Clinical Characteristics and Outcomes of 217 Kidney Transplantation Recipients Hospitalized with COVID-19: A Systematic Review

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ABSTRACT

Immunosuppressed kidney transplant recipients may have increased risk of causing severe disease during hospitalization of COVID-19. We conducted this review for better understanding the clinical characteristics and outcomes of this population. A literature search was undertaken to identify the studies which reported outcomes of kidney transplant recipients hospitalized with COVID-19 by searching MEDLINE, EMBASE, Web of Science and Google Scholar from January 1, 2019 to July 1, 2020. 38 studies reporting 217 KTR hospitalized with COVID-19 were included in the current study. All patients experienced fever, cough or dyspnea before hospitalization. 52.6% of recipients were classified as severe patients. The mortality of overall patients and discharged patients including those discharged alive and dead was 20.3% and 30.8%, respectively. Among discharged patients, 53.3% of those admitted to ICU, 73.3% requiring invasive ventilation and 38.5% receiving non-invasive ventilation died. 47.3% of in-hospital KTR developed AKI. Among the severe patients who developed AKI, 32.1% requiring renal replacement therapy during hospitalization. In conclusion, immunosuppressed kidney transplant recipients hospitalized with COVID-19 are at higher risk of developing severe disease (53.3%) at a relatively young age and have higher mortality (30.8%) and higher prevalence of acute kidney injury (47.3%) compared to the general population with COVID-19.

Keywords: Acute kidney injury; COVID-19; mortality; SARS-CoV-2; systematic review; transplantation

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) outbreak caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has become a global pandemic over the past few months with the number of global confirmed COVID-19 cases exceeding twelve million as of 10 July, 2020. Although most individuals with COVID-19 present with mild symptoms, such as fever and dry cough, and are able to recover without any treatment, some patients develop severe complications including sepsis, respiratory failure, acute kidney injury (AKI) and multi organ failure and even die.

There is no consensus on to what extent immunosuppression can alter the clinical presentation, courses and outcomes of solid organ transplant recipients with COVID-19. Immunosuppressed patients may experience prolonged viral shedding time and virus-induced complications. On the other hand, immunosuppressive therapy may provide transplant recipients with some protective effect by suppressing the hyperactive immune response to virus and preventing the cytokine release syndrome (CRS) which is associated with the acute respiratory distress syndrome (ARDS) and respiratory failure, the leading causes of death in patients with COVID-19.

Kidney transplant recipients (KTR) are the largest population amongst solid organ transplant patients who are potentially vulnerable during the pandemic of COVID-19. However, only a handful of case reports, series and cohort studies with small sample size and diverse results exist in the current literature to explore the clinical features and outcomes of hospitalized COVID-19 positive KTR. Thus, we performed this systematic review to synthesize data for better understanding clinical characteristics, the prevalence of acute kidney injury and outcomes of this population.

MATERIALS AND METHOD

We conducted the review according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines.

Data Sources and Searches

A comprehensive literature search was undertaken to identify the studies which reported clinical characteristics and outcomes of hospitalized kidney transplant recipients infected with COVID-19 by using 4 databases including MEDLINE, EMBASE, Web of Science and Google Scholar from January 1, 2019 to July 1, 2020. We used the combinations of the following search terms: COVID-19 OR coronavirus OR SARS-CoV-2 OR 2019-nCoV AND kidney transplantation. A hand search was also performed by checking the reference lists of the relevant studies identified through the above method and key journals regarding kidney diseases.
Eligibility Criteria
The studies were included if they met the following inclusion criteria: (1) the studies reported clinical characteristics and outcomes of kidney transplant recipients diagnosed with COVID-19, (2) published on peer-reviewed journals between December 1, 2019 and July 1, 2020, (3) written in English. Exclusion criteria for cases were as follows: (1) the patient who accepted non-kidney solid organ transplant, (2) repeated cases, (3) the patients under 18 years of age, (4) the studies not reporting clinical outcomes, (5) the patients who were not hospitalized.

Study Selection and Data Extraction
Two authors (YS and ST) independently performed study selection, evaluation of methodological quality and data abstraction with disagreement resolved by consensus discussion between them. Ineligible studies were excluded based on reviewing their titles, abstracts and full text of the studies.

The data collected from the eligible studies includes first author, country, publication status, age, sex, time from transplant, comorbidities, symptoms before admission, highest values of inflammatory biomarkers, creatinine and lowest values of lymphocyte count and estimated glomerular filtration Rate (eGFR), AKI, clinical courses and outcomes of the individual patients.

Quality Assessment
The CARE (CAse REport) guidelines including 8 items was applied to evaluate the methodological quality of the included studies in this systematic review. We classified studies as low quality if they have a quality score of 1-3, moderate quality if 4-6 and high quality if 7-8.

Data Synthesis and Statistical Analyses
Different units for the same laboratory result were converted into a same unit for analysis. Statistical analysis was conducted using STATA version 14.2 software, with continuous variables demonstrated with mean ± standard deviation (SD), median, range and interquartile range (IQR) and categorical variables expressed as number of cases and percentages.

Based on the adjustment of the classification criteria for COVID-19, we stratified the included patients by their disease severity. Those were classified as severe if they were reported to be admitted to ICU, required mechanical ventilation (MV) including invasive ventilation (IV) and non-invasive ventilation (NIV) or experienced severe COVID-19 complications including sepsis, respiratory failure and other organ failure. The remaining patients were classified as non-severe. The extracted data were compared between the severe and non-severe groups and between those who died and those discharged alive. Also, the mortality of different countries and age groups was analyzed. AKI is defined according to the KDIGO criteria. The outcome of AKI was classified as resolved if serum creatinine return to within 1.5 times
baseline and is less than 0.3 mg/dl (26.5 mmol/l) increase from baseline and ongoing if serum creatinine does not return to that range.

RESULTS AND DISCUSSION

Eligible Studies

A total of 392 studies were screened and finally, 38 peer-reviewed articles from nine countries were included\(^4,^{14-50}\) (figure 1). The methodological quality of each study was evaluated and summarized, suggesting the majority of the included studies show moderate to high quality. 6 studies rank as low quality, 20 as moderate quality and 12 as high quality according the CARE guideline.

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**Figure 1: Literature search flow diagram**

Demography and Comorbidities

217 hospitalized COVID-19 positive kidney transplant recipients (median age, 54 years old; range, 21-80 years old) were included for analysis (table 1). 52.6% of patients were classified into the severe group. The majority patients (74%) were male and the proportions of male patients in the non-severe and severe groups was 80% and 71%, respectively. Male KTR are more likely to be admitted to hospital, but there is no significant difference in mortality between
male and female population in this review. The median age (59 vs 50 years) and the median time from transplant (8.3 vs 4.5 years) of the severe patients was larger compared with those non-severe (table 1).

Among 109 KTR, 80 (73.4%) reported at least one comorbidity. Hypertension (56.9%), diabetes (27.5.0%), cardiovascular disease (CVD) (17.4%) and overweight or obesity (4.6%) are the most prevalent comorbidities (table 1). The severe group had a higher proportion of hypertension (66.7% vs 56.5%) and cardiovascular disease (21.6% vs 15.2%) than the non-severe group, but the prevalence of diabetes was similar between the two groups.

**Clinical Presentation and Laboratory Results**

All patients experienced at least one of the following three common COVID-19 symptoms: fever, cough or dyspnea. Symptoms started mean 7 days before hospitalization (table 1). Fever (86.5%) is the commonest symptom for KTR before admission in this review, follow by cough (71.2%), dyspnea (49.0%), fatigue (26%), and gastrointestinal (GI) symptoms (23.1%) such as diarrhea or vomiting, and myalgia (19.2%).

The mean values of the highest IL-6, CRP, procalcitonin, serum ferritin, D-dimer and serum creatinine and the lowest lymphocyte count and eGFR during hospitalization have significantly exceeded clinical normal ranges (table 1). These laboratory results were even worse in the severe patients than in the non-severe patients.

**Clinical Outcomes**

We found the mortality of KTR with COVID-19 requiring hospitalization is high. The overall mortality is 20.3% and the mortality is 30.8% among those discharged alive and dead (table 2). The mortality between different countries ranging from 10.5% in China to 69.2% in Iran has been noted (table 3). The mortality rate by 10-year age intervals was demonstrated in the table 4 and it was noted that 41.4% of those who died were less than 60 years of age.

The mean follow up days from diagnosis of COVID-19 was 24 (table 2). For those who needed NIV or IV, the mean days from diagnosis to ventilation was 6 days. Among 51 severe patients, 15 were discharged, 19 died and 17 remained in hospital. However, none of patients in the non-severe group died at the end of follow up.

Furthermore, 47.3% of KTR with COVID-19 develop acute kidney injury during hospitalization (table 5). We found severe patients are more likely to experience AKI (54.9% vs 39.1%), less likely to resolve it (10.7% vs 77.8%) and more frequently require renal replacement therapy (32.1% vs 5.6%) compared to non-severe patients.
| Demographic/Comorbidities/Symptoms/Laboratory Results | Total N | Non-severe | Severe |
|------------------------------------------------------|---------|------------|--------|
| **Age**                                              |         |            |        |
| N                                                    | 124     | 46         | 51     |
| Median (IQR) [range], y                               | 54 (44.5, 65) [21, 80] | 50 (38, 61) [24, 80] | 59 (50, 67) [32, 80] |
| **Sex**                                              |         |            |        |
| Male, N (%)                                          | 92 (74) | 37 (80)    | 36 (71) |
| Female, N (%)                                        | 32 (26) | 9 (20)     | 15 (29) |
| **Time from transplant,**                            |         |            |        |
| N                                                    | 112     | 38         | 47     |
| Median (IQR) [range], y                               | 7.0 (3.0, 13.5) [0, 30.1] | 4.5 (2.5, 12.0) [0, 30.1] | 8.3 (2.7, 14.7) [0, 30.1] |
| **Time from symptom onset to diagnosis,**            | 7 ± 5 (46) | 8 ± 6 (30) | 6 ± 5 (16) |
| mean ± SD, d (N)                                     |         |            |        |
| **Time from symptom onset to admission,**            | 6 ± 6 (66) | 7 ± 7 (31) | 5 ± 3 (20) |
| mean ± SD, d (N)                                     |         |            |        |
| **Comorbidities, N (%)**                             |         |            |        |
| N                                                    | 109     | 46         | 51     |
| N of comorbidities, mean ± SD                        | 1.3 ± 1.0 | 1.2 ± 1.1 | 1.5 ± 1.0 |
| Hypertension                                         | 62 (56.9) | 26 (56.5) | 34 (66.7) |
| Diabetes                                             | 30 (27.5) | 15 (32.6) | 15 (29.4) |
| CVD                                                  | 19 (17.4) | 7 (15.2) | 11 (21.6) |
| Overweight or obesity                                | 5 (4.6) | 2 (4.3) | 3 (5.9) |
| HCV infection                                        | 4 (3.7) | 0 (0) | 4 (7.8) |
| Chronic respiratory disease                          | 3 (2.8) | 0 (0) | 2 (3.9) |
| **Symptoms, N (%)**                                  |         |            |        |
| N                                                    | 104     | 40         | 37     |
| Fever                                                | 90 (86.5) | 35 (87.5) | 32 (86.5) |
| Cough                                                | 74 (71.2) | 30 (75.0) | 26 (70.3) |
| Dyspnea                                              | 51 (49.0) | 16 (40.0) | 26 (70.3) |
| Fatigue                                              | 27 (26.0) | 17 (42.5) | 7 (18.9) |
| Gastrointestinal symptoms                            | 24 (23.1) | 8 (20.0) | 9 (24.3) |
| Myalgia                                              | 20 (19.2) | 9 (22.5) | 7 (18.9) |
| Rhinorrhea                                           | 7 (6.7) | 5 (12.5) | 2 (5.4) |
| Chest pain or tightness                              | 6 (5.8) | 3 (7.5) | 3 (8.1) |
| Sore throat                                          | 2 (1.9) | 1 (2.5) | 1 (2.7) |
| Anosmia, dysgeusia                                   | 2 (1.9) | 2 (5.0) | 0 (0) |
| Loss of appetite                                     | 2 (1.9) | 1 (2.5) | 1 (2.7) |
| Headache                                             | 1 (1.0) | 0 (0) | 1 (2.7) |
| Hemoptysis                                           | 1 (1.0) | 0 (0) | 0 (0) |
| **Laboratory results, mean ± SD (N)**                |         |            |        |
| Lymphocyte count, x 10^9/l                           | 0.68 ± 0.40 (85) | 0.72 ± 0.38 (33) | 0.55 ± 0.37 (28) |
| IL-6[^b^](#) pg/ml                                   | 339 ± 967 (25) | 197 ± 244 (7) | 1101 ± 1864 (6) |
| CRP[^b^](#) mg/l                                     | 94 ± 85 (72) | 79 ± 87 (25) | 138 ± 88 (22) |
| Procalcitonin[^b^](#), ng/ml                         | 2.82 ± 6.13 (29) | 0.95 ± 2.01 (6) | 2.97 ± 7.45 (10) |
| Serum ferritin[^b^](#), ng/ml                        | 3038 ± 9376 (30) | 2471 ± 2793 (6) | 5699 ± 14623 (12) |
| D-dimer[^b^](#), mg/l                                | 3.51 ± 5.45 (21) | 1.13 ± 0.64 (9) | 5.30 ± 6.75 (12) |
| Creatinine[^b^](#), mg/dl                            | 2.56 ± 1.64 (87) | 2.23 ± 1.79 (39) | 3.00 ± 1.56 (36) |
| eGFR[^a^](#), ml/min per 1.73m²                       | 37 ± 18 (29) | 44 ± 22 (13) | 31 ± 13 (16) |
Abbreviations: COVID-19, coronavirus disease 2019; CRP, C-reactive protein; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; HCV, hepatitis C virus; KTR, kidney transplant recipients;

a The highest value of the laboratory result reported by the study was collected.

b The lowest value of the laboratory result reported by the study was collected.

Table 2: Outcome and Mortality of In-hospital KTR with COVID-19

|                     | Total, N | Died, N | Discharged alive, N | In hospital, N | Mortality of those discharged (%) |
|---------------------|----------|---------|---------------------|----------------|----------------------------------|
| N                   | 217      | 44      | 99                  | 74             | 30.8                             |
| Age, Median (IQR), y| 54 (44.5, 65) | 63 (57, 70) | 49 (36, 61)       | 54 (47, 65)   | N/A                              |
| Sex                 |          |         |                     |                |                                  |
| Male                | 92       | 22      | 42                  | 28             | 34.4                             |
| Female              | 32       | 7       | 15                  | 10             | 31.8                             |
| Non-severe          | 46       | 0       | 30                  | 16             | 0                                |
| Severe              | 51       | 19      | 15                  | 17             | 55.9                             |
| ICU                 | 21       | 8       | 7                   | 6              | 53.3                             |
| MV                  | 44       | 16      | 12                  | 16             | 57.1                             |
| NIV                 | 21       | 5       | 8                   | 8              | 38.5                             |
| IV                  | 23       | 11      | 4                   | 8              | 73.3                             |
| AKI                 | 53       | 11      | 23                  | 19             | 32.4                             |
| Those without AKI   | 60       | 10      | 30                  | 19             | 25.0                             |
| RRT                 | 12       | 4       | 0                   | 8              | 100                              |
| LOS, mean ± SD (N)  | 20 ± 12 (50) | 15 ± 4 (15) | 20 ± 12 (33)       | 22 ± 11 (13)  | N/A                              |
| Length of follow up, mean ± SD (N) | 24 ± 14 (56) | 15 ± 14 (35) | 26 ± 14 (35) | 22 ± 11 (13) | N/A |

Abbreviations: AKI, acute kidney injury; COVID-19, coronavirus disease 2019; ICU, intensive care unit; IV, invasive ventilation; KTR, kidney transplant recipients; LOS, length of stay; MV, mechanical ventilation; NIV, non-invasive ventilation; RRT, renal replacement therapy.

Table 3: Mortality of discharged KTR with COVID-19 in Different Countries

| Outcome | China | Iran | The USA | Italy | Spain |
|---------|-------|------|---------|-------|-------|
| N       | 19    | 13   | 69      | 20    | 16    |
| Died, N | 2     | 9    | 14      | 10    | 8     |
| Mortality of those discharged (%) | 10.5 | 69.2 | 20.3    | 50.0  | 50.0  |

Abbreviations: COVID-19, coronavirus disease 2019; KTR, kidney transplant recipients.

Table 4: Mortality Disposition by 10-Year Age Intervals of In-hospital KTR with COVID-19

| Age intervals, y | Total, N | Died, N | Mortality of those discharged (%) |
|------------------|----------|---------|----------------------------------|
| 20-29            | 7        | 0       | 0                                |
| 30-39            | 14       | 2       | 14.3                             |
| 40-49            | 13       | 2       | 15.4                             |
| 50-59            | 20       | 8       | 40.0                             |
| 60-69            | 16       | 9       | 56.3                             |
| 70-79            | 15       | 8       | 53.3                             |
80-89 | 1 | 0 | 0
Abbreviations: COVID-19, coronavirus disease 2019; KTR, kidney transplant recipients.

Table 5: Prevalence and Outcomes of Acute Kidney Injury of In-hospital KTR with COVID-19

|                  | Total | Non-severe | Severe |
|------------------|-------|------------|--------|
| N                | 112   | 46         | 51     |
| AKI, N (%)       | 53 (47.3) | 18 (39.1) | 28 (54.9) |
| Outcome of AKI   |       |            |        |
| N                | 53    | 18         | 28     |
| Resolveda        | 18 (34.0) | 14 (77.8) | 3 (10.7)  |
| Ongoinga         | 24 (45.3) | 3 (16.7)  | 16 (57.1) |
| Unknown          | 11 (20.8) | 2 (11.1)  | 9 (32.1)  |
| RRT              | 12 (22.6) | 1 (5.6)   | 9 (32.1)  |

Abbreviations: AKI, acute kidney injury; COVID-19, coronavirus disease 2019; KTR, kidney transplant recipients; RRT, renal replacement therapy.

a The outcome of AKI was classified as resolved if serum creatinine return to within 1.5 times baseline and is less than 0.3 mg/dl (26.5 mmol/l) increase from baseline and ongoing if serum creatinine does not return to that range.

DISCUSSION

Our study suggests KTR are very likely to develop severe COVID-19 during hospitalization who require ICU admission or mechanical ventilation or develop severe complications such as respiratory failure. 47.4% patients were classified into the non-severe group and 52.6% into the severe group.

Time from transplant is associate with the severity and mortality of COVID-19 in this population. The median age (59 vs 50 years) and the median time from transplant (8.3 vs 4.5 years) of the severe patients was larger compared with those non-severe (table 1). Our study does not support the hypothesis that KTR may have increased risk of developing severe disease with viral infection within the first few months due to intensive immunosuppressive therapy and early complication of transplant. Only 1 of 8 patients died within the first 6 months after transplant. The current study indicates KTR with longer time from transplantation is more vulnerable with COVID-19.

Majority of KTR have at least one comorbidity. Since end stage renal disease is often caused by hypertension or diabetes, KTR appear to have higher prevalence of comorbidities than the general population. This would result in the increased risk of developing severe disease and poor prognosis during COVID-19. CVD is a common morbidity in our study. Research found patients with severe COVID-19 exhibited significantly elevated high-sensitivity cardiac troponin I which indicates myocardial injury caused by viral infection51.
The symptoms of COVID-19 are nonspecific in KTR compared to the general population. Main clinical symptoms were similar between severe and non-severe KTR except dyspnea. Severe patients were more likely to present with dyspnea (70.3% vs 40.0%) on admission, were diagnosed with COVID-19 (mean days from symptom onset, 6 vs 8 days) and admitted to hospital (mean days from symptom onset, 5 vs 7 days) earlier than the non-severe patients. Immunocompromised status may alter clinical symptoms and courses of COVID-19. Several studies\textsuperscript{15, 30, 33, 40} reported patients had the sudden onset of the severe symptom of dyspnea on admission without any other common COVID-19 symptoms. The lack of common symptoms may lead to delayed diagnosis and poor prognosis. Clinicians need to be prepared to monitor and treat solid organ transplant recipients with sudden onset of severe COVID-19.

The mean values of the inflammatory biomarkers and kidney function had beyond the normal clinical range. They could be used to estimate the severity of COVID-19. Lymphopenia is very common in patients with COVID-19 and a study found low blood lymphocyte percentage could be used as a predictor of severe COVID-19\textsuperscript{52}. Those who died often exhibited the blood lymphocyte percentage lower than 5% within 2 weeks after symptom onset\textsuperscript{52}, while when patients recover, their lymphocyte count significantly increased\textsuperscript{19}. D-dimer is another important biomarker for mortality. The D-dimer less than 2.0 µg/mL on admission often predicts in-hospital death in patients with COVID-19\textsuperscript{53}.

We found the mortality of KTR with COVID-19 requiring hospitalization is high. The overall mortality is 20.3% and the mortality is 30.8% among those discharged alive and dead (table 2). Several studies have reported the mortality ranging from 5.8% to 17.1% in the discharged general COVID-19 positive population\textsuperscript{54-56}. Also, the mortality of the discharged patients in our review is higher than in Lubetzky et al study which reported a mortality of 12.0% in 39 hospitalized KTR infected with COVID-19 in New York\textsuperscript{49}. The high prevalence of underlying kidney disorders, existing co-morbidities such as diabetes and hypertension, the complications related to kidney transplant and the side effects of immunosuppressive medication in kidney transplant population may contribute to the extra mortality.

With further analysis, an obvious discrepancy in mortality between different countries has been observed in our study (table 3). The mortality of different countries ranged from 10.5% to 69.2%. Whether it is caused by different admission criteria, demography of the population or the management guidelines for KTR with COVID-19 in different countries is unclear. Future research is warranted to investigate it for identifying the optimal treatment option.

Additionally, although advanced age is associated with the severe COVID-19 and high mortality in our study population, young immunosuppressed KTR is also vulnerable to COVID-19. The mortality rate by 10-year age intervals was demonstrated in the table 4 and it was noted that 41.4% of those who died were less than 60 years of age. Our research indicates
a higher proportion of younger KTR could develop severe COVID-19 and die compared to the general population.

Two patients were readmitted to hospital due to recurrence of symptoms within 48 hours from discharge, with one discharged alive again after 7 days of hospitalization and another staying in hospital with new-onset consolidations on the chest X-ray. Additionally, 6 KTR were reported to be confirmed with bacterial co-infection during hospitalization with COVID-19. Although KTR are commonly expected to suffer from bacterial co-infection with hospitalization due to their long-term immunosuppressed status, patients in our studies does not demonstrated the elevated risk of bacterial co-infection.

Our study indicates a large proportion of in-hospital KTR developed severe COVID-19 and the clinical outcome is dire if they need ICU admission or mechanical ventilation (table 2). 52.6% of patients developed severe COVID-19 according to our criteria. The mortality of those with ICU admission is 53.3%. The mortality (73.3% vs 38.5%) is significantly higher in patients requiring IV compared to those only requiring NIV.

Furthermore, this review indicates that a higher proportion of KTR (47.3%) with COVID-19 develop acute kidney injury during hospitalization compared to the general COVID-19 population (table 5). The studies with a large number of general COVID-19 population reported the rates of AKI from 11.0% to 36.6%. Additionally, we found severe patients are more likely to experience AKI (54.9% vs 39.1%), less likely to resolve it (10.7% vs 77.8%) and more frequently require renal replacement therapy (32.1% vs 5.6%) compared to non-severe patients. Several studies have explored the potential mechanisms of the development of AKI during COVID-19, such as the cytopathic effects of COVID-19 on proximal straight tubule cells, the occlusion of microvascular lumens, the glomerular and vascular damage and direct kidney parenchyma infection of SARS-CoV-2. Also, underlying kidney disorders of KTR and the nephrotoxicity of immunosuppressive and antiviral drugs may be related to the high prevalence of AKI in this population. Finally, when clinicians make treatment plans for KTR, they need to balance between the uncertain benefit of antiviral drugs and their side effects which may lead to acute kidney injury. Lopinavir, for example, can disturb the metabolism of tacrolimus. Several included studies reported significantly elevated tacrolimus trough levels in KTR with COVID-19 after using lopinavir and/or ritonavir. One patient in our review developed tacrolimus-induced nephrotoxicity when using lopinavir/ritonavir therapy and needed renal replacement therapy. Tacrolimus trough levels should be monitored closely in COVID-19 positive KTR with hospitalization.

Limitations

The main limitation is missing data of the included studies. Secondly, the methodological quality of eligible studies is diverse and their reporting bias cannot be ruled out. Future studies...
with large sample size and intact data of patients’ clinical characteristics and courses are warranted.

CONCLUSION

Although the symptoms of in-hospital kidney transplant recipients with COVID-19 are nonspecific, they are at high risk of developing severe disease at a relatively young age. They have higher mortality and the higher prevalence of acute kidney injury compared to the general population with COVID-19. The outcome of acute kidney injury is poor in kidney transplant recipients with severe COVID-19.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, data extraction and curation, Y.S. and S.T.; software, formal analysis, investigation, writing original draft preparation, Y.S.; writing review and editing, Y.S. and S.T. All authors have read and agreed to the published version of the manuscript.

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