Original Article

The clinical course and risk factors in COVID-19 patients with acute kidney injury

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Abstract

Background: Acute kidney injury (AKI) has the most prevalent complications in COVID-19 patients. A variety of factors is involved in the disease progression and its associated outcomes. The present study aimed at both examining the correlated clinical features of COVID-19 disease and AKI and evaluating its clinical outcomes. **Materials and Methods:** In the present retrospective study, 102 COVID-19 patients that encountered AKI were enrolled and categorized into three AKI stages. Basic and clinical characteristics, clinical signs and symptoms, laboratory and imaging findings, and treatment approaches were examined. Then, clinical outcomes as well as the factors associated with the mortality of patients were evaluated. **Results:** Diabetes was the only significant clinical characteristic among the patients ($P = 0.004$). An increasing trend was observed for neutrophil-to-lymphocyte ratio ($P = 0.027$) and potassium (K) ($P = 0.006$), and a decreasing trend was seen for hemoglobin ($P < 0.001$), albumin ($P = 0.005$), and calcium ($P < 0.001$) factors at higher stages of AKI. Secondary infection ($P = 0.019$) and hypoproteinemia ($P = 0.018$) were the most significant clinical outcomes. Chronic obstructive lung disease (OR = 1.362, $P = 0.007$), renal replacement therapy (OR = 2.067, $P = 0.005$), lung consolidation (OR = 0.722, $P = 0.032$), and bilateral pulmonary infiltration (OR = 4.793, $P = 0.002$) were the factors associated with mortality rate of COVID-19 patients with AKI. **Conclusion:** AKI, as an important complication of COVID-19, that can predict the higher mortality rate as well as the laboratory and clinical characteristics should receive more due consideration in order to employ proper preventive or supportive treatment approaches that are the pivotal key to reduce the mortality rate in target patients.

Keywords: Acute kidney injury, complication, COVID-19, mortality, SARS-CoV-2

Introduction

In late 2019, an acute respiratory illness caused by a novel member of the coronavirus family occurred in Wuhan, Hubei Province, China, was named as the coronavirus-2019 (COVID-19) by the World Health Organization (WHO), and has spread rapidly from China to all around the world.[1] The clinical course of COVID-19 disease is associated with various factors such as weakness, physical disability, elderly, and a history of previous diseases such as cardiovascular, lung, kidney, immunosuppression, and autoimmune diseases.[2]

Although sporadic alveolar damage, which results in acute respiratory failure, is the major complication of COVID-19 disease, the involvement of other organs should be meticulously considered. In severe lung infections, viremia accumulates virus particles in kidneys and causes damage to kidney cells. Clinical examinations of patients with severe acute respiratory syndrome

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reported an impaired renal function, resulting in a severe renal impairment.[3]

Acute kidney injury (AKI) is a major risk factor for COVID-19 patients if the disease progression is not controlled. The health outcome of AKI is poor with a high mortality rate, especially for patients at a higher risk.[4]

Considering the fact that examining the underlying factors associated with COVID-19 patients with AKI can help clinicians to effectively predict the progression of the disease and better manage vulnerable population,[5] the present study aimed at surveying basic and clinical characteristics and outcomes of COVID-19 patients with different stages of AKI.

Materials and Methods

The current retrospective study represented the analysis of health information system (HIS) records of the COVID-19 patients that encountered AKI from March 1 to May 31, 2020.

Inclusion criteria were all patients that referred to the hospital with positive COVID-19 test results diagnosed by clinical symptoms including fever, cough, shortness of breath, tachycardia, blood oxygen saturation (O_2sat) level of less than 93%, positive COVID-RT-PCR, and lung CT scans with positive manifestations according to the WHO clinical diagnosis and treatment guideline.[6] Among the mentioned group of patients, AKI has been diagnosed during the time of hospitalization. Exclusion criteria were the lack of complete and proper information of patients in HIS records. A total of 102 COVID-19 patients with AKI were recruited from the total of 437 hospital-admitted patients.

AKI was categorized based on the acute kidney injury network (AKIN) criteria, in which creatinine (Cr) level increases up to 1.5-fold from the baseline in the first stage, 2- to 3-fold from the baseline in the second stage, and more than 3-fold from the baseline in the third stage. The patients of this study were divided into three groups based on the AKIN criteria.[7] The severity of COVID-19 was defined according to the Chinese management guideline for COVID-19.[8] The following items were gathered from the HIS records for each COVID-19 patient: age, gender, location, travel and smoking history, comorbidities, COVID-19-associated clinical symptoms (fever, nasal congestion, headache, cough, sore throat, sputum, fatigue, hemoptysis, shortness of breath, nausea or vomiting, diarrhea, myalgia or arthralgia, chills, and chest pain), vital signs (respiratory rate, diastolic blood pressure, systolic blood pressure, pulse rate, temperature, and time from illness onset to hospital admission), disease severity (mild, moderate, and severe), laboratory findings and arterial blood gases, imaging features (consolidation, ground-glass opacity, bilateral pulmonary infiltration, and pleural effusion), and a history of treatments (antibiotics, antiviral treatment, corticosteroids, intravenous immunoglobulin, high-flow nasal cannula oxygen therapy, invasive mechanical ventilation, renal replacement therapy (RRT), and hemoperfusion).

Finally, the collected data were entered into SPSS software (ver. 23). The data were presented as means ± standard deviation or frequency (percentage). Besides, the analysis of variance and the Chi-square tests were used to compare the means of quantitative variables and to compare the frequency distribution of discrete data, respectively. Moreover, logistic regression with the forward method was used to evaluate the effective factors in the incidence of patient mortality. A significance level of less than 0.05 was considered in all analyses.

Results

In the present study, the information of patients with COVID-19 over 3 months (March–May, 2020) was gathered. The findings showed that 102 COVID-19 patients out of 437 cases developed AKI. According to AKIN criteria, 63 patients (61.8%), 26 patients (25.5%), and 13 patients (12.7%) were in stages I, II, and III of AKI disease, respectively. Moreover, 39 patients (38.2%) were female and 63 patients (61.8%) were male with the mean age of 65.98 ± 17.95 years. There was no statistically significant difference in terms of the age, gender, place of residence, and smoking history among different stages of AKI ($P > 0.05$). Furthermore, the comorbidity of diabetes present in stage III was significantly higher than that of the other stages ($P = 0.004$). The presence of other comorbidities was not significant among the three stages ($P > 0.05$) [Table 1].

The highest frequencies of clinical symptoms at the time of hospital admission for COVID-19 patients were recorded for fever, cough, fatigue, and shortness of breath with 75.5, 67.6, 78.4, and 65.7%, respectively. In addition, the severity of COVID-19 did not differ among the three stages of AKI ($P > 0.05$) [Table 2].

Moreover, laboratory findings of the patients indicated that levels of blood urea nitrogen (BUN) and Cr were higher in stage III as compared with the other two stages. Furthermore, levels of hemoglobin, albumin, calcium, and potassium were lower in stage III as compared with other stages ($P < 0.05$). It can be stated that the possibility of hypokalemia, hypoalbuminemia, and hypocalcemia was more pronounced in severe stages of AKI. Besides, the most common imaging finding was ground glass opacity (84.3%) although in general, imaging findings did not differ significantly among the three AKI stages ($P > 0.05$). In addition, neutrophil-to-lymphocyte ratio (NLR) with a mean of 10.53 ± 6.61 was significantly higher in stage III of AKI as compared with stages I and II of AKI with the means of 7.24 ± 6.14 and 7.64 ± 6.02, respectively ($P = 0.027$). Furthermore, the frequency distribution of treatment approaches was not significantly different in three stages of AKI. RRT was used only in the severe stage of AKI ($P < 0.05$) [Table 3].

The clinical outcomes of COVID-19 patients with AKI are presented in Table 4. According to Table 4, although the

Table 1: Demographic and clinical characteristics of studied COVID-19 patients

Variables	Total (*n*=102)	Stage I (*n*=63)	Stage II *n*=26)	Stage III (*n*=13)	*P*
Age; year	65.98±17.95	65.22±16.36	69.42±18.29	62.62±24.02	0.472
Gender, *n* (%)					
Female	39 (38.2%)	26 (41.3%)	10 (38.5%)	3 (23.1%)	0.470
Male	63 (61.8%)	37 (58.7%)	16 (61.5%)	10 (76.9%)	
Location					
City	75 (73.5%)	45 (71.4%)	20 (76.9%)	10 (76.9%)	0.980
Suburb	27 (26.5%)	18 (28.6%)	6 (23.1%)	3 (23.1%)	
Travel history	6 (5.9%)	4 (6.3%)	1 (3.8%)	1 (7.7%)	0.838
Smoking history					
Never	90 (88.23%)	58 (92.1%)	20 (76.9%)	12 (92.3%)	0.541
Exposure	8 (7.8%)	2 (3.2%)	5 (19.3%)	1 (7.7%)	
Current	4 (3.9%)	3 (4.7%)	1 (3.8%)	0 (0%)	
Comorbidities					
Hypertension	46 (45.1%)	24 (38.1%)	16 (61.5%)	6 (46.2%)	0.129
Diabetes	37 (36.3%)	15 (23.8%)	14 (53.8%)	8 (61.5%)	0.004
Coronary heart disease	32 (31.4%)	16 (25.4%)	11 (42.3%)	5 (38.5%)	0.248
Cerebrovascular disease	6 (5.9%)	4 (6.3%)	1 (3.8%)	1 (7.7%)	0.862
BMI >40	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-
Chronic obstructive lung disease	13 (12.7%)	9 (14.3%)	3 (11.5%)	1 (7.7%)	0.792
Cancer	7 (6.9%)	4 (6.3%)	3 (11.5%)	0 (0.0%)	0.392
Chronic kidney disease	10 (9.8%)	3 (4.8%)	5 (19.2%)	2 (15.4%)	0.087
Hepatic B infection	1 (1%)	0 (0%)	1 (3.8%)	0 (0%)	0.229
Immunodeficiency	5 (4.9%)	1 (1.6%)	3 (11.5%)	1 (7.7%)	0.125
Other	28 (27.5%)	15 (23.8%)	11 (42.3%)	2 (15.4%)	0.119

Table 2: Clinical signs and symptoms of studied COVID-19 patients

Variables	Total (*n*=102)	Stage I (*n*=63)	Stage II (*n*=26)	Stage III (*n*=13)	*P*
Clinical symptoms					
Fever	77 (75.5%)	48 (76.2%)	20 (92.3%)	9 (69.2%)	0.902
Nasal congestion	7 (6.9%)	4 (6.3%)	2 (7.7%)	1 (7.7%)	0.958
Headache	11 (10.8%)	5 (7.9%)	4 (15.4%)	2 (15.3%)	0.472
Cough	69 (67.6%)	44 (69.8%)	19 (73.1%)	6 (46.1%)	0.293
Sore throat	5 (4.9%)	3 (4.8%)	2 (7.7%)	0 (0%)	0.586
Sputum	23 (22.5%)	14 (22.2%)	8 (30.8%)	1 (7.7%)	0.300
Fatigue	80 (78.4%)	48 (76.2%)	22 (84.6%)	10 (76.9%)	0.701
Hemoptysis	3 (2.9%)	2 (3.2%)	1 (3.8%)	0 (0%)	0.809
Shortness of breath	67 (65.7%)	43 (68.2%)	16 (61.5%)	8 (61.5%)	0.675
Nausea or vomiting	28 (27.5%)	19 (30.2%)	7 (26.9%)	2 (15.3%)	0.645
Diarrhea	13 (12.7%)	10 (15.9%)	2 (7.7%)	1 (7.7%)	0.441
Myalgia or arthralgia	44 (43.1%)	23 (36.5%)	16 (61.5%)	5 (38.5%)	0.110
Chills	44 (43.1%)	29 (46.0%)	8 (30.8%)	7 (53.8%)	0.407
Chest pain	8 (7.8%)	4 (6.3%)	4 (15.4%)	0 (0%)	0.263
Vital Signs					
Respiratory rate, breaths per minute	25.96±11.354	26.62±13.24	24.61±7.41	25.41±7.18	0.743
Diastolic blood pressure, mm Hg	78.98±15.21	94.92±124.97	79.60±12.57	74.58±14.05	0.710
Systolic blood pressure, mm Hg	129.06±28.01	129.60±30.42	129.81±24.10	125.00±24.58	0.857
Pulse rate, beats per minute	90.72±20.07	91.90±20.78	86.50±16.78	93.54±22.79	0.449
Temperature, °C	37.16±3.54	36.98±4.49	37.36±0.86	37.65±0.94	0.785
Severity of coronavirus disease					
General	56 (54.9%)	37 (58.7%)	14 (53.8%)	5 (38.5%)	0.154
Severe	35 (34.3%)	22 (34.9%)	9 (34.6%)	4 (30.8%)	
Critical	11 (10.8%)	4 (6.3%)	3 (11.5%)	4 (30.8%)	
Time from illness onset to hospital admission, days	6.80±4.98	6.87±4.73	6.81±5.25	6.42±6.01	0.960

mortality rate was higher in patients with advanced stages of AKI, the incidence of mortality was not significantly different among the three stages of AKI ($P > 0.05$). In contrast, complications of secondary infection and hypoproteinemia

Table 3: Laboratory, imaging, and treatments findings of the studied patients

Variables	Total (*n*=102)	Stage I (*n*=63)	Stage II (*n*=26)	Stage III (*n*=13)	*P*
Laboratory findings and ABG					
White blood cell, $\times 10^9$/L	7.54±5.13	7.03±4.89	7.33±4.34	10.46±6.84	0.086
Lymphocyte, $\times 10^9$/L	15.59±8.28	16.47±8.50	15.84±8.30	10.84±5.62	0.080
Neutrophil, $\times 10^9$/L	79.20±9	78.02±10.43	79.30±9.43	84.64±5.59	0.088
NLR %	7.84±6.30	7.24±6.14	7.64±6.02	10.53±6.61	0.027
Hemoglobin, g/dL	12.48±2.25	12.82±2.07	12.74±2.04	10.14±2.41	<0.001
Platelet count, $\times 10^9$/L	174.42±69.67	173.98±63.60	174.92±65.50	175.67±107.37	0.996
Albumin, g/dL	3.65±0.78	3.79±0.76	3.63±0.80	3.03±0.54	0.005
Alanine aminotransferase, U/L	27.31±18.76	25.83±16.82	26.12±20.13	37.12±23.57	0.154
Aspartate aminotransferase, U/L	40.08±17.23	40.12±15.97	38.93±16.09	42.23±25.26	0.866
Alkaline phosphatase, U/L	200.95±235.41	179.53±85.80	262.43±453.82	189.18±85.36	0.355
Creatinine, mg/dL	1.78±1.27	1.15±0.27	2.01±0.52	4.39±1.79	<0.001
Blood urea nitrogen, mg/dL	35.24±29.88	24.79±24.07	39.81±16	75.98±38.85	<0.001
Calcium, mEq/L	8.16±0.81	8.37±0.76	8.02±0.78	7.32±0.48	<0.001
Magnesium, mEq/L	1.97±0.57	1.94±0.26	1.89±0.22	2.23±1.42	0.203
Potassium, mEq/L	3.92±0.51	3.80±0.46	4.07±0.56	4.22±0.53	0.006
Sodium, mEq/L	132.84±8.48	132.78±10.16	133.28±4.13	132.31±6.09	0.942
D-dimer, μg/mL	263.85±281.05	321.36±387.73	200.60±200.89	200.60±196.89	0.640
Erythrocyte sedimentation rate, mm/h	58.47±31.15	56.45±29.25	55.30±27.98	74.00±42.38	0.179
Blood pH	7.30±0.16	7.31±0.15	7.28±0.17	7.29±0.17	0.700
Oxygen saturation, %	56.21±21.76	55.86±22.17	61.55±22.62	47.23±15.20	0.150
Carbon dioxide, mmol/L	49.59±18.23	50.67±14.49	49.58±25.20	44.48±18.57	0.542
Bicarbonate, mmol/L	23.74±8.38	24.87±8.69	22.43±8.00	20.96±7.01	0.204
Imaging features					
Consolidation	4 (3.9%)	4 (6.3%)	0 (0%)	0 (0%)	0.288
Ground glass opacity	86 (84.3%)	57 (90.5%)	17 (65.4%)	12 (92.3%)	0.128
Bilateral pulmonary infiltration	18 (17.6%)	9 (14.3%)	7 (26.9%)	2 (15.4%)	0.276
Pleural effusion	4 (3.9%)	3 (14.3%)	1 (3.8%)	0 (0%)	0.722
Treatments					
Antibiotics	95 (93.1%)	57 (90.5%)	26 (100%)	12 (92.3%)	0.702
Antiviral treatment	69 (67.6%)	47 (74.6%)	18 (69.2%)	10 (76.9%)	0.835
Corticosteroids	51 (50.0%)	25 (55.6%)	17 (65.4%)	9 (69.2%)	0.525
Intravenous immunoglobulin	12 (11.8%)	8 (12.7%)	1 (3.8%)	3 (23.1%)	0.167
High-flow nasal cannula oxygen therapy	61 (59.8%)	36 (57.1%)	18 (69.2%)	7 (53.8%)	0.754
Invasive mechanical ventilation	31 (30.4%)	18 (28.6%)	8 (30.8%)	5 (38.5%)	0.601
Renal replacement therapy	9 (8.8%)	0 (0%)	0 (0%)	9 (69.2%)	-
Hemoperfusion	6 (5.9%)	5 (7.9%)	0 (0%)	1 (7.7%)	0.337

Table 4: Frequency distribution of clinical outcomes and length of stay in ICU and hospital in COVID-19 patients

Outcomes	Total (*n*=102)	Stage I (*n*=63)	Stage II (*n*=26)	Stage III (*n*=13)	*P*
Death	33 (32.4%)	18 (28.6%)	9 (34.6%)	6 (46.2%)	0.448
Sepsis	40 (39.2%)	21 (33.3%)	10 (38.5%)	9 (69.2%)	0.064
Respiratory failure	45 (44.1%)	26 (41.3%)	11 (42.3%)	8 (61.5%)	0.398
Acute respiratory distress syndrome (ARDS)	37 (36.3%)	20 (31.7%)	10 (38.5%)	7 (53.8%)	0.309
Heart failure	8 (7.8%)	4 (6.3%)	3 (11.5%)	1 (7.7%)	0.710
Septic shock	27 (26.5%)	14 (22.2%)	7 (26.9%)	6 (46.2%)	0.204
Coagulopathy	15 (14.7%)	8 (12.7%)	4 (15.4%)	3 (23.1%)	0.626
Acute cardiac injury	24 (23.5%)	15 (23.8%)	6 (23.1%)	3 (23.1%)	0.996
Secondary infection	64 (62.7%)	40 (63.5%)	12 (46.2%)	12 (92.3%)	0.019
Hypoproteinemia	43 (42.2%)	25 (39.7%)	8 (30.8%)	10 (76.9%)	0.018
Acidosis	66 (64.7%)	36 (57.1%)	20 (76.9%)	10 (76.9%)	0.127
ICU admission	46 (45.1%)	24 (38.1%)	13 (50.0%)	9 (69.2%)	0.102
ICU length of stay, days	10.50±8.50	12.26±9.33	7.92±4.56	9.44±10.04	0.335
Hospital length of stay, days	10.75±8.29	10.73±8.58	9.38±5.94	13.62±10.65	0.327

were significantly different among different stages of AKI. In detail, COVID-19 patients with stage III of AKI had the highest incidence rate of these two complications ($P < 0.05$). Other complications of COVID-19 disease did not differ significantly among different stages of AKI ($P > 0.05$) [Table 4].

Ultimately, the results of logistic regression addressing the evaluation of factors (such as comorbidities, clinical factors, imaging findings, and performed treatments) affecting mortality of these patients revealed that chronic obstructive lung disease (OR = 1.362), lung consolidation (OR = 0.722), bilateral pulmonary infiltration (OR = 4.793), and RRT (OR = 2.067) increased the rate of mortality in COVID-19 patients with AKI ($P < 0.05$) [Table 5].

Discussion

The present study could not find any significant difference among three AKI stages in terms of demographic and clinical characteristics, except for diabetes that was presented more in the higher stages of AKI. Recent studies have demonstrated that diabetes is associated with adverse immune responses to viral infections that lead to a reduced protection ability against virus invasion, which may consequently contribute to an increased mortality rate.[9] As diabetic patients with COVID-19 are more susceptible to comorbidities[10] and diabetes is one of the most important risk factors for the mortality in patients with AKI,[11] the presence of diabetes in COVID-19 patients with AKI could be considered as a hint for the treatment priority, especially in higher stages of AKI.

Laboratory findings showed that hemoglobin, albumin, and calcium were decreased in COVID-19 patients with higher stages of AKI. In contrast, Cr, BUN, and K were increased in COVID-19 patients with higher AKI stages. In addition, NLR was significantly increased in patients with higher stages of AKI. NLR is an indicator of the systemic inflammatory response that is the dominant prognostic factor for viral infection, especially viral pneumonia. Higher values of NLR are directly associated with disease severity and poor clinical outcomes.[12] Immunologically speaking, neutrophil can trigger a systemic inflammation and release various immune system-related mediators that help the immune cells to kill viruses more efficiently; however, with a higher systemic inflammation, lymphocyte depletion occurs as a consequence of the inhibitory effect of the systemic inflammation on cellular immunity. Therefore, viral-induced inflammation can increase NLR.[13] Furthermore, NLR has been identified as a potential noninvasive indicator that demonstrates developed AKI, which means it can be used for prognosis of higher stages of AKI in COVID-19 patients at the time of hospital admission.[14]

Table 5: The results of logistic regression to identify the factors affecting the mortality rate of COVID-19 patients

Factors	OR	95% CI	*P*
Chronic obstructive lung disease	1.362	0.409-4.537	0.007
Renal replacement therapy	2.067	0.511-8.353	0.005
Lung consolidation	0.722	0.072-7.234	0.032
Bilateral pulmonary infiltration	4.793	1.638-14.026	0.002

The results revealed that the decreased trend of hemoglobin was associated with higher stages of AKI. Hemoglobin has an emerging role in acute respiratory viral infection. A lower level of hemoglobin in patients deteriorates blood O_2 saturation, which substantially causes severe stages of the viral disease. On this occasion (hypoxemia), blood transfusion is recommended.[15] Noteworthy, the experimental investigation has revealed that despite the decreasing O2-carrying capacity due to anemia in COVID-19 disease, O_2 affinity remained unchanged.[16] In addition, anemia has been reported to be a risk factor for AKI and if the hemoglobin level is decreased, O_2 will be less delivered to the kidney that in turn makes kidney prone to activity disturbance and further kidney dysfunction.[17]

Albumin is another laboratory indicator that was decreased more in severe stages of AKI. Hypoalbuminemia is one of the most common complications in COVID-19 patients, and the lower level of albumin is associated with a poor prognosis of disease.[18] Moreover, the lower level of albumin is prevalent among AKI patients.[19] The negotiated reasons behind the decreased albumin level in COVID-19 patients with AKI are inflammation, oxidative stress, protein-losing disorders, and severe infection. Albumin inhibits toxic agent to inter and make an adverse effect on kidney and helps kidney to preserve optimal oncotic pressure and kidney perfusion.[19] The lower level of albumin could be a pivotal clinical element for COVID-19 patients with AKI.

The present study found that BUN and Cr were increased with the higher AKI stages. In various studies, stages of AKI have been categorized as serum Cr and BUN.[20,21] Of interest, it has been found that COVID-19 patients with severe stages of AKI had higher BUN and Cr levels than those with mild or recently identified AKI.[20]

The present study found that calcium and potassium act differently in COVID-19 patients with AKI. Likewise, Cheng *et al.*[22] reported the elevated potassium level in COVID-19 patients with higher stages of AKI. A decrease in calcium, which is common among patients with renal failure, has also been reported in order to take appropriate management actions for COVID-19 patients with higher AKI stages.[23]

Clinical outcomes of COVID-19 patients with AKI were secondary infection and hypoproteinemia with an upward trend in AKI stages. In another study, it has been shown that one of the risk factors for COVID-19 is secondary infection that is associated with poor clinical outcomes and finally patient mortality;[24] hence, an appropriate management action should be taken into consideration to prevent the development of severe stages of the disease. Hypoproteinemia is also reported to have a significant association with a poor recovery and the worst clinical outcomes[25]

Chronic obstructive pulmonary disease (COPD) was another most observed complication among COVID-19 patients and was correlated with developing AKI that prones the patients to a poor outcome and a severe clinical condition.[26] The present study found that COPD was among the most prevalent elements observed in dead patients. COPD causes a severe exacerbation of respiratory infection and could lead to fatal outcomes in case of not being managed properly.[27]

The current study showed that lung consolidation mostly appears in COVID-19 patients and causes hypoxia and further organ damages. Disease progression from pneumonia to pulmonary consolidation causes death because of multiple organ failures.[28] Another imaging feature that was significantly observed in deceased COVID-19 patients with AKI was bilateral pulmonary infiltration. Similar to consolidation, a prolonged treatment in COVID-19 patients that have developed AKI leads to bilateral pulmonary infiltration, which forces clinicians to choose ICU care and further invasive mechanical ventilation, at the end of which death of patients would be expected.[24]

RRT is a standard treatment approach proposed for patients with renal failure. Although RRT is the standard treatment protocol for these complications, tough clinical conditions of patient care and the unavailability of treatment equipment lead to the achievement of the least promising treatment outcomes.[29] COVID-19 has been reported to be involved in the kidney disease initiation that substantially makes patients prone to kidney dysfunction. The findings of this study revealed that COVID-19 patients with AKI that were treated by RRT were more at the risk of death. Similarly, Mohamed *et al.* stated that mortality among the COVID-19 patients with AKI that required RRT was considerably high, which meant that 72% of RRT-treated patients died, while only 22% of patients that did not require RRT was expired.[30]

This study has some limitations. First, the study population was relatively small and needs to be expanded in future studies. Second, the time of encounter with AKI in COVID-19 patients was not addressed. Third, the effect of various medications on the stages of AKI was not evaluated, especially after admitting patients to ICU. Nevertheless, the very aim of the present study was to demonstrate the main complications of AKI on the COVID-19 patients to provide the predictive factors that help clinicians to prevent further complications of the disease before initiation.

Conclusion

The present study examined the most crucial clinical features of COVID-19 patients that experienced AKI. According to the obtained findings, diabetes could be a risk factor for COVID-19 patients with AKI. Furthermore, laboratory findings could be predictive factors for disease outcomes. Moreover, clinical outcomes such as secondary infection and hypoproteinemia should be monitored in COVID-19 patients with AKI. In addition, the complication factors like chronic obstructive lung disease or treatment approaches such as RRT as well as imaging findings including lung consolidation and bilateral pulmonary infiltration would be alarms for disease exacerbation and higher mortality rate.

Ethics committee approval

The present study was approved by the Ethics Committee of Isfahan University of Medical Sciences (Approval Number: IR.MUI.MED.REC.1399.237).

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Conflicts of interest

There are no conflicts of interest.

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