nature
REVIEWS

# *Nature Reviews* referee guidelines

## Review articles

*Nature Reviews* publishes timely, authoritative articles that are of broad interest and exceptional quality. Thank you for taking the time to help us to ensure that our articles meet these high standards.

Review articles in *Nature Reviews* journals provide accessible, authoritative and balanced overviews of a field or topic. These articles are targeted towards readers from advanced undergraduate level and upwards, including researchers, academics and clinicians, and should be accessible to readers working in any discipline.

Please submit your report in narrative form and provide detailed justifications for all statements. Confidential comments to the editor are welcome, but it is helpful if the main points are stated in the comments for transmission to the authors.

Please note that all *Nature Reviews* articles will be thoroughly edited before publication and all figures will be redrawn by our in-house art editors. We therefore request that you concentrate on the scientific content of the article, rather than any minor errors in language or grammar.

### Please consider and comment on the following points when reviewing this manuscript:

- Is the article timely and does it provide a useful addition to the existing literature?
- Are the scope and aims of the article clear?
- Are the ideas logically presented and discussed?
- Is the article accessible to a wide audience, including readers who are not specialists in your own field?
- Does the article provide a balanced overview of the literature? Please bear in mind that it may not be possible to cover all aspects of a field within such a concise article.
- Does the article provide new insight into recent advances?
- Is the discussion fair and accurate? Although our authors are encouraged to be opinionated, they should not ignore alternative points of view.
- Do the figures, boxes and tables provide clear and accurate information? Are there any additional or alternative display items that you think that the authors should include?
- Are the references appropriate and up-to-date? Do they reflect the scope of the article?
- Are you aware of any undeclared conflicts of interest that might affect the balance, or perceived balance, of the article?

# Impact of the COVID-19 pandemic on the kidney community: lessons learned and future directions

Duvuru Geetha*, Andreas Kronbichler*, Megan Rutter, Divya Bajpai, Steven Menez, Annemarie Weißenbacher, Shuchi Anand, Eugene Lin, Nicholas Carlson, Steve Sozio, Kevin Fowler, Ray Bignall, Kathryn Ducharlet, Elliot Koranteng Tannor, Eranga Wijewickrama, Muhammad Iqbal Abdul Hafiz, Vladimir Tesar, Robert Hoover, Deidra Crews, Charles Varnell, Lara Danziger-Isakov, Vivekananda Jha, Sumit Mohan, Chirag Parikh, Valerie Luyckx

*DG and AK contributed equally to the review

Abstract word count: 162

Body of manucript word count: 7105

## Abstract

The coronavirus disease 2019 (COVID-19) pandemic has disproportionately affected patients with kidney disease, amplified profound disparities in marginalized populations and posed significant challenges in the management of patients with kidney disease, kidney research and trainee education. For patients, the increased infection risk and disease severity, often complicated by acute kidney injury, contributed to high mortality. Clinicians were faced with high clinical demands, resource shortages and novel ethical dilemmas in providing patient care. In this review, we address the impact of COVID-19 on the entire spectrum of kidney care, including acute kidney injury, chronic kidney disease, dialysis and transplantion, trainee education, disparities in health care, changes in health care policies, moral distress, and the patient perspective. Based on current evidence, we provide a framework for the management and support of patients with kidney disease, infection mitigation strategies, resource allocation and support systems for the nephrology workforce.

## Introduction

The COVID-19 pandemic has impacted the kidney community at multiple levels. Acute kidney injury (AKI) is a common consequence of hospitalization with COVID-19 and portends high mortality [1]. The rates of severe COVID-19 have been high in patients with chronic kidney disease (CKD) including dialysis patients and kidney transplant recipients[1-3]. There have been dilemmas surrounding the delivery of safe clinical care, triaging provision of kidney replacement therapy (KRT), the safety of donors and recipients for kidney transplantation, managing COVID-19 in patients with kidney disease, modulating immunosuppression in immune-mediated kidney disease and transplant recipients, and best ways to protect patients and health care providers during the pandemic. Despite their high risk and increased mortality and concern that CKD may alter the safety profile of drugs, patients with kidney disease were excluded from therapeutic clinical trials of COVID-19 and a lack of pre-specified subgroup analyses resulted in the application of novel therapies to this population with low evidence. Nephrologists have faced multiple challenges in patient care including nursing shortages and supply chain issues. The pandemic has raised ethically challenging questions about the allocation of scant health care resources. There has been a significant impact on trainee education and on the emotional well-being of the nephrology workforce and patients. In this review, we discuss the challenges encountered in the care of patients across the spectrum of kidney disease during the pandemic, strategies that were adopted to address them, innovations in patient care delivery and advocacy efforts. We discuss the global inequities in provision of health care and highlight how the pandemic may exacerbate preexisting disparities in kidney disease. While some lessons learned by the kidney community during the pandemic have been heartening and stimulating innovation, others have been devastating with profound effects. These experiences by the kidney community shape preparedness efforts for future pandemics. From the lessons learned thus far, we provide a framework for management of patients with kidney disease for future pandemics.

## Managing kidney disease in the times of COVID-19: Challenges and opportunities

### Acute kidney injury incidence throughout the pandemic

Acute kidney injury (AKI) is common in patients diagnosed with COVID-19. AKI due to COVID-19 infection is multifactorial and includes direct invasion of the virus and indirect mechanisms through acute tubular necrosis, dysregulation of the immune system, hypercoagulopathy and collapsing glomerulopathy[4]. In the early stages of the pandemic, the reported incidence of AKI ranged from 0.5 to 42% [1,5,6], with a large percentage of these patients requiring dialysis. Charytan and colleagues explored the changing incidence of AKI in critically ill patients with COVID-19 [6]and found that, while the overall incidence of AKI was 29.3%, the rates of AKI and KRT declined over time in the pandemic, attributable to multiple factors including improved recognition and management, vaccine rollout and transmission of less virulent strains[7]. In Africa, AKI in COVID-19 patients occurred in 33.9% of 1102 patients in a study in two teaching hospitals in South Africa. About a quarter of patients with AKI required ICU management and 8.6% received KRT[8]. There were challenges in the management of COVID-19 associated AKI in low and low-middle income countries[9].

**APOL1 and risk for COVID-19 associated AKI**

In April of 2020, initial case reports described collapsing glomerulopathy in the setting of COVID-19, and a case series published soon afterwards described 6 patients with collapsing glomerulopathy each with high-risk *APOL1* genotypes[10]. In the largest study to date, out of 240 native kidney biopsies in patients with COVID-19, 62 (26%) had evidence of collapsing glomerulopathy [11]. *APOL1* genotyping studies have demonstrated that patients with high-risk alleles had significantly higher odds of AKI, and death compared to low-risk patients with 0 to 1 risk variants[12]. Furthermore, in African Americans who tested positive for COVID-19, *APOL1* high-risk alleles were associated with greater odds of AKI and higher rates of persistent AKI and requirement of dialysis.

Possible reasons for the higher risk of adverse kidney outcomes in individuals carrying *APOL1* high-risk alleles include a heightened inflammatory response to COVID-19, leading to inflammatory kidney injury. Thus, the incidence and severity of AKI are likely increased in the presence of *APOL1* variants, with an increased requirement for chronic dialysis.

**Long-term kidney complications after acute COVID-19**

Hospitalized patients with COVID-19 had a higher incidence of AKI overall, and AKI stage when compared to patients with influenza[13]. In an observational study from the UK, 16% of AKI survivors, progressed to CKD at 90 days[14]. Similarly, about 20% of AKI patients requiring KRT had no recovery

at 3 months after discharge in a multicenter study from the U.S.[15]. A Veterans administration study on Long COVID reported a higher risk of CKD with COVID-19[16,17]. Similarly, in a Chinese cohort study, a third of COVID-19 infected patients had reduced kidney function 6 months post-hospitalization[16]. Patients developing AKI during their COVID-19 disease course ahd no increased risk of CKD at 12 months follow up when compared to non-COVID-19 AKI cases[18].Further studies are needed to evaluate risk factors for progression to CKD following COVID-19-associated AKI.

**Patients with chronic kidney disease**

The incidence of COVID-19 in CKD patients is difficult to establish due to under-reporting, under-diagnosis of CKD, and variations in access to SARS-CoV2 testing. A large nationally representative cohort from United Kingdom demonstrated a CKD incidence and prevelance ranging from 0.5% to 37% and, that CKD is associated with high co-morbidity burden and high one-year mortality[19]. CKD, including end-stage kidney disease (ESKD), is associated with increased risk of COVID-19 and subsequent adverse outcomes including hospitalization, respiratory failure, and mortality[2,20-22], with risk proportional to kidney dysfunction[20,22]. There have been care delivery repercussions, including the postponement of kidney biopsies[23], delays in arteriovenous fistula surgery and salvage, and disruption in initiation of KRT[24]. There was a notable decline in incident ESKD in the U.S. early in the pandemic, both due to increased mortality in patients with advanced CKD and compromised access preparation for KRT[25]. Large-scale lockdowns resulted in interruption of routine healthcare, including access to dialysis leading to preventable deaths, especially in those parts of the world with already compromised access to dialysis while highlighting the advantages of telemedicine in CKD patients[26-28].

There is a lack of guidelines related to the management of COVID-19 in patients with CKD. Dexamethasone was associated with both reduced requirement for KRT and lower mortality in all patients with severe COVID-19, however fewer than 10% of patients in this trial had eGFR less than 30 mL/min/1.73 $m^2$ [29]. Remdesivir, a direct-acting antiviral, remains off-label in patients with an eGFR < 30 mL/min/1.73 $m^2$ [30]. Several monoclonal antibody therapies have been afforded emergency use authorization but their net benefit in patients with CKD remains untested. Tocilizumab, a recombinant anti-IL-6 receptor antibody was granted emergency use authorization in patients with moderate-to-severe COVID-19[31], and case reports demonstrate successful

deployment in patients with ESKD. Phase III trials evaluating vaccination benefit have however afforded limited focus on specific subgroups such as patients with CKD[32]. Patients with CKD were prioritized for vaccination and mounted a comparable seroconversion rate to the general population (Table 1). However, patients who did not receive a third dose of the vaccine had a significant decline in antibody titer after 3 to 6 months [33].

**Patients with immune-mediated kidney disease**

Managing patients with immune-mediated glomerular disease has presented unique challenges. At the start of the pandemic, the primary concerns for patients receiving immunosuppression included the assessment of the risk and severity of COVID-19, ways to mitigate infection risk, methods of clinical and laboratory surveillance, strategies to treat active disease and evaluation of the need for continued immunosuppressive therapy. After the vaccine rollout, questions were posed regarding the immunogenicity and safety of the vaccine, measurement of vaccine efficacy and need for modification of immunosuppressive therapy to improve vaccine response.

Although immunosuppressive therapy increases the risk of infection, there was no evidence to support deviation in the standard of care treatment of active disease [34]. COVID-19 in patients with immune-mediated kidney disease conferred an increased risk of AKI and death [35]. Additionally, case reports of de novo immune-mediated kidney disease, including collapsing focal and segmental glomerulosclerosis, vasculitis, IgA nephropathy have been described with COVID-19 infection. Among the immunosuppressive medications commonly used in this cohort, rituximab and prednisone dose ≥ 10 mg were associated with increased severity of COVID-19[36], while information on other therapies such as cyclophosphamide has remained scarce.

Although patients were prioritized for vaccines, understanding of the safety and immunogenicity of vaccines in this cohort was based only on observational studies. Studies in patients with rheumatic diseases on immunosuppressive therapy have consistently shown impaired humoral response with largely preserved cellular response (Table 1). Additionally, these studies have shown that prednisone dose ≥ 10 mg, mycophenolate mofetil and rituximab were associated with impaired humoral response and that the response in rituximab-treated patients was improved when B cells were reconstituted or time elapsed from last rituximab administration was longer[37]. Temporary cessation of mycophenolate mofetil augmented humoral response in patients with rheumatic disease [38]. In

non-responders, administration of a booster vaccine dose was shown to increase the response rate. *De-novo* or relapsing autoimmunity triggered by COVID-19 vaccines remain a concern and isolated reports of de-novo and relapsing minimal change disease, membranous nephropathy, IgA nephropathy and ANCA vasculitis have been described[39]. However, large series with increased inflammatory disease incidences have not been described following COVID-19 vaccination.

In the absence of guidelines, caring during a pandemic requires personalizing immunosuppressive therapy balancing the risk of infection and disease control, and recognizing that treatment of active disease cannot be delayed. An important lesson learned is that the early establishment of global collaborative registries is critical to assessing the severity and risk factors of infection and guiding modulation of immunosuppressive therapy in this population.

**Patients on chronic dialysis**

Early data from Wuhan foreshadowed the major challenges other regions would have to tackle in caring for patients on dialysis during the COVID-19 pandemic. Patients on dialysis were amongst those at highest risk of death, not just due to propensity for serious illness but due to missed treatments. These data generated a mandate for dialysis facilities to intensify infection prevention protocols to reassure patients and staff, to ultimately prevent missed sessions and loss of workforce. There was a strong recommendation for transition to home modalities[40].

But without additional resources to match the guidance, there was a constant shortage of personal protective equipment (PPE)[41], and SARS-CoV-2 tests. Data from universal screening of a single dialysis unit in the U.K. showed that patients experienced a spike in infection after the health care workers' spike, implying potential transmission[42]. Nonetheless, widespread in-facility transmission was not reported. Lack of transportation, staff shortages and possibly personal fear or symptoms may have contributed to missed treatments in up to half of the surveyed facilities in Africa, Latin America, Middle East, South East Asia and South Asia[41]. Mortality among infected and hospitalized patients receiving dialysis exceeded 50% in most regions of the world. The pivot to home modalities was not feasible in many already strained environments. Thus, despite early and sensible guidance on infection prevention and management—a majority of which still holds relevance in face of the changing nature of the pandemic—there was a stark loss of life among patients receiving dialysis[43]. With improvement in testing capacity and identification of patients with no or minimal symptoms,

there has been improvement in crude mortality rates between the first and second wave of COVID-19 [44].

The success of vaccines has been accompanied by challenges. Among countries that procured vaccine supply in late 2020 or early 2021, European countries prioritized vaccination for patients receiving dialysis. In the U.S., there was no specific prioritization until March 2021, at which point policy makers acknowledged that patients receiving dialysis were disproportionately from underserved populations and at high risk for complications from COVID-19 illness leading to a federal effort to offer vaccination in dialysis clinics. This vaccine allocation in dialysis clincis improved vaccines access, especially for the Hispanic and black patients [45].Compared with the general population, a smaller proportion of patients on dialysis expressed vaccine hesitancy. Capitalizing on central record keeping, the U.S. Centers for Disease Control and Prevention has created a real-time dashboard tracking vaccination in dialysis facilities, indicating that more than 75% of patients on dialysis have had at least two doses of COVID-19 vaccines.

Several lines of evidence suggest that immunogenicity of vaccination is lower among patients on dialysis, compared with the general population (Table 1). Although the majority of patients 'seroconverted' post-vaccination, the strength of the early antibody response to vaccination was suboptimal. Furthermore, 20% lost a detectable antibody response within 6 months. Concordant to data from hepatitis B vaccination, low circulating antibody titers were associated with a 10-fold higher risk for infection among patients who had completed the initial vaccination series. Data from a large not-for-profit dialysis center indicated efficacy against hospitalization or death of 81%, only slightly lower than contemporaneous data for the general population noting vaccine effectiveness around 86-87%. Vaccine immunogenicity by vaccine type has been studied closely, and concerns raised regarding the lack of immunogenicity of Ad26.COV2.S, although clinical effectiveness of this vaccine may be similar to the mRNA platform vaccines[46]. Furthermore, there was no difference in vaccine response by vaccine type among home dialysis versus in-center patients [47].

Boosters (third doses for persons with mRNA platform vaccines) have seen lower uptake among patients on dialysis in the US, with roughly 50% of patients reporting an additional dose thus far. Again, there was a heterogenous policy implementation, with countries in Europe implementing

earlier offers of third doses among patients on dialysis. Data from France and the U.S. on immunogenicity are encouraging, with strong responses reported even among older patient groups.

In this landscape, given the uncertainty around persistent immunogenicity to COVID-19 vaccines and substantial risk for 'breakthrough' infection—a majority of which will have some clinical consequences for patients receiving dialysis, at the very least a need for isolation during incenter dialysis—it will be critical to continue to develop future protocols for prevention, detection, and early treatment of COVID-19.

## Lessons for Policymakers

Policymakers have important lessons to learn from the COVID-19 pandemic that are specific to the dialysis population[27]. Below, we outline key lessons learned from the US.

First, policymakers should strongly consider extending waivers to exempt providers from pre-existing value-based purchasing programs, including the Quality Incentive Program[48] and the End-stage Renal Disease Treatment Choices model[49]. These programs have laudable goals but might pose a distraction for dialysis facilities that need to remain nimble during a public health emergency. To its credit, the Centers for Medicare and Medicaid Services (CMS) rapidly implemented waivers early in the pandemic, allowing facilities to focus on the emergency[50].

Second, we address the risk that in-center dialysis poses for patients, particularly with airborne diseases. Early in the pandemic, providers rightly recognized that facilities could quickly become hubs for widespread infection[51]. One welcome addition was the broad expansion of telehealth benefits[52]. However, the beginning of the COVID-19 pandemic was also fraught because of strapped supply chains that exacerbated the already limited supply of PPE. American Society of Nephrology (ASN), European Renal Association (ERA) and International Society of Nephrology (ISN) issued calls for governments around the world to prioritise PPE for dialysis personnel and increasing access to lifesaving dialysis. To prepare for the next pandemic, not only should policymakers stockpile more emergency medical equipment, they should also be more aggressive in distributing these supplies to providers of vulnerable populations, including dialysis facilities. A major concern is ongoing shortages in dialysis supplies, including dialysate.

Third, we must customize policies to address the specific needs of the dialysis population. For instance, per CMS guidance, many hospitals deferred "nonessential" surgical procedures. However, these deferrals may have inadvertently harmed incident ESKD patients who needed dialysis access procedures [25].

New therapeutics that can treat COVID-19 have shown incredible promise in reducing hospitalizations and mortality[53,54]. Dialysis facilities are unique in the healthcare industry because patients must return to the facility regularly. In the future, dialysis facilities should be considered a major site for the distribution of new therapeutics and vaccines.

**Kidney transplant recipients**

The pandemic has created significant challenges for kidney transplantation. Transplant candidates and recipients, especially in the early post-transplant period, experienced significant excess mortality related to COVID-19, with a disproportionate impact on racial minorities and socioeconomically disadvantaged individuals[55,56]. Both the innate and adaptive immune systems seemed profoundly altered in the transplanted cohort, with significantly lower levels of anti-spike antibodies up to two months following the onset of COVID-19 symptoms compared to patients on dialysis [57]. The prime concerns centered around continuing kidney transplant surgeries, minimizing the risk of infection and management of post-transplant immunosuppression. Globally, living and deceased donor transplantation has been adversely impacted to various extents and at different periods of time, due to efforts to conserve resources during a surge and concern for the risk of newly immunocompromised individuals, particularly in periods of high community transmission given their increased risk and poor outcomes [3]. Mortality rate was 20 to 30% in kidney transplant recipients,with reduction in mortality during the second wave [44], . While there was a 16% global decrease in transplant activity most notable in the first 3 months of the pandemic, there were substantial differences in transplant activiy between the countries[58]. Whilst living donation came to a near complete stop during the early pandemic, it has resumed since but does not appear to have reached pre-pandemic levels [59]. Notably, deceased donor transplantation rates have continued to increase in the U.S. allocation system despite a dramatic increase in organ discards reflecting increased selectivity of organs and patients[60]. There are notable differences in mortality rates of

waitlisted individuals compared to transplant recipients, with the United States reporting a higher mortality in waitlisted individuals, and Europe and United Kingdom reporting higher mortality in transplant recipients. The decision to continue transplant during a pandemic needs to be individualized for each country and should take into consideration the mortality risk of waitlisted individuals and transplant recipients and infection risk in the immediate post-transplant period. The pandemic has also impacted transplant activity due to concern for donor derived viral transmission. A systematic review of 69 transplants from 57 donors infected with SARS-CoV-2 demonstrated than non-lung transplantation was safe with a low risk of transmission [61].

Efforts to lower the risk of transmission along with overwhelmed healthcare systems created significant challenges in the care of these patients. Healthcare systems pivoted quickly to telehealth strategies and there was increased interest in the use of non-invasive biomarkers when performing kidney biopsies became a challenge[62-64]. While the value of monitoring strategies for allograft health remains uncertain, there does not appear to have been a dramatic uptick in acute rejection episodes[65].

The mainstay of treatment for COVID-19 in transplant recipients included reduction or cessation of antimetabolite therapy for 2 weeks or longer in addition to standard adjuvant therapies used in the general population[66]. While this approach also contributed to early concerns about adverse allograft consequences, recent data suggests that brief cessation of therapy was not associated with the development of donor-specific antibodies (DSA). Additional concerns in the SARS-CoV-2 infected recipient include the abrupt increase in tacrolimus levels that has been observed at the time of presentation [67]. Immunosuppressed individuals also appear to have a prolonged high viral burden with persistent positive polymerase chain reaction (PCR) results which may have implications for when to allow patients with prior COVID-19 back in to the transplant clinic setting.

While immunosuppressed patients and those with kidney disease were excluded from the initial vaccine trials, significant real-world experience has been gained in these groups. Studies of immunogenicity after vaccination revealed poor humoral responses to 2 doses of both mRNA and viral vector vaccines [68,69]. Older age, impaired allograft function, use of triple maintenance immunosuppression, belatacept, steroids and anti-metabolite were associated with poor humoral response. Additionally, breakthrough infections were observed frequently in kidney transplant

recipients, even before the omicron surge. An enhanced humoral response was observed after a third and fourth vaccine dose, use of heterologous vaccination and modulation of immunosuppression [70-72].

## A Special Population: Kids, Kidneys and COVID-19

### Outcomes in children with kidney disease and COVID-19

Children and adolescents are a vulnerable group and subject to special considerations in health care, research, and public policy. While the clinical impact of COVID-19 on pediatric patients has been less profound than in adults so far, successive waves of the pandemic have led to more children being directly impacted. There was an initial decrease in deceased and living donor kidney transplantation in the US at the start of the pandemic, however rates of transplantation returned to pre-pandemic levels by May 2020[73]. Unlike in adults, children taking immunosuppression for kidney disease or kidney transplant and children on dialysis have not had worse outcomes from COVID-19 infection than the general pediatric population[74-77]. When sick enough to be admitted, however, 12-23% of hospitalized children with COVID-19 developed AKI[78-80] and AKI is more common in patients with the multisystem inflammatory syndrome in children (MIS-C)[78]. Consistent with other studies of AKI in children, AKI was associated with increased levels of care, length of hospital stay, and worse outcomes[78,80-82].

### Gaps in science and child health policy

Gaps remain for the pediatric population compared to adults. Long-term COVID-19 outcomes will be important to study, and we should be developing safe and effective strategies to incorporate children in such studies. Research studying “long COVID” is lacking in children, despite evidence that it is at least as common for children as adults[83]. What’s more, while vaccination rates are much lower for children than adults, we need to learn more about vaccination patterns and perceptions among children with kidney disease and their caregivers[84]. It will take years to understand the impact of educational disruptions that affected children with CKD, who already have lower cognition compared to the general population[85]. Moreover, pediatric research addressing the impact of pandemic disruptions on access to transplant, the early detection of kidney disease, and the impact

on family dynamics could aid in the development of more equitable and durable pediatric care delivery models and public policy.

Table 2 outlines the challenges and missed opportunities faced by the kidney community in managing patients during the pandemic.

## Human consequences of the COVID-19 pandemic; psychosocial and ethical implications

The COVID-19 pandemic has necessitated a change in almost every aspect of kidney care. Healthcare resources shifted to prevent, detect and manage waves of COVID-19, leading to dramatic alterations in routine kidney care in many countries. This section highlights some of the changes instituted, and their impact on patients, caregivers and healthcare providers.

As the potential severity of COVID-19 disease became clear, international efforts were made to identify people at-risk. Many nations endorsed targeted public health measures to minimize both mortality and economic impact [86,87]. For example, in the U.K., a targeted national policy of "shielding" was implemented. Those considered most at-risk from COVID-19 were centrally identified using electronic records, and government letters were issued advising individuals to socially isolate themselves, restricting contact even within their household group, with the help of financial and logistical support. Many people with advanced kidney disease, kidney transplantation, and/or those requiring immunosuppressive treatment, were advised to shield [88,89]. Whilst these measures were broadly supported, the personal impact varied, with some feeling protected while others felt fearful and isolated [89]. In countries without such protective policies, public health messaging likely encouraged similar exposure-avoidant behaviors, particularly in at-risk groups [90-92].

Additional strategies to minimize infection were implemented internationally, including reduced visitor access in hospitals [93,94] and dialysis units [95] End-of-life care provision was dramatically altered due to the restrictions, with limitations of social contact and rituals before and after death [96]. Even with technological innovations to provide human connection, the impact of reduced physical contact between patients, caregivers and clinicians were significant. Some patients experienced loneliness and depressive symptoms, and caregivers described heightened anxiety and an increased

desire for information from healthcare professionals [97]. Many patient and provider groups described ethical compromise and psychological distress, as they felt unable to provide or receive care at pre-pandemic levels [98,99].

Patient and provider groups have described adversity, fear, abandonment, hope and resilience [100-103]. A multinational mixed methods study of 251 kidney healthcare providers found nearly one-third of respondents were at high risk of burnout and mental health distress during the pandemic, with feelings of emotional exhaustion, depersonalization, and a reduced sense of personal accomplishment [104].

Moral distress in healthcare during the COVID-19 pandemic has been extensively described and may explain some of the negative psychological consequences illustrated above [99]. Moral distress can occur when an individual perceives they are unable to act according to their ethical values due to external barriers [105]. If individuals perceive their ethical duties are compromised in settings of severe resource constraints, where institutional, health policy or financial barriers limit access to optimal treatments that are clinically indicated, moral distress may occur [106,107]. It occurs in both patients and caregivers and has been described in relation to the intentional separation between loved ones during end-of-life care and hospital visitation restrictions [98,103]. The consequences of moral distress include experiences of anger, guilt, depersonalization and, for healthcare professionals, a desire to leave the workforce entirely [108]. If persistent, moral distress can result in moral injury causing long-term social and psychological trauma[109,110].

Children and young adults with kidney disease face unique and pervasive mental and behavioral health challenges with higher rates of depression, anxiety, and neurocognitive disorders compared to their peers[85]. One survey reported that they felt they were missing out on work-related and educational opportunities, missing family and friends, and compared to their peers, they lived with more COVID-related restrictions[85]. Health-related quality of life and physical activity decreased significantly for both children and adolescents during the pandemic due to school closings, social distancing, and home confinement[111]. While these strategies are employed to reduce the viral spread, their prolonged use requires assessment to mitigate the adverse psychological effects, especially on vulnerable populations. Furthermore, parents and caregivers of children with kidney disease experience significant psychosocial stressors that leave many families dysfunctional and

disempowered. During the pandemic, this often-unseen care burden has been experienced disproportionately by families struggling with adverse social determinants of health and health disparities. Caregivers of children with kidney disease reported feelings of stress, anxiety, depression, and insomnia during the pandemic, mirroring findings in parents of children with other chronic conditions[112,113]. Children with medical complexity have lost access to therapies, educational services, and peer interactions, all while parents and caregivers have taken on additional responsibilities to navigate changes in employment and keeping their families healthy[114].

## Health equity/global health perspective

The COVID-19 pandemic with its rapid spread across the globe revealed that most health systems were unprepared for or underestimated the challenge. Initially, the lack of readiness, and almost a lack of belief that such a pandemic could occur in the current day and age, resulted in acute shortages of many items needed for an effective response. Early on, the scarcity of PPE sometimes resulted hoarding by countries and by individuals. This "catastrophic breakdown in global cooperation"[115] highlighted the need to develop global strategies to improve equity and access equipment, treatment and vaccines to treat COVID-19 [115,116]. This lack of equity and empathy persists, with booster doses of vaccines being administered to most adults and children in some countries before adults at risk of poor outcomes even receive their first vaccine in others[117]. Hoarding, pricing, protection of intellectual property and dissemination of misinformation regarding vaccines have exacerbated inequities and contributed to deaths [118]. These persistent and pervasive inequities, which impact how individuals and nations have been (un)able to tackle the challenges posed by the pandemic have coined a new term: "political determinants of health"[119].

Political and social determinants of health exist within as well as between countries, and the same populations who have experienced centuries of structural violence, e.g. African Americans and indigenous populations, are those most vulnerable to COVID-19 and at most risk of poor outcomes [120-126]. People living with chronic diseases, and especially kidney disease, are at the highest risk[127]. These facts have finally raised global awareness that non-communicable diseases cannot continue to be overlooked, including when looking beyond the pandemic[128,129]. As the demand for hospital beds and health care services outstripped availability at various stages, triage guidance had to be

urgently drawn up to allocate scarce intensive care unit beds, raising debates around which criteria would be morally acceptable[130,131]. Rationing of healthcare services became a reality, faced by many for whom until now the concept had been merely theoretical[132-135].

The nephrology community was rapidly drawn into the eye of the storm. The capacity to provide dialysis became strained in some settings, leading to complex triage algorithms and in some cases deaths even in high income countries (HICs) because of lack of access to dialysis[135,136]. People living with kidney disease are often vulnerable at baseline, tending to have lower socio-economic status, belonging to minority populations and living with multiple co-morbidities[137].

The pandemic has had a significant global impact on health care delivery in general, with consequences being particularly evident in low and lower-middle income countries (LLMICs)[41]. There were gross inequities in the provision of dialysis services[138]. Many guidelines were developed and disseminated for the management of patients with kidney disease, including those on dialysis, but most of these guidelines could not be adhered to because of the lack of resources in most LLMICs[139]. Surveys conducted by the International Society of Nephrology (ISN) in partnership with the Dialysis Outcomes and Practice Patterns group aimed to understand how clinical practice was being impacted by the pandemic, and if and how people living with kidney disease were being prioritized across the globe[41,140]. Challenges affecting both staff and patients were common in LLMICs. The patient level impact reported by survey respondents included challenges in accessing diagnostic testing, interruptions in hemodialysis delivery, restricted access to intensive care, mechanical ventilation, and in-hospital hemodialysis, affecting patients in LLMICS more frequently compared to upper middle-income countries (UMIC) and high-income countries (HIC). Staff in dialysis units in LLMICs had less access to COVID-19 testing, PPE (Fig 1) and training in infection control, and suffered a greater psychological impact [41].

At the time of the survey, conducted during the first year of the pandemic, diagnostic tests for SARS-CoV-2 were unavailable or of limited availability with longer turnaround times for test results in the majority of low income (LIC) and lower-middle income (LMICs) countries[41]. Patients in LIC frequently had to pay out-of-pocket for diagnostic (PCR) testing. Due to multiple factors including lockdowns, curfews and delays awaiting COVID-19 test results, patients in LIC and LMIC missed dialysis with a greater frequency than pre-pandemic and these delays cost lives.

A subsequent survey focused on access to vaccination for people living with advanced kidney disease. At least one COVID-19 vaccine was available in 97% of respondent countries. Over 90% of the respondent countries reported prioritization of healthcare workers within the first two phases of vaccine rollout, whereas patients living with stage 4/5 CKD, dialysis, or kidney transplants were prioritized within the first two phases in 51%, 71%, and 62% of countries respectively. Overall, at least 50% of patients receiving in-center hemodialysis, peritoneal dialysis or living with a kidney transplant were reported to have completed vaccination in around half of respondent countries, with the lowest rates reported in Africa and the highest rates in Western Europe. Vaccine hesitancy, vaccine shortages and difficulties in mass distribution of vaccines were common and reported more in LLMICs compared to HICs. Although the vaccination rate in the dialysis population may appear relatively high in lower income settings, indicating that the vulnerability of this group has been acknowledged globally, the global disparities echo the call by the World Health Organization for more equitable access to vaccines, having set a global target of 40% of the population of every country to have completed vaccination by the end of 2021 and 70% by mid-2022. Two major global efforts, COVAX and ACT- Accelerator, where richer countries should contribute to supplying and distributing vaccines to poorer countries, have been launched to facilitate global vaccination[115,116,141]. These schemes however, have not yet translated into action in terms of global solidarity, although equity gaps may be beginning to narrow[142,143].

Children are an inherently vulnerable population which modern society has a duty to protect. However, the unique social status of children places them at an equally unique risk of health inequities. Current research and pharmaceutical development processes are designed to protect children by studying drugs and diseases in adults first; however, the lack of timely available interventions and immunizations for children including those with underlying chronic disease during the pandemic has raised concern for age-based health inequity that should be reevaluated. Protection of children is paramount; however, equipoise with timely availability of emerging therapies and robust safety information are critical to this endeavor. At a national level, the prevalence of childhood poverty, specifically its relationship to health and its disproportionality across sociodemographic groups most at risk during the pandemic, highlights another important pediatric kidney health risk [114]. Evidence of social deprivation along racial, ethnic, and class divisions

have been shown to have adverse consequences in both children and adults with kidney disease, but the specific effect of the pandemic on this population is yet to be studied[144,145].

The almost miraculous rapidity with which the scientific community tackled the COVID-19 problem has been a simultaneous triumph and a failure. The rapid development of tests, vaccines and therapeutics has been life-saving for many, but has left many behind. The early robust efforts to identify and publish potential management strategies led to great advances in clinical understanding and rapid knowledge sharing but also led to dissemination of pseudoscience and misinformation. This has severely impacted trust in health systems globally and has led to loss of life. The COVID-19 pandemic has revealed how necessary solidarity is at all levels, beginning with global governance and trickling down to the individual in the dialysis chair in a remote dialysis unit (Fig 2)[118,146,147]. This requires attention being paid to justice and ethics at all levels. Global collaboration and cooperation are needed between countries, institutions, industry and academia. Collaborative focus on "building back better" is required such that health systems and societies emerge from the pandemic stronger, more resilient and fairer.

## Trainee education

The surge of patients with COVID-19 also impacted nephrology training. Nephrology trainees have been at the front-line of care for COVID-19 patients, including in the intensive care units, dedicated COVID-19 wards, and the new era of telemedicine. While this comes with the possibility of reinvigorating interest in nephrology, it also comes with the threats of increased workload, stress, and burnout for our trainees.

Activities our nephrology trainees have typically relied on for education and career advancement have undergone significant adjustments in this era. Major conferences such as the ASN Kidney Week and the ERA meetings were held virtually with fewer opportunities for networking. Local conferences at one's own institution were also shifted overnight to virtual formats, limiting in-person interaction with faculty, and requiring additional effort to stay engaged.

In the U.S., adult and pediatric fellows and recent graduates of nephrology training were surveyed by the ASN Workforce and Training Committee in August-September 2020 using our Annual Fellows' Survey instrument[148]. The impact of COVID-19 on fellows' training experiences and wellbeing was

measured, yielding 425 respondents (42% response rate). The majority of current fellows (84%) felt their education was maintained during the pandemic. Fellows needed to adapt to this new landscape in real-time, with up to 91% reporting adoption of telemedicine and 76% remote conferences. While their education was maintained overall, 42% of fellows reported a negative impact of the pandemic on their overall quality of life, 33% reported a poorer work-life balance, and 15% scored as experiencing high distress measured using the Resident Well-Being Index. Similar findings were seen for trainees in the U.K.[149], France and Belgium[150].

The pandemic has offered opportunities to better understand, develop, and train future nephrologists. Training programs, such as those in Canada[151], have have seized this opportunity to develop personalized learning plans for postgraduate nephrology trainees. It remains to be seen whether resilience of nephrology fellows will be maintained through this pandemic, and what impact the pandemic will have for board certification, job prospects, and recruitment of the next generation of nephrologists.

## A Patient's Voice on the COVID19 Pandemic

Telehealth offered a safe way to cotninue medical care and conferred multiple advantages but limitations exist and must be acknowledged and addressed. A scoping review identified technical difficulties, digital literacy, lack of physical exam, privacy and confidentiality and loss of interpersonal interaction as main barriers to telehealth (PMID: 35338610).

COVID-19 patient communication impacted the entie spectrum of patients with kidney disease throughout the pandemic. Since the beginning of the COVID-19 pandemic, COVID-19 patient communication with kidney disease patient communities has remained unclear. From a patient perspective, the most impactful communications centered around use of personal protective measures, risk and consequences of AKI, vaccine efficacy and update and guidance on use of COVID-19 therapeutics. In the absence of direction, navigation was dependent upon the patient activation skills of the individual. Town halls were conducted by the American Society of Transplantation and webinars were facilitated by the American Society of Nephrology but these were accessed only by patients who were part of professional patient advocacy groups.

Patient organizations such as the American Association of Kidney Patients, National Kidney Foundation and Kidney Care UK and have attempted to address the gap in COVID-19 information. While their efforts have been successful, they have reached only a small percentage of the CKD and ESKD patients. A process is needed in which all patients hear directly from their care team about the current guidance, and what actions they can take to avoid COVID-19.

## Future guidance

The pandemic has highlighted the challenges posed by surges in hospital occupancy, forced the digital transformation of many healthcare systems, underscored the need for authoritative and consistent communication from local, state and federal governments and identified striking global inequities in the care of patients with kidney disease. Additionally, the pandemic has highlighted the importance of proactively addressing psychosocial and ethical issues to ensure patient, caregiver, and clinician wellbeing. The strategies to address the challenges faced by the kidney community during a pandemic is displayed in Fig 3. For obvious reasons, these strategies will differ between low, lower-middle, upper-middle and high income countries and global colloboration and cooperation is required at all levels to ensure equity in health care delivery for patients with kidney disease.

## Conclusions

The COVID-19 pandemic has been one of the worst infectious disease crisis in over a century and given the increase in emerging diseases, pandemic threats may become a new normal. Our experience within the nephrology community has been extremely challenging. Hospitalization surges during the pandemic exposed fundamental weaknesses in all health care systems. While this led to innovations in health care delivery and policy change, there remains an urgent need to invest in resilient health care systems and develop transparent and fair triage guidelines for scarce resources. The breakdown of global cooperation further exacerbated existing healthcare inequities. The pandemic illustrated that building public trust in scientific recommendations is critical to avoiding social and political divisions over following risk mitigation strategies. Moral distress has increased and must be recognized and addressed. One in 10 people is living with kidney disease.

There is a need to include patients with kidney disease in clinical trials especially during pandemics to accelerate access to potential therapeutics, and to invest in the establishment of global collaborative disease registries to study risk factors and outcomes. Finally, we must be prepared to run a leaner regulatory state during future public health emergencies. Strategic deregulation would accelerate the development and distribution of new therapeutics.

## Key points

1. Acute kidney injury is common in severe COVID-19 and associated with increased mortality
2. Patients with chronic kidney disease are at high risk for severe COVID-19 and severe outcomes, and should be prioritized for therapeutics including vaccines
3. Establishment of global collaborative registries is key to assessing the severity and risk factors of infection
4. Interruptions in routine care was common and highlighted the advantages of temporary implementation of telemedicine and home dialysis
5. There were gross inequities in access to COVID-19 testing, personal protective equipment, provision of dialysis services, COVID-19 vaccines and therapeutics rollout
6. To prepare for future pandemics, it is important to stock pile emergency medical equipment, invest in resilient health care systems, have global cooperation in providing care, explore and advance remote care globally, address moral distress to improve well-being of patients and care providers, build public trust in scientific recommendations and advocate for kidney patients to be included in clinical trials and global registries.

## References


1 Chan, L. *et al.* AKI in Hospitalized Patients with COVID-19. *J Am Soc Nephrol* **32**, 151-160, doi:10.1681/ASN.2020050615 (2021).

2 Brogan, M. & Ross, M. J. The Impact of Chronic Kidney Disease on Outcomes of Patients with COVID-19 Admitted to the Intensive Care Unit. *Nephron* **146**, 67-71, doi:10.1159/000519530 (2022).

3 Pereira, M. R. *et al.* COVID-19 in solid organ transplant recipients: Initial report from the US epicenter. *Am J Transplant* **20**, 1800-1808, doi:10.1111/ajt.15941 (2020).

4 Hilton, J., Boyer, N., Nadim, M. K., Forni, L. G. & Kellum, J. A. COVID-19 and Acute Kidney Injury. *Crit Care Clin* **38**, 473-489, doi:10.1016/j.ccc.2022.01.002 (2022).

5 Hirsch, J. S. *et al.* Acute kidney injury in patients hospitalized with COVID-19. *Kidney Int* **98**, 209-218, doi:10.1016/j.kint.2020.05.006 (2020).

6 Charytan, D. M. *et al.* Decreasing Incidence of Acute Kidney Injury in Patients with COVID-19 Critical Illness in New York City. *Kidney Int Rep* **6**, 916-927, doi:10.1016/j.ekir.2021.01.036 (2021).

7 Dellepiane, S. *et al.* Acute Kidney Injury in Patients Hospitalized With COVID-19 in New York City: Temporal Trends From March 2020 to April 2021. *Kidney Med* **3**, 877-879, doi:10.1016/j.xkme.2021.06.008 (2021).

8 Diane NE, K. I., Wearne N,Kariv S, Davidson B. Acute kidney injury during the COVID-19 pandemic–experience from two tertiary centres in South Africa. 2020. *Wits Journal of Clinical Medicine* **2(3):189-98.** (2020).

9 Tannor, E. K. Challenges in Kidney Care in a Lower Middle Income Country During the COVID-19 Pandemic - the Ghanaian Perspective. *Kidney Int Rep* **6**, 2014-2016, doi:10.1016/j.ekir.2021.06.019 (2021).

10 Wu, H. *et al.* AKI and Collapsing Glomerulopathy Associated with COVID-19 and APOL1 High-Risk Genotype. *Journal of the American Society of Nephrology* **31**, 1688, doi:10.1681/ASN.2020050558 (2020).

11 May, R. M. *et al.* A multi-center retrospective cohort study defines the spectrum of kidney pathology in Coronavirus 2019 Disease (COVID-19). *Kidney International* **100**, 1303-1315, doi:10.1016/j.kint.2021.07.015 (2021).

12 Hung, A. M. *et al.* APOL1 Risk Variants, Acute Kidney Injury, and Death in Participants With African Ancestry Hospitalized With COVID-19 From the Million Veteran Program. *JAMA Internal Medicine*, doi:10.1001/jamainternmed.2021.8538 (2022).

13 Strohbehn, I. A. *et al.* Acute Kidney Injury Incidence, Recovery, and Long-term Kidney Outcomes Among Hospitalized Patients With COVID-19 and Influenza. *Kidney International Reports* **6**, 2565-2574, doi:10.1016/j.ekir.2021.07.008 (2021).

14 Lumlertgul, N. *et al.* Acute kidney injury prevalence, progression and long-term outcomes in critically ill patients with COVID-19: a cohort study. *Ann Intensive Care* **11**, 123, doi:10.1186/s13613-021-00914-5 (2021).

15 Gupta, S. *et al.* AKI Treated with Renal Replacement Therapy in Critically Ill Patients with COVID-19. *J Am Soc Nephrol* **32**, 161-176, doi:10.1681/ASN.2020060897 (2021).

16 Yende, S. & Parikh, C. R. Long COVID and kidney disease. *Nat Rev Nephrol* **17**, 792-793, doi:10.1038/s41581-021-00487-3 (2021).

17 Bowe, B., Xie, Y., Xu, E. & Al-Aly, Z. Kidney Outcomes in Long COVID. *J Am Soc Nephrol* **32**, 2851-2862, doi:10.1681/ASN.2021060734 (2021).

18 Sun, S. *et al.* Short- and Long-Term Recovery after Moderate/Severe AKI in Patients with and without COVID-19. *Kidney360* **3**, 242-257, doi:10.34067/KID.0005342021 (2022).

19 Dashtban, A. *et al.* A retrospective cohort study measured predicting and validating the impact of the COVID-19 pandemic in individuals with chronic kidney disease. *Kidney Int*, doi:10.1016/j.kint.2022.05.015 (2022).

20 Uribarri, A. *et al.* Impact of renal function on admission in COVID-19 patients: an analysis of the international HOPE COVID-19 (Health Outcome Predictive Evaluation for COVID 19) Registry. *J Nephrol* **33**, 737-745, doi:10.1007/s40620-020-00790-5 (2020).

21 Portoles, J. *et al.* Chronic kidney disease and acute kidney injury in the COVID-19 Spanish outbreak. *Nephrol Dial Transplant* **35**, 1353-1361, doi:10.1093/ndt/gfaa189 (2020).

22 Carlson, N. *et al.* Increased vulnerability to COVID-19 in chronic kidney disease. *J Intern Med* **290**, 166-178, doi:10.1111/joim.13239 (2021).

23 Hakroush, S., Tampe, D., Korsten, P. & Tampe, B. Impact of the COVID-19 Pandemic on Kidney Diseases Requiring Renal Biopsy: A Single Center Observational Study. *Front Physiol* **12**, 649336, doi:10.3389/fphys.2021.649336 (2021).

24 Seet, C. *et al.* The management of dialysis access thrombosis during the COVID-19 pandemic. *J Vasc Access*, 11297298211045578, doi:10.1177/11297298211045578 (2021).

25 Wetmore, J. B. *et al.* Changes in Treatment of Patients with Incident ESKD during the Novel Coronavirus Disease 2019 Pandemic. *J Am Soc Nephrol* **32**, 2948-2957, doi:10.1681/ASN.2021040579 (2021).

26 Chen, G. *et al.* When the COVID-19 pandemic changed the follow-up landscape of chronic kidney disease: a survey of real-world nephrology practice. *Ren Fail* **42**, 733-739, doi:10.1080/0886022X.2020.1798783 (2020).

27 Truong, T., Dittmar, M., Ghaffari, A. & Lin, E. Policy and Pandemic: The Changing Practice of Nephrology During the Coronavirus Disease-2019 Outbreak. *Adv Chronic Kidney Dis* **27**, 390-396, doi:10.1053/j.ackd.2020.06.003 (2020).

28 Ramachandran, R. & Jha, V. Adding insult to injury: kidney replacement therapy during COVID-19 in India. *Kidney Int* **98**, 238-239, doi:10.1016/j.kint.2020.04.019 (2020).

29 Group, R. C. *et al.* Dexamethasone in Hospitalized Patients with Covid-19. *N Engl J Med* **384**, 693-704, doi:10.1056/NEJMoa2021436 (2021).

30 Adamsick, M. L. *et al.* Remdesivir in Patients with Acute or Chronic Kidney Disease and COVID-19. *J Am Soc Nephrol* **31**, 1384-1386, doi:10.1681/ASN.2020050589 (2020).

31 Salvarani, C. *et al.* Effect of Tocilizumab vs Standard Care on Clinical Worsening in Patients Hospitalized With COVID-19 Pneumonia: A Randomized Clinical Trial. *JAMA Intern Med* **181**, 24-31, doi:10.1001/jamainternmed.2020.6615 (2021).

32 Hou, Y. C., Lu, K. C. & Kuo, K. L. The Efficacy of COVID-19 Vaccines in Chronic Kidney Disease and Kidney Transplantation Patients: A Narrative Review. *Vaccines (Basel)* **9**, doi:10.3390/vaccines9080885 (2021).

33 Quiroga, B. *et al.* Humoral Response to Third Dose of SARS-CoV-2 Vaccines in the CKD Spectrum. *Clin J Am Soc Nephrol* **17**, 872-876, doi:10.2215/CJN.01770222 (2022).

34 Salas, A. *et al.* ANCA Vasculitis Induction Management During the COVID-19 Pandemic. *Kidney Int Rep* **6**, 2903-2907, doi:10.1016/j.ekir.2021.08.009 (2021).

35 Waldman, M. *et al.* Results from the IRoc-GN international registry of patients with COVID-19 and glomerular disease suggest close monitoring. *Kidney Int* **99**, 227-237, doi:10.1016/j.kint.2020.10.032 (2021).

36 Strangfeld, A. *et al.* Factors associated with COVID-19-related death in people with rheumatic diseases: results from the COVID-19 Global Rheumatology Alliance physician-reported registry. *Ann Rheum Dis* **80**, 930-942, doi:10.1136/annrheumdis-2020-219498 (2021).

37 Prendecki, M., Willicombe, M. & McAdoo, S. P. COVID-19 vaccination in patients with immunity-mediated kidney disease. *Nat Rev Nephrol* **17**, 790-791, doi:10.1038/s41581-021-00502-7 (2021).

38 Connolly, C. M. *et al.* Temporary hold of mycophenolate augments humoral response to SARS-CoV-2 vaccination in patients with rheumatic and musculoskeletal diseases: a case series. *Ann Rheum Dis* **81**, 293-295, doi:10.1136/annrheumdis-2021-221252 (2022).

39 Kronbichler, A., Jung, S. Y., Kim, M. S. & Shin, J. I. Distinct glomerular disease association after vaccination with BNT162b2 and mRNA-1273: a VigiBase analysis. *Kidney Int* **101**, 415-416, doi:10.1016/j.kint.2021.11.013 (2022).

40 Oliver, M. J. & Crabtree, J. H. Prioritizing Peritoneal Catheter Placement during the COVID-19 Pandemic: A Perspective of the American Society of Nephrology COVID-19 Home Dialysis Subcommittee. *Clin J Am Soc Nephrol* **16**, 1281-1283, doi:10.2215/CJN.19141220 (2021).

41 Aylward, R. *et al.* The Global Impact of the COVID-19 Pandemic on In-Center Hemodialysis Services: An ISN-Dialysis Outcomes Practice Patterns Study Survey. *Kidney Int Rep* **7**, 397-409, doi:10.1016/j.ekir.2021.12.011 (2022).

42 Corbett, R. W. *et al.* Epidemiology of COVID-19 in an Urban Dialysis Center. *J Am Soc Nephrol* **31**, 1815-1823, doi:10.1681/ASN.2020040534 (2020).

43 Ziemba, R. *et al.* Excess Death Estimates in Patients with End-Stage Renal Disease - United States, February-August 2020. *MMWR Morb Mortal Wkly Rep* **70**, 825-829, doi:10.15585/mmwr.mm7022e2 (2021).

44 Priya Vart, K. J. J., Miha Arnol, Raphaël Duivenvoorden, Casper F.M. Franssen, Marc Groeneveld, Marc H. Hemmelder, Fanny Lepeytre, Thomas Malfait, Karsten Midtvedt, Sandip Mitra, Carme Facundo, Marlies Noordzij, Carlos C. Reina, Seda Safak, Nestor Toapanta, Luuk B. Hilbrands, Ron T. Gansevoort,. COVID-19 pandemic waves and mortality among patients on kidney replacement therapy. *Kidney International Reports* **https://doi.org/10.1016/j.ekir.2022.06.007.** (2022).

45 Patel, P. R. *et al.* Assessment of Provision of COVID-19 Vaccination in Dialysis Clinics and Patient Vaccination Coverage. *JAMA Intern Med* **182**, 676-678, doi:10.1001/jamainternmed.2022.0627 (2022).

46 Brunelli, S. M. *et al.* Comparative Effectiveness of mRNA-based BNT162b2 Vaccine versus Adenovirus Vector-Based Ad26.COV2.S Vaccine for the Prevention of COVID-19 among Dialysis Patients. *J Am Soc Nephrol*, doi:10.1681/ASN.2021101395 (2022).

47 Garcia, P. *et al.* COVID-19 Vaccine Type and Humoral Immune Response in Patients Receiving Dialysis. *J Am Soc Nephrol* **33**, 33-37, doi:10.1681/ASN.2021070936 (2022).

48 Services, C. f. M. M. Medicare Program; End-Stage Renal Disease Prospective Payment System, Payment for Renal Dialysis Services Furnished to Individuals With Acute Kidney Injury, and End-Stage Renal Disease Quality Incentive Program. *Federal Register 85, 42132–42208* **CMS-1732-P. 42 CFR Part 413** (2020).

49 (CMS), C. f. M. a. M. S. HHS. Medicare Program; Specialty Care Models To Improve Quality of Care and Reduce Expenditures. *Federal Register 85, 61114–61381* **CMS-5527-F.** (2020).

50 Services, C. f. M. a. M. COVID-19 Emergency Declaration Blanket Waivers for Health Care Providers. *https://www.cms.gov/files/document/summary-covid-19-emergency-declaration-waivers.pdf* (2021).

51 Rombola, G. & Brunini, F. COVID-19 and dialysis: why we should be worried. *J Nephrol* **33**, 401-403, doi:10.1007/s40620-020-00737-w (2020).

52 Lew, S. Q. & Sikka, N. Operationalizing Telehealth for Home Dialysis Patients in the United States. *Am J Kidney Dis* **74**, 95-100, doi:10.1053/j.ajkd.2019.01.023 (2019).

53 Mahase, E. Covid-19: Pfizer's paxlovid is 89% effective in patients at risk of serious illness, company reports. *BMJ* **375**, n2713, doi:10.1136/bmj.n2713 (2021).

54 Wen, W. *et al.* Efficacy and safety of three new oral antiviral treatment (molnupiravir, fluvoxamine and Paxlovid) for COVID-19a meta-analysis. *Ann Med* **54**, 516-523, doi:10.1080/07853890.2022.2034936 (2022).

55 Schold, J. D. *et al.* COVID-19 mortality among kidney transplant candidates is strongly associated with social determinants of health. *Am J Transplant* **21**, 2563-2572, doi:10.1111/ajt.16578 (2021).

56 Mohan, S., King, K. L., Husain, S. A. & Schold, J. D. COVID-19-Associated Mortality among Kidney Transplant Recipients and Candidates in the United States. *Clin J Am Soc Nephrol* **16**, 1695-1703, doi:10.2215/CJN.02690221 (2021).

57 Alberici, F. *et al.* SARS-CoV-2 infection in dialysis and kidney transplant patients: immunological and serological response. *J Nephrol*, doi:10.1007/s40620-021-01214-8 (2022).

58 Aubert, O. *et al.* COVID-19 pandemic and worldwide organ transplantation: a population-based study. *Lancet Public Health* **6**, e709-e719, doi:10.1016/S2468-2667(21)00200-0 (2021).

59 Lentine, K. L. *et al.* Survey of US Living Kidney Donation and Transplantation Practices in the COVID-19 Era. *Kidney Int Rep* **5**, 1894-1905, doi:10.1016/j.ekir.2020.08.017 (2020).

60 Li, M. T., King, K. L., Husain, S. A., Schold, J. D. & Mohan, S. Deceased Donor Kidneys Utilization and Discard Rates During COVID-19 Pandemic in the United States. *Kidney Int Rep* **6**, 2463-2467, doi:10.1016/j.ekir.2021.06.002 (2021).

61 Martinez-Reviejo, R. *et al.* Solid organ transplantation from donors with recent or current SARS-CoV-2 infection: A Systematic Review. *Anaesth Crit Care Pain Med*, 101098, doi:10.1016/j.accpm.2022.101098 (2022).

62 Chang, J. H. *et al.* Home Care Delivery and Remote Patient Monitoring of Kidney Transplant Recipients During COVID-19 Pandemic. *Prog Transplant* **31**, 381-384, doi:10.1177/15269248211046005 (2021).

63 Biancone, L. *et al.* Telemedicine monitoring in the follow-up of kidney transplant recipients: consensus indications from an Italian panel of surgeons and nephrologists after the COVID-19 experience. *J Nephrol*, doi:10.1007/s40620-021-01193-w (2022).

64 Potter, S. R., Hinojosa, R., Miles, C. D., O'Brien, D. & Ross, D. J. Remote monitoring using donor-derived, cell-free DNA after kidney transplantation during the coronavirus disease 2019 pandemic. *Kidney Res Clin Pract* **39**, 495-500, doi:10.23876/j.krcp.20.107 (2020).

65 Masset, C. *et al.* Occurrence of de novo Donor Specific Antibodies after Covid-19 in kidney transplant recipients is low despite immunosuppression modulation. *Kidney Int Rep*, doi:10.1016/j.ekir.2022.01.1072 (2022).

66 Abu Jawdeh, B. G. COVID-19 in Kidney Transplantation: Outcomes, Immunosuppression Management, and Operational Challenges. *Adv Chronic Kidney Dis* **27**, 383-389, doi:10.1053/j.ackd.2020.07.004 (2020).

67 Salerno, D. M. *et al.* SARS-CoV-2 infection increases tacrolimus concentrations in solid-organ transplant recipients. *Clin Transplant* **35**, e14193, doi:10.1111/ctr.14193 (2021).

68 Watcharananan, S. P. *et al.* Comparison of the immunogenicity of ChAdOx1 nCoV-19 vaccine against the wild-type and delta variants in kidney transplant recipients and healthy volunteers. *Am J Transplant*, doi:10.1111/ajt.16966 (2022).

69 Boyarsky, B. J. *et al.* Antibody Response to 2-Dose SARS-CoV-2 mRNA Vaccine Series in Solid Organ Transplant Recipients. *JAMA* **325**, 2204-2206, doi:10.1001/jama.2021.7489 (2021).

70 Masset, C. *et al.* A third injection of the BNT162b2 mRNA COVID-19 vaccine in kidney transplant recipients improves the humoral immune response. *Kidney Int* **100**, 1132-1135, doi:10.1016/j.kint.2021.08.017 (2021).

71 Masset, C. *et al.* Observations on improving COVID-19 vaccination responses in kidney transplant recipients: heterologous vaccination and immunosuppression modulation. *Kidney Int* **101**, 642-645, doi:10.1016/j.kint.2021.11.024 (2022).

72 Cristelli, M. P., Nakamura, M. R., Viana, L. A., Tedesco-Silva, H. & Medina-Pestana, J. The Fourth Dose of CoronaVac Vaccine Results in a Small Increase of Seroconversion and Antibody Values Among Kidney Transplant Recipients. *Transplantation*, doi:10.1097/TP.0000000000004219 (2022).

73 Charnaya, O. *et al.* Effects of COVID-19 pandemic on pediatric kidney transplant in the United States. *Pediatr Nephrol* **36**, 143-151, doi:10.1007/s00467-020-04764-4 (2021).

74 Marlais, M. *et al.* COVID-19 in children treated with immunosuppressive medication for kidney diseases. *Arch Dis Child*, doi:10.1136/archdischild-2020-320616 (2020).

75 Varnell, C. D. *et al.* COVID-19 in Pediatric Kidney Transplantation: The Improving Renal Outcomes Collaborative. *Am J Transplant* **21**, 2740-2748 (2021).

76 Canpolat, N. *et al.* COVID-19 in pediatric patients undergoing chronic dialysis and kidney transplantation. *Eur J Pediatr* **181**, 117-123, doi:10.1007/s00431-021-04191-z (2022).

77 Mastrangelo, A. *et al.* Impact of COVID-19 Pandemic in Children with CKD or Immunosuppression. *Clin J Am Soc Nephrol* **16**, 449-451, doi:10.2215/CJN.13120820 (2021).

78 Basalely, A. *et al.* Acute kidney injury in pediatric patients hospitalized with acute COVID-19 and multisystem inflammatory syndrome in children associated with COVID-19. *Kidney Int* **100**, 138-145, doi:10.1016/j.kint.2021.02.026 (2021).

79 Kari, J. A. *et al.* Acute kidney injury in children with COVID-19: a retrospective study. *BMC Nephrol* **22**, 202, doi:10.1186/s12882-021-02389-9 (2021).

80 Chopra, S. *et al.* Acute Kidney Injury in Hospitalized Children with COVID19. *J Trop Pediatr* **67**, doi:10.1093/tropej/fmab037 (2021).

81 Wang, X. *et al.* Be aware of acute kidney injury in critically ill children with COVID-19. *Pediatr Nephrol* **36**, 163-169, doi:10.1007/s00467-020-04715-z (2021).

82 Kaddourah, A., Basu, R. K., Bagshaw, S. M., Goldstein, S. L. & Investigators, A. Epidemiology of Acute Kidney Injury in Critically Ill Children and Young Adults. *N Engl J Med* **376**, 11-20, doi:10.1056/NEJMoa1611391 (2017).

83 Long COVID and kids: more research is urgently needed. *Nature* **602**, doi:https://doi.org/10.1038/d41586-022-00334-w (2022).

84 Yilmaz, M. & Sahin, M. K. Parents' willingness and attitudes concerning the COVID-19 vaccine: A cross-sectional study. *Int J Clin Pract* **75**, e14364, doi:10.1111/ijcp.14364 (2021).

85 Tse, Y. *et al.* COVID-19: experiences of lockdown and support needs in children and young adults with kidney conditions. *Pediatr Nephrol* **36**, 2797-2810, doi:10.1007/s00467-021-05041-8 (2021).

86 Acemoglu, D., Chernozhukov, V., Werning, I. & Whinston, M. D. *A multi-risk SIR model with optimally targeted lockdown*. Vol. 2020 (National Bureau of Economic Research Cambridge, MA, 2020).

87 Neufeld, Z., Khataee, H. & Czirok, A. Targeted adaptive isolation strategy for COVID-19 pandemic. *Infectious Disease Modelling* **5**, 357-361 (2020).

88 Rutter, M. *et al.* Estimation of the burden of shielding among a cross-section of patients attending rheumatology clinics with SLE—data from the BSR audit of systemic lupus erythematosus. *Rheumatology (Oxford, England)* (2020).

89 Sloan, M. *et al.* COVID-19 and shielding: Experiences of UK patients with lupus and related diseases. *Rheumatology Advances in Practice*, doi:10.1093/rap/rkab003 (2021).

90 Qian, M. *et al.* Anxiety levels, precautionary behaviours and public perceptions during the early phase of the COVID-19 outbreak in China: a population-based cross-sectional survey. *BMJ open* **10**, e040910 (2020).

91 Yıldırım, M., Geçer, E. & Akgül, Ö. The impacts of vulnerability, perceived risk, and fear on preventive behaviours against COVID-19. *Psychology, health & medicine* **26**, 35-43 (2021).

92 Bavel, J. J. V. *et al.* Using social and behavioural science to support COVID-19 pandemic response. *Nature human behaviour* **4**, 460-471 (2020).

93 Lanphier, E., Mosley, L. & Antommaria, A. H. M. Assessing visitor policy exemption requests during the COVID-19 pandemic. *Pediatrics* **148** (2021).

94 Downar, J. & Kekewich, M. Improving family access to dying patients during the COVID-19 pandemic. *The Lancet Respiratory Medicine* **9**, 335-337 (2021).

95 Nogueira, G. M., Oliveira, M. S., Moura, A. F., Cruz, C. M. S. & Moura-Neto, J. A. COVID-19 in dialysis units: A comprehensive review. *World Journal of Virology* **10**, 264 (2021).

96 Janssen, D. J. Palliative care in COVID-19. *Current opinion in supportive and palliative care* **15**, 199 (2021).

97 Hugelius, K., Harada, N. & Marutani, M. Consequences of visiting restrictions during the COVID-19 pandemic: An integrative review. *International journal of nursing studies* **121**, 104000 (2021).
98 Vittone, S. & Sotomayor, C. R. in *HEC forum.* 415-423 (Springer).
99 Ducharlet, K. *et al.* Moral Distress and Moral Injury in Nephrology During the COVID-19 Pandemic. *Semin Nephrol* **41**, 253-261 (2021).
100 Sloan, M. *et al.* Will'the feeling of abandonment'remain? Persisting impacts of the Covid-19 pandemic on rheumatology patients and clinicians. *Rheumatology (Oxford, England)* (2022).
101 Shaw, S. C. Hopelessness, helplessness and resilience: The importance of safeguarding our trainees' mental wellbeing during the COVID-19 pandemic. *Nurse Educ Pract* **44**, 102780 (2020).
102 Ripp, J., Peccoralo, L. & Charney, D. Attending to the Emotional Well-Being of the Health Care Workforce in a New York City Health System During the COVID-19 Pandemic. *Acad Med* **95**, 1136-1139, doi:10.1097/ACM.0000000000003414 (2020).
103 Morley, G., Sese, D., Rajendram, P. & Horsburgh, C. C. Addressing caregiver moral distress during the COVID-19 pandemic. *Cleveland Clinic journal of medicine* (2020).
104 Mc Keaveney, C. *et al.* Experiences of renal healthcare practitioners during the COVID-19 pandemic: a multi-methods approach. *BMC nephrology* **22**, 1-10 (2021).
105 Jameton, A. *Nursing practice: The ethical issues*. (Prentice-Hall, 1984).
106 Flood, D. *et al.* Challenges in the provision of kidney care at the largest public nephrology center in Guatemala: a qualitative study with health professionals. *BMC nephrology* **21**, 1-10 (2020).
107 Cervantes, L. *et al.* Clinicians' Perspectives on Providing Emergency-Only Hemodialysis to Undocumented Immigrants: A Qualitative Study. *Ann Intern Med*, doi:10.7326/M18-0400 (2018).
108 Lamiani, G., Borghi, L. & Argentero, P. When healthcare professionals cannot do the right thing: A systematic review of moral distress and its correlates. *Journal of health psychology* **22**, 51-67 (2017).
109 Myran, D. T. *et al.* Physician Health Care Visits for Mental Health and Substance Use During the COVID-19 Pandemic in Ontario, Canada. *JAMA Netw Open* **5**, e2143160, doi:10.1001/jamanetworkopen.2021.43160 (2022).
110 Litz, B. T. *et al.* Moral injury and moral repair in war veterans: a preliminary model and intervention strategy. *Clin Psychol Rev* **29**, 695-706, doi:10.1016/j.cpr.2009.07.003 (2009).
111 Nobari, H. *et al.* Effect of COVID-19 on Health-Related Quality of Life in Adolescents and Children: A Systematic Review. *Int J Environ Res Public Health* **18**, doi:10.3390/ijerph18094563 (2021).
112 Sharma, R. *et al.* Distress, anxiety, and its correlates among caregivers of children with kidney diseases during COVID-19 pandemic lockdown. *Arch Pediatr*, doi:10.1016/j.arcped.2022.01.003 (2022).
113 Alessi, J., de Oliveira, G. B., Feiden, G., Schaan, B. D. & Telo, G. H. Caring for caregivers: the impact of the COVID-19 pandemic on those responsible for children and adolescents with type 1 diabetes. *Sci Rep* **11**, 6812, doi:10.1038/s41598-021-85874-3 (2021).
114 Smitherman, L. C., Golden, W. C. & Walton, J. R. Health Disparities and Their Effects on Children and Their Caregivers During the Coronavirus Disease 2019 Pandemic. *Pediatr Clin North Am* **68**, 1133-1145, doi:10.1016/j.pcl.2021.05.013 (2021).
115 Moon, S. *et al.* Governing the Access to COVID-19 Tools Accelerator: towards greater participation, transparency, and accountability. *Lancet* **399**, 487-494, doi:10.1016/S0140-6736(21)02344-8 (2022).
116 Herzog, L. M., Norheim, O. F., Emanuel, E. J. & McCoy, M. S. Covax must go beyond proportional allocation of covid vaccines to ensure fair and equitable access. *BMJ* **372**, m4853, doi:10.1136/bmj.m4853 (2021).
117 McIntyre, P. B. *et al.* COVID-19 vaccine strategies must focus on severe disease and global equity. *Lancet* **399**, 406-410, doi:10.1016/S0140-6736(21)02835-X (2022).
118 Binagwaho, A., Mathewos, K. & Davis, S. Time for the ethical management of COVID-19 vaccines. *Lancet Glob Health* **9**, e1169-e1171, doi:10.1016/S2214-109X(21)00180-7 (2021).

119 Patel, M. S. & Phillips, C. B. COVID-19 and the moral imagination. *Lancet* **397**, 648-650, doi:10.1016/S0140-6736(21)00151-3 (2021).

120 Ismail, S. J., Tunis, M. C., Zhao, L. & Quach, C. Navigating inequities: a roadmap out of the pandemic. *BMJ Glob Health* **6**, doi:10.1136/bmjgh-2020-004087 (2021).

121 Bignall, O. N. R., 2nd & Crews, D. C. Stony the road we trod: towards racial justice in kidney care. *Nat Rev Nephrol* **17**, 79-80, doi:10.1038/s41581-020-00389-w (2021).

122 Shadmi, E. *et al.* Health equity and COVID-19: global perspectives. *Int J Equity Health* **19**, 104, doi:10.1186/s12939-020-01218-z (2020).

123 Aldridge, R. W. *et al.* Black, Asian and Minority Ethnic groups in England are at increased risk of death from COVID-19: indirect standardisation of NHS mortality data. *Wellcome Open Res* **5**, 88, doi:10.12688/wellcomeopenres.15922.2 (2020).

124 Baqui, P., Bica, I., Marra, V., Ercole, A. & van der Schaar, M. Ethnic and regional variations in hospital mortality from COVID-19 in Brazil: a cross-sectional observational study. *Lancet Glob Health* **8**, e1018-e1026, doi:10.1016/S2214-109X(20)30285-0 (2020).

125 Laster Pirtle, W. N. Racial Capitalism: A Fundamental Cause of Novel Coronavirus (COVID-19) Pandemic Inequities in the United States. *Health Educ Behav* **47**, 504-508, doi:10.1177/1090198120922942 (2020).

126 Yaya, S., Yeboah, H., Charles, C. H., Otu, A. & Labonte, R. Ethnic and racial disparities in COVID-19-related deaths: counting the trees, hiding the forest. *BMJ Glob Health* **5**, doi:10.1136/bmjgh-2020-002913 (2020).

127 Council., E.-E. & Group., E. W. Chronic kidney disease is a key risk factor for severe COVID-19: a call to action by the ERA-EDTA. *Nephrol Dial Transplant* **36**, 87-94, doi:10.1093/ndt/gfaa314 (2021).

128 WHO NCD Department. *COVID-19 AND NCDS*, <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiMjPyu7ovrAhVt-yoKHU2MBi0QFjAIegQICBAB&url=https%3A%2F%2Fwww.who.int%2Fdocs%2Fdefault-source%2Fncds%2Fncd-covid-19%2Ffor-web---rapid-assessment---29-may-2020-(cleared).pdf%3Fsfvrsn%3D6296324c_8%26download%3Dtrue&usg=AOvVaw2fh7BVQyYEc4eozvMEaZxT> (2020).

129 Luyckx, V. A. Equity Is Key to Build Back Better after COVID-19: Prioritize Noncommunicable Diseases and Kidney Health. *Kidney360* **2**, 747-750, doi:https://doi.org/10.34067/KID.0006932020 (2021).

130 Vergano, M. *et al.* SIAARTI recommendations for the allocation of intensive care treatments in exceptional, resource-limited circumstances. *Minerva anestesiologica* **86**, 469-472, doi:10.23736/s0375-9393.20.14619-4 (2020).

131 Jobges, S., Vinay, R., Luyckx, V. A. & Biller-Andorno, N. Recommendations on COVID-19 triage: international comparison and ethical analysis. *Bioethics* **34**, 948-959, doi:10.1111/bioe.12805 (2020).

132 Moosa, M. R. & Luyckx, V. A. The realities of rationing in health care. *Nat Rev Nephrol* **17**, 435-436, doi:10.1038/s41581-021-00404-8 (2021).

133 Robert, R. *et al.* Ethical dilemmas due to the Covid-19 pandemic. *Ann Intensive Care* **10**, 84, doi:10.1186/s13613-020-00702-7 (2020).

134 White, D. B. & Lo, B. A Framework for Rationing Ventilators and Critical Care Beds During the COVID-19 Pandemic. *Jama*, doi:10.1001/jama.2020.5046 (2020).

135 Butler, C. R., Wong, S. P. Y., Wightman, A. G. & O'Hare, A. M. US Clinicians' Experiences and Perspectives on Resource Limitation and Patient Care During the COVID-19 Pandemic. *JAMA Netw Open* **3**, e2027315, doi:10.1001/jamanetworkopen.2020.27315 (2020).

136 Stevens, J. S. *et al.* Dashboards to Facilitate Nephrology Disaster Planning in the COVID-19 Era. *Kidney Int Rep* **5**, 1298-1302, doi:10.1016/j.ekir.2020.06.033 (2020).

137 Norton, J. M. *et al.* Social Determinants of Racial Disparities in CKD. *J Am Soc Nephrol* **27**, 2576-2595, doi:10.1681/ASN.2016010027 (2016).

138 Adapa, S. *et al.* COVID-19 and renal failure: challenges in the delivery of renal replacement therapy. *Journal of clinical medicine research* **12**, 276 (2020).
139 Hopman, J., Allegranzi, B. & Mehtar, S. Managing COVID-19 in low-and middle-income countries. *Jama* **323**, 1549-1550 (2020).
140 Tannor, E. K. *et al.* The COVID-19 pandemic identifies significant global inequities in hemodialysis care in Low and Lower Middle-Income countries - an ISN/DOPPS survey. *Kidney Int Rep*, doi:10.1016/j.ekir.2022.02.027 (2022).
141 Storeng, K. T., de Bengy Puyvallee, A. & Stein, F. COVAX and the rise of the 'super public private partnership' for global health. *Glob Public Health*, 1-17, doi:10.1080/17441692.2021.1987502 (2021).
142 Storeng, K. T., Stein, F. & de Bengy Puyvallee, A. COVAX and the many meanings of sharing. *BMJ Glob Health* **6**, doi:10.1136/bmjgh-2021-007763 (2021).
143 Binagwaho, A., Mathewos, K. & Davis, S. Equitable and Effective Distribution of the COVID-19 Vaccines - A Scientific and Moral Obligation. *Int J Health Policy Manag*, doi:10.34172/ijhpm.2021.49 (2021).
144 Plumb, L. A. *et al.* Associations between Deprivation, Geographic Location, and Access to Pediatric Kidney Care in the United Kingdom. *Clin J Am Soc Nephrol* **16**, 194-203, doi:10.2215/CJN.11020720 (2021).
145 Goldberg, A. M. & Bignall, O. N. R., 2nd. Mind the Gap: Acknowledging Deprivation Is Key to Narrowing Kidney Health Disparities in Both Children and Adults. *Clin J Am Soc Nephrol* **16**, 185-187, doi:10.2215/CJN.19321220 (2021).
146 Alfano, G. *et al.* Ethical challenges in managing unvaccinated patients receiving chronic in-centre haemodialysis. *Clinical Kidney Journal*, doi:10.1093/ckj/sfab276 (2021).
147 Taylor, A. L. *et al.* Solidarity in the wake of COVID-19: reimagining the International Health Regulations. *Lancet* **396**, 82-83, doi:10.1016/S0140-6736(20)31417-3 (2020).
148 Pivert, K. A. *et al.* Impact of the COVID-19 Pandemic on Nephrology Fellow Training and Well-Being in the United States: A National Survey. *J Am Soc Nephrol* **32**, 1236-1248, doi:10.1681/ASN.2020111636 (2021).
149 Selvaskandan, H. *et al.* Burnout and long COVID among the UK nephrology workforce: results from a national survey investigating the impact of COVID-19 on working lives. *Clin Kidney J* **15**, 517-526, doi:10.1093/ckj/sfab264 (2022).
150 Belfer, J. *et al.* The Effect of the COVID-19 Pandemic on Pediatric Physician Wellness: A Cross-Sectional Study. *Int J Environ Res Public Health* **19**, doi:10.3390/ijerph19063745 (2022).
151 Cunningham, A., Hung, W., Levin, A. & Jamal, A. Adapting Nephrology Training Curriculum in the Era of COVID-19. *Can J Kidney Health Dis* **8**, 2054358120988446, doi:10.1177/2054358120988446 (2021).
152 Al Jurdi, A. *et al.* Suboptimal antibody response against SARS-CoV-2 Omicron variant after third dose of mRNA vaccine in kidney transplant recipients. *Kidney Int* **101**, 1282-1286, doi:10.1016/j.kint.2022.04.009 (2022).
153 Angel-Korman, A. *et al.* Diminished and waning immunity to COVID-19 vaccination among hemodialysis patients in Israel: the case for a third vaccine dose. *Clin Kidney J* **15**, 226-234, doi:10.1093/ckj/sfab206 (2022).
154 Ashby, D. R. *et al.* Severity of COVID-19 after Vaccination among Hemodialysis Patients: An Observational Cohort Study. *Clin J Am Soc Nephrol* **17**, 843-850, doi:10.2215/CJN.16621221 (2022).
155 Benotmane, I. *et al.* A fourth dose of the mRNA-1273 SARS-CoV-2 vaccine improves serum neutralization against the Delta variant in kidney transplant recipients. *Kidney Int* **101**, 1073-1076, doi:10.1016/j.kint.2022.02.011 (2022).
156 Bensouna, I. *et al.* SARS-CoV-2 Antibody Response After a Third Dose of the BNT162b2 Vaccine in Patients Receiving Maintenance Hemodialysis or Peritoneal Dialysis. *Am J Kidney Dis* **79**, 185-192 e181, doi:10.1053/j.ajkd.2021.08.005 (2022).

157 Charmetant, X. *et al.* Infection or a third dose of mRNA vaccine elicits neutralizing antibody responses against SARS-CoV-2 in kidney transplant recipients. *Sci Transl Med* **14**, eabl6141, doi:10.1126/scitranslmed.abl6141 (2022).
158 Chavarot, N. *et al.* Weak antibody response to three doses of mRNA vaccine in kidney transplant recipients treated with belatacept. *Am J Transplant* **21**, 4043-4051, doi:10.1111/ajt.16814 (2021).
159 Espi, M. *et al.* A prospective observational study for justification, safety, and efficacy of a third dose of mRNA vaccine in patients receiving maintenance hemodialysis. *Kidney Int* **101**, 390-402, doi:10.1016/j.kint.2021.10.040 (2022).
160 Masset, C. *et al.* A fourth SARS-CoV-2 mRNA vaccine in strictly seronegative kidney transplant recipients. *Kidney Int* **101**, 825-826, doi:10.1016/j.kint.2022.01.017 (2022).
161 Oliver, M. J. *et al.* Vaccine Effectiveness Against SARS-CoV-2 Infection and Severe Outcomes in the Maintenance Dialysis Population in Ontario, Canada. *J Am Soc Nephrol* **33**, 839-849, doi:10.1681/ASN.2021091262 (2022).
162 Prendecki, M. *et al.* Immunological responses to SARS-CoV-2 vaccines in kidney transplant recipients. *Lancet* **398**, 1482-1484, doi:10.1016/S0140-6736(21)02096-1 (2021).
163 Reindl-Schwaighofer, R. *et al.* Comparison of SARS-CoV-2 Antibody Response 4 Weeks After Homologous vs Heterologous Third Vaccine Dose in Kidney Transplant Recipients: A Randomized Clinical Trial. *JAMA Intern Med* **182**, 165-171, doi:10.1001/jamainternmed.2021.7372 (2022).
164 Sanders, J. F. *et al.* The RECOVAC Immune-response Study: The Immunogenicity, Tolerability, and Safety of COVID-19 Vaccination in Patients With Chronic Kidney Disease, on Dialysis, or Living With a Kidney Transplant. *Transplantation*, doi:10.1097/TP.0000000000003983 (2021).
165 Sibbel, S. *et al.* Real-World Effectiveness and Immunogenicity of BNT162b2 and mRNA-1273 SARS-CoV-2 Vaccines in Patients on Hemodialysis. *J Am Soc Nephrol* **33**, 49-57, doi:10.1681/ASN.2021060778 (2022).
166 Smith, R. M. *et al.* SARS-COV-2 vaccine responses in renal patient populations. *BMC Nephrol* **23**, 199, doi:10.1186/s12882-022-02792-w (2022).
167 Stumpf, J. *et al.* Humoral and cellular immunity to SARS-CoV-2 vaccination in renal transplant versus dialysis patients: A prospective, multicenter observational study using mRNA-1273 or BNT162b2 mRNA vaccine. *Lancet Reg Health Eur* **9**, 100178, doi:10.1016/j.lanepe.2021.100178 (2021).
168 Floyd, L. *et al.* SARS-CoV-2 Vaccine Response in Patients With Antineutrophil Cytoplasmic Autoantibody-Associated Vasculitis. *Kidney Int Rep* **7**, 629-632, doi:10.1016/j.ekir.2021.12.004 (2022).
169 Prendecki, M. *et al.* Humoral and T-cell responses to SARS-CoV-2 vaccination in patients receiving immunosuppression. *Ann Rheum Dis* **80**, 1322-1329, doi:10.1136/annrheumdis-2021-220626 (2021).
170 Yahav, D. *et al.* Immune Response to Third Dose BNT162b2 COVID-19 Vaccine Among Kidney Transplant Recipients-A Prospective Study. *Transpl Int* **35**, 10204, doi:10.3389/ti.2022.10204 (2022).

**Table 1: Important studies with a focus on vaccine response after one, two and more COVID-19 vaccine doses.**

| Author | Population | Primary objective | Vaccine doses | Main outcomes | Risk factors |
|---|---|---|---|---|---|
| Al Jurdi A et al.[152] | Transplant: 51 | Anti-S levels/ Neutralizing antibody responses against variants of concers | 3 | -Anti-S leves were higher for wild-type (WT) SARS-CoV-2 compared with the omicron variant, and similar between WT and the delta variant<br>-The % of neutralization was lower for the omicron compared with the WT and delta variants | - Older age and steroid use: lower odds of developing neutralizing responses to WT and delta variant<br>- Belatacept use: lower odds of developing neutralizing responses to the delta variant |
| Angel-Korman A et al. [153] | Dialysis: 409<br>COVID-19 naive controls: 148 | Seroconversion rate; anti-S and neutralizing antibodies | 2 | Seroconversion<br>-Anti-S: 89% (69.6 versus 196.5)<br>Neutralizing antibodies: -77% (23.3 versus 222.7)*[1] | Dialysis: age, immunosuppression, low serum albumin, and low lymphocyte count, and time to sampling |
| Ashby DR et al.[154] | Dialysis: 1,323 COVID-19 cases | Effectiveness on the vaccine (hospitalization, death) | 2 | Outcome:<br>75% lower risk of admission<br>88% fewer deaths | No loss of protection in population over 65 years of age, increasing time since vaccination, and no difference between vaccine types |
| Benotmane I et al. [155] | Transplant: 77 patients | Response to 4$^{th}$ dose | 4 | - Anti-S titers increased from 13 to 112.5 BAUs/ml<br>- Neutralizing antibodies against the delta variant (increase from 16% to 66% after 4$^{th}$ dose) | Patients with undetectable neutralizing antibodies after the 3$^{rd}$ dose were less likely to have their neutralizing capacity increased after the 4$^{th}$ dose |
| Bensouna I et al.[156] | Dialysis: 69 | Effects of a 3$^{rd}$ dose on antibody levels | 3 | -Anti-S: from 284 (IQR 83-1,190) increase to 7,554 (IQR 2,268-11,736)<br>-1/3 seroconversion after 3$^{rd}$ dose<br>-1/12 “weak” responders remained below 50 AU/mL | Ratio increase of antibody titers after 3$^{rd}$ dose (>43; 7.5-43; <7.5):<br>- Low anti-S antibodies after 2$^{nd}$ dose (94 versus 347 versus 1,718 AU/mL)<br>- Interval between 2$^{nd}$ and 3$^{rd}$ doses (74 versus 73 versus 59 days) |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | - Ratio of antibodies after 3rd versus 2nd dose (99.9 versus 23.0 versus 1.6) |
| Brunelli S et al. [46] | Dialysis: 2,572 (BNT162b2); 2,572 (Ad26.COV2.S) | SARS-CoV-2 infection within six months after vaccination | 1+ | - COVID-19: 75 versus 83<br>- Hospitalizations: 36 versus 44<br>- Deaths: 5 versus 3<br>- Seroconversion (Ad26.COV2.S): 59.4% (244 patients) | - |
| Charmetant X et al.[157] | Transplant: 873 (137 group "infected"; 736 group vaccinated) | Re-infection, infection after mRNA-1273 | 2 (3) | - COVID-19: No symptomatic re-infection (n=137), symptomatic COVID-19 in 20 out of 736 vaccinated | - Vaccinated and infected patients: 14% detectable anti-S antibodies, and no sample indicated neutralization<br>- Non-responders received significantly higher doses of MMF<br>- A third vaccine dose led to an increase in % with an antibody response and 41% developed neutralizing antibodies |
| Chavarot N et al. [158] | Transplant: 62 belatacept-treated patients | Seroconversion rate | 3 | Seroconversion:<br>- 4 (6.4%) developed anti-S antibodies (with low antibody titers)<br>- 5 patients with prior infection mounted a strong antibody response | - |
| Espi M et al. [159] | Dialysis:<br>- 1,474 COVID-19 cases<br>- 75 patients with a 3rd dose | Rate of infection in unvaccinated, partially and fully vaccinated patients | 0-3 | - Infection incidence (France): 1.98% (unvaccinated), 0.65% (1st dose), 0.25% (2nd dose)<br>- Fatality rate: 11% (2 doses)<br>- Patients with low/no humoral response after 2 doses experienced a significant increase in anti-S antibodies (10.5 versus 353.1 BAU/mL) | Response to a 3rd dose more likely if presence of low titers of anti-S antibodies and spike-specific CD4+ T cell IGRA positive after 2nd dose |

| | | | | | |
|---|---|---|---|---|---|
| Garcia P et al. [47] | Dialysis:<br>- 2367 patients | Seroconversion rate | 1-2 | Fully vaccinated (day 14-28):<br>- No response (mRNA-1273: 2.6%; BNT162b2: 4.3%; Ad26.COV2.S: 58.4%)<br>Fully vaccinated (day 29-60):<br>- No response (mRNA-1273: 2.0%; BNT162b2: 4.0%; Ad26.COV2.S: 33.3%) | - Patients receiving Ad26.COV2.S had a higher likelihood of no seroconversion/no detectable or diminished IgG response<br>- Antibody positivity resulted in higher seroconversion rates, and better quantitative results |
| Masset C et al. [160] | Transplant:<br>- 49 (non-responders after 3 vaccine doses) | Seroconversion rate | 4 | 21 (42.8%) seroconverted after a 4$^{th}$ dose; with a median titer of 82 BAU/mL (four of them had a titer considered as neutralizing) | - No statistical significance, but higher response rates when lower steroid usage, less frequent lymphopenia, longer time between 3$^{rd}$ and 4$^{th}$ dose and use of BNT162b2 |
| Oliver MJ et al. [161] | Dialysis:<br>- 13,759 patients (2,403 unvaccinated) | SARS-CoV-2 infection, and severe outcomes (hospitalization, death) | 1 or 2 | 1 dose:<br>SARS-CoV-2 infection (HR 0.59);<br>Severe outcomes (HR 0.54)<br>2 doses:<br>SARS-CoV-2 infection (HR 0.31),<br>Severe outcomes (HR 0.17) | No significant differences in vaccine effectiveness among age groups, dialysis modality, or vaccine type |
| Prendecki M et al. [162] | Transplant:<br>- 920 patients (previous infection in 152 (17%) | Seroconversion rate | 2 | - Seroconversion occurred in 269 (66%) receiving BNT162b2 (median antibody level 58 BAU/mL)<br>- Seroconversion occurred in 156 (44%) receiving ChAdOx1-nCoV19 (median antibody level 7.1 BAU/mL)<br>- Negative seroconversion in only 8/152 (5%) of patients with previous infection | - Tacrolimus monotherapy associated with seroconversion<br>- Vaccination with BNT162b2 (as opposed to ChAdOx1-nCoV19<br>- Reduced likelihood if transplanted less than a year ago and with a diagnosis of diabetes |
| Reindl-Schwaighofer et al. [163] | Transplant:<br>- 197 patients with no | Seroconversion rate | 3 | - 76 patients (39%) with seroconversion | - Patients not on triple-maintenance immunosuppression had |

| | | | | | |
|---|---|---|---|---|---|
| | response to 2 doses of mRNA vaccine | | | - 35% (mRNA vaccine)<br>- 42% Ad26.COV2.S<br>- Only 22% with functional neutralizing capacity | higher chance of seroconversion<br>- Lower TTV level were associated with response<br>- Longer time since last kidney transplant |
| Sanders JSF et al. [164] | - CKD stages 4/5: 162<br>- Dialysis: 159<br>- Transplant: 288<br>- Controls: 191 | Seroconversion rate | 2 | - CKD stages 4/5: 100% (2405 BAU/mL)<br>- Dialysis: 99.4% (PD 100%) (1650 BAU/mL)<br>- Transplant: 56.9% (25 BAU/mL)<br>- Controls: 100% (3186 BAU/mL) | - Transplant: higher age, lower lymphocyte count, lower eGFR, not using steroids, shorter time after transplantation, and the use of MMF/MPA |
| Sibbel S et al. [165] | Dialysis: 35206 patients (12169 BNT162b2, 23037 mRNA-1273) and matched unvaccinated controls (44377 and 64243) | Vaccine effectiveness | 1-2 | - BNT162b2 and mRNA-1273 (COVID-19 free survival after 1st dose, vs. unvaccinated): d1-21, d22-42, and d≥43 HR 0.83/0.96, 0.61/0.51 and 0.22/0.27<br>- BNT162b2 and mRNA-1273 (hospitalization vs. unvaccinated): 28.0%/37.2% vs. 43.4%/45.6%<br>- BNT162b2 and mRNA-1273 (mortality vs. unvaccinated): 4.2%/5.6% vs. 12.1%/14.5% | - |
| Smith RM et al[166] | Dialysis: 260<br>Transplant: 209<br>Autoimmune disease: 223<br>Healthy controls: 144 | Seroconversion rate | 2 | Seroconversion:<br>-Dialysis: 96%<br>-Transplant: 52%<br>Autoimmune patients: 70%<br>Healthy controls: 100% | Poor response predictors:<br>Transplant: Triple immunosuppression; MMF<br>Autoimmune patients: RTX within 12 months; immunosuppression with eGFR 15-29 ml/min/1.73 $m^2$ |
| Stumpf J et al. [167] | Dialysis: 1135 (humoral)*, 119 (cellular)<br>Transplant: 333 (humoral)*, 124 (cellular) | Seroconversion rate; cellular response | 2 | Seroconversion:<br>-Dialysis: 1083 (95.3%)<br>-Transplant: 140 (42%)<br>Cellular response: | - Dialysis: time on dialysis, immunosuppression, vaccine type (mRNA-1273 > BNT162b2)<br>- Transplant: age (per year), time (after transplantation), number |

| | | | | | |
|---|---|---|---|---|---|
| | | | | - Dialysis: 93 (78.2%)<br>- Transplant: 37 (29.8%) | of immunosuppressive drugs, vaccine type (mRNA-1273 > BNT162b2), immunosuppression: CNI, MMF/MPA, belatacept |
| Floyd L et al. [168] | ANCA-associated vasculitis:<br>- 159 patients | Seroconversion rate | 2 | - 87 (55%) with detectable antibodies | - The use of rituximab was associated with poor humoral response and the absence of anti-S antibodies, especially in those treated within 6 months before the first vaccine dose<br>- CD19 reconstitution associated with the likelihood. Of a positive humoral vaccine response |
| Prendecki M et al. [169] | - Mixed cohort (AAV/anti-GBM, podocytopathy, membranous nephropathy, SLE, and others (n=4): 119 patients | Seroconversion rate; T cell response | 2 | - 54/91 (59.3%) with detectable antibodies<br>- 42/50 (84%) had a detectable T cell response | - ChAdOx1-nCoV19 and increasing age associated with lower seroconversion rate (rituximab users)<br>- B cell depletion at the time of vaccination associated with lower seroconversion rate<br>- Age associated with absence of T cell response<br>- The magnitude of response was lower in tacrolimus users |
| Yahav D et al.[170] | Transplant: 190 patients | Seroconversion rate; cellular response (in 53 patients) | 3 | - 133/190 (70%) seropositive, 70/190 (37%) after 2nd dose<br>- T-cell response in 7/53 (13%) | Factors associated with seropositivity:<br>- Higher antibody levels after the 2nd dose<br>- Discontinuation of antimetabolite prior to vaccination |

* 8 weeks after first vaccination (5 weeks after 2nd dose of BNT162b2, and 4 weeks after 2nd dose of mRNA-1273)

*1 Comparison of hemodialysis patients compared to COVID-19 naïve controls, and age was significantly different (71.9 years versus 48.5 years)

**Table 2: Challenges and missed opportunities in managing patients with kidney disease during the COVID-19 pandemic**

| Cohort type | Challenges | Solutions | Actions required |
|---|---|---|---|
| Acute kidney injury (AKI) | Increased demand for bedside dialysis and CRRT. Shortage of dialysis solutions and workforce | Organization of multidisciplinary crisis team to include nephrologists, nurses and hospital administrators.<br>Taking inventory of all aspects of RRT<br>Tracking daily need for RRT<br>Modification of HD and CRRT protocols to meet increased demand<br>Utility of acute PD<br>Redeployment of faculty, trainees and nurses to meet needs | Develop a framework for addressing system capacity, challenges in communication and allocating resources founded on ethical principles<br>Educate patients about AKI and risks |

| | | | |
|---|---|---|---|
| Chronic kidney disease (CKD) | Interruption of new consultations and follow up care<br>Laboratory monitoring of CKD<br>Limited pre-dialysis access care due to the pandemic<br>Lack of data on therapeutics and vaccine response in the CKD population | Adoption of telemedicine for all except urgent cases requiring in-person evaluation<br>Restrict laboratory tests to those with rapid turnaround for clinical care and using non-hospital-based labs for blood draw<br>Home urine dipstick monitoring<br>Include vascular access surgeries and PD catheter placement among essential procedures during a pandemic | Evaluate disparities in digital literacy and establish a protocol to include telemedicine navigators to facilitate telemedicine<br>Advocacy for inclusion of CKD cohort in clinical trials of therapeutics and vaccines |

| | | | |
|---|---|---|---|
| End stage kidney disease (ESKD) patients on maintenance dialysis | Safe continuation of thrice weekly in-center dialysis<br>Training for home dialysis modalities<br>Longitudinal care for home dialysis patients<br>Delay in dialysis access placement<br>Delays in transplant evaluation and placement on wait list<br>Lack of data on therapeutics and vaccine response in the CKD population | Protocol for symptom screening for infection and universal masking<br>Cohorting infected patients in designated COVID units. Wider adoption of home dialysis modalities<br>Conversion from in-person to televisit for in-center and home dialysis patients<br>Inclusion of dialysis access as an essential procedure<br>Reduction of dialysis sessions to twice a week<br>Conversion to home dialysis | Universal viral testing for symptomatic in-center dialysis patients<br>Stock-piling of emergency medical equipment and dialysis supplies<br>Adoption of assisted peritoneal dialysis and home hemodialysis.<br>Development of algorithms to accelerate evaluation and placement of medically stable on wait list<br>Inclusion of ESKD patients in clinical trials of therapeutics and vaccines |

| | | | |
|---|---|---|---|
| | | | |
| Kidney transplant recipients | Strategies to reduce risk of infection<br>Continuation of evaluation for transplant candidacy<br>Continuation of transplant surgeries<br>Evaluating vaccine efficacy | Adoption of telemedicine and remote monitoring<br>Suspension of live donation and decrease in DDKT<br>Vaccine prioritization, booster doses, vaccination of household contacts | Leveraging health care technology to aid remote monitoring of vital signs and glucose<br>Algorithm for individualized approach to continuing transplant surgery<br>Strategies to enhance vaccine efficacy |
| Immune mediated kidney disease | Strategies to reduce risk of infection<br>Identifying immunosuppressive classes associated with increased risk of infection | Adoption of telemedicine and remote monitoring<br>Decrease in frequency of laboratory monitoring | Leveraging health care technology to aid remote monitoring of disease activity and adoption of urine dipstick monitoring<br>Comparing utility of non-invasive disease |

| | | | |
|---|---|---|---|
| | Evaluating vaccine efficacy | Delaying use of biologics in stable patients<br>Vaccine prioritization, booster doses, vaccination of household contacts | biomarkers and kidney biopsy for glomerular diseases<br>Algorithms to personalize maintenance immunosuppressive therapy for relapsing diseases<br>Strategies to enhance vaccine efficacy |
| Children living with kidney disease | Interruption of follow up care for CKD<br>Continuation of transplant surgeries<br>Lack of data on therapeutics and vaccine response in the CKD population | Adoption of telemedicine and remote monitoring<br>Suspension of live donation | Wider adoption of home dialysis<br>Strategies to address caregiver burden<br>Inclusion of children in clinical trials and prioritization of high-risk groups for vaccines.<br>Research to study the kidney health |

| | | | |
|---|---|---|---|
| | Psychologic impact of isolation and shielding<br>Caregiver burden | | and cardiovascular consequences of the pandemic<br>Address pediatric health equity through research and public policy<br>Ensuring resources to maintain critical services for children on dialysis<br>Utilizing patient-reported outcomes along with relevant health measures |

**Acknowledgements and disclosures:**

Duvuru Geetha: Consultant to ChemoCentryx, Aurinia Inc and GSK. Support from the Johns Hopkins Center for Innovative Medicine

Andreas Kronbichler: consultant Vifor, Otsuka, Delta4, Catalyst Biosciences and UriSalt and funding from Vifor and Otsuka. No relevant CoIs.

Megan Rutter: funded by a Versus Arthritis Clinical Research Fellowship. No other COI to declare

Divya Bajpai: None

Steven Menez: none

Annemarie Wibenbacher: none

Shuchi Anand: Grant from the National Institute of Diabetes and Digestive and Kidney Diseases (R01DK127138). Ascend Clinical Laboratory funded sample testing for Dr. Anand's work on SARS-CoV-2 seroepidemiology among patients on dialysis.

Eugene Lin: Cconsulting fee from Acumen, LLC, a federal contractor. Funding from National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) K08 DK118213 and from the University Kidney Research Organization.

NicholasCarlson: Lecture fees Bristol Myers Squibb. Funding sources: The Danish Heart Foundation

Steve Sozio: none

Kevin Fowler: none

Ray Bignall: none

Kathryn Ducharlet: none

Elliot Koranteng Tannor: none

Eranga Sanjeewa Wijewikrama: none

Muhammad Iqbal Abdul Hafiz: none

Vladimir Tesar: Consultant for Abbvie, Amgen, Baxter, Bayer,Boehringer Ingelheim, Calliditas, ChemoCentryx, and Fresenius Medical Care, Omeros, and Travere; speaker bureaus for Bayer and Boehringer Ingelheim; and receiving travel expenses for AbbVie.

Robert Hoover: none

Deidra Crews: supported by grant 1 K24 HL148181 from the National Heart, Lung and Blood Institute, National Institutes of Health. Reports receiving research grant funding from Somatus Medical, Inc. and Baxter International, for unrelated work.'

Chuck Varnell: none

Lara Danzinger-Isakow: none

Vivekananda Jha: Grant funding from GSK, Baxter Healthcare, and Biocon and honoraria from Bayer, AstraZeneca, Boehringer Ingelheim, NephroPlus and Zydus Cadilla, under the policy of all monies being paid to the organization

Sumit Mohan: grants from the NIH (DK126739, DK114893, DK130058, MD014161, DK116066) and the Kidney Transplant collaborative as well as personal fees from Kidney International Reports and HSAG, outside the submitted work.

Dr. Parikh is a member of the advisory board of and owns equity in RenalytixAI. He also serves as a consultant for Genfit and Novartis.Dr. Parikh is supported by NIH grants R01HL085757, UH3DK114866, U01DK106962 and R01DK093770

Valerie Luyckx: None. Funding from Swiss Kidney Foundation

1086

1087

1088

1089

1090

1091

1092

1093

1094