney injury, *KDIGO* Kidney Disease Improving Global Outcomes, *CKD* chronic kidney disease

**Table 4** Multivariate proportional hazard model analysis of risk factors for AKI 90-day outcomes

| Risk factor | 90-day mortality | | New-onset CKD | |
|---|---|---|---|---|
| | HR (95% CI) | *P*-value | OR (95% CI) | *P*-value |
| Duration of AKI | | <0.001 | | <0.001 |
| 1–2 | – | – | – | – |
| 3–4 | 2.512 (1.021–6.181) | 0.045 | 0.982 (0.247–3.900) | 0.980 |
| 5–7 | 3.154 (1.250–7.960) | 0.015 | 1.322 (0.381–4.592) | 0.661 |
| >7 | 6.212 (2.383–16.192) | <0.001 | 7.007 (2.417–20.311) | <0.001 |
| AKI Stage | | <0.001 | – | – |
| 1 | – | – | – | – |
| 2 | 7.365 (4.114–13.183) | <0.001 | – | – |
| 3 | 28.414 (16.360–49.350) | <0.001 | – | – |
| BMI | 0.910 (0.870–0.953) | <0.001 | – | – |
| Baseline eGFR | – | – | 0.928 (0.901–0.956) | <0.001 |

**Abbreviations:** *AKI* acute kidney injury, *BMI* body mass index, *eGFR* estimated glomerular ftration rate, *CKD* chronic kidney disease, *HR* hazard ratio, *OR* odds ratio, *CI* confidence interval

# Figures

### Figure 1

Flow chart for patient inclusion and exclusion.

### Figure 2

Kaplan–Meier survival curves according to AKI duration (log-rank test: P = 0.002).

### Figure 3

Kaplan–Meier plot of cumulative rates of 90-day mortality by KDIGO AKI stage (log-rank test: P < 0.001).

### Figure 4

Kaplan–Meier survival curves according to AKI duration and the KDIGO stage.

### Figure 5

Renal function outcomes of different AKI durations in patients with AKI (log-rank test: P < 0.001).