Review

COVID-19 and the Kidneys, Implications and Outcomes

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Keywords. SARS-CoV, angiotensin converting enzyme 2, hypertension, acute kidney injury, chronic kidney failure, kidney transplantation

Coronavirus disease (COVID-19), declared as a pandemic has affected millions of people and caused unprecedented number of death. The disease is caused by a severe acute respiratory syndrome related coronaviruses-2 virus which enters cells by binding with the host angiotensin converting enzyme-2 and CD147 protein. Among COVID-19 patients admitted to a hospital, hypertension, diabetes and obesity are the most common co-morbidities. A majority of COVID-19 hospitalized patients are found to have proteinuria and hematuria which is associated with higher risk of in-hospital mortality. Studies have reported high incidence of acute kidney injury (AKI) among COVID-19 patients admitted to hospital (10 to 43%) and intensive care unit (43-75%). These patients with AKI have much higher need for mechanical ventilation, vasopressor use and critical care. In addition, proportion of patients with AKI who require renal replacement (RRT) therapy is greatly increased. Acute tubular injury, cytokine storm induced systemic inflammatory response, endothelial injury and dysfunction are the main mechanisms of AKI. In addition, direct viral invasion of tubules, lymphocytic infiltration and complement mediated (C5b-9) related injury is also seen. Mortality risk among patients with AKI and those in need of RRT is greatly amplified. Appropriate timing and choice of RRT for these patients is not well defined but will need to take in account the clinical condition, anticipation of their clinical course and availability of dialysis resources. Risk of AKI and death is also increased among kidney recipients and patients with chronic kidney disease.

IJKD 2021;15:1-9
www.ijkd.org

INTRODUCTION

Since the emergence of coronavirus disease (COVID-19) in 2019, the world has witnessed its rapid transmission. As of June 7, 2020, 6.9 million people have been diagnosed with it and 401,932 people have died.[1] World health organization has declared it as a global pandemic and a public health emergency.[2] It is caused by a severe acute respiratory syndrome related coronaviruses-2 (SARS-CoV-2) which enters cells by binding with host angiotensin converting enzyme 2 (ACE2) and CD147 protein, both of which are almost ubiquitously expressed.[3,4] Therefore, virus has the capability to access many different organs and potential to cause multi-system organ injury. The kidneys can be particularly vulnerable owing to their high concentration and activity of ACE2.[5] Patients with co-morbidities such as diabetes, hypertension, obesity, cardiovascular disease, and chronic kidney disease (CKD) are found to be particularly susceptible to COVID-19 illness.[5-9] Proteinuria, hematuria and acute kidney injury (AKI) are common findings among COVID-19 patients which happen early in the course and are associated with an increased risk of complications including the need for mechanical ventilation,

vasopressor use and death[6,10] In addition, significant proportion of patients with AKI especially those mechanically ventilated, were found to be in need of renal replacement therapy (RRT) with exceptionally high mortality rates.[7] Mechanisms of AKI caused by COVID-19 are under intense research and evolving by the day. In this review, we would like to explore the impact of COVID-19 on the kidneys, predisposing factors for such severe illness and outcomes of AKI. In addition, we will review the impact of COVID-19 on patients with CKD and those treated with kidney transplantation.

PATHOPHYSIOLOGY OF COVID-19

SARS-CoV-2 is a single stranded, positive sense, enveloped RNA virus which belongs to the betacoronavirus family. Its envelope contains club shaped S-glycoprotein which enables the virus to enter the host cells by binding to ACE2 receptor with the help of a cellular transmembrane protease serine 2 (TMPRSS2). The S-glycoprotein contains 2 subunits as S1 which determines the virus host range and cellular tropism and S2 which mediates virus-host cell membrane fusion by 2 tandem domains heptad repeat 1 (HR1 and HR2). Once the virus invade a cell, its genome is transcribed and translated and genomic replication ensues.[11-3] Recently, SARS-Cov-2 has been shown to invade cells additionally by binding with another ubiquitously expressed transmembrane protein (CD147); which is also a red blood cell receptor for malarial parasite.[14,15] Also, known as EMMPRIN (extracellular matrix metalloproteinase inducer), CD147 is highly expressed in proximal tubular epithelium and inflammatory cells and is known to play a role in promoting AKI, ischemic-reperfusion injury, glomerulonephritis and renal fibrosis.[4] It is possible that SARS-CoV-2 may be able to promote renal injury by affecting CD147 activity and resultant increase in matrix metalloproteinases. CD147 is shown to be upregulated in chronic inflammatory states, asthmatic and diabetics and may explain the risk of COVID-19 in this patient population.[14] Azithromycin and anti-malarial therapy with hydroxychloroquine, hypothesized in reducing COVID-19 spread, probably act by inhibiting CD147 protein. In fact, a clinical trial involving an anti-CD147 agent (Meplazumab) to treat patients with COVID-19 is ongoing ({"type":"clinical-trial","attrs":{"text":"NCT04275245","term_id":"NCT04275245"}} NCT04275245).[14] ACE2, an integral component of renin angiotensin system (RAS), metabolizes a powerful vasoconstrictor angiotensin II to a vasodilator; angiotensin 1-7.[3] It is widely present in human cells including lung type I and II alveolar epithelial cells, small intestine enterocytes, endothelial cells and arterial smooth muscle cells of many organs including brain, heart and muscles.[3] It is also highly expressed in glomerular parietal epithelial cells, brush border of proximal tubular cells and weakly in glomerular visceral epithelial cells, distal tubules and collecting duct.[16] In the lungs, ACE2 plays a role in regulating the balance of vasoconstrictor (angiotensin II) and vasodilator (angiotensin 1-7) agents which is essential for adaptive responses to lung injury or pneumonia.[3] Imbalance of local RAS milieu due to altered ACE2 activity may be one of mechanism by which organ injury is initiated by the virus.[5] Interestingly, increasing ACE2 expressions has been identified as therapeutic target in experimental models and has led to stabilization of atherosclerotic plaques, lowering of blood pressure, attenuation of diabetic kidney injury, oxidative stress and fibrosis.[3] On the contrary, once SARS-CoV-2 interacts with host cell using S protein, subsequent downregulation of ACE2 protein on cell surfaces is noted owing to increased activity of ADAM17 which cleaves ACE2 from the cell membranes.[17]

PATHOPHYSIOLOGY OF COVID-19 AND AKI

Mechanisms of AKI caused by COVID-19 is multifaceted and an evolving subject (Table 1). In an autopsy series of 26 patients who died from COVID-19, diffuse proximal tubular injury with loss of brush border, vacuolar degeneration and

Table 1. Potential Mechanisms Behind COVID-19 and AKI[8,15,18,37]

Cytokine storm induced systemic inflammatory response
Acute tubular injury/necrosis
Endothelial injury and dysfunction
Lymphocytic infiltration of tubules
Direct viral invasion of tubules
Microvascular thrombosis
Complement mediated MAC (C5b-9) related injury
Rhabdomyolysis
Modulation of ACE2 and CD147 receptor
Collapsing glomerulopathy

Abbreviations: AKI, acute kidney injury; MAC, membrane attack complex; ACE, angiotensin converting enzyme

dilation of tubular lumen with cellular debris were noted. In addition, immunostaining for viral nucleoprotein was positive in tubules. On electron microscopy, SARS-CoV-2 like particles with spike were noted in tubular epithelium and podocytes. Peritubular and glomerular capillary loops had diffuse erythrocyte aggregation and obstruction. Pattern of significant endothelial injury was also noted. In three patients with high level of creatinine phosphokinase, pigmented casts were also seen possibly representing rhabdomyolysis.[15] Similar findings were reported in another autopsy series of six patients with COVID-19 whereby significant acute tubular injury and lymphocytic infiltration of tubulo-interstitium area was noted. Virus like particles were also seen by immunohistochemistry analysis and electron microscopy. In addition, there was strong deposition of complement membrane attack complex (C5b-9) in tubules. Immune cells as $CD68^+$ macrophages and $CD8^+$ T cells were seen infiltrating tubules and interstitium.[18] Direct role of ACE2 in kidney health/injury is yet to be elucidated but imbalance between ACE and ACE2 level leading to higher Angiotensin II, a vasoconstrictor, is a potential mechanism.[19] Since, ACE2 is highly expressed in renal tubules, its direct modulation by SARS-CoV-2 can't be excluded. In fact, ACE2 activity was reported to be upregulated in tubules, especially in areas of severe acute tubular injury.[15]

COVID-19, RISKS AND PREDISPOSITION FACTORS

Among COVID-19 patients admitted to hospital, hypertension (32 to 83%), diabetes (23 to 53%) and obesity (27%) were the most common co-morbidities.[6-9] COVID-19 patients with pre-existent hypertension (HTN) were noted to be at higher risk of stage 3 AKI (adjusted odd ratio [aOR] = 1.01 per mm Hg, 95% CI: 1 to 1.02). Of the 1193 hypertensive patients admitted to hospital with COVID-19, half of them developed AKI (51.8%).[6] Prevalence of HTN was noted to be much higher among patients who developed AKI as compared to those who did not develop AKI (64.8% versus 50.5%, $P < .001$).[7] If there is a connection between hypertension, severity of COVID-19 illness and AKI, it need to be explored further. RAS system is the key regulator of hypertension. ACE2 in addition to its primary substrate angiotensin II, also metabolizes angiotensin I and des-arg-9-bradykinin, an agonist for B1 bradykinin receptor, further consolidating its position in controlling the fine balance of vasoconstrictor and vasodilator agents. In rostral ventrolateral medulla of spontaneous hypertensive rats, an area which provide supra-spinal excitatory input to sympathetic preganglionic neurons, ACE2 activity was noted to be decreased. This finding points toward the contribution of ACE2 in the central regulation of blood pressure. In the experimental model, role of central ACE2 in controlling baroreceptor responsiveness has been appreciated.[3] Another aspect of RAS system which deserves special attention are the medications as angiotensin convertase enzyme inhibitors (ACEI) and angiotensin receptor blockers (ARB), commonly used to treat hypertension in general population. In experimental hypertension, renal ACE 2 expression was noted to be reduced but increased after treatment with ACEI or ARB.[19] While some of animal data showed increased ACE2 level after treatment with ACEI/ARB, other did not. Human studies also gave inconsistent results and not able to answer if and to what extent ACE2 level or activity may be affected by these medications.[5] In conclusion, activity of ACE2 seems to be the link between the hypertension, ACEI/ARB treatment and COVID-19 illness.

In a retrospective analysis, COVID-19 patients with AKI had lower prior use of ACEI/ARB as compared to those without AKI (45% versus 51%). Authors also reported that higher proportion of patients with AKI did not have prior use of ACEI/ARB as compared to those without AKI (46% versus 39%).[8] However, use of ACEI/ARB was not found to be a risk factor for AKI in adjusted models (aOR = 0.87, 95% CI: 0.73 to 1.04; $P = 0.12$).[7] Furthermore, ACEI/ARB treatment before hospitalization was a negative risk factor for remission of proteinuria (OR = 0.08, 95% CI: 0.01 to 0.68) and hematuria (OR = 0.11, 95% CI: 0.02 to 0.73).[9] In a population based case control study from Italy, authors did not find any evidence if ACEI or ARB use affect the risk of COVID-19 among 6272 patients diagnosed with it.[20] Similarly, Reynolds *et al* did not find any increased risk of COVID-19 or severe illness with the use of ACEI/ARB treatment.[21] While there are plausible hypotheses for both benefits and risks with use of ACEI/ARB in COVID-19 patients, its continued use is recommended in stable patients.[5] But, initiating

treatment with ACEI/ARB to prevent or treat COVID-19 is not suggested at this time.[22]

COVID-19 has been disproportionately affecting males as compared to females.[7,9,23] In fact, proportion of critically ill males was almost double of critically ill females throughout the various age groups.[23] In an analysis of 333 patients (54.7% males) admitted to hospital for COVID-19 pneumonia, majority of patients with severe (59.4%) and critical illness (64.3%) were males.[9] Data from intensive care units (ICUs) of England showed that of all the COVID-19 patients admitted to ICU in 2020, 71% were males; a much higher proportion when compared to the patients (54% males) admitted to their ICUs for viral pneumonia from 2017 to 2019.[23] Regulation of RAS system and angiotensin II metabolism is known to vary based upon gender. ACE2 is located on X-chromosome which likely adds to the variation in its activity based upon gender.[24] Hormones also had an effect on ACE2 activity as ovariectomy reduced adipose ACE2 activity while estrogen increased it. When fed high fat diet, male mouse showed reduced renal ACE2 activity in contrast to female mouse who expressed increased adipose ACE2 activity.[25] These experimental findings bring our attention towards gender, obesity and their impact on ACE2 activity. In conclusion, there seems to be a complex interplay of ACE2 activity with gender, obesity, diabetes, hypertension status and ACEI/ARB treatment and whether it can explain the vulnerability to COVID-19 illness and severity in population with these co-morbidities, remains to be seen.

COVID-19 AND AKI EPIDEMIOLOGY

In the retrospective analyses of hospitalized COVID-19 patients, majority were found to have proteinuria (44 to 74%) and hematuria (26 to 64%).[7,9,10] In addition, incidence of proteinuria was far greater among patients with severe (81.2%) or critical (85.7%) COVID-19 pneumonia and AKI (88.6%). Similar findings were noted for hematuria among patients with severe (39.1%) or critical (69.6%) COVID-19 pneumonia and AKI (60%).[9] Proteinuria (2 to 3+) and hematuria (2 to 3+) were associated with very high risk of in-hospital mortality ([hazard ratio (HR) for mortality with proteinuria = 10.92, 95% CI: 5.0 to 23.8; $P < .001$], [HR for mortality with hematuria = 12.2, 95% CI: 6.32 to 23.53; $P < .001$]).[10] Whether the findings of proteinuria and/or hematuria among COVID-19 patients could be a marker of direct viral renal injury is not known at present. But, it may reflect towards an evidence of renal injury before noticed by serum creatinine measurements. Presence of proteinuria and or hematuria among COVID-19 patients portend a poor renal and overall poor prognosis. Based upon these findings, patients with COVID-19 illness should be evaluated with complete urinalysis as well.

Recent studies have reported AKI incidence as 10 to 43% among COVID-19 patients admitted to hospital and 43 to 75% among ICU patients (Table 1). In one study, intrinsic AKI was suspected in majority of patients (18 out of 22).[9] Similarly, 60% of AKI were attributed to ischemic acute tubular injury by Mohamed *et al*.[8] In a large database of 3,235 COVID-19 patients hospitalized in New York City (NYC), of those with AKI, many had it at the time of admission (40%). As compared to those without AKI, patients with AKI had much higher need of ICU care (39.3% versus 14.3%, $P < .001$), mechanical ventilation (43.8% versus 8.2%, $P < .002$) and vasopressor use (46.7% versus 11.5%, $P < .002$).[6] When compared to the patients admitted to ICU with viral pneumonia between 2017 to 2019, patients with COVID-19 pneumonia were much likely to be mechanically ventilated within 24 hours (62.8% versus 43%) and die (44.3% versus 22%).[23] In another retrospective analysis of 5,449 COVID-19 patients admitted to the hospitals in New York City, 37.3% of AKI developed early in course (diagnosed within 24 hours of hospitalization). Incidence of AKI was quite high among patients with mechanical ventilation (89.7%) as compared to those without need of mechanical ventilation (21.7%). In addition, the need for RRT was mostly among ventilated patients (23.3%, 276 out of 1190) and uncommon among non-ventilated patients (0.2%, 9 out of 4259).[7] Whether association of mechanical ventilation and AKI reflect some sort of major pulmonary-renal cross talk or just the severity of underlying COVID-19 illness remains to be seen. COVID-19 patients with AKI have very high mortality (35 to 96%) as reported in multiple studies (Table 1). In a meta-analysis of 6 studies involving COVID-19 patients, risk of mortality with AKI was tripled (RR = 3.08, 95% CI: 1.54 to 6.19).[26] In-fact, AKI patients needing RRT had

exceptionally highest mortality rates ranging from 66 to 100% (Table 1). These findings have important implications as COVID-19 patients with AKI seem to experience much higher chances of complications such as need for RRT, acute respiratory failure needing mechanical ventilation, shock requiring vasopressors, critical illness requiring ICU care and death (Table 2).[6,7,9,23] Also, patients hospitalized with COVID-19 illness are far sicker and deteriorate more quickly than patients with non-COVID illness. Hence, these study findings can help hospitals and government be better prepared for future surge and allocate resources accordingly. Previously, trials of early versus late initiation of dialysis in patients with AKI have not shown difference in terms of their clinical outcomes or mortality.[27] However, optimal timing of dialysis in COVID-19 related AKI need to be readdressed as these patients have unusually high catabolic state and rapid decline in their clinical condition. As noted, 52.2% of patients developed AKI within 24 hours of intubation and median time period from time of intubation to dialysis initiation was 0.3 (-41.1, 92.3) hours.[7] Hyperkalemia, hyponatremia and acidosis reported to occur early in course of these AKI cases.[8] Based upon recent studies (Table 1), as many as 15 to 55% of AKI patients will require RRT during the course of hospitalization. Due to rapid surge in patients during the COVID-19 outbreak needing hospitalizations, mechanical ventilation and RRT, there were media reports of shortage of resources to meet the acute RRT need.[28] Hence, hospitals should be prepared to provide all forms of RRT as intermittent hemodialysis, CRRT and acute peritoneal dialysis in order to meet the need of large number of patients require RRT at a given time, and not rely on a sole RRT modality.

COVID-19 AND CHRONIC KIDNEY DISEASE

Worldwide, 10% of population is known to suffer from kidney disease. Patients with pre-existent CKD are noted to be at higher risk of AKI and especially severe (stage 3) AKI (aOR = 1.8, 95% CI: 1.2 to 2.7) when hospitalized with COVID-19 infection. Of the 323 patients with CKD admitted to hospital, majority of the patients developed AKI (75%).[6] Baseline serum creatinine was higher among patients who developed AKI as compared to those who did not develop AKI (1.23 mg/dL versus 0.95 mg/dL, $P < .001$).[7] In another subset of 172 stage 3 to 5 CKD patients admitted to hospital with COVID-19, 32% developed superimposed AKI. Out of those who developed AKI on CKD, 48% patients needed RRT.[8] In addition, presence of CKD is also associated with an increased severity of COVID-19 illness (OR = 3.0, 95% CI: 1.09 to 8.47).[22] In a retrospective review of 43 CKD patients with COVID-19, a significant proportion of patients (58%) were admitted with severe illness.[29] Treatment of COVID-19 among patients with CKD is even more challenging as medications such as remdesivir and tocilizumab are not approved for use when creatinine clearance is < 30 mL/min.[22] ACE2 levels are increased in patients with diabetes. Those with severe or critical COVID-19 disease were found to have diabetes, hypertension and treatment history with ACEI/ARB, all of which are quite common findings among patients with CKD.[9] Moreover, diabetes (aOR = 1.76, 95% CI: 1.49 to 2.07; $P < .001$) and hypertension (aOR = 1.25, 95% CI: 1.04-1.50; $P = .02$) were noted to be risk factors for development of AKI.[7] These observations raise alarm among the nephrologists about the risks and implications of COVID-19 infection among patients with pre-existing CKD.

COVID-19 AND KIDNEY TRANSPLANTATION

The initial information regarding the infectious course of COVID-19 with regards to immune-compromised individuals, particularly transplant recipients out of China has been relatively sparse with several small case reports only. Given the immunosuppressed state, there was a great degree of anticipation and apprehension for higher risk of infection as well as mortality from COVID-19 among this subset of patients. However, it has also been unclear if the cytokine storm associated COVID-19 would be tempered by the immunosuppression. In one of the larger case series from Wuhan, China, the course of 10 renal transplant patients were described by Zhu *et al*. The clinical, laboratory and radiologic characteristics of COVID-19 infection were similar among the renal transplant recipients as they were to general population. Among these patients, 80% (8/10) presented with severe or critical infection, 60% (6/10) presented with AKI, and 10% mortality was described.[30] A small case series was also published describing the clinical outcomes of 7 kidney transplant recipient patients with COVID-19 in south London. Of

Table 2. Incidence and Outcomes of AKI and RRT Among COVID-19 Patients

Authors	Study Design	Study Participants	Outcomes							
			Overall AKI (%)	AKI in ICU patients (%)	RRT need among patients with AKI (%)	RRT need among all ICU patients (%)	Mortality overall (%)	Mortality among all ICU patients (%)	Mortality among patients with AKI (%)	Mortality among patients on RRT (%)
Chan et al. [6]	Retrospective observational	n = 3,235	43 (1406 of 3235)	68 (553 of 815)	20 (280 of 1406)	34 (277 of 815)	23.8 (771 of 3235)	38 (310 of 815)	45 (632 of 1406)	Not reported
Hirsch et al. [7]	Retrospective observational	n = 5449	36.6 (1993 of 5449)	76 (1060 of 1395)	14.3 (285 of 1993)	Not reported	21.3 (888 of 4168)*	Not reported	35 (697 Of 1993)	94.6 (157 of 166)#
Mohamed et al. [8]	Retrospective observational	n = 575	28 (161 of 575)	65 (105 of 173)	55 (89 of 161)	44.5 (77 of 173)	13.9 (80 of 575)	Not reported	50 (80 of 161)	72 (64 of 89)
Pei et al. [9]	Retrospective observational	n = 333	10.5 (35 of 333)	42.9 (24 of 56)	31.4 (11 of 35)**	Not reported	8.7 (29 of 333)	52.8 (29 of 56)	86.4 (19 of 22)	90.9 (10 of 11)**
ICNARC [23]	Retrospective observational	n = 9026 (all ICU patients)	Not reported	Not reported	24.3 (1758 of 7224)	24.3 (1758 of 7224)	Not applicable	44.3 (3302 of 7447)	Not reported	66 (1219 of 1848)##
Zhou et al. [38]	Retrospective observational	n = 191	15 (28 of 191)	56 (28 of 50)	35.7 (10 of 28)	20 (10 of 50)	28.3 (54 of 191)	72 (39 of 54)	96 (27 of 28)	100 (10 of 10)
Ruan et al. [39]	Retrospective observational	n = 150	15.3 (23 of 150)	Not reported	21.7 (5 of 23)&	12.2 (5 of 41)&	45.3 (68 of 150)	73 (30 of 41)	91 (21 of 23)	100 (5 of 5)&

*1281 patients were still on treatment and not counted toward this calculation
#119 were still undergoing treatment in the hospital, with 108 still on RRT and not counted towards this calculation
**Reported as Stage 3 AKI
##Includes 119 patients requiring maintenance RRT for ESRD prior to ICU care
&Reported as CRRT
Abbreviations: AKI, acute kidney injury; RRT, renal replacement therapy; ICU, intensive care unit; ESRD, end stage renal disease; ICNARC, intensive care national audit and research center; CRRT, continuous renal replacement therapy

these 7 patients, 5 were hospitalized, 40% (2/5) requiring mechanical ventilation, 80% (4/5) developed AKI, and 20% (1/5) suffered with in-hospital mortality.[31] NYC has been an epicenter of the pandemic in the United States and is home to several large academic transplant centers who have published some preliminary data in regards to outcomes among transplant recipients. Three case series have been reported in this population so far. First one reports 10 hospitalized kidney transplant patients – 30% of which died, 50% of which developed AKI.[32] Hospitalized patients all had their antimetabolites held and were treated with hydroxychloroquine and azithromycin.[32] The second case series described 15 hospitalized kidney transplant recipients with clinical presentation similar to non-immunosuppressed patients. They found that 27% (4/15) required mechanical ventilation, 40% (6/15) developed AKI, and 13% (2/15) had fatal outcome.[33] Finally, the last one by Akalin *et al.* identified 36 kidney transplant recipients of which 28 required hospitalization. Out of those hospitalized, 39% (11/28) required mechanical ventilation, 21% (6/28) developed AKI, and an overall mortality rate of 28% (10/36).[34] The management of immunosuppression in kidney transplant recipients with COVID-19 remains an area of active interest and of unproven anecdotal case reports. The ERA-EDTA has published an expert opinion piece to describe current thoughts regarding immunosuppression management. In brief summary, there is suggestion of discontinuation of mycophenolic acid (MPA)/azathioprine (AZA)/mTOR inhibitors (mTORi) in mild disease and asymptomatic COVID-19 patients that are high risk or with comorbidities. In those patients with more severe disease or evidence of pneumonia, their recommendation is to stop MPA/AZA/mTORi, stop calcineurin inhibitors and increase (or start) steroids.[35] In addition to immunosuppression, clinicians must be wary of the use of antivirals and immunomodulatory therapy and their potential effects on the renal allograft and commonly used immunosuppressive medications. For example, there is a significant interaction between antivirals as lopinavir-ritonavir and darunavir-cobicstat, which are undergoing trials in COVID-19, and calcineurin inhibitors which would require a large dose reduction and/or halting of CNI therapy with a close monitoring of levels.[22,36] Overall, kidney recipients are at increased risk of COVID-19 and resultant complications. Management of these patients is complex and challenging partly due to uncertainties regarding decision to withhold or continue with their immunosuppressive regimen.

CONCLUSION

COVID-19 is indeed a public health emergency with major concerns especially for people with co-morbidities. Since SARS-CoV-2 is able to invade cells using widely present ACE2 receptor and CD147 protein on host cell membrane, it is resulting in to multi-system organ injury. Kidneys are equally vulnerable and the affected patients had a staggering high need of mechanical ventilation, RRT and death. This has the potential to overwhelm the hospital systems especially the dialysis resources to provide timely RRT to all those in need, which has been faced by many centers who dealt with the first wave of this pandemic. Multifaceted approach will be needed to tackle the renal complications of this pandemic. Patients with underlying CKD and those who are treated with kidney transplantation require special attention. Strategies to mitigate risk and complications among all those who are at risk will need to be planned at the earliest.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

FINANCIAL DISCLOSURES

NG has served on nephrology advisory board meeting for Horizon Therapeutics.

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Received August 2020
Revised September 2020
Accepted November 2020