ORIGINAL ARTICLE

Evaluation of Predictors, Kinetics of Renal Recovery and Outcomes of COVID-19 Patients with Acute Kidney Injury Admitted to Intensive Care Unit: An Observational Study

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Abstract

Background: The incidence of acute kidney injury (AKI) is greater than 50% among coronavirus disease-2019 (COVID-19) patients admitted to the intensive care unit (ICU). However, the literature on predictors and kinetics of renal recovery remains unclear.

Patients and methods: This observational study was conducted in a 30-bedded mixed ICU of a tertiary care center from May 2020 to July 2021. A total of 200 consecutive adult COVID-19 patients who had AKI in ICU were included. Using logistic regression with the best subset selection, predictors of renal recovery were identified. Outcomes and kinetics of AKI recovery were determined.

Results: Among 200 patients, 67 recovered from AKI, of which 38, 17, and 12 patients had transient AKI, persistent AKI, and acute kidney disease (AKD), respectively. A total of 25 patients had AKI relapse, primarily associated with hospital-acquired infections. Results of logistic regression showed that the combination of Acute Physiology and Chronic Health Evaluation (APACHE II) {odds ratio (OR) 1.1 [$p < 0.001$; 95% confidence interval (CI) 1.06–1.16]}, day onset of AKI [OR 1.6 ($p = 0.001$; 1.24–2.24)] and severity of AKI [OR 2.9 ($p < 0.001$; 2.03–4.36)] were the predictors associated with poor renal recovery. This model had sufficient discrimination with the area under the curve (AUC) of 0.86. Renal replacement therapy requirement and mortality among COVID–AKI patients were 68 and 84%, respectively.

Conclusion: A higher APACHE II at admission, a longer time to onset of AKI, and the severity of AKI during ICU stay predicted poor renal recovery. Study results emphasize the need for stepping-up dialysis resources in the likely case of future waves of COVID-19. The relapse of AKI was associated with sepsis, and mortality rates were substantially high.

Keywords: Acute kidney injury, Acute kidney injury recovery, Acute kidney injury relapse, Coronavirus disease-2019, Intensive care unit.

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Highlights

Higher admission APACHE II score and delayed onset AKI were important predictors of poor renal recovery in COVID-19 patients. Sepsis due to hospital-acquired infections is the major etiology for relapse of AKI. The probability of renal replacement therapy (RRT) requirement is very high for COVID-19-infected patients admitted to the ICU with AKI.

Introduction

Coronavirus disease 2019 infection predominantly affects the respiratory system. However, moderate-to-severe infections might result in multiple organ dysfunction, where AKI is the most apparent finding.[1] The incidence of AKI among COVID-19 patients ranges from 1–40% and is even greater than 50% among those admitted to ICU.[2,3] As in other settings, mortality among COVID-19 patients who sustained AKI is higher than among those patients without AKI.[4,5]

To our knowledge, there is a paucity of literature describing the kinetics and predictors of renal recovery. Also, the outcomes of critically ill COVID-19 AKI patients remain unclear. It was shown that the pattern of AKI recovery has an important implication on the outcome of AKI patients in non-COVID-19 infections.[6] Identifying such recovery patterns in COVID-19-infected patients might help clinicians prognosticate patients. Recovery from AKI is an essential dimension as few patients may progress to chronic kidney disease (CKD) or have varied cardiovascular complications.[7] The primary objective of this study was to identify the predictors of renal recovery in critically ill COVID-19 patients with AKI. We also sought to describe various aspects of the phenomenology of AKI, such as the kinetics of recovery and factors associated with poor outcomes.

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Patients and Methods

Study Design

A single-center observational study was conducted in a 30-bedded medical–surgical ICU of a tertiary care hospital after obtaining permission from the Institute Ethical Committee (IEC; Approval Nos. 218/2020 and AIIMS/BBN/IEC/SEP/2021/129).

Patient Selection and Data Extraction

Consecutive patients admitted to the ICU between May 2020 and July 2021 with a diagnosis of COVID-19 infection and AKI were included.

A waiver of consent was taken from IEC. Patients were screened for eligibility with the help of the hospital information system (HIS). Serum creatinine values were extracted from HIS for patients admitted to the ICU. We identified AKI patients by coding serum creatinine-based kidney disease: improving global outcomes (KDIGO) AKI definitions.[8] Inclusion criteria were adult patients (>18 years) admitted to ICU with a diagnosis of COVID-19 infection via RT-PCR or rapid antigen tests AND sustained severe acute respiratory infection (SARI) AND admitted with AKI or who developed AKI within 7 days of ICU admission. The basis for 7 days cut-off was that a more extended period of hospitalization might lead to additional factors that may precipitate AKI in ICU. Therefore, an arbitrary 7-day cut-off was chosen. Day entry into the study was the ICU admission. We have included direct ICU admissions from the emergency room or ICU admissions from the ward within the first 24 hours of their hospitalization. So that we can avoid additional confounding factors that may predispose patients to AKI from prior ward admission. Three authors screened the medical records and excluded patients who did not have any documentable blood investigations, withdrew from care/comfort care, had recent (<3 months) renal transplantation, were discharged from ICU within 24 hours, developing AKI after 7 days of ICU stay, known CKD receiving on RRT before hospitalization. Baseline, demographic characteristics, medical history, hemodynamic and oxygenation parameters were recorded from the eligible medical records.

Study Outcomes and Definitions

Primary endpoint: To evaluate the predictors of non-recovery and to determine the proportion of patients who recovered from AKI.

Secondary endpoints: Onset, severity, and duration of AKI in hospitalized patients, RRT days, and proportion of patients dependent on RRT at discharge.

Composite outcomes: Major adverse kidney events on day 30 (MAKE-30) and composite cardiovascular events were captured till the discharge of the patient.

Severe acute respiratory infection was defined as the new onset of the following symptoms within 7 days of hospitalization: fever (>38°C), cough, and difficulty breathing. Acute kidney injury was defined and staged per 2012 KDIGO practice guidelines [Fig. 1, Column (A)].[8] Baseline creatinine was estimated by one of the following methods: Pre-admission value, admission value, or nadir value during the entire hospitalization.[9] The day of onset of AKI refers to the admission date to ICU as "day 0." Acute kidney injury recovery was defined as at least a 33% reduction of serum creatinine levels from the baseline or reference value without the need for RRT, during the time frame of hospitalization and until 90 days of follow-up. Death without recovery from AKI during the study period is considered non-recovery. The extent of renal recovery was defined and staged per retrospective AKI recovery criteria [Fig. 1, Column (B)].[10] The onset of recovery was described as decreasing serum creatinine for two consecutive days without RRT. Acute kidney injury progression was further categorized into transient, persistent, AKD, and CKD (Fig. 1, Column (C)].[10] Acute kidney injury relapse was defined as the deterioration of renal functions (same

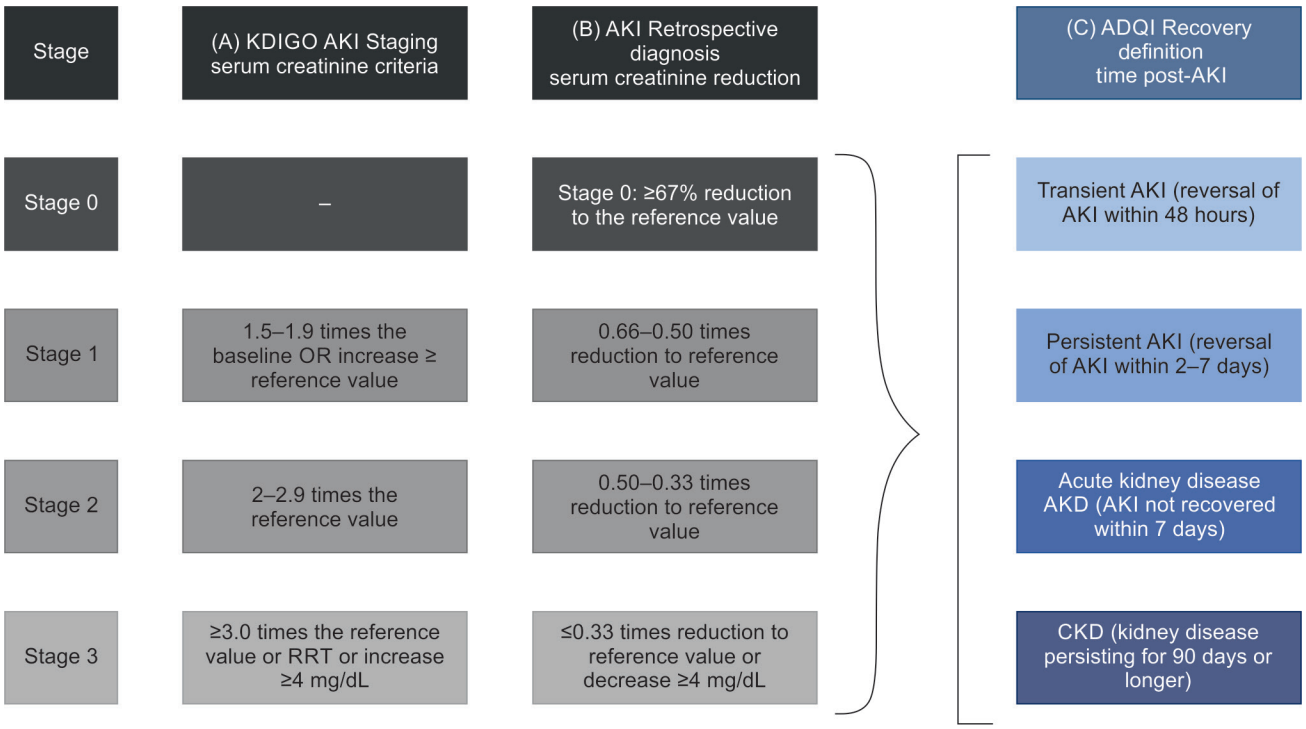
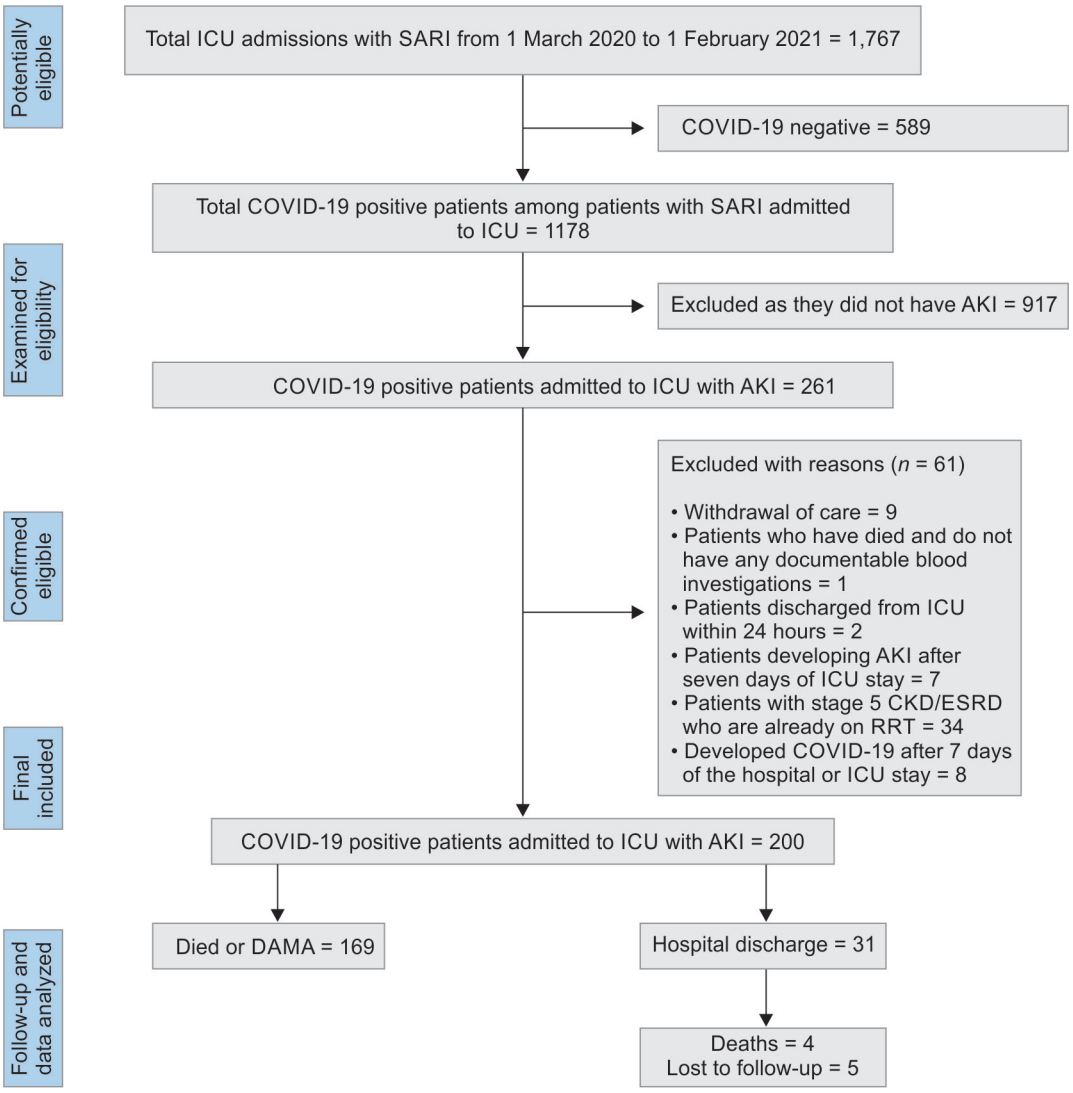


Fig. 1: Study definitions: Column (A) KDIGO AKI staging; Column (B) AKI retrospective diagnosis; Column (C) Acute dialysis quality Initiative (ADQI) recovery definition

Flowchart 1: Study flowchart



DAMA, discharge against medical advise; ESRD, end stage renal disease; RRT, renal replacement therapy

as KDIGO AKI definition) after a period of improvement during the hospitalization and until 90 days of post-discharge. Follow-up was conducted telephonically or upon patients' visit to outpatient services until 90 days post-hospital discharge.

Composite cardiovascular events were acute coronary syndrome (ACS), stroke or transient ischemic attack, arrhythmias, or peripheral arterial disease during hospitalization. Composite MAKE-30 endpoints were death, RRT, or persistent renal dysfunction occurring within 30 days of ICU admission.

Statistical Methods

Based on AKI recovery status, patients were categorized into two groups, and predictor variables were evaluated using bivariate statistics. Logistic regression with best subset selection was performed with renal non-recovery as an outcome and APACHE II, rapidity of onset and progression of AKI, severity of AKI, inflammatory markers, comorbidities, and Arterial oxygen partial pressure/fractional inspired oxygen (PaO_2/FiO_2) ratios as predictor variables. Imputation of missing variables was not performed. Variables were examined for multicollinearities and influential observations. Penalized-likelihood criteria [Akaike's Information Criteria (AIC) and Bayesian Information Criteria (BIC) models] were applied, and a model with the lowest AIC or BIC was considered the best fit to predict non-recovery from AKI. Receiver operating characteristic (ROC) curves were constructed to evaluate the predictive power of each or combination of variables that can predict non-recovery from AKI. Time-to-event analysis was performed using Cox proportional hazard model; $p < 0.05$ were considered significant. Statistical analyses were performed using STATA-v17.

Results

Among 1,767 adult (>18 years) patients with SARI identified during the study period, 589 COVID-19 negative and 917 COVID-19 without AKI were excluded. The remaining 261 patient records were thoroughly screened, and 200 patients were deemed eligible for the final quantitative analyses (Flowchart 1). The incidence of AKI was 17% among critically ill COVID-19 patients admitted to ICU during the study period.

Acute kidney injury recovery and relapse: Among 200 patients, 67 (33.5%) recovered from AKI (Tables 1 and 2). Acute kidney injury

Table 1: Baseline characteristics of COVID-19 AKI patients in two groups

Baseline variable	*AKI recovery n = 67*	*AKI non-recovery n = 133*	*p-value*
Age, median (IQR)	57 (49–70)	60 (50–69)	0.39
Male, *n* (%)	48 (71)	90 (68.7)	0.72
BMI, median (IQR)	22.9 (21.9–23.6)	22.5 (20.9–23.2)	**0.01**
DM, *n* (%)	44 (65)	91 (69)	0.61
HTN, *n* (%)	42 (62)	87 (65)	0.70
CKD (stages1–4), *n* (%)	06 (0.1)	19 (14)	0.28
Prior medication (ACE/ARB), *n* (%)	11 (16)	14 (10)	0.23
APACHE, median (IQR)	21 (14–27)	30 (23–34)	<**0.001**
Noticeable events during the first 24 hours of ICU admission			
• Cardiac arrest *n* (%)	0 (0)	05 (3.7)	0.56
• ACS/MI, *n* (%)	07 (10)	19 (14)	0.44
• Hypotension, *n* (%)	12 (18)	43 (32)	**0.03**
Baseline, median [IQR]			
• Hemoglobin in gm/dL	12.5 [10.7–14]	12.4 [10.5–14]	0.82
• Total leukocyte count (*10^3/µL)	13,000 [7,240–19,480]	15,400 [10,580–24,180]	**0.03**
• Procalcitonin in ng/mL	[*n* = 28] 0.6 [0.1–2.1]	[*n* = 79] 1.6 [0.4–8.1]	**0.03**
• CRP mg/dL	[*n* = 53] 17.7 [7–32]	[*n* = 82] 16 [7–25]	0.23
• D-dimer ng/mL	[*n* = 48] 935 [627–1274]	[*n* = 87] 1,009 [667–1,537]	0.35
Proteinuria, *n* (%)	(*n* = 37)	(*n* = 89)	
• 0/Trace	04 (11)	10 (11)	0.129
• 1+	20 (54)	27 (30)	
• 2+	09 (24)	36 (41)	
• 3+	04 (11)	16 (18)	
Onset of AKI in days, mean (se)	0.4 (0.1)	1.5 (0.2)	**0.002**

ACE, angiotensin converting enzyme; APACHE II, Acute Physiology and Chronic Health Evaluation; ARB, angiotensin receptor blocker; DM, diabetes mellitus; HTN, hypertension; IQR, interquartile range; MI, myocardial infarction; se, standard error

Table 2: Outcome characteristics of two groups of COVID-19 AKI patients

Outcome variable	*AKI recovery n = 67*	*AKI non-recovery n = 133*	*p-value*
Maximum stage of AKI, *n* (%)			
• Stage 1	25 (37)	4 (3)	<**0.001**
• Stage 2	12 (18)	5 (4)	
• Stage 3	30 (44)	124 (93)	
Cardiovascular outcomes during hospitalization, *n* (%) (ACS/CVA/TIA/arrhythmia/PVD/thromboembolism)	13 (19)	38 (28)	0.16
Inotrope days, median [IQR]	2 [0–4]	3 [2–6]	**0.009**
Secondary infections, *n* (%)	36 (54)	58 (44)	0.17
Total patients receiving RRT, *n* (%)	26 (39)	110 (83)	0.74
IHD, *n*	04	14	
SLEDD, *n*	22	96	
RRT days, median [IQR]	4.5 [2–10]	4 [1–8]	0.46
Invasive ventilation days*, median [IQR]	[*n* = 53] 10 [7–15]	[*n*= 130] 5 [3–9]	<**0.001**
Length of hospital in days, median [IQR]	19 [12–26]	8 [5–14]	<**0.001**
Length of ICU in days, median [IQR]	10 [5–17]	6 [3–9]	<**0.001**
Death, *n* (%)	38 (57)	131 (98)	<**0.001**
Days from onset AKI to death, median [IQR]	15 [9–21]	7 [3–13]	<**0.001**

*17 patients did not receive invasive mechanical ventilation. All 17 patients received non-invasive ventilation. CVA, cerebrovascular acident; IHD, intermittent haemodialysis; PVD, peripheral vascular disease; SLEDD, sustained low-efficiency daily dialysis; TIA, transient ischemic attack

recovery was further stratified into transient AKI (*n* = 38), persistent AKI (*n* = 17), and AKD (*n* = 12) (Supplementary Fig. 1). Among those recoveries, 38 patients died, primarily due to hospital-acquired infections. Twenty-five patients had AKI relapse, many associated with sepsis due to hospital-acquired infections (*n* = 20). The median duration for AKI recovery from the onset of AKI was 6 days [interquartile range (IQR), 3–9]. The stage of AKI recovery at hospital discharge is presented in Table 3. Patients with stage 3 AKI ± RRT were significantly higher in AKI non-recovery group compared to recoveries (Table 2).

Table 3: Characterization of renal recovery among COVID AKI patients

AKI recovery, n		*67*
Recovery category, *n*	Total	Died
• Transient (< 48 hours)	38	27
• Persistent (2–7 days)	17	09
• AKD (7–90 days)	12	02
Relapse of AKI, *n*	25	24
Patients recovered from AKI at hospital discharge, *n* (%)		41 (61)
Stage of recovery of AKI at hospital discharge, *n* (%)		
• Stage 0		33 (81)
• Stage 1		4 (10)
• Stage 2		1 (2)
• Stage 3		3 (7)
Days to recover from AKI, median (IQR)		6 (3–9)

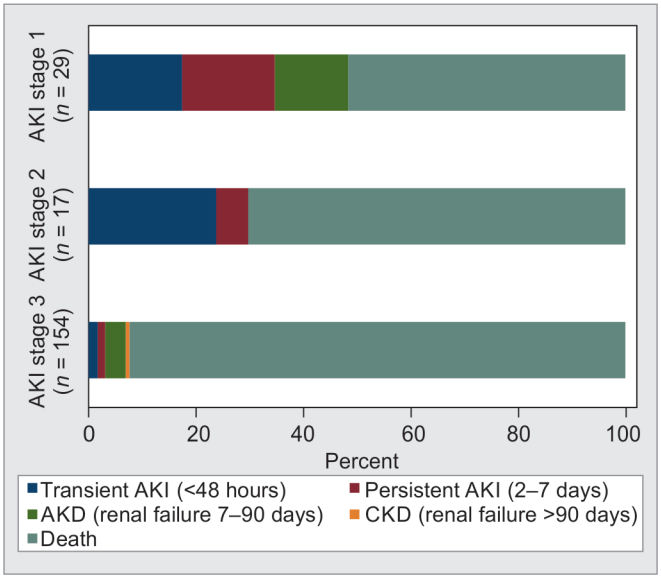


Fig. 2: Proportional stacked bar graph showing maximum AKI stage reached by study population and their outcomes

Predictors of AKI recovery: Baseline and outcome variables were evaluated through bivariate statistics and presented in Tables 1 and 2. There were statistically significant differences among patients with AKI recoverees and non-recoverees concerning APACHE [21 (14–27) vs 30 (23–34), $p \leq 0.001$], body mass index (BMI) [22.9 kg/m^2 (21.9–23.6) vs 22.5 (20.9–23.2), $p = 0.01$], procalcitonin [0.6 ng/mL (0.1–2.1) vs 1.6 (0.4–8.1), $p = 0.03$] and the onset of AKI [0.4 days (± 0.1) vs 1.5 (± 0.2), $p = 0.002$].

Logistic regression and survival analysis: Results of logistic regression showed admission APACHE II, day onset of AKI, and severity of AKI were statistically significant in predicting non-recovery from AKI [OR 1.1 (95% CI 1.06–1.16, $p < 0.001$), OR 1.6 (95% CI 1.24–2.24, $p = 0.001$), and OR 2.9 (95% CI 2.03–4.36, $p < 0.001$), respectively]. This was the best fit model with the lowest BIC. This model had acceptable discrimination with an AUC of 0.86 and was calibrated with marginal non-significance [Hosmer–Lemeshow (HL) chi2, $p = 0.06$] (Supplementary Fig. 2). Survival analysis using Cox proportional hazard model showed APACHE II and severity of AKI as significant predictors of non-recovery from AKI [HR 1.32 (1.12–1.55, $p = 0.001$), heart rate (HR) 1.02 (1.01–1.05), respectively] (Supplementary Table 1).

Severity of AKI: The AKI severity was stratified as per AKI KDIGO 2012. AKI Stages 1, 2, and 3 (including RRT dependent) were experienced by 29 (14.5%), 17 (8.5%), and 154 (77%), respectively. Figure 2 depicts the maximum stage of AKI and their respective outcomes. Mortality proportionately increased with the severity of AKI.

Clinical Outcomes

Noticeable clinical events during the first 24 hours of ICU admission are illustrated in Supplementary Figure 3. Hypotension, ACS, and cardiac arrest were the common events during the first 24 hours in ICU. Overall mortality among COVID–AKI patients was 84% ($n = 169$). Median length of stay (LOS), ICU, and hospital stay were 7 days (4–13) and 12 days (7–18), respectively. Median ventilator and vasopressor days were 5.5 days (3–10) and 3 days (1–6), respectively. A total of 143 patients were admitted with AKI or developed AKI within the first 24 hours of ICU admission (Supplementary Fig. 4). Mean arterial pressures, positive end expiratory pressure (PEEP), PaO_2/FiO_2 ratio, standard base excess, fluid balance, and glycemic variability a day before the onset of AKI were not different between AKI recoverees and non-recoverees. However, meaningful inferences cannot be derived due to considerable missing data (Supplementary Table 2). Types of hospital infections and their frequencies were presented in Supplementary Fig. 5. Furthermore, possible ventilator associated pneumonia (P-VAP) and blood stream infection (BSI) are the most frequent infections found in the study cohort. Moreover, RRT was required in 136 (68%) patients. Intermittent hemodialysis (IHD) and sustained low-efficiency daily dialysis (SLEDD) were our study's two commonly used RRT modalities. There was no perceivable difference in AKI recovery with these RRT modes. The median duration from the onset of AKI and progression to RRT was 1 day (0–3). The median RRT days was 4 (1–8.5).

Composite outcomes: A total of 172 (86%) patients experienced MAKE30 composite outcomes. Combined cardiovascular events were experienced by 51 (25.5%) patients (Supplementary Fig. 6).

Follow-up: Thirty-one patients were discharged from the hospital. During the follow-up period of 90 days, we could contact 26 patients. Four patients died during this period. One patient progressed to CKD stage 5 and continued to require IHD.

Discussion

In our cohort of the first wave of hospitalized critically ill COVID-19 patients, nearly one in five patients developed AKI during their ICU stay. Other studies observed a similar incidence of AKI in COVID-19, whereas AKI in mixed non-COVID ICUs ranges from 20–50%.[11–15] Primarily, COVID-19 infection affects the respiratory system, but other organs, such as kidneys, are often involved in moderate-to-severe disease.[1] A significant proportion of our study cohort developed or presented with AKI within the first 24 hours of ICU admission. This may be linked to hemodynamic instability, cytokine surge, and hypoxic multiorgan damage, with which patients are usually admitted to ICU. About three-fourths of our patients progressed to stage 3 AKI; this is comparatively higher than that reported in a large cohort study of the ward and ICU patients (42–46%).[16,17] We attribute a greater severity of AKI in our study to two reasons; first, our target population was patients

with a critical illness. Second, due to limited ICU bed availability during the pandemic, at our institute, only sicker patients who sustained AKI or required RRT were admitted and treated in the ICU. This was reflected by the high median APACHE score of our study population, 27(19–33), and a large number of stage 3 AKI (41%) at admission, with 29% among them receiving RRT day 1 itself. Overall, RRT was required in 68% ($n = 136$) of our study population. A significant proportion of patients who received RRT (94%) died during their ICU stay. Most of the deaths were attributed to septic shock with multiorgan failure. A notable observation was that the average time for initiation of RRT from hospital admission was 53 hours (2.2 days). Our data suggest that AKI, particularly when severe, had higher mortality. For patients requiring RRT, the prognosis appears even worse. Such data will guide treatment physicians in managing resources and prognosticating AKI patients early in their ICU stay.

We adopted AKI recovery definitions and staging from the consensus definition described by Duff and Murray et al.[10] Stratification of AKI recoverees demonstrated 57% as transient AKI, 25% as persistent AKI, and 18% as AKD. One-third of AKI recoverees died due to infections and sepsis. It is interesting to note that none of the survivors had a relapse of their AKI. This emphasizes that relapse of AKI is a significant risk factor for death. In a logistic regression model, the following three parameters: APACHE score, the severity of AKI, and the rapidity of AKI onset, were identified as significant predictors for non-recovery. We hypothesized that a higher APACHE score would mean more substantial organ dysfunction, greater severity of AKI signifies severe renal injury, and later the onset of AKI had a relatively lower chance of recovery than early-onset AKI; since early-onset AKI might be due to hypoxia or dehydration (prerenal AKI) or cytokine dysregulation which occurs early in the course of illness, this could have responded better with rapid interventions in ICU via optimization of hypoxia (initiation of non-invasive or invasive ventilation), optimization of hemodynamics and early steroid therapy. There seems to be a bimodal distribution of AKDs by AKI stage, with more significant percentages from stage 1 and stage 3 AKIs. We hypothesized that a longer survival time among stage 1 AKI patients would have contributed to higher AKDs in this group.

Worldwide the therapeutic strategies for COVID-19 varied considerably during the study period. At our center, hydroxychloroquine and steroids were the mainstays of treatments for moderate-to-severe COVID-19 infections. In mid-2020, the results of the RECOVERY trial brought a significant breakthrough by recommending steroid usage in moderate-to-severe COVID-19 infections. Nevertheless, we routinely administered 1–1.5-mg/kg/day of methylprednisolone or equivalent during the study period. However, the usage of dexamethasone has increased ever since the publication of the Randomised Evaluation of COVID-19 Therapy (RECOVERY) trial.

One in five patients in this study experienced composite cardiovascular endpoints. Most common being non-ST-elevation myocardial infarction (NSTEMI; 11.5%) and atrial fibrillation (4%).[18,19] Possible mechanisms include direct cardiotoxicity, systemic inflammation, myocardial demand–supply mismatch, sepsis leading to DIC, and electrolyte imbalances.[20,21] This study's high mortality (84%) contrasts with 23–60% mortality observed across other AKI cohort studies without COVID-19 infection.[19,21] However, pooled mortality in a meta-analysis of COVID-19 AKI patients was 78%.[22] To our knowledge, mortality data derived purely from COVID-19 patients admitted to ICU with AKI is sparse. Historically, mortality rates with AKI have been higher in viral pandemics such as SARS and MERS (86.6 and 68.5%, respectively).[22] High mortality could be due to the following factors: Direct viral cytopathic effects, hypoxic renal injury, activation of the coagulation pathway, low cardiac output, hypotension, and multi organ dysfunction syndrome (MODS) in COVID.[11,23] Notably, our study showed considerably higher mortality among the AKI recoverees (57%, $n = 38$). On examination, most of these patients had an AKI relapse associated with hospital-acquired infections. Our record review showed that higher mortality was attributed to septic shock secondary to possible VAP and bloodstream infections. Although not easy to elucidate, the higher mortality among AKI recoveries may be due to a breach in infection control practices during the initial phase of the pandemic associated with hospital capacity strain with limitations in the workforce and ICU infrastructure. The unvaccinated status of our study cohort might also contribute to high mortality.

The median days for onset of AKI to death are shorter in the AKI non-recovery group compared to recoverees (7 vs 15 days). This brings us to the question of whether the AKI non-recovery patients are simply the patients who died very early on in their COVID-19-related illness before their renal function could recover. It is evident from the data that deaths dominate the non-recovery group, and the inferences related to this group may extrapolate to early all-cause mortality. A time-to-event analysis that factored in the time variable showed similar predictors that predicted the non-recovery of AKI through a logistic regression model.

Interestingly, among the patients in the "recovery" group, those with the fastest recovery times (i.e., transient AKI) had the highest mortality. The record review identified a considerable number of transient AKIs experienced MAKE 30 outcomes, such as cerebrovascular accidents and ACS, which could have contributed to higher mortality. On follow-up of 31 survivors for 90 days, four patients died, and five were lost to follow-up. Further, we did not find any association between pre-existing CKD and renal recovery.

Our study has particular strengths. This is one of the few studies on critically ill COVID-19 patients that focused on AKI recovery kinetics and which evaluated the predictors of renal non-recovery. Considering that we had a large cohort of patients and evidence-based treatment protocols that have been followed, incidence and mortality related to COVID–AKI were similar to that of other studies, our study results may be generalized and provide helpful insight into recovery kinetics of COVID-19 AKI patients. Furthermore, with different strains and unvaccinated and immunosuppressed are still developing severe covid, the finding from this study will help understand AKI with COVID-19 and in prognosticating such patients.

Limitations

Being an observational study, we cannot make inferences regarding causal relationships between risk factors and AKI recovery. Although we have adjusted for known confounders in logistic regression analysis, there may be potential unmeasured confounders. Second, serum creatinine measurement has limitations in critically ill populations.[24] Third, we did not measure biomarkers for renal recoveries, such as tissue inhibitor of metalloproteinase 2 (TIMP-2), neutrophil gelatinase-associated lipocalin (NGAL), etc., which could have helped in quantifying the extent of renal recovery in our cohort. Fourth, we excluded patients with onset of AKI after 7 days as we postulated that the etiology of AKI may become multifactorial as the ICU stay increases, especially with high rates

of nosocomial infections. However, we have only seven patients that were excluded for this reason.

Conclusion

In our study, a higher APACHE II score at admission, a longer time interval between admission and the onset of AKI, and greater severity of AKI during ICU stay were the predictors of AKI non-recovery. Our data indicates the heightened requirement of RRT in COVID-19 patients who sustained AKI and were admitted to the ICU. Further, the results of this study emphasize stepping-up dialysis units and resource management in the likely case of future waves of COVID-19 infection. Relapse of AKI was associated with sepsis due to hospital-acquired infections with high mortality rates.

Acknowledgments

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Supplementary Material

The supplementary figures and tables are available online on the website of https://www.theijccm.org.

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