SARS-CoV-2 Infection Risk Factors among Maintenance Hemodialysis Patients and Health Care Personnel In Outpatient Hemodialysis Centers

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Key Points
- Increased risk of SARS-CoV-2 infection was associated with community prevalence.
- Increased risk of SARS-CoV-2 infection was associated with exposure to infected family members and personal infection prevention measures.

Materials and Methods
This study was conducted in three outpatient HD units at Washington University School of Medicine (WUSM) in St. Louis, Missouri and was approved by the WUSM Human Research Protection Office. Adult patients on in-center HD and dialysis center HCPs were enrolled after obtaining informed consent. During September 2020, a survey was administered to patients and HCPs to assess household characteristics, SARS-CoV-2 exposures, personal prevention activities, and history of SARS-CoV-2 infection since March 1, 2020. Previous exposure to SARS-CoV-2 was assessed using the Abbott SARS-CoV-2 IgG serologic assay that targets the viral nucleocapsid protein (Abbott, Abbott Park, IL). The result unit for the SARS-CoV-2 IgG assay is index (signal/calibrator), and a value of ≥1.40 index (signal/calibrator) is considered as positive. The sensitivity and specificity of the Abbott assay are approximately 90%–99% and >99%, respectively (7,8).

Electronic medical records of patients from March through September 2020 were reviewed to obtain relevant clinical information, including dates of SARS-CoV-2 PCR test(s), hospitalizations due to SARS-CoV-2 infection, and comorbid conditions. Cumulative SARS-CoV-2 cases per 1000 population by zip code through the first week of September were obtained from St. Louis University’s Missouri COVID-19 Tracking Project GitHub data repository (https://github.com/slu-openGIS/MO_HEALTH_Covid_Tracking.git) and the Illinois Department of Public Health COVID-19 dashboard (https://www.dph.illinois.gov/covid19/covid19-statistics).

For study purposes, a SARS-CoV-2 case was defined as either history of a positive PCR test.
Table 1. Univariate analysis of characteristics of patients on hemodialysis who tested positive or negative for severe acute respiratory syndrome coronavirus 2 infection

| Variable                                      | Severe Acute Respiratory Syndrome Coronavirus 2-Infected | Noncase, N=205 (91%) | P Value (Mann–Whitney U Test or Fisher Exact) |
|------------------------------------------------|---------------------------------------------------------|-----------------------|-----------------------------------------------|
| Demographics                                   |                                                         |                       |                                               |
| Women                                          | 11 (52.4)                                               | 106 (51.7)            | >0.99                                         |
| Age, median [IQR], yr                          | 54 [47–64]                                              | 60 [49–69]            | 0.08                                          |
| Age (>65 yr)                                   | 4 (19.0)                                                | 71 (34.6)             | 0.22                                          |
| Race (Black)                                   | 18 (85.7)                                               | 179 (87.3)            | 0.74                                          |
| BMI, median [IQR], kg/m²                       | 32.7 [24.6–37.8]                                        | 29.13 [25.2–35.6]     | 0.73                                          |
| Hemodialysis unit                              |                                                         |                       |                                               |
| Facility A                                     | 11 (52.5)                                               | 91 (44.4)             | Reference                                     |
| Facility B                                     | 5 (23.8)                                                | 90 (43.9)             | 0.20                                          |
| Facility C                                     | 5 (23.8)                                                | 24 (11.7)             | 0.35                                          |
| Transportation to and from the hemodialysis unit|                                                         |                       |                                               |
| By private car (self or family member/friend)  | 11 (52.4)                                               | 111 (54.1)            | >0.99                                         |
| By public transportation                       | 1 (4.8)                                                 | 38 (18.5)             | 0.14                                          |
| By medical transport company                   | 9 (42.8)                                                | 55 (26.8)             | 0.13                                          |
| Cause of ESKD                                  |                                                         |                       |                                               |
| Diabetes mellitus                              | 7 (33.3)                                                | 89 (43.4)             | 0.49                                          |
| Hypertension                                   | 14 (66.7)                                               | 133 (64.9)            | >0.99                                         |
| Glomerular disease                             | 4 (19.0)                                                | 11 (5.3)              | 0.04                                          |
| Other etiologies                               | 4 (19.0)                                                | 68 (32.2)             | 0.23                                          |
| Dialysis vintage, median [IQR], mo             | 37 [20–66]                                              | 36 [13–79]            | 0.31                                          |
| Comorbidities                                  |                                                         |                       |                                               |
| Diabetes mellitus                              | 10 (47.6)                                               | 110 (53.7)            | 0.65                                          |
| Hypertension                                   | 21 (100.0)                                              | 193 (94.1)            | 0.61                                          |
| Cerebral vascular accident                     | 2 (9.5)                                                 | 19 (9.3)              | >0.99                                         |
| Cardiovascular disease                         | 9 (42.8)                                                | 72 (35.1)             | 0.49                                          |
| Neurologic disease (excluding cerebral vascular accident) | 2 (9.5)                                                | 9 (4.4)               | 0.27                                          |
| COPD/asthma                                     | 6 (28.6)                                                | 39 (19.0)             | 0.39                                          |
| Smoking                                        | 1 (4.8)                                                 | 22 (10.8)             | 0.70                                          |
| Active hepatitis C                             | 1 (4.8)                                                 | 8 (3.9)               | 0.59                                          |
| Cirrhosis                                      | 1 (4.8)                                                 | 4 (2.0)               | 0.39                                          |
| HIV with CD4<200                               | 1 (4.8)                                                 | 1 (0.5)               | 0.18                                          |
| Active malignancies                            | 1 (4.8)                                                 | 10 (4.9)              | >0.99                                         |
| Medications 30 d prior to serology test (no. of patients on dialysis) | 2 (9.5)                                                | 26 (12.7)             | >0.99                                         |
| Immunosuppressive medications                  | 20 (95.2)                                               | 40 (80.5)             | 0.14                                          |
| Cardiovascular disease medications             | 18 (85.7)                                               | 168 (82.0)            | >0.99                                         |
| Diabetes medications                           | 5 (23.8)                                                | 62 (30.2)             | 0.62                                          |
| Asthma/COPD medication                         | 3 (14.3)                                                | 50 (24.4)             | 0.42                                          |
| No. of hospitalizations since March 1st, 2020, median [IQR] | 1 [0–1]                                                | 0 [0–2]               | 0.13                                          |
| SARS-CoV-2 exposures                           |                                                         |                       |                                               |
| Household member tested for SARS-CoV-2         | 11 (52.4)                                               | 57 (27.9)             | 0.03                                          |
| Household member diagnosed with SARS-CoV-2     | 5 (23.8)                                                | 6 (2.9)               | 0.001                                         |
| Extended family/friend positive for SARS-CoV-2 | 4 (19.0)                                                | 10 (4.9)              | 0.03                                          |
| Travel outside of the St. Louis area           | 6 (28.6)                                                | 24 (11.8)             | 0.04                                          |
| Resided in long-term care facility             | 4 (19.0)                                                | 5 (1.5)               | 0.002                                         |
| Household size                                 |                                                         |                       |                                               |
| Lives alone                                    | 1 (4.8)                                                 | 55 (26.8)             | Reference                                     |
| Two or more people                             | 8 (38.1)                                                | 144 (70.2)            | 0.45                                          |
| No. of generations in the household           |                                                         |                       |                                               |
| One generation                                 | 4 (19.0)                                                | 102 (49.8)            | Reference                                     |
| Two generations                                | 10 (47.6)                                               | 70 (34.1)             | 0.05                                          |
| Three generations or more                      | 3 (14.3)                                                | 26 (12.7)             | 0.17                                          |
documented in the medical record any time from March to September 2020 or a positive IgG serology result at the time of study enrollment (September 2020). Univariate analysis of the patient characteristics among SARS-CoV-2 cases and noncases was performed using Fisher exact tests or univariate logistic regression for categorical variables and Mann–Whitney U tests for continuous variables. Correlation between positive SARS-CoV-2 test results (antibody, PCR, or both) of patients on HD and community SARS-CoV-2 infection prevalence by patient’s home zip code was performed using the Spearman correlation test. To determine potential acquisition of SARS-CoV-2 infection inside HD units, we examined the distribution of cases by dialysis day and shift in each HD unit. Statistical analyses were performed using Python pandas, SciPy, and Matplotlib packages.

**Results**

Among the three HD units, 226 patients and 39 HCPs were enrolled into the study (Supplemental Table 1). Of the 226 patients, 21 patients (9%) were considered to be SARS-CoV-2 cases on the basis of history of positive PCR or positive serology. During the study period, 130 (58%) patients

| Variable                                      | Severe Acute Respiratory Syndrome Coronavirus 2-Infected Case, N=21 (9%) | Noncase, N=205 (9%) | P Value (Mann–Whitney U Test or Fisher Exact) |
|-----------------------------------------------|------------------------------------------------------------------------|----------------------|-----------------------------------------------|
| Household density (household size per no. of bedrooms) | 1 [1.0–2.3]                                                           | 1 [0.8–1.2]          | 0.27                                          |
| First quartile (0–0.75)                        | 4 (19.0)                                                               | 55 (26.8)            | Reference                                     |
| Second and third quartiles (0.75–1.2)          | 10 (47.6)                                                              | 93 (45.4)            | 0.77                                          |
| Fourth quartile (>1.2)                        | 3 (14.3)                                                               | 52 (25.4)            | >0.99                                         |
| SARS-CoV-2 infection prevention behaviors      |                                                                        |                      |                                               |
| Reported mask use at dialysis centers          |                                                                        |                      |                                               |
| All of the time                                | 21 (100.0)                                                             | 196 (95.6)           | Reference                                     |
| Less than all of the time                     | 0 (0.0)                                                                | 8 (3.9)              | >0.99                                         |
| Reported social distancing at dialysis center (% adherence) |                                    |                      |                                               |
| All of the time                                | 16 (76.2)                                                              | 140 (68.3)           | Reference                                     |
| Less than all of the time                     | 5 (23.8)                                                               | 64 (31.2)            | 0.62                                          |
| Reported hand hygiene at dialysis center prior to sitting on dialysis chair |                              |                      |                                               |
| All of the time                                | 19 (90.5)                                                              | 174 (84.9)           | Reference                                     |
| Less than all of the time                     | 2 (9.5)                                                                | 30 (14.5)            | 0.75                                          |
| Reported mask use during daily life outside of home |                        |                      |                                               |
| All of the time                                | 14 (66.7)                                                              | 155 (75.6)           | Reference                                     |
| Less than all of the time                     | 3 (14.3)                                                               | 45 (22.0)            | 0.77                                          |
| Sometimes (about 50% of the time) or less     | 3 (14.3)                                                               | 4 (2.0)              | 0.02                                          |
| Visit to other health facilities (doctor offices, dentist offices) between March and September 2020 |                          |                      |                                               |
| First tertile 0–1 health visits               | 6 (28.6)                                                               | 75 (36.6)            | Reference                                     |
| Second tertile 2–5 health visits              | 9 (42.9)                                                               | 63 (30.7)            | 0.42                                          |
| Third tertile >5 health visits                 | 6 (28.6)                                                               | 66 (32.2)            | >0.99                                         |
| Visit to public spaces for daily activities between March and September 2020 |                          |                      |                                               |
| First tertile 0–6 visits                      | 10 (47.6)                                                              | 62 (30.2)            | Reference                                     |
| Second tertile 7–28 visits                    | 7 (33.3)                                                               | 71 (34.6)            | 0.44                                          |
| Third tertile >28 visits                      | 4 (19.0)                                                               | 71 (34.6)            | 0.10                                          |
| No. of gatherings with >10 people attending b  |                                                                        |                      |                                               |
| First tertile (0 gatherings)                  | 7 (33.3)                                                               | 105 (51.2)           | Reference                                     |
| Second tertile (1 gathering)                  | 5 (23.8)                                                               | 35 (17.1)            | 0.30                                          |
| Third tertile (>1 gathering)                  | 9 (42.9)                                                               | 64 (31.2)            | 0.18                                          |

IQR, interquartile range; BMI, body mass index; COPD, chronic obstructive pulmonary disease; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

*a*Defined as a positive PCR and/or serology for SARS-CoV-2.

*b*Types of gatherings include house of worship/religious services, funerals, weddings, family/friend gatherings (birthdays, dinners, cookouts, etc.), graduations, concerts or plays/theater productions, eating at a restaurant, visits to a bar, in-person school or classes, protests, and others.
had greater than or equal to one PCR test performed (114 patients were asymptomatic, and PCR was performed as a screening test prior to a procedure) (Supplemental Table 2).

None of the HCPs had evidence of SARS-CoV-2 infection by either PCR or serology.

In univariate analysis, SARS-CoV-2–infected patients were significantly more likely to reside in an LTCF (19% of cases versus 1.5% of noncases; \( P = 0.002 \)), had a household family member (24% versus 3%; \( P = 0.001 \)) or extended family member/friend diagnosed with SARS-CoV-2 infection (19% versus 5%; \( P = 0.03 \)), traveled outside of the local metropolitan area (29% versus 12%; \( P = 0.04 \), and reported less adherence to mask use outside of the home (14% versus 2%; \( P = 0.02 \)) (Table 1). The SARS-CoV-2 infection prevalence among patients on HD correlated with SARS-CoV-2 infection prevalence in their community as assessed by zip code (\( r = 0.346 \); \( P = 0.01 \)) (Figure 1). The prevalence per 1000 persons of SARS-CoV-2 infection was significantly lower in the HCPs’ home residence zip codes compared with patients on HD (median: 1.73 [interquartile range [IQR], 1.45–1.97] versus 19.50 [IQR, 18.11–21.39], respectively; \( P < 0.001 \)).

Among the 21 SARS-CoV-2–infected patients, ten (48%) patients had both a positive PCR test in the past and positive IgG antibody in September (eight patients with symptomatic disease; the two asymptomatic patients included an LTCF resident and a worker in an LTCF), with median time from the positive PCR and positive IgG antibody of 128 days (IQR, 85–140) (Supplemental Table 3). Two (10%)

![Graph showing the correlation between severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection prevalence among patients on maintenance hemodialysis and community SARS-CoV-2 infection cumulative incidence per 1000 population by patients’ home zip code.]

Figure 1. | Correlation between severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection prevalence among patients on maintenance hemodialysis and community SARS-CoV-2 infection cumulative incidence per 1000 population by patients’ home zip code.

### Table 2. Number of severe acute respiratory syndrome coronavirus 2–infected patients by hemodialysis facility, pod, and shift

| Center | Pod | Shift          | Case Identification | Positive PCR or IgG Positive Only | Know Exposure Outside Hemodialysis Facility | Has Other Risk Factor* |
|--------|-----|----------------|---------------------|-----------------------------------|---------------------------------------------|------------------------|
| A      | A   | M/W/F second shift | 16                  | IgG positive                      | No                                          | No                     |
| A      | A   | M/W/F third shift  | 4                   | PCR positive                      | Yes                                         | No                     |
| A      | A   | T/T/S first shift  | 2                   | PCR positive                      | Yes                                         | Yes                    |
| A      | A   | T/T/S second shift | 1, 3                | Both PCR positive                 | 1 wk apart                                   | Yes                    |
| A      | B   | T/T/S first shift  | 5                   | PCR positive                      | 3: Yes                                       | No                     |
| A      | C   | M/W/F first shift  | 6, 16               | One PCR positive                  | 6: No                                        | Yes                    |
| A      | C   | T/T/S first shift  | 18                  | IgG positive                      | Yes                                         | No                     |
| A      | Rotate different pods | M/W/F second shift | 19                  | IgG positive                      | No                                          | Yes                    |
| A      | Rotate different pods | T/T/S third shift  | 13                  | IgG positive                      | Yes                                         | Yes                    |
| B      | 2   | M/W/F first shift  | 11                  | PCR positive                      | Yes                                         | No                     |
| B      | 3   | T/T/S first shift  | 9                   | PCR positive                      | Yes                                         | No                     |
| B      | 3   | T/T/S second shift | 7                   | PCR positive                      | No                                          | No                     |
| B      | 1   | T/T/S second shift | 8, 14               | One PCR positive                  | 8: Yes                                       | No                     |
| C      | 3   | M/W/F first shift  | 21                  | IgG positive                      | 3 mo apart                                   | Yes                    |
| C      | 4   | M/W/F first shift  | 12                  | PCR positive                      | No                                          | Yes                    |
| C      | 1   | T/T/S first shift  | 10, 15              | One PCR positive                  | 10: Yes                                      | No                     |
| C      | Not sure | T/T/S second shift | 20                  | IgG positive                      | No                                          | Yes                    |

M/W/F, Monday/Wednesday/Friday; T/T/S, Tuesday/Thursday/Saturday.

* On the basis of univariate analysis in Table 1.
asymptomatic patients had prior positive PCR with negative IgG antibody results. For these two patients, the time intervals from positive PCR test to negative IgG antibody test were 124 and 139 days. Nine patients (43%) had positive IgG antibody without a positive PCR test; of these, six had no PCR test performed, and three had a negative PCR test as part of preprocedure screening (median time from latest negative PCR test to positive IgG antibody test was 45 days). Of these nine patients, four reported having contact or living with a known SARS-CoV-2-infected patient, one lived in an LTCF, three reported travel outside of the metropolitan area, and one patient had no obvious SARS-CoV-2 risk factor. No clustering of SARS-CoV-2-infected patients was observed among the three HD units by shift and day of the week (Table 2). Except for one patient, all SARS-CoV-2-infected patients had one or more risk factors for exposure to SARS-CoV-2 outside the HD unit.

**Discussion**

A few studies have examined risk factors for SARS-CoV-2 infection among patients on HD (1,6,9,10). However, none of the previous studies included HCPs or reported on household characteristics, SARS-CoV-2 exposures, and personal prevention activities of patients and HCPs while evaluating the risk factors for SARS-CoV-2 infection. Our results indicate that the risk of infection among patients on in-center maintenance HD and dialysis HCPs is associated with the local community prevalence of SARS-CoV-2 infection, diagnosis of SARS-CoV-2 infection among immediate family members or friends, residence in an LTCF, and personal SARS-CoV-2 infection prevention activities, such as adherence to face mask use and travel outside the local metropolitan area. Residence in an LTCF has been identified as a SARS-CoV-2 infection risk factor previously, and our results support this finding (5,6). Notably, none of the enrolled HCPs had a positive IgG serology result, which suggests that CDC infection prevention guidance can help limit SARS-CoV-2 transmission within dialysis centers.

There are several limitations to this study. Because of the small number of cases, we could not perform multivariate analysis to identify independent risk factors for SARS-CoV-2 infection. We are currently in the process of obtaining follow-up serology and survey data from study participants and may be able to perform multivariable modeling in future analyses. Survey responses regarding reported activities, SARS-CoV-2 exposures, and prevention activities (such as mask use) may be subject to recall bias or “good behavior” bias. Direct observation of behaviors and activities would be optimal. This is not feasible outside of the dialysis centers, but direct observations within the dialysis centers are currently ongoing. Future analyses of these data can be used to validate the survey data regarding in-center COVID-19 prevention practices. Additionally, we did not perform periodic surveillance testing for asymptomatic patients or HCPs using PCR test, and thus, the overall SARS-CoV-2 infection prevalence may be underestimated as some patients and HCPs could have asymptomatic SARS-CoV-2 infection with no detectable antibody response or had not yet developed antibodies. Finally, the majority (87.2%) of patients in our cohort were Black, and thus, this may limit the generalizability of our findings as adult Black patients account for only 35% of all United States patients on dialysis (1).

Our results suggest that although some SARS-CoV-2 risk factors are not easily modifiable, others are, and adherence to infection prevention practices outside of HD units, such as consistent use of face masks (11), may help decrease the risk of SARS-CoV-2 in patients on HD. We did not find clear evidence for SARS-CoV-2 infection acquisition by patients or HCPs within HD units, suggesting that CDC SARS-CoV-2 infection prevention measures were effective. However, with the ongoing increases in community prevalence and the strong association found here between risk of SARS-CoV-2 and community rates, it is important to continue to examine the effectiveness of CDC SAR-CoV-2 infection prevention measures and risk factors for SARS-CoV-2 among patients on HD and HCPs. The longitudinal follow-up of this study is ongoing and will help address these questions.

**Disclosures**

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**Author Contributions**

C.W. Farnsworth, V.J. Fraser, S. Gandra, J.H. Kwon, T. Li, and D.K. Warren conceptualized the study; N.L. Dang, M. A. Olsen, and K.A. Reske were responsible for data curation; N.L. Dang, M. A. Olsen, and K.A. Reske were responsible for formal analysis; V.J. Fraser, S. Gandra, K.G. Hock, J.H. Kwon, T. Li, C. Miller, K.A. Reske, and D.K. Warren were responsible for project administration; K.G. Hock was responsible for validation; V.J. Fraser was responsible for funding acquisition; V.J. Fraser was responsible for resources; C.W. Farnsworth, V.J. Fraser, S. Gandra, T. Li, and D.K. Warren provided supervision; C.W. Farnsworth, V.J. Fraser, S. Gandra, J.H. Kwon, T. Li, M.A. Olsen, K.A. Reske, and D.K. Warren were responsible for methodology; C.W. Farnsworth, V.J. Fraser, S. Gandra, K.G. Hock, J.H. Kwon, T. Li, C. Miller, M.A. Olsen, and D.K. Warren were responsible for investigation; S. Gandra and T. Li wrote the original draft; 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.0001282021/-/DCSupplemental.

Supplemental Table 1. Outpatient hemodialysis facilities characteristics included in the study.

Supplemental Table 2. SARS-CoV-2 IgG antibody and SARS-CoV-2 PCR results in the study population (patients only; N=226).

Supplemental Table 3. Characteristics of patients on hemodialysis who tested positive for SARS-CoV-2 PCR or IgG antibody.

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