Clinical Course of SARS-CoV-2 Infection in Adults with ESKD Receiving Outpatient Hemodialysis

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Key Points

• Patients with ESKD on dialysis had persistent and intermittently positive RT-PCR tests for severe acute respiratory syndrome coronavirus 2.
• Evidence for presence of infectious virus was lacking in most cases.
• A symptom-based approach, instead of a test-based approach, should be used to decide when to discontinue transmission-based precautions.

Abstract

Background Patients with ESKD on maintenance dialysis receive dialysis in common spaces with other patients and have a higher risk of severe SARS-CoV-2 infections. They may have persistently or intermittently positive SARS-CoV-2 RT-PCR tests after infection. We describe the clinical course of SARS-CoV-2 infection and the serologic response in a convenience sample of patients with ESKD to understand the duration of infectivity.

Methods From August to November 2020, we enrolled patients on maintenance dialysis with SARS-CoV-2 infections from outpatient dialysis facilities in Atlanta, Georgia. We followed participants for approximately 42 days. We assessed COVID-19 symptoms and collected specimens. Oropharyngeal (OP), anterior nasal (AN), and saliva (SA) specimens were tested for the presence of SARS-CoV-2 RNA, using RT-PCR, and sent for viral culture. Serology, including neutralizing antibodies, was measured in blood specimens.

Results Fifteen participants, with a median age of 58 (range, 37–77) years, were enrolled. Median duration of RT-PCR positivity from diagnosis was 18 days (interquartile range [IQR], 8–24 days). Ten participants had at least one, for a total of 41, positive RT-PCR specimens ≥10 days after symptoms onset. Of these 41 specimens, 21 underwent viral culture; one (5%) was positive 14 days after symptom onset. Thirteen participants developed SARS-CoV-2-specific antibodies, 11 of which included neutralizing antibodies. RT-PCRs remained positive after seroconversion in eight participants and after detection of neutralizing antibodies in four participants; however, all of these samples were culture negative.

Conclusions Patients with ESKD on maintenance dialysis remained persistently and intermittently SARS-CoV-2–RT-PCR positive. However, of the 15 participants, only one had infectious virus, on day 14 after symptom onset. Most participants mounted an antibody response, including neutralizing antibodies. Participants continued having RT-PCR–positive results in the presence of SARS-CoV-2-specific antibodies, but without replication-competent virus detected.

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Introduction
Participants with ESKD receiving in-center hemodialysis typically undergo dialysis three times a week in close proximity to other patients. Individuals with ESKD have been observed to have a higher risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, with high rates of hospitalization and mortality (1–3).

Case series have documented that patients with ESKD on maintenance dialysis diagnosed with SARS-CoV-2 infection can have persistently or intermittently positive SARS-CoV-2 real-time RT-PCR tests after recovery, but the significance of these findings is not well understood (4–6). In other populations, the significance of persistently positive RT-PCR results and the duration of shedding viable (i.e., infectious) virus has been described (7–9). Specifically, in a cohort of hospitalized patients with coronavirus disease 2019 (COVID-19), the median duration of shedding viable virus from symptom onset was 7 days (95% CI, 5 to 10 days) (7); whereas, in patients with severe immunosuppression after undergoing hematopoietic stem-cell transplantation or receiving cellular therapies, shedding viable virus occurred for at least 2 months after symptom onset (8). Although a positive RT-PCR test is a measure of viral shedding, the test cannot differentiate infective from inactive virus (10).

Studies have shown that patients with ESKD on maintenance dialysis mount an antibody response to SARS-CoV-2 infection (11,12). However, little is known about the clinical significance of detected SARS-CoV-2 antibodies in this population and how they may relate to shedding viable virus (13).

Centers for Disease Control and Prevention (CDC) guidance recommends using a symptom-based strategy to discontinue transmission-based precautions (TBP) in patients with SARS-CoV-2 infection (14). This strategy takes into account the time period since symptoms first appeared and whether symptoms are improving, patient’s immune status, and severity of illness. In contrast, a test-based strategy (TBS) requires two consecutive negative respiratory specimens collected ≥24 hours apart, in addition to the resolution of fever and improvement of symptoms, and has limited utility in most situations because many individuals will have prolonged shedding. A TBS could be considered for some patients (e.g., those who are severely immunocompromised) in consultation with an infectious disease expert if concerns exist for the patient being infectious for >20 days.

We describe the clinical course of SARS-CoV-2 infection in a convenience sample of patients with ESKD on maintenance dialysis to better understand the duration of infectivity and serologic response in this population.

Materials and Methods
Setting, Participant Identification, and Participant Enrollment
This assessment was conducted in collaboration with three dialysis providers in the Atlanta metropolitan area. Enrollment occurred from August 29, 2020 to November 14, 2020. Participating dialysis facilities identified potentially eligible patients who agreed to discuss enrollment with CDC, and CDC staff subsequently verified that enrollment criteria were met. Eligible patients included those with SARS-CoV-2 infection diagnosed by RT-PCR or antigen test who met criteria to be included in one of the following groups: group 1, diagnosis of SARS-CoV-2 infection ≤5 days before enrollment; group 2, diagnosis of SARS-CoV-2 infection 6–15 days before enrollment; and group 3, diagnosis of SARS-CoV-2 infection >15 days before enrollment and evidence of recent RT-PCR positivity (i.e., positive RT-PCR ≤5 days of enrollment). These groups were identified a priori to account for enrolling patients at different time points after diagnosis (e.g., patients who were hospitalized after diagnosis would not be immediately available to enroll) and to ensure that we were not enrolling patients when it was unlikely they would have positive RT-PCRs. We excluded patients who were not on dialysis before COVID-19 diagnosis, those who were unable to provide informed consent, or patients who were medically unstable. We enrolled a convenience sample of patients diagnosed with SARS-CoV-2 infection. Participation was voluntary and participants provided written informed consent. This assessment was determined not to be human subjects research as part of public health response, consistent with applicable federal law and CDC policy (see, e.g., 45 Code of Federal Regulations part 46.102[j][2], 21 Code of Federal Regulations part 56; 42 US Code [U.S.C.] section 241[d]; 5 U.S.C. section 552a; 44 U.S.C. section 3501 et seq.).

Enrollment and Follow-Up Data Collection
Participants were assessed at the enrollment visit and then followed for up to nine visits over approximately 6 weeks. For the first 3 weeks, visits were performed twice per week and then weekly for 3 weeks. Assessments coincided with the patient’s scheduled dialysis treatments. Each visit included a questionnaire and collection of specimens. Questionnaires included data on demographics, dialysis history, comorbidities, exposures, symptoms, medications, laboratory test results, and hospitalizations, and were completed with information from patient interviews and review of medical records.

Collection of oropharyngeal (OP), anterior nasal (AN), and saliva (SA) specimens was attempted at enrollment and each visit; blood sample collection was attempted at five visits (enrollment, and visits 2, 4, 7 and 9). In the event of dialysis schedule changes or missed dialysis treatments, visits and scheduled sample collections were rescheduled when possible.

Definitions
Date of diagnosis was defined as the date of the first positive SARS-CoV-2 test, as reported by participating facilities. The date of symptom onset was the earliest date of COVID-19 symptoms obtained from participant interviews and medical records. Infectivity was defined as the isolation of replication-competent virus using cell culture (15). The opposite result, not recovering replication-competent virus, cannot be interpreted as not infectious. Using an adaptation of the CDC definition (14), severe to critical COVID-19 was defined as supplemental oxygen requirement or a diagnosis of respiratory failure, and mild to moderate COVID-19 as the absence of those criteria.
Participants for whom we did not have access to hospital records and other outpatient provider records were classified as having unknown COVID-19 severity. For each visit, a composite RT-PCR result was determined on the basis of available RT-PCR results from all samples collected at each visit (OP, AN, and SA). We defined RT-PCR results as positive if any specimen was RT-PCR positive, inconclusive if there were no positive RT-PCR results but at least one was inconclusive, and negative if all RT-PCRs were negative. Time to seroconversion was defined as time from diagnosis to first positive antibody. Because we did not begin testing for antibodies immediately after diagnosis for groups 2 and 3, time to seroconversion was described only for group 1.

Data Analysis
Data were summarized by measures of central tendency, frequencies, and proportions using SAS software version 9.4 (SAS Institute, Cary, NC).

Specimen Collection and Testing
OP and AN specimens with a positive RT-PCR result of a cycle threshold of ≤34 were submitted for viral culture. Because of the stabilizing solution in the OMNIgene kit, viral culture was not performed on SA (16). More information on specimen collection and testing is included in Supplemental Appendix 1.

Results
Fifteen patients with ESKD on maintenance dialysis were enrolled. The median age of participants was 58 years (range, 37–77); ten (67%) were male, 11 (73%) were Black, and two (13%) were Hispanic or Latino persons (Table 1). Thirteen (87%) participants had three or more comorbidities; hypertension (93%), diabetes (73%), and cardiovascular disease (73%) were the most frequent underlying conditions. Participants D and H had a history of kidney allograft failure and were taking immunosuppressive medications. Participant A had rheumatoid arthritis and was taking 5 mg/d prednisone (Figure 1A). Thirteen participants completed the assessment and two withdrew from the assessment (Supplemental Appendices 2 and 3).

COVID-19 severity was mild to moderate for four participants, severe to critical for six participants, and unknown for three participants; two participants were asymptomatic from diagnosis through the end of the assessment follow-up. Ten participants were hospitalized. On the basis of medical review, six hospitalizations were related to COVID-19, and there were insufficient records available to determine the reason for hospitalization for four participants. Two patients had admissions to the intensive care unit. No patient required mechanical ventilation, and no patient died. Among the 13 participants who were symptomatic, the most frequently reported symptoms were rhinorrhea (67%), diarrhea (67%), fatigue (53%), and cough (53%) (Table 1). The median duration of symptoms was 32 days (interquartile range [IQR], 23–51 days). Six (40%) participants reported having symptoms intermittently (Figure 1B).

Table 1. Demographics, clinical characteristics, and laboratory results of participants with ESKD on maintenance dialysis with SARS-CoV-2 infection (N=15)

| Characteristic                              | N (%) or Median (range) |
|---------------------------------------------|------------------------|
| Age, yr                                     | 58 (37–77)             |
| Male                                        | 10 (67)                |
| Race                                        |                        |
| Black                                       | 11 (73)                |
| White                                       | 3 (20)                 |
| All other races                             | 1 (7)                  |
| Hispanic or Latino ethnicity                | 2 (13)                 |
| Time on dialysis, yr                        | 3.6 (0.7–9.9)          |
| Comorbidities                               |                        |
| Three or more comorbidities                 | 13 (87)                |
| Hypertension                                | 14 (93)                |
| Diabetes                                    | 11 (73)                |
| Cardiovascular disease                      | 11 (73)                |
| Heart failure                               | 8 (53)                 |
| Coronary artery disease                     | 6 (40)                 |
| Cerebrovascular accident/stroke             | 1 (7)                  |
| Chronic lung disease                        | 3 (20)                 |
| Emphysema or chronic obstructive pulmonary disease | 2 (13)          |
| Asthma                                      | 1 (7)                  |
| Neurologic disease                          | 3 (20)                 |
| Immuno compromised condition                | 2 (13)                 |
| Cancer: current/in treatment or diagnosed in the last 12 months | 0 (0)            |
| History of solid organ transplant           | 2 (13)                 |
| Liver disease                               | 0 (0)                  |
| Symptoms consistent with COVID-19 during the clinical course |         |
| Any symptoms                                | 13 (87)                |
| Rhinorrhea                                  | 10 (67)                |
| Diarrhea                                    | 10 (67)                |
| Cough                                       | 8 (53)                 |
| Fatigue                                     | 8 (53)                 |
| Muscle aches                                | 7 (47)                 |
| Loss of taste                               | 7 (47)                 |
| Fever >38°C                                 | 6 (40)                 |
| Shortness of breath                         | 6 (40)                 |
| Chills                                      | 6 (40)                 |
| Headache                                    | 5 (33)                 |
| Nausea/vomiting                             | 4 (27)                 |
| Dizziness                                   | 4 (27)                 |
| Chest pain                                  | 4 (27)                 |
| Confusion/not thinking clearly              | 4 (27)                 |
| Abdominal pain                              | 4 (27)                 |
| Subjective fever                            | 4 (27)                 |
| Loss of smell                               | 3 (20)                 |
| Wheezing                                    | 3 (20)                 |
| Sore throat                                 | 2 (13)                 |
| Laboratory results of specimens collected during assessment | |
| At least one positive RT-PCR test           | 10 (67)                |
| during the assessment                       |                        |
| SARS-CoV-2–specific antibodies              | 13 (87)                |
| Neutralizing antibodies                     | 11 (73)                |

SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; COVID-19, coronavirus disease 2019.
SARS-CoV-2 RT-PCR and Viral Culture Results

Overall, 356 respiratory specimens were collected as part of the assessment: 121 (34%) AN, 118 (33%) OP, and 116 (33%) SA. One SA specimen was discarded due to leakage. Ten participants had a total of 59 RT-PCR-positive specimens: 24 AN, 19 OP, and 16 SA (Supplemental Figure 1); five participants did not have RT-PCR-positive specimens during enrollment and follow-up visits. Among the ten...
participants with RT-PCR-positive specimens, median duration of RT-PCR positivity from diagnosis was 18 days (IQR, 8–24 days), and from symptom onset was 17 days (IQR, 11–26 days). Ten participants (67%) had at least one RT-PCR-positive specimen ≥10 days after symptom onset (41 positive RT-PCRs total). Five (33%) participants had RT-PCR-positive results after having had negative results from previous visits (Figure 1A). Of the 41 RT-PCR-positive specimens detected ≥10 days after symptoms onset, 26 had cycle threshold values <34, and 21 (AN and OP) of the 26 underwent viral culture, with only one (5%) positive culture (participant G) (Figure 1A). The remaining five were SA specimens and were not sent for viral culture. Participant G had a history of diabetes, hypertension, and cardiovascular disease and no history of immunosuppressive medications. Participant G had mild to moderate disease and did not require hospitalization. Ten days before COVID-19 diagnosis, participant G developed runny nose, dizziness, and chills. Seven days after symptom onset, she developed diarrhea and, 14 days later, abdominal pain. The specimen with a positive culture was an AN specimen collected at enrollment, 4 days after diagnosis and 14 days after symptom onset; at that time the participant’s symptoms were improving but still present.

**SARS-CoV-2 Antibody Response**

A total of 67 blood specimens were collected from 15 participants; 13 (87%) participants had positive SARS-CoV-2-specific antibodies, and two participants (D and E) did not have documented seroconversion (Figure 1A). Participant D withdrew from the assessment after the enrollment visit. Participant E was initially diagnosed with a positive RT-PCR collected outside the dialysis facility. At enrollment and during follow-up, the participant reported no symptoms, and all specimens collected during this assessment were RT-PCR negative.
In group 1, median time to seroconversion was 14.5 days (IQR, 10.5–27 days). Among all participants, eight (53%) participants had 22 RT-PCR–positive specimens after appearance of antibodies with no positive viral cultures (Figure 1A). Among all participants, over the course of the assessment, IgM titers ranged from 104 to 272,882; IgG titers from 836 to 1,051,544; and IgA titers from 126 to 699,960 (Figures 2 and 3 and Supplemental Figure 2). Participant L received treatment for COVID-19 with convalescent plasma and Ig during the 2 days after diagnosis and had very high antibody titers (Figure 3 and Supplemental Figure 2).

Of the 13 participants with IgG antibodies, two participants (participants H and I) had no detectable IgA nor IgM and did not develop neutralizing antibodies. Participant H was on tacrolimus and mycophenolate for kidney allograft failure. Participant I had ESKD secondary to GN, hypertension, and no immunosuppressive conditions. The remaining 11 (85%) participants had surrogate neutralization activity (Figure 4). In group 1, median time to appearance of neutralizing antibody from diagnosis was 33 days (IQR, 24.5–41 days). Four (27%) participants had ten RT-PCR–positive specimens and no positive viral cultures after appearance of neutralizing antibodies (Figure 1B). Participants reported symptoms even after the appearance of SARS-CoV-2–specific antibodies, including neutralizing antibodies. Three out of four participants with mild to moderate illness and five out of six participants with severe to critical illness developed neutralizing antibodies. Neutralizing antibodies persisted until the end of follow-up visits in all 11 participants.

**Discussion**

This assessment shows that patients with ESKD on maintenance dialysis often had persistent or intermittently positive SARS-CoV-2 RT-PCR tests after recovery from clinical COVID-19 illness. However, of the ten participants who had positive RT-PCRs, we detected replication-competent virus in only one participant, on day 14 after symptom onset. Most participants mounted a SARS-CoV-2–specific antibody response, including developing neutralizing antibodies. Further, participants continued to have RT-PCR–positive specimens, despite the presence of SARS-CoV-2–specific antibodies, including neutralizing antibodies, but none of these antibody-positive participants had replication-competent virus. This suggests the presence of such antibodies may be a marker of noninfectivity. Other arms of the adaptive immune response are also activated at approximately the same time as antibody development; therefore, antibodies may not be solely responsible for patients no longer shedding culturable virus (17).

These findings are consistent with other publications specific to the outpatient dialysis population (4–6,11) that illustrate the frequency of persistently positive RT-PCR results after recovery and highlight the challenge of using RT-PCRs as a marker of infectivity. Small observational studies involving patients with ESKD on maintenance
dialysis with SARS-CoV-2 infection reported persistent viral RNA detected by RT-PCR 19–40 days from an initial positive test (5,6,11). However, to our knowledge, only Lacson et al. (4) performed viral culture to assess infectivity. In 45 specimens with positive SARS-CoV-2 molecular tests from 29 patients on in-center hemodialysis who were followed weekly after diagnosis, only two patients had positive viral cultures (4). One occurred in a patient who was asymptomatic 7 days after diagnosis, and the second occurred 29 days after diagnosis in a patient with diabetes and hypertension, demonstrating that isolating viable virus in patients with persistent positive RT-PCR tests is uncommon. Only one participant in our assessment, who had a history of kidney allograft failure and was taking immunosuppressive medications. Participant L received convalescent plasma and Ig in the first 2 days after diagnosis. Participants K withdrew before the end of the assessment. Participants D and E were excluded because they did not have documented seroconversion.

Figure 3. | Pan-Ig, IgA, IgG, and IgM antibody response to the SARS-CoV-2 spike protein per case-patient since diagnosis (N=13). Antibody to the SARS-CoV-2 spike protein was positive if ≥100 (1E2). All antibody results are displayed in this figure, including those that are not considered positive (i.e., <100). Day of diagnosis is displayed as day 0 in the x axis and represents the day of diagnosis recorded in the facility’s medical record (either RT-PCR or antigen test). Participant A had rheumatoid arthritis and was taking 5 mg/d prednisone. Participant H had a history of kidney allograft failure and was taking immunosuppressive medications. Participant L received convalescent plasma and Ig in the first 2 days after diagnosis. Participants K withdrew before the end of the assessment. Participants D and E were excluded because they did not have documented seroconversion.

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Current CDC guidance for discontinuation of TBP (14) supports the use of a symptom-based strategy over a TBS in most cases. Our findings highlight the potential challenges of a test-based approach in the dialysis population. A TBS alone can prolong the time that patients are isolated unnecessarily, which may have unintended consequences. Some dialysis facilities dialyze SARS-CoV-2–infected patients at dedicated locations (which may not be where these patients are routinely dialyzed), affecting the patient’s dialysis schedule, and possibly requiring significant resources to coordinate (e.g., transportation) and deliver patient care, including personnel protective equipment and healthcare personnel.

There is insufficient evidence in the dialysis population to determine the effect of underlying immunosuppression on the duration of TBP. In the current CDC guidance for discontinuation of TBP (14), patients with ESKD are not classified as severely immunocompromised, meaning that TBP can be discontinued in patients with ESKD with mild to moderate illness 10 days after symptom onset, and 10–20 days after symptom onset in those with severe illness, if symptoms have improved and at least 24 hours have passed since the last fever without the use of fever-reducing medications (14). Our findings and those from Lacson et al.’s (4) study suggest that a small number of patients with ESKD continue shedding viable virus for a
longer period of time, suggesting that applying the TBP guidance for patients with severe illness or those who are severely immunocompromised (i.e., remain in TBP for up to 20 days) for all patients with ESKD could be reasonable. In many cases, using a symptom-based strategy can allow patients to return to their normal dialysis schedule more quickly than a TBS. However, successful implementation of the symptom-based strategy requires a clinical evaluation to determine if the patient’s symptoms are improving. In our assessment, some participants’ symptoms persisted after seroconversion and were not always associated with RT-PCR–positive results. Several symptoms of COVID-19 overlap with symptoms of advanced kidney disease (19), making it difficult to interpret whether they are related to COVID-19. It is critical that clinicians and nephrologists support the frontline staff by helping to determine when symptoms are improving and the criteria for discontinuation of TBP are met. Further, the single case with a positive culture highlights the importance of dialysis facilities having robust infection prevention and control practices and promoting COVID-19 vaccination to reduce intrafacility transmission when patients with SARS-CoV-2 infection are no longer under TBP.

Most participants mounted an antibody response to their SARS-CoV-2 infection. The median time to first positive antibody detection was 14.5 days after diagnosis, comparable with persons who are immunocompetent (20). Similarly, the persistence of IgG antibodies over time, and the decrease in IgM titers in most cases in the first month after diagnosis, was consistent with the findings in the general population (21). One patient was asymptomatic throughout the duration of the assessment and had no antibody response 5 weeks from diagnosis. This could represent a false positive initial RT-PCR test (22) or a patient who did not develop an antibody response after an asymptomatic SARS-CoV-2 infection (21).

Among participants who developed antibodies, most also developed neutralizing antibodies that remained positive at the end of the assessment. These findings are consistent with other studies that demonstrated little or no decrease in neutralizing antibodies titers at 75 days after symptom onset (22). The lack of neutralizing antibodies in participant H could be explained by immunosuppressive medications (12). Participant I’s lack of neutralizing antibodies may be due to mild COVID-19 disease and a less robust antibody response, as indicated by lower antibody titers. The magnitude of the antibody response has been associated with the severity of the disease, because some patients with mild infection have less immune response and do not develop detectable neutralizing antibodies (23).

IgA antibodies are important for mucosal immunity, although their clinical significance in SARS-CoV-2 infection is still to be determined (21). A study suggested that patients who did not mount an IgA response, but mounted an IgM response, also developed neutralizing antibodies.
(24). This is consistent with our findings that showed that all patients with either IgA response or lacking IgA but with IgM response developed neutralizing antibodies, whereas those without an IgA or IgM response did not develop neutralizing antibodies.

Even when RT-PCR-positive specimens were detected after developing SARS-CoV-2-specific antibodies, no culture was positive. This finding has already been described in the nursing home population (25) and in patients hospitalized with COVID-19, in whom the shedding of infectious virus dropped rapidly to undetectable levels upon seroconversion (26). More studies are needed to better understand whether positive serology correlates with negative viral cultures, and the role that the presence of SARS-CoV-2-specific antibodies could play as a marker of noninfectivity.

Our assessment has several limitations. First, we used a convenience sample of patients with ESKD who agreed to participate, and the number of participants was small; therefore, the findings may not be representative of or generalizable to all patients with ESKD receiving maintenance dialysis. It is possible that we missed patients with characteristics that would affect duration of infectivity and humoral immune response. Second, we enrolled patients at different times during their course of infection, and, in many instances, we missed the initial phase of the infection. Because we did not begin testing for antibodies immediately after diagnosis for groups 2 and 3, we are unable to describe timing to seroconversion in those groups. Third, patient recall bias may have prevented precise recording and interpretation of the presence and duration of symptoms. The study team had limited access to medical records and were not always able to obtain complete information from patients. Finally, a positive viral culture was interpreted as a proxy for infectivity. Although positive virus isolation implies infectiousness, the inability to isolate the virus does not mean that an individual is not infectious. Viral load, limit of detection, and type of cell line used can affect the detection of replication-competent virus in cell culture (25).

Our findings affirm that patients with ESKD on maintenance dialysis commonly have persistently and intermittently positive SARS-CoV-2 RT-PCR results; however, evidence for presence of infectious virus was lacking in most cases in this small convenience sample. In our cohort, patients continued to have positive SARS-CoV-2 RT-PCR results but without replication-competent virus after seroconversion and the appearance of neutralizing antibodies, indicating the antibody response may be a marker of noninfectivity. In the context of current evidence, these results support the use of a symptom-based approach over the test-based approach to discontinue TBP (14) in patients on dialysis. These findings also highlight the importance of dialysis facilities having a process to assess patient symptoms when deciding when to discontinue TBP, robust infection prevention and control practices, and promotion of COVID-19 vaccination for patients and dialysis staff to reduce intrafacility transmission of SARS-CoV-2 infection.

Disclosures
I. Apat reports having consultancy agreements with the CDC. L. S. Dalrymple reports having ownership interest in Fresenius Medical Care (via share options) and owning stock in GE; serving as a member of the Kidney Care Quality Alliance Steering Committee, cochair of the Kidney Health Initiative (KHI) ESRD Global Data Standard Workgroup, and cochair of the National Quality Forum Renal Standing Committee; and serving on the Kidney Medicine editorial board. L. S. Dalrymple also reports her husband owned stock in Bayer, CVS, and GE in the last 36 months, and has shares in The Permanente Medical Group. P. R. Patel reports having other interests in/relationships with American Association of Kidney Patients. R. L. Wingard reports having ownership interest in Fresenius Medical Care North America (via stock options), serving as a member of the KHI Muscle Cramping PRO Project, and serving as a volunteer for Welcome Home of Chattanooga (a nonprofit). All remaining authors have nothing to disclose.

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Author Contributions
J. Alvarez, I. Apat, A.C. Bardossy, E. Beshearse, N.E. Brown, L.S. Dalrymple, J.M. Folster, P. Gable, C. Grate, A.S.L. Halpin, A.C. Hernandez-Romieu, C. Herzog, M. Hudson, P.K. Kutty, J. Lea, A. K. Lyons, S. Novosad, R. Overton, P.R. Patel, K. Roman, S. Sabour, S. Schatzman, E. Soda, N.J. Thornburg, K. Varela, M.K. Weng, and R.L. Wingard were responsible for investigation; I. Apat, A.C. Bardossy, A.C. Brown, L.S. Dalrymple, J.M. Folster, P. Gable, A.S.L. Halpin, C. Herzog, L. Korhonen, P.K. Kutty, J. Lea, L.C. McDonald, S. Novosad, S. Sabour, E. Soda, N.J. Thornburg, M. Tobin-D’Angelo, and R.L. Wingard were responsible for methodology; I. Apat, A.C. Bardossy, A.C. Brown, P. Gable, P.K. Kutty, L.C. McDonald, and S. Novosad conceptualized the study; A.C. Bardossy, E. Beshearse, C. Herzog, S. Novosad, and K. Varela were responsible for project administration; A.C. Bardossy, A.C. Brown, L. Korhonen, P.K. Kutty, and S. Novosad were responsible for visualization; A.C. Bardossy, N.E. Brown, L. Korhonen, and S. Novosad were responsible for formal analysis; A.C. Bardossy, P. Gable, A.S.L. Halpin, L. Korhonen, S. Novosad, S. Schatzman, and N.J. Thornburg were responsible for data curation; A.C. Bardossy, L. Korhonen, and S. Novosad wrote the original draft; A.C. Bardossy and N.J. Thornburg were responsible for validation; P.K. Kutty and S. Novosad provided supervision; and all authors reviewed and edited the manuscript.

Supplemental Material
This article contains the following supplemental material online at http://kidney360.asnjournals.org/lookup/suppl/doi:10.34067/KID.0004372021/-/DCSupplemental.

Supplemental Appendix 1. Supplemental methods.
Supplemental Appendix 2. Supplemental results.
Supplemental Appendix 3. Supplemental references.
Supplemental Figure 1. RT-PCR Cycle threshold (Ct) values per specimen type over time from end-stage renal disease (ESRD) participants on maintenance dialysis with SARS-CoV-2 infection (N=59 specimens).

Supplemental Figure 2. Detection of SARS-CoV-2 IgM, IgG and IgA antibody titers among participants with positive antibodies (N=13) since diagnosis.

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