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# Acute kidney injury in Coronavirus disease-19 related pneumonia in the intensive care unit: a retrospective multicenter study, Saudi Arabia

**Safwat A.M. Eldaboosy,[1,2] Amgad Awad,[2,3] Abdullah Farouk,[2,4] Waheed Mahdy,[2,5] Eman Abdelsalam,[6,7] Sameh O. Nour,[1] Ahmed Kabil,[1] Ahmad Taha,[1] Sameh Makled,[1] Ahmed Lotfi,[1] Usama Nabway,[1] Hatem Kanany[8]**

*[1]Department of Chest Diseases, Faculty of Medicine, Al-Azhar University, Cairo, Egypt*
*[2]Almoosa Specialist Hospital, Al Ahsa, Saudi Arabia*
*[3]Department of Internal Medicine, Faculty of Medicine, Al-Azhar University, Cairo, Egypt*
*[4]Department of Critical Care, Alexandria Faculty of Medicine, Alexandria, Egypt*
*[5]Department of Chest Diseases, Banha Faculty of Medicine, Banha, Egypt*
*[6]Department of Internal Medicine, Al-Azhar Faculty of Medicine for Girls, Cairo, Egypt*
*[7]King Khalid hospital, Hail, Saudi Arabia*
*[8]Department of Anesthesia and Critical Care, Faculty of Medicine, Al-Azhar University, Cairo, Egypt*

ABSTRACT

**Background:** Acute kidney injury (AKI) poses a significant morbidity and mortality risk to critically ill COVID-19 patients. The aim of this study was to investigate the incidence, predictors, and outcomes of AKI in patients admitted to the intensive care unit (ICU) with critically ill COVID-19 pneumonia.

**Methods:** A multicenter retrospective study in Saudi Arabia of adult patients aged at least 18 years diagnosed with COVID-19 pneumonia and admitted to the intensive care unit between May 2020 and May 2021 was conducted. The occurrence of AKI and associated risk factors, the need for continous renal replacement therapy (CRRT), and the outcome were reported.

**Results:** The study included 340 patients admitted to the ICU with COVID-19. Their mean age was 66.7±13.4 years, ranging from 49 to 84 years, and most of them were men (63.8%). The most common concomitant diseases were hypertension (71.5%), diabetes (62.4%), IHD (37.6%), CKD (20%), heart failure (19.4%), and 81.2% suffered from ARDS. AKI occurred in 60.3% of patients, 38% were stage 1, 16.6% were stage 2, and 45.4% were stage 3. Approximately, 39% of patients required CRRT, out of which 76.2% were stage 3, which was significantly higher than the other stages ($p<0.001$). AKI patients suffered significantly from asthma and had lower levels of C-reactive protein (CRP), ferritin, lactate dehydrogenase (LDH), and blood urea nitrogen (BUN) and higher creatinine levels than patients without AKI ($p<0.05$ all). The overall mortality rate was 39.4%, and the mortality rate was significantly higher in patients with AKI than in patients without AKI (48.3% *versus* 25.9%; $p<0.001$).

**Conclusion**: AKI is common in adults admitted to the ICU with COVID-19 and is associated with an increased risk of death. Early detection of AKI and appropriate treatment can positively impact COVID-19 outcome. CRRT is the preferred dialysis method in critically ill ICU patients with AKI.

**Key words:**Acute kidney injury; COVID-19 pneumonia; intensive care unit; renal replacement therapy; Saudi Arabia.



**Correspondence:**Dr. Safwat Eldaboosy, Department of Pulmonary Medicine, Almoosa Specialist Hospital, box code 5098, Al Ahsa, Saudi Arabia, Tel. +966.590050316. E-mail: safwatchest@gmail.com

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## Introduction

Coronavirus disease-19 (COVID-19) is associated with high morbidity and mortality worldwide and has overwhelmed many healthcare systems and economies. It is caused by a strain of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. According to the World Health Organization (WHO), more than 590,000,000 people worldwide have been diagnosed with COVID-19 as of August 18, 2022, resulting in more than 6.4 million deaths [2]. About 30% of people infected with COVID-19 remain asymptomatic, 80% of symptomatic cases have mild and moderate disease (40% each) and 15% have severe disease requiring oxygen support. Approximately 5% develop critical COVID-19 illness characterized by pneumonia, acute respiratory failure, septic shock, and/or multiple organ dysfunction [2].

The manifestations of renal involvement in patients with COVID-19 may include proteinuria, hematuria, or acute kidney injury (AKI) and are associated with a high risk of adverse prognosis [3]. The main pathogenesis of COVID-19 associated renal disease is unknown and probably multifactorial and could be due to direct viral cytotoxic damage, the renin-angiotensin-aldosterone system (RAAS) imbalance, associated hyperinflammatory state due to re-released cytokines, microvascular injury and prothrombotic state, hypovolemia, potentially nephrotoxic agents, and nosocomial sepsis [4].

There are data on the temporal evolution of the incidence of COVID-19-associated AKI. Preliminary data suggest that AKI rates declined during the duration of the pandemic, although the reason for this evolution is unclear [5,6]. In a meta-analysis of approximately 13,000 mostly hospitalized patients, the incidence of AKI was 17 percent (range 0.5 to 80%), and about 5% of patients needed renal replacement therapy (RRT). Incidence appears to vary by geographic location and proportion of critically ill patients in each study [7].

In two large observational studies of more than 5,000 patients hospitalized with COVID-19, approximately 32 to 37 percent were found to have AKI. Out of the patients with AKI, about 50% had the mild disease (1.5- to 2-fold increase in serum creatinine) and the remainder had moderate or severe disease (more than a doubling of creatinine) [5,8]. Independent predictors of AKI included advanced age or maleness, obesity, essential hypertension, diabetes mellitus, cardiovascular disease, and low estimated glomerular filtration rate (eGFR), as well as higher interleukin-6 levels and need for mechanical ventilation or vasopressor therapy [9,10]. Continuous renal replacement therapy (CRRT) is the preferred treatment for AKI or end-stage renal disease (ESRD) in critically ill patients in the ICU, usually with hemodynamic instability, when dialysis is required (e.g., volume overload, electrolyte disturbances including hyperkalemia, acidosis, and complications of uremia) [11]. The aim of this study was to investigate the incidence, risk factors, and consequences of AKI in patients admitted to the intensive care unit with critically ill COVID-19 pneumonia.

## Methods

This study was part of a larger project investigating various clinical and epidemiological aspects of COVID-19 pneumonia in Saudi Arabia. It was a retrospective, multicenter study of 340 adult patients ≥18 years of age admitted to the intensive care unit of a Saudi Almoosa Specialist Hospital-Al Ahsa, Obeid General Hospital-Hofuf, and King Khaled Hospital-Hail for confirmed COVID-19 pneumonia. This study was conducted from May 2021 to May 2022. Ethical approval was obtained from the Institutional Review Board of our hospitals (Almoosa Academic Affairs: IRB log No: ARC -21.02.02).

### Inclusion criteria

Adult patients (≥18 years) with COVID-19 pneumonia and hypoxemia (positive SARS-CoV-2 real-time polymerase chain reaction (PCR) nasopharyngeal swabs or respiratory secretions) were admitted to the ICU.

### Exclusion criteria

Patients with COVID-19 pneumonia who did not not fulfill the criteria of ICU admission, patients admitted to the ICU for reasons other than COVID-19 pneumonia, patients who had COVID-19 infection but were not hospitalized, and pediatric COVID-19 patients were excluded. Patients with ESRD and kidney transplant patients were also excluded.

### Data collections and outcomes

All the cases were diagnosed and treated according to the Saudi Ministry of Health protocol for confirmed cases of COVID-19 infection [12].

The following data were collected (within 24 h of hospitalization): age, sex, body mass index (BMI), comorbidities (such as hypertension, asthma, type 2 diabetes, and other concomitant diseases), patient symptoms, and general and local examination findings, including vital signs. The following examination results were obtained from the electronic medical record: identification of SARS-CoV-2 virus by nasopharyngeal swab using PCR, chest radiograph (portable), oxygen saturation with a pulse oximeter, arterial blood gases, complete blood count (CBC), complete metabolic panel (serum sodium, potassium, and magnesium), serum ferritin, D-dimer, lactate dehydrogenase (LDH), C-reactive protein (CRP), renal function test (urea and creatinine), liver function test, procalcitonin, troponin, and electrocardiogram (ECG). ICU course, including length of stay, need for ventilatory support (noninvasive or invasive ventilation), need for vasopressors, prophylactic anticoagulants, antibiotics, systemic steroids, anti-interleukin 6 (tocilizumab), empiric antibiotics (per local protocol), and need for CRRT and AKI outcome and outcomes either mortality or discharge to ward. Acute kidney injury was defined as per the Kidney Disease Improving Global Outcome (KDIGO) criteria [13].

Baseline creatinine is the last serum creatinine in the last 7-365 days before admission. In patients in whom no previous serum creatinine has been measured, the serum creatinine at admission is considered the baseline creatinine. Estimated glomerular filtration rate (eGFR) is calculated based on a Modification of Diet in Renal Disease (MDRD) equation. Renal recovery is defined as a decrease in serum creatinine of more than 50%.

### Statistical analysis

We used the SPSS program for Windows (IBM SPSS Statistics V 25.0, IBM Corp., Armonk, NY, USA). Mean ± SD and median and interquartile range (IQR) were used for quantitative variables, whereas frequency and percentage were used for qualitative variables. Chi-square or Fischer exact tests were used to assess differences in frequencies of qualitative variables. Independent-samples *t*-test was used to evaluate the differences in the means of the quantitative variables, whereas the Mann-Whitney U test was used for nonparametric statistics. Logistic regression analysis was used with odds ratios (OR) and 95% confidence intervals (CI) to predict factors associated with COVID-19 mortality. Only significant independent variables from the univariate analysis were included in the logistic analysis. Statistical methods were reviewed, using a significance level of $p<0.05$ (double-tailed).

## Results

The study included 340 patients admitted to the ICU with COVID-19. Their mean age was 66.7±13.4 years and ranged from 49 to 84 years; most of them were men (63.8%). The most common concomitant diseases were hypertension (71.5%), diabetes (62.4%), IHD (37.6%), CKD (20%), heart failure (19.4%), and 81.2% suffered from ARDS. Associated clinical and laboratory parameters showed elevated mean HR (97.5±19.3) and RR (27.7±4.2), elevated median CRP (81 [36-136]), ferritin (964 [792-1642]), LDH (652 [452-895]), D-dimer (2.9 [2.5-3.4]), creatinine (89 [73.3-142]), and lower median $PaO_2/FIO_2$ ratio (62 [53-112]). The majority (91.8%) received steroid therapy and 43.5% received vasopressors. The mortality rate was 134 patients (39.4%) (Table 1). AKI occurred in 205 patients (60.3%), out of whom 78 (38%) were stage 1, 34 (16.6%) were stage 2, and 93 (45.4%) were stage 3. Eighty of 205 patients (39%) required CRRT, including 15 of 80 patients (18.8%) in stage 1, 4 patients (5%) in stage 2, and 61 patients (76.2%) in stage 3, which was significantly higher than the other stages ($p<0.001$) (Table 2). More than three-quarters (76.8%) of the patients received mechanical ventilation (MV), 14.6% received oxygen therapy with a high-flow nasal cannula (HFNC), and 4.4% received oxygen therapy with a nasal cannula (NC) (Figure 1). Patients with AKI suffered significantly from asthma, required CRRT, and had lower median CRP, ferritin, LDH, and BUN levels, and higher median creatinine levels than patients without AKI ($p<0.05$ all) (Table 3). The mortality rate was significantly higher in patients with AKI than in patients without AKI (48.3% *vs* 25.9%; $p<0.001$). Overall, 106 out of 205 patients (51.7%) with AKI were discharged; complete improvement occurred in 97 patients (47.3%), and 9 patients (4.4%) required regular dialysis because of ESRD (Figure 2).

## Discussion

The pandemic COVID-19 causes numerous cases of illness and death and has overwhelmed health services and disrupted normal life and the economy. COVID-19 is characterized by a systemic inflammatory response and an increased risk of respiratory failure and AKI [1,2]. AKI is one of the most common complications of COVID-19 in hospitalized patients and is associated with a highly unfavorable outcome [5].

In this study, AKI occurred in 60.3% of patients admitted to the ICU for critical COVID-19 pneumonia. This is consistent with many studies from the United States, in which 60-80% of critical COVID-19 patients were found to have AKI [14,15]. Other studies from the USA involving COVID-19 cases admitted to the ICU, showed that more than 60% (61-78%) of them had AKI [16,17]. The incidence of AKI reached 68% in critically ill COVID-19 patients admitted to the intensive care unit. In a large cohort study in New York City [18]. Alenezi *et al*. conducted a systematic review and meta-analysis (out of 618 studies identified and reviewed, 31 studies met inclusion criteria), and the incidence of AKI was 50% in eight studies that included only COVID-19 patients admitted to the ICU (n=1,540) [19]. Our results on the incidence of AKI were lower than those of other studies. Schaubroeck *et al*. performed a multicenter cohort analysis of AKI in critically ill patients of COVID-19 in Belgium (from seven large hospitals) and found a high rate of AKI (85.1% of 1,286 cases) [20]. Lumlertgul *et al*. reported that AKI occurred in 76% of critical COVID-19 patients [21]. de Almeida *et al*. observed an increased incidence of AKI > 70%, with more than half of these patients meeting KDIGO 3 criteria within 7 days of hospitalization [22]. Our results on AKI rates in critically ill COVID-19 cases in the ICU were higher than in many

**Table 1. General, clinical, laboratory and outcome characteristics of the studied patients.**

| Variables | n=340 | (%) |
|---|---|---|
| Age (years) | 66.7±13.4 | |
| Sex | | |
| Male | 217 | 63.8 |
| Female | 123 | 36.2 |
| BMI (kg/m²) | 26.9±7.0 | |
| HTN | 243 | 71.5 |
| DM2 | 212 | 62.4 |
| Asthma | 19 | 5.6 |
| IHD | 128 | 37.6 |
| CHF | 66 | 19.4 |
| CKD | 68 | 20.0 |
| HR (beats/min) | 97.5±19.3 | |
| Temperature (°C) | 37.8±1.01 | |
| RR (breaths/min) | 27.7±4.2 | |
| GCS | 14.5±0.78 | |
| $PaO_2$ (mmHg) | 59 (50.3-65) | |
| CRP | 81 (36-136) | |
| Ferritin (ng/mL) | 964 (792-1642) | |
| LDH (IU/L) | 652 (452-895) | |
| D-dimer | 2.9 (2.5-3.4) | |
| HB (gm/dl) | 11.4±2.2 | |
| WBCs (cells/mm³) | 11.3 (8.2-15.4) | |
| Creatinine (mg/dl) | 89 (73.3-142) | |
| BUN (mg/dl) | 12.4 (9.4-18.8) | |
| $PaO_2/FIO_2$ ratio | 62 (53-112) | |
| <300 | 276 | 81.2 |
| >300 | 64 | 18.8 |
| Need for vasopressors | 148 | 43.5 |
| ARDS | 276 | 81.2 |
| Mild (200-300) | | |
| Moderate (100-200) | | |
| Severe <100 | | |
| Steroid therapy | 312 | 91.8 |
| Hospital stays (days) | 11 (4-18) | |
| Outcome | | |
| Discharged | 206 | 60.6 |
| Death | 134 | 39.4 |

Qualitative variables present as number and percent; quantitative variables present as mean ±SD or as median (IQR).

**Table 2. Renal impairment among the studied patients.**

| Variables | n=340 | (%) |
|---|---|---|
| AKI | 205 | 60.3 |
| AKI stage | | |
| Stage 1 | 78/205 | 38.0 |
| Stage 2 | 34/205 | 16.6 |
| Stage 3 | 93/205 | 45.4 |
| CRRT | 80/205 | 39.0 |
| CRRT *vs* AKI stage | | |
| Stage 1 | 15/80 | 18.8 |
| Stage 2 | 4/80 | 5.0 |
| Stage 3 | 61/80 | 76.2 |
| p | <0.001* | |

Qualitative variables are present as numbers and percent and analyzed by Chi-square test; *significant.

other studies. The incidence of AKI was reported to be 36% in hospitalized patients with COVID-19, in a study from Saudi Arabia conducted by Farooqui *et al*. [23]. In another Saudi Arabian study examining critically ill COVID-19 patients in a multicenter study, AKI occurred in 46.8% of cases [24]. In contrast, AKI is common in critically ill patients with COVID-19 and affects approximately 20-40% of patients admitted to the ICU [25, 26]. About 29% of patients admitted to the intensive care unit have AKI, and the figure is as high as 78% for patients requiring intubation [18]. Several studies have reported that more than 30-50% of hospitalized

**Table 3. Comparing different variables among COVID-19 patients with and without acute kidney injury.**

| Variables | Patients with AKI, n=205 (%) | Patients without AKI, n=135 (%) | p |
|---|---|---|---|
| Age | 67.5±11.8 | 65.4±15.4 | 0.169 |
| Sex | | | |
| Male | 128 (62.4) | 89 (65.9) | 0.565 |
| Female | 77 (37.6) | 46 (34.1) | |
| BMI | 27.3±6.8 | 26.4±7.1 | 0.275 |
| HTN | 154 (75.1) | 89 (65.9) | 0.085 |
| DM2 | 133 (64.9) | 79 (58.5) | 0.254 |
| Asthma | 19 (9.3) | 2 (1.5) | 0.003* |
| IHD | 83 (40.5) | 45 (33.3) | 0.209 |
| CHF | 42 (20.5) | 24 (17.8) | 0.577 |
| CKD | 42 (20.5) | 26 (19.3) | 0.890 |
| HR (beats/min) | 98.4±20.2 | 96.1±17.8 | 0.286 |
| CRRT | 80 (39.0) | 0 (0.0) | <0.001* |
| Need for vasopressors | 84 (41.0) | 64 (47.4) | 0.264 |
| ARDS | 164 (80.0) | 112 (83.0) | 0.571 |
| Temp (℃) | 37.9±1.0 | 37.9±1.1 | 0.254 |
| RR (breaths/min) | 27.9±4.4 | 27.3±3.9 | 0.265 |
| GCS | 14.55±0.78 | 14.5±0.78 | 0.621 |
| Need for MV | 48 (23.4) | 34 (25.2) | 0.796 |
| $PaO_2$ (mmHg) | 62 (51-67) | 55 (50-64) | 0.784 |
| $PaO_2/FIO_2$ ratio | 64 (56-125) | 59 (52-66) | 0.087 |
| CRP | 68 (34-124) | 101 (43-164) | 0.006* |
| Ferritin (ng/mL) | 900 (735-1348) | 1261 (854-2354) | 0.040* |
| LDH (IU/L) | 635 (364- 831) | 745 (521-952) | 0.014* |
| D-dimer | 2.9 (2.5-3.4) | 2.9 (2.55-3.36) | 0.137 |
| HB (gm/dl) | 11.5±2.2 | 11.3±2.4 | 0.359 |
| WBCs (cells/$mm^3$) | 9.6 (8.2-14.8) | 12.6 (8.2-16.4) | 0.765 |
| Creatinine (mg/dl) | 95 (74-133) | 88.5 (72-195) | 0.004* |
| BUN (mg/dl) | 12 (8.4-18.2) | 14 (11-20.4) | <0.001* |

Qualitative variables are present as numbers and percent an analyzed by Fisher exact test; quantitative variables present as mean ±SD or as median (IQR) and analyzed by independent samples t-test or Mann-Whitney *U* tests; *significant.



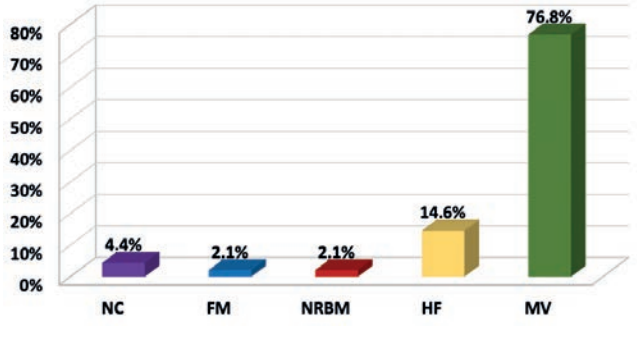


**Figure 1. Type of $O_2$ therapy among the studied patients. NC = nasal cannula; FM = face mask; NRBM = non-rebreather mask function; HF = high-flow; MV = mechanical ventilation.**

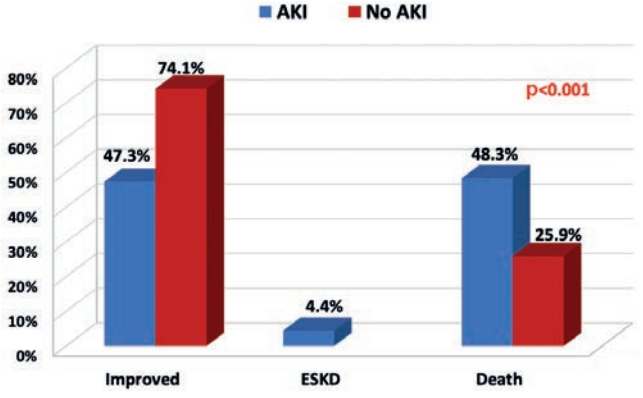


**Figure 2. Outcome of COVID-19 pneumonic patients with and without acute kidney injury. ESKD = End Stage Kidney Disease.**

patients with COVID-19 develop AKI, with a higher proportion of patients requiring ICU admission [27,28]. Yang *et al*. performed a meta-analysis of 51 studies, and the incidence of AKI in ICU patients was 39% and may reach 42% in deceased patients, and 16.3% of ICU patients required CRRT [29]. Jewell *et al*. analyzed data from hospitalized adults with COVID-19 in two London hospitals and reported that 39% developed AKI (51% in stage 1 and 49% in stages 2 and 3) [30]. Oweis *et al*. conducted a study of AKI in hospitalized patients with COVID-19 from Jordan. The incidence of AKI was 25.3%, and most patients were at stage 1 [31]. CRRT is the preferred treatment for AKI in critically ill patients in the ICU because it provides hemodynamic stability and large fluid removal. Selection of this modality should be based on local experience but is expensive and time-consuming. In this study, 39% of AKI in critically ill COVID-19 pneumonia cases required CRRT, and most of them (81.2%) were in stages 2 and 3. Out of the patients with AKI, 81.2% had ARDS, 43.5% of them required vasopressors, and 76.8% of them required mechanical ventilation. The use of CRRT in our critical patients with COVID-19 was consistent with previous epidemiological studies in which the use of CRRT was required in approximately 44% of patients [16]. Many studies reported that AKI is a common complication in critical COVID-19 cases and occurred in 25-76% of cases, with 5-44% of them requiring CRRT [32,33]. About 35-50.9% of patients with AKI in the ICU associated with COVID-19 pneumonia required CRRT in some studies from the United States [9,15]. Many studies report that 30-40% of COVID-19 infected patients in the ICU require RRT [33,34]. Cummings *et al.* reported that out of 257 critically ill patients with COVID-19, 31% received RRT [27]. In one study it was reported that up to 20% of patients underwent renal replacement therapy (KRT) [5]. This is in contrast to a study from India and Pakistan, which reported that CRRT was required in 22.9% of cases [35]. The incidence of AKI was 43.7%, and 18.2% of patients underwent CRRT, and in this group, 90-day in-hospital mortality was 45.1%. A study by Eriksson *et al*. on CRRT in ICU patients with COVID-19 [36]. In a study from Saudi Arabia, CRRT was required in 18.9% of cases with AKI associated with COVID-19 pneumonia [24]. This is in contrast also to other studies reporting that CRRT was required in 4% to 23% of patients with AKI in critically ill COVID-19 patients [8,37].

In this study, the mortality rate was significantly higher in patients with AKI (48.3%) than in patients without AKI (25.9%), which is often the case in several studies. According to Jewell *et al*., the mortality rate was significantly higher in patients WHO with AKI (44.4%) than in patients WHO without AKI (17.3%) [30]. Alenezi *et al*. performed a scientific review and meta-analysis of the incidence and risk factors of AKI in COVID-19 patients with and without white lung and found that mortality was 38.7% once the studies considered only COVID-19 patients admitted to the department [19]. In a study from Asia conducted by Farooqui *et al*., the presence of AKI was associated with a higher 30-day mortality of 40.7%, compared with 3.7% in patients without AKI [23]. In another study from an Asian country, AKI was found to be much more common in patients who died WHO within thirty days on the ward (74.7%) than in patients who survived WHO on the ward (26.2%) [24]. Eriksson *et al*. performed a study of CRRT in patients with COVID-19 and found that the mortality rate in this group was 45.1% [36]. Our results were lower than those of many other studies. Fominskiy *et al*. found that mortality was higher in patients with AKI (52.9%) than in patients without AKI (38.9%) [37]. Several studies found that overall hospital mortality in patients with COVID-19 and AKI was 66.2% [3,39], and in several studies, it ranged from 60-80% within the AKI-RRT cluster [40, 41]. According to Oweis *et al*., 75% of patients with AKI died within the unit [31]. Compared with patients without AKI, mortality was higher in patients with AKI (32.5% versus 10.4%), and 39.2% of patients with AKI did not recover from urinary organ performance by the end of the follow up period or after ninety days [42]. On the other hand, other studies have not shown AKI to be a risk factor for COVID-19 deaths [30,43].

In this study, the mean age of patients with AKI was 67.5±11.8 years, 62.4% were male, the mean BMI was 27.3±6.8, and the major comorbidities were HTN 75.1%, DM2 64.9%, IHD 40.5%, CHF 20.5%, and CKD 20.5% without significant differences when compared to the group without AKI. These findings were comparable with other studies that showed variable values and percentages. In a study from Saudi Arabia, the mean age was 65 years, 74.5% of patients were male, and the most common comorbidities were DM2 (57.7%), HTN (53.6%), and dyslipidemia (22.7%) [23]. In another study from Saudi Arabia, the mean age was 66 years, 56.7% of participants were male, and the most common comorbidities were DM2 (70.2%), HTN (73.9%), heart failure (21.4%), CHF (16.8%), and a mean BMI of 29.7 [24] also, without significant differences between both groups with and without AKI. In a multicenter ICU study involving 5,866 COVID-19 patients from 55 hospitals in Spain, the main age was 63 years, most of them were men (70.4%), and the most common concomitant diseases were HTN (50.4%), obesity (35.5%), and DM2 (24.9%) [43]. In a systematic review of patients with COVID-19 and AKI, the most common comorbidities were HTN 61.4%, hyperlipidemia 57.1%, DM2 40%, and CKD 22.2 % [44].

In contrast, other studies reported that independent significant predictors of AKI included being older, black American, or male; being overweight; having diabetes; having HTN; having the cardiovascular disease; having a low eGFR or higher interleukin-6 levels; or requiring mechanical ventilation or vasopressor medications [9,10]. Most biomarkers that showed a significant correlation with AKI have been established in relation to the severity of COVID-19, including d-dimer, LDH, neutrophil and leukocyte counts, troponin-I, and CRP [44-47]. In our study, inflammatory markers were high in both groups (AKI and without AKI). Oweis *et al*. reported that comorbidities such as HTN and diabetes, as well as previous renal disease and increasing age, increase the risk of AKI in patients with COVID-19 but not significantly in terms of the degree of inflammation and the increase in CRP [31].

The differences between our results and the others can be explained by many factors: inclusion criteria, quality of the health care system, differences in referral policies, duration of follow up, the experience of the first centers affected by COVID-19 outbreaks, and differences in population characteristics or prevalence of comorbidities.

### Study limitations

First: the retrospective nature of the study raises the possibility that differences in the quality of care may affect patient recovery. Second, we used KIGO rather than GMFR to define AKI. Third, some data were not collected, such as urine output, and the mortality rate was used only as in-hospital mortality without post-discharge follow up. In addition, the relation between the percentage of lung parenchyma affected by COVID-19 and the severity of renal involvement was not investigated in the current study. Further prospective studies are recommended to cover these issues.

## Conclusion

AKI is common in adults admitted to the intensive care unit with COVID-19 and is associated with an increased risk of death. Early recognition of AKI and appropriate treatment can have a positive impact on the outcome of COVID-19. CRRT is the preferred dialysis method in critically ill ICU patients with AKI.

## Abbreviations

AKI: acute kidney injury;
ARDS: acute respiratory distress syndrome;
BMI: body mass index;
BUN: blood urea nitrogen;
CBC: Complete blood count;
CHF: congestive heart failure;
CI: confidence intervals;
CKD: chronic kidney disease;
COVID-19: coronavirus disease 19;
CRP: C reactive protein;
CRRT: continuous replacement therapy;
DM2: type 2 diabetes mellitus;
ECG: electrocardiogram;
FIO2: fractionated inspired oxygen;
GCS: Glasgow coma scale;
GMFR: glomerular filtration rate;
HB: hemoglobin;
HR: heart rate;
HTN: hypertension;
ICU: intensive care unit;
IHD: ischemic heart disease;
IQR: interquartile range,
KDIGO: Kidney Disease Improving Global Outcome;
LDH: lactate dehydrogenase;
MV: mechanical ventilation;
OR: odds ratios;
$PaO_2$: partial pressure of oxygen tension;
RAAS: renin-angiotensin-aldosterone system;
RR: respirator rate;
RRT: renal replacement therapy;
SARS: severe acute respiratory distress;
WBCs: white blood cells;
WHO: World Health Organization.

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