Evaluation of mortality of COVID-19 patients with acute kidney injury (AKI) in comparison to the non-AKI patients

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ABSTRACT

Introduction: Acute kidney injury (AKI) is prevalent in the coronavirus disease-2019 (COVID-19). There is little data on the relationship between renal dysfunction and COVID-19 prognosis.

Objectives: The aim of this research was to investigate the effects of AKI in COVID-19 patients hospitalized to the Golestan and Razi hospitals in Ahvaz, Iran.

Patients and Methods: In this retrospective cohort study, a total of 194 COVID-19 patients were included, consisting of 79 patients with AKI and 115 patients without AKI. Primary and secondary outcomes were compared between the two groups.

Results: According to the findings, mortality was significantly different between the two groups, and mortality was higher in the AKI group (P<0.001). The mean length of hospital stay was statistically significantly higher in the AKI group (P=0.024). Moreover, there was a significant correlation between intensive care unit (ICU) admission and the study group (P<0.001). Staging of AKI group were seen as; stage I (49.37%), stage II (36.71%), and stage III (13.92%). No significant correlation was observed between outcome and the stages of AKI (P=0.496). Furthermore, 14 patients (17.72%) needed renal replacement therapy (RRT) in the AKI group.

Conclusion: Although AKI is a common finding in COVID-19 patients, most patients were in stage I disease, which returned to normal after COVID-19 treatment. According to our research, COVID-19 rarely leads to serious and persistent kidney injury. However, the risk of death is increased in COVID-19 patients with AKI. Therefore, it is necessary to evaluate the renal function tests during the course of disease.

Implication for health policy/practice/research/medical education:
Some studies reported that the incidence of acute kidney injury (AKI) in COVID-19 patients was higher than the incidence of AKI in non-COVID-19 patients. The study was conducted on 194 COVID-19 patients admitted to Golestan and Razi hospitals in Ahvaz, Iran. According to our results, COVID-19 does not cause serious and permanent kidney injury. Since the rate of mortality of COVID-19 patient is higher in the AKI group, it is recommended that patients with COVID-19 should be assessed for AKI.

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Introduction

The coronavirus disease 2019 (COVID-19) outbreak began in Wuhan, Hubei province, China, in December 2019 and quickly spread to other countries throughout the world (1,2). While respiratory infections are the most prevalent cause of COVID-19, it may affect any organ system (3). Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) had the greatest impact on the lungs, followed by the kidneys (4). Although initial findings from China suggested that only 3%-5% of COVID-19 patients suffered from acute kidney injury (AKI) (4,5), European and American findings depicted a rate of up to 34% (6,7).

Current knowledge suggests nonspecific mechanisms for COVID-19-related AKI. However, particular mechanisms, such as direct viral infection through angiotensin-converting enzyme 2 (ACE2) receptor, which is extremely expressed in the kidney, renin-angiotensin-
aldosterone system (RAAS) disorder, and increased pro-
inflammatory cytokines in terms of the viral infection and
microvascular thrombosis have been proposed (8).
SARS-CoV-2 starts the infection process by attaching to
receptors on the host cell membrane that are functional.
The post-mortem examination of COVID-19 patients
showed varying degrees of acute tubular necrosis,
lymphocyte infiltration, and viral RNA, suggesting a
direct invasion to the renal tubules (3). AKI is known to
cause fluid overload, metabolic disorders, fluid-electrolyte
imbalance, impaired neutrophil function and immune
system dysfunction, all of which might additionally make
contributions to worsening outcomes in COVID-19
individuals (9).

In brief, AKI affects the prognosis of patients with
COVID-19, expanded mortality and morbidity and, the
need for renal replacement therapy (RRT), and imposes a
greater burden on the hospitals and patients (10).
The link between renal dysfunction and COVID-19
prognosis is in general poorly understood. As well as,
it is unclear how much the AKI condition predisposes
COVID-19 individuals to severe illness and negative
outcomes (11). In this regard, a rapid and primary
diagnosis of AKI, leads physicians to help manage patients
with COVID-19.

Objectives
This study aimed to determine the consequences of AKI
in COVID-19 patients admitted to Golestan and Razi
hospitals in Ahvaz, Iran.

Patients and Methods
Study design
This is a retrospective cohort study of AKI prevalence
in admitted COVID-19 patients at Razi and Golestan
hospitals from 20 December 2021 to 20 March 2022.
COVID-19 infection was defined based on positive
reverse transcription polymerase chain reaction (RT-PCR)
for SARS-CoV-2 nucleic acid. The medical documents of
194 individuals with laboratory-confirmed COVID-19,
more than 18 years old, were analyzed. Children, those
with established end-stage renal disease, and people who
had a kidney transplant were all excluded. Two groups of
patients were formed. The control group was COVID-19
patients who have normal kidney function and the case
group was characterized by the COVID-19 patients who
showed AKI during their hospitalization.

Acute kidney injury was determined based on KDIGO
guidelines; including 1) increase in serum creatinine by
≥0.3 mg/dL within 48 hours, 2) increase in creatinine by
>1.5 times the base in the last 7 days, and 3) urine output
<0.5 mL/kg/h for> 6 hours. AKI stage was determined
using the peak serum creatinine level from baseline
after diagnosis of AKI, therefore the increase in serum
creatinine by 1.5-1.9 mg/dL, 2–2.9 mg/dL, and 3 times
the baseline values were determined as stages 1, 2, and 3
of AKI, respectively (12).

The severity of lung involvement was defined as mild
ground glass opacity (GGO) (less than 25%), moderate
(25%-50%), and severe (more than 50%) (13). The
daily values of urea and creatinine were recorded. For
each patient, we collected baseline patient features such
as primary laboratory tests, consisting lung computed
tomography (CT) scan information, demographic data,
medications usage, clinical characteristics, treatment
(respiratory supports), RRT and clinical outcomes in the
designed questionnaire. Laboratory data included serum
electrolytes, complete blood count, admission time serum
creatinine, discharge time serum creatinine, blood gas
analysis, and serum albumin and also urine analysis tests.
Finally, primary outcomes such as death were recorded, as
well as secondary outcomes such as duration of admission,
intensive care unit (ICU) admission, degree of pulmonary
involvement, use of mechanical ventilation in the ICU
and its duration, requirement for RRT, and renal function
status at discharge.

Statistical analysis
Statistical analysis was performed by SPSS software
version 22 (IBM, Chicago, USA). The quantitative and
qualitative variables were indicated as mean ± SD and
number (percentage), respectively. Kolmogorov–Smirnov
and Shapiro–Wilk tests were conducted to test for the
distribution. Differences were compared by using the t test
or Mann–Whitney U test as appropriate. For the test of
significances, chi-square/Fisher’s exact test was calculated
to compare the frequencies among groups. P value less
than 0.05 was considered statistically significant.

Results
A total of 194 patients were included in this study, with
115 having normal creatinine levels and being referred
to the non-AKI group, since 79 having abnormal serum
creatinine levels (rising tendency) and being referred to
the AKI group. There was no significant association
between gender and the groups (P =0.053). Moreover, the
clinical symptoms were not different among the groups;
however, vital signs, blood pressure, and temperature were
different. Furthermore, the history of the pre-existing
disease has shown 49 (25.2%) with diabetes mellitus, 50
(27.75%) with hypertension, 17 (8.76%) with ischemic
heart disease, and 10 (5.15%) with heart failure, and
also nine patients (4.63%) with malignancies. Further,
18 (22.78%) and 13 (16.45%) in the AKI group had
used non-steroidal anti-inflammatory drugs and ACE
inhibitors and angiotensin II receptor blockers (ARBs),
respectively. Patients with AKI were more likely to have ICU admission ($P<0.001$) and thereby had a higher death rate than the normal group ($P<0.001$; Table 1). Moreover, patients with AKI stayed at the hospital longer than the non-AKI group ($9.34 \pm 5.5$ versus $7.51 \pm 5.45$, $P=0.024$).

According to AKI stages, 39 patients (49.37%) were classified as stage 1, 29 patients (36.71%) as stage 2 and 11 patients (13.92%) as stage 3. For 17.72% of AKI patients, RRT was conducted. Our study showed serum creatinine levels at baseline and before discharge differed considerably across stages. There was no statistically significant correlation between AKI severity and outcome ($P=0.49$; Table 2). The prevalence of leukopenia and anemia in COVID-19 patients with AKI was significantly higher, although the lymphopenia between two groups was not significant (Table 3). Besides, in AKI group, the value of erythrocyte sedimentation rate (ESR), and serum concentrations of lactate dehydrogenase (LDH), creatine phosphokinase (CPK), blood sugar, ferritin and potassium was significantly higher, which represents the relation between disease severity and kidney involvement.

As well, the rate of metabolic acidosis was considerably higher in this group (Table 4).

**Discussion**

The aim of this study was to detect how AKI affected COVID-19 patients at Ahvaz’s Golestan and Razi hospitals. According to our findings, the lungs are the most damaged organ, causing symptoms such as cough and shortness of breath. The ACE2 is considered a cell receptor in COVID-19. Interestingly, ACE2 expression in renal tissue is approximately 100-fold higher than in respiratory organs, which illustrates that renal cells may be the target of SARS-CoV and SARS-CoV-2 infection. There are limited clinical information on AKI during SARS-CoV-2 infection (14). AKI is a common complication among hospitalized COVID-19 patients for an extensive variety of diagnoses. The reason for AKI in COVID-19 cases is not completely perceived (15).

The incidence of hyperglycemia, hyperkalemia, hyperphosphatemia, elevated lactate dehydrogenase, CPK, ESR, and ferritin were higher in AKI patients. In addition, the AKI group had a greater incidence of

### Table 1. Baseline and clinical features of patients

| Variables                  | Non-AKI (n=115) | AKI (n=79) | $P$ value |
|----------------------------|-----------------|------------|-----------|
| Gender                     |                 |            |           |
| Male                       | 46 (40%)        | 21 (26.58%)| 0.053     |
| Female                     | 69 (60%)        | 58 (73.41%)|           |
| Age (year)                 |                 |            |           |
| 18-65 years                | 74 (64.34%)     | 37 (46.83%)| 0.015     |
| ≥ 65 years                 | 41 (35.35%)     | 42 (53.16%)|           |
| BMI (kg/m$^2$)             |                 |            |           |
| 19                         | 2 (1.73%)       | 2 (2.53%)  |           |
| 19-25                      | 37 (32.17%)     | 7 (8.86%)  | 0.002     |
| 25-30                      | 52 (45.21%)     | 51 (64.55%)|           |
| ≥ 30                       | 24 (20.86%)     | 19 (24.05%)|           |
| Clinical symptoms          |                 |            |           |
| Edema                      | 24 (20.86%)     | 20 (25.31%)| 0.46      |
| Myalgia                    | 100 (86.95%)    | 62 (78.48%)| 0.43      |
| Gastrointestinal symptoms  | 61 (53.04%)     | 31 (39.24%)| 0.059     |
| Respiratory distress       | 73 (63.47%)     | 52 (65.82%)| 0.73      |
| Vital signs                |                 |            |           |
| Low BP                     | 19 (16.52%)     | 27 (34.17%)|           |
| High BP                    | 8 (6.95%)       | 5 (6.32%)  |           |
| Normal BP                  | 88 (76.52%)     | 47 (59.49%)|           |
| Low fever                  | 43 (37.39%)     | 45 (56.96%)|           |
| High fever                 | 56 (48.69%)     | 27 (34.17%)|           |
| Normal temperature         | 16 (13.91%)     | 7 (8.86%)  |           |
| $O_2$ saturation <93%      | 62 (53.91%)     | 46 (58.22%)| 0.552     |
| $O_2$ saturation ≥93%      | 53 (46.08%)     | 33 (41.77%)|           |
| Normal respiratory rate    | 52 (45.21%)     | 26 (32.91%)|           |
| Increasing respiratory rate| 63 (54.78%)     | 53 (67.08%)|           |
| Pulmonary CT scan          |                 |            |           |
| Mild GGO                   | 14 (12.17%)     | 7 (8.86%)  |           |
| Moderate GGO               | 48 (41.73%)     | 33 (41.77%)| 0.748     |
| Severe GGO                 | 53 (46.08%)     | 39 (49.36%)|           |
| Outcome                    |                 |            |           |
| Death                      | 17 (14.78%)     | 33 (41.77%)| < 0.001   |
| Discharge                  | 98 (85.21%)     | 46 (58.22%)|           |
| Admission                  |                 |            |           |
| ICU                        | 28 (24.34%)     | 41 (51.89%)| < 0.001   |
| General                    | 87 (75.65%)     | 38 (48.10%)|           |

BP: Blood pressure, GGO: Ground-glass opacification, ICU: Intensive care unit
metabolic acidosis. However, there were no significant differences in the serum levels of sodium, calcium, C-reactive protein, albumin, D-dimer, and liver enzymes between the two groups. The mortality in the AKI group was 41.7%, and in the non-AKI group was about 14.7%. The current study findings demonstrated a significant correlation between outcome and the study group (\( P < 0.001 \); Table 1).

The study by Robbins-Juarez et al showed that AKI was related to the increased risk of mortality among COVID-19 patients, which was similar to our findings (16). The death rate in AKI cases was 63.9% in the study by Dai et al, which was substantially higher than in patients without AKI (17). Patients with AKI also had a higher death rate in the study by Xiao et al (14). The results of these studies are the same as our study. Regarding urinary findings, in AKI group, the incidence of hematuria was significantly higher than the non-AKI group, whereas the incidence of proteinuria and leukocyturia were not different between the two groups. Our study showed most of the patients were in stage I of AKI (43.36%). Furthermore, 29 out of 79 patients (36.70%) and 11 patients (13.92%) were stages 2 and 3, respectively. In a study by Fominskiy et al in Italy, out of 99 patients, 72 (75%) developed AKI. Most patients had stage I of AKI (45.8%), while 15 patients (20.8%) and 24 patients (33.4%) had stage II and III of AKI, respectively (2). In another cohort study by Hirsch et al, evaluated the manifestations, risk factors, and consequences of AKI in hospitalized COVID-19 patients. Their results showed that out of 5499 patients with COVID-19, AKI was detected in 993 (36.6%) of cases. The prevalence of stages I, II and III of AKI were 46.5%, 22.4%, and 31.1%, respectively (18). In these studies, similar to our findings, most of AKI patients were in stage I, indicating that renal involvement in COVID-19 patients is more reversible and mild. Of note, the occurrence of stage I of AKI is high in critically ill patients; since most patients of this category seems having favorable outcomes. However, progression to stage III of AKI is associated with an extremely high mortality rate. In this regard, evaluation of renal function and prevention of AKI play a significant role in the clinical

| Table 2. Evaluations based on AKI stages |
|----------------------------------------|
| Variables                             | Stage I (n=39) | Stage II (n=29) | Stage III (n=11) | \( P \) value |
| Serum creatinine (mg/dL)              |               |                 |                 |               |
| On admission                          | 1.59 ± 0.21   | 2.45 ± 0.49     | 5.02 ± 0.84     | <0.001        |
| Pre discharge                         | 1.31 ± 1.05   | 1.97 ± 1.72     | 2.60 ± 1.64     | 0.019         |
| Pulmonary CT scan                     |               |                 |                 |               |
| Mild GGO                              | 4 (13.79%)    | 3 (7.69%)       | 0 (0%)          | 0.148         |
| Moderate GGO                          | 21 (72.41%)   | 9 (23.07%)      | 3 (27.27%)      |               |
| Sever GGO                             | 14 (48.27%)   | 17 (43.58%)     | 8 (72.72%)      |               |
| Outcome                               |               |                 |                 |               |
| Death                                 | 14 (48.27%)   | 13 (33.33%)     | 6 (54.54%)      | 0.49          |
| Discharge                             | 25 (86.20%)   | 16 (41.02%)     | 5 (45.45%)      |               |

GGO: Ground-glass opacification.

| Table 3. Laboratory findings in patients |
|-----------------------------------------|
| Laboratory findings                     | Range | Groups | \( P \) value |
|-----------------------------------------|-------|--------|---------------|
| White blood cell (×10^9/L)              |       | Non- AKI (n=115) | With AKI (n=79) |               |
| Normal                                  | 112 (97.39%) | 71 (89.87%)     | 0.026          |
| Abnormal                                | 3 (2.60%) | 8 (10.12%)      |               |
| Lymphocyte (%)                          |       | Non- AKI (n=115) | With AKI (n=79) |               |
| Normal                                  | 65 (56.52%) | 37 (46.33%)     | 0.18           |
| Abnormal                                | 50 (43.47%) | 42 (53.16%)     |               |
| Platelet (×10^9/L)                      |       | Non- AKI (n=115) | With AKI (n=79) |               |
| Normal                                  | 98 (85.21%) | 61 (77.21%)     | 0.154          |
| Abnormal                                | 17 (14.78%) | 18 (22.78%)     |               |
| Hemoglobin (g/dL)                       |       | Non- AKI (n=115) | With AKI (n=79) |               |
| Normal                                  | 30 (26.08%) | 11 (13.92%)     | 0.041          |
| Abnormal                                | 85 (73.91%) | 68 (86.07%)     |               |
| AST/ALT (U/L)                           |       | Non- AKI (n=115) | With AKI (n=79) |               |
| Normal                                  | 62 (53.91%) | 40 (50.63%)     | 0.65           |
| Abnormal                                | 53 (46.08%) | 39 (49.36%)     |               |
| PTT/PT (s)                              |       | Non- AKI (n=115) | With AKI (n=79) |               |
| Normal                                  | 105 (91.30%) | 69 (87.34%)     | 0.37           |
| Abnormal                                | 10 (8.69%) | 10 (12.65%)     |               |
| AST: Aspartate transaminase, ALT: Alanine transaminase, PTT: Partial thromboplastin time, PT: Prothrombin time, ALP: Alkaline phosphatase.
management of COVID-19 (14). According to our findings, a notable association between the age of patients and the study group ($P = 0.015$) was detected. Our study showed a greater proportion of patients with AKI were 65 years or older than patients without AKI. In accordance with our findings, Xiao et al found that patients with AKI were older than those without AKI (14). Similarly to the study by Hirsch et al, older age was a risk factor for AKI(18). In the study of Dai et al, AKI patients with COVID-19 had significantly higher rates of C-reactive protein than patients without AKI (17), indicating a secondary bacterial infection in these patients. While in our study, no significant difference was observed between the mean of CRP in the two groups ($P = 0.596$).

The mechanical ventilation usage was significantly different between the two groups. In the group of patients with AKI, using the mechanical ventilation was higher ($P < 0.001$). While in the study of Trifi et al, the mechanical ventilation usage between the two groups was not significantly different ($P = 0.12$) (19). There was no significant difference in the mean length of ICU admission between the two groups ($P = 0.211$). Similar to our findings, Trifi et al found no statistically significant difference in ICU hospitalization duration among the groups. Other variables, such as underlying conditions such as heart failure, diabetes, and cancer, may also be implicated. Our findings are consistent with reports of the intensive care national audit and research center, which illustrated AKI patients generally had more severe disease and required persistent lymphopenia, invasive mechanical ventilation, and vasopressor support(20).

Based on our results, no significant difference was reported between lung CT-scan and the study groups ($P = 0.748$). Similar to our results, in the study of Trifi et al, lung CT-scan in the group with and without AKI was not significantly different ($P = 0.999$) (19). In addition, in the current investigation, no correlation between the stages of AKI and the severity of lung CT-scan results was seen, indicating that variables other than the degree of pulmonary involvement contributed to the development of AKI. No significant correlation between stages and the patients’ outcome ($P = 0.496$) was detected in our study. Probably because most patients were in stage I and accordingly other factors beyond the AKI were involved in mortality. In our study, 14 patients (17.72%) received RRT. In the study of Fominskiy et al and Hirsch et al, 17.7% and 14.3% of patients required RRT (2, 18). However, there was a lot of variations across researches throughout the world. According to our findings and previous studies, the occurrence of AKI during COVID-19 exacerbated the complications of disease and increased the mortality (21). The study by Cheng et al showed that patients with primary renal abnormalities (increased serum creatinine, proteinuria, hematuria, and AKI) had higher mortality rates (1). Additionally, according to the study by Azeeem et al, the overall hospital mortality rate for patients with and without AKI were 6.7% and 1%, respectively. This study also showed that the probability of survival was lower in patients with AKI (15). In brief, it seems that that AKI is associated with negative clinical consequences, including increased hospital expenditures, death, and long-term hospitalization (21).

Table 4. Biochemical laboratory tests

| Laboratory tests | Non- AKI (n=115) | With-AKI (n=79) | $P$ value |
|------------------|-----------------|----------------|-----------|
| BS (mg/dL)       | 165.07 ± 86.63  | 214.86 ± 114.13| $0.001$   |
| BUN1 (mg/dL)     | 18.47 ± 7.26    | 53.00 ± 31.03  | $<0.001$  |
| Sodium (mEq/L)   | 139.42 ± 6.06   | 139.09 ± 15.82 | 0.84      |
| Kalium (mg/dL)   | 4.21 ± 0.75     | 4.71 ± 0.92    | $<0.001$  |
| Calcium (mg/dL)  | 8.47 ± 0.87     | 8.43 ± 2.09    | 0.87      |
| Phosphorus s(mg/dL) | 3.81 ± 1.55  | 4.35 ± 1.95    | $0.043$   |
| Albumin (g/dL)   | 3.63 ± 0.85     | 3.40 ± 0.67    | 0.05      |
| LDH (IU/L)       | 951.31 ± 351.11 | 1235.38 ± 618.55| $<0.05$   |
| CPK (IU/L)       | 164.00 ± 158.66 | 309.72 ± 344.19| $0.001$   |
| ESR (mm/h)       | 41.40 ± 20.09   | 48.71 ± 22.49  | $0.019$   |
| CRP (mg/L)       | 1.93 ± 0.92     | 1.86 ± 0.85    | 0.59      |
| D-dimer (ng/mL)  | 1713.66 ± 1360.19| 5837.38 ± 23445.86| 0.273    |
| Ferritin (ng/mL) | 1023.52 ± 507.65| 1288.33 ± 492.39| $0.01$   |
| pH               | 7.38 ± 0.07     | 7.32 ± 0.12    | $<0.001$  |
| PCO2 (mm Hg)     | 41.44 ± 11.34   | 36.56 ± 11.66  | $0.004$   |
| HCO3 (mEq/L)     | 36.56 ± 11.66   | 24.52 ± 8.97   | $<0.001$  |

BS: Blood Sugar, LDH: Lactate dehydrogenase, CPK: Creatine Phosphokinase, ESR: erythrocyte sedimentation rate, CRP: C-reactive protein.
Conclusion
In conclusion, AKI is linked to a noticeably higher mortality rate among hospitalized COVID-19 patients as compared to non-AKI patients. The kidneys are the target organ of SARS-CoV-2 and the outbreak of AKI in admitted COVID-19 patients is high. Accordingly, the deterioration of kidney function exacerbates damage to other organs. Additionally, COVID-19 cases have a higher mortality rate when it is associated with AKI. In our study, AKI is a common finding in COVID-19 patients. Our study showed most patients were in stage I, which returned to normal kidney function after COVID-19 treatment. According to our study, COVID-19 leads to less severe and permanent kidney damage. We recommend that kidney function should be evaluated in COVID-19 patients and renal function monitoring should be continued after discharge to control for progression to CKD. We recommend that larger, multicenter studies to be conducted in the future to learn more about the impact of AKI on prognosis and disease outcomes.

Limitations of the study
There were various limitations in this study. Since non-hospitalized patients were not included in the present investigation, we were unable to extrapolate our findings to outpatient AKI settings. Second, we received no follow-up information after discharge. Third, the causality interpretation of the association between effects and exposures was not attainable owing to the observational character of the research.

Authors’ contribution
Conceptualization: LSN. Methodology: HSH, MT and LSN. Validation: AGH. Formal Analysis: FJM. Investigation: LSN and AGH. Resources: SHA. Data Curation: MT. Writing—Original Draft Preparation: MT. Writing—Review and Editing: MT and AGH. Visualization: HSH, LSN. Supervision: AGH, SHA. Project Administration: HSH, MT and LSN. Funding Acquisition: HSH.

Ethical issues
The study protocol conforms to the ethical guidelines of Declaration of Helsinki (1975). The study was approved by the Ethics Committee of Ahvaz Jundishapur University of medical sciences, Ahvaz, Iran (Ethics number: IR.AJUMS.REC.1400.023). Written informed consent was obtained from all patients. The present research was extracted from the nephrology fellowship dissertation of Mina Tafazoli at this university (registration no: 4386). Besides, ethical issues (including plagiarism, data fabrication and double publication) have been completely observed by the authors.

Conflicts of interest
The authors declare that they have no competing interests.

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References
1. Cheng Y, Luo R, Wang K, Zhang M, Wang Z, Dong L, et al. Kidney disease is associated with in-hospital death of patients with COVID-19. Kidney Int. 2020;97:829-38. doi: 10.1016/j.kint.2020.03.005.
2. Fominskiy EV, Scandroglio AM, Monti G, Calabro MG, Landoni G, Dell’Acqua A, et al; COVID-BioB Study Group. Prevalence, Characteristics, Risk Factors, and Outcomes of Invasively Ventilated COVID-19 Patients with Acute Kidney Injury and Renal Replacement Therapy. Blood Purif. 2021;50:102-109. doi: 10.1159/000508657.
3. Han X, Ye Q. Kidney involvement in COVID-19 and its treatments. J Med Virol. 2021;93:1387-95. doi: 10.1002/jmv.26653.
4. Zhang G, Hu C, Luo L, Fang F, Chen Y, Li J, et al. Clinical features and short-term outcomes of 221 patients with COVID-19 in Wuhan, China. J Clin Virol. 2020;127:104364. doi: 10.1016/j.jcv.2020.104364.
5. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med. 2020;8:475-81. doi: 10.1016/S2213-2600(20)30079-5.
6. Richardson S, Hirsch JS, Narasimhan M, Crawford JM, McGinn T, Davidson KW, et al. Presenting Characteristics, Comorbidities, and Outcomes Among 5700 Patients Hospitalized with COVID-19 in the New York City Area. JAMA. 2020;323:2052-9. doi: 10.1001/jama.2020.6775.
7. Kolhe NV, Fluck RJ, Selby NM, Tal MW. Acute kidney injury associated with COVID-19: A retrospective cohort study. PLoS Med. 2020;17: e1003406. doi: 10.1371/journal.pmed.1003406.
8. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical Characteristics of 138 Hospitalized Patients with 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. JAMA. 2020;323:1061-9. doi: 10.1001/jama.2020.1585.
9. Ronco C, Bellomo R, Kellum JA. Acute kidney injury. Lancet. 2019;394:1949-64. doi: 10.1016/S0140-6736(19)32563-2.
10. Akikian H, Ozturk S, Tokgoz B, Dursun B, Seyahi N, Trabulus S, et al. Characteristics and outcomes of acute kidney injury in hospitalized COVID-19 patients: A multicenter study by the Turkish society of nephrology. PLoS One. 2021;16:e0256023. doi: 10.1371/journal.pone.0256023.
11. Ertuğlu LA, Kanbay A, Aşfar B, Elsüre Aşfar R, Kanbay M. COVID-19 and acute kidney injury. Tuberk Toraks. 2020;68:407-18. doi: 10.5578/rt.70010.
12. Kdigo A. Work Group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl. 2012;2:1-138. doi:
13. Greffier J, Hoballah A, Sadate A, de Oliveira F, Claret PG, de Forges H, et al. Ultra-low-dose chest CT performance for the detection of viral pneumonia patterns during the COVID-19 outbreak period: a monocentric experience. Quant Imaging Med Surg. 2021;11:3190-9. doi: 10.21037/qims-20-1176.

14. Xiao G, Hu H, Wu F, Sha T, Zeng Z, Huang Q, et al. Ultra-low-dose chest CT performance for the detection of viral pneumonia patterns during the COVID-19 outbreak period: a monocentric experience. Quant Imaging Med Surg. 2021;11:3190-9. doi: 10.21037/qims-20-1176.

15. Azeem HA, Abdallah H, Abdelnaser MM. Acute kidney injury in hospitalized patients with COVID-19 (retrospective study). Egypt J Bronchol. 2021;15:1-7. doi: 10.1186/s43168-021-00056-z.

16. Robbins-Juarez SY, Qian L, King KL, Stevens JS, Husain SA, Radhakrishnan J, et al. Outcomes for Patients with COVID-19 and Acute Kidney Injury: A Systematic Review and Meta-Analysis. Kidney Int Rep. 2020;5:1149-1160. doi: 10.1016/j.kir.2020.06.013.

17. Dai Y, Liu Z, Du X, Wei H, Wu Y, Li H, et al. Acute Kidney Injury in Hospitalized Patients Infected with COVID-19 from Wuhan, China: A Retrospective Study. Biomed Res Int. 2021;2021:6655185. doi: 10.1155/2021/6655185.

18. Hirsch JS, Ng JH, Ross DW, Sharma P, Shah HH, Barnett RL, et al. Northwell COVID-19 Research Consortium; Northwell Nephrology COVID-19 Research Consortium. Acute kidney injury in patients hospitalized with COVID-19. Kidney Int. 2020;98:209-18. doi: 10.1016/j.kint.2020.05.006.

19. Trifi A, Abdellatif S, Masseoudi Y, Mehdi A, Benjima O, Seghir E, et al. COVID-19-induced acute kidney injury in critically ill patients: epidemiology, risk factors, and outcome. Acute Crit Care. 2021;36:308-16. doi: 10.4266/acc.2021.00934.

20. Audit I. ICNARC report on COVID-19 in critical care. April. 2020;10:2020. doi: 10.1177/1751143720961672.

21. Chertow GM, Burdick E, Honour M, Bonventre JV, Bates DW. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. J Am Soc Nephrol. 2005;16:3365-70. doi: 10.1681/ASN.2004090740.