Comparative analysis of the incidence and mortality of COVID-19 in Korean end-stage kidney disease patients: hemodialysis, peritoneal dialysis, and transplantation

Ajin Cho,1,2 Seon A Jeong,3 Hayne Cho Park,1,2 Do Hyoun Kim,1,2 Kyung Don Yoo,4 Hye Eun Yoon,5 Yang Gyun Kim,6 Young-Ki Lee;1,2 on behalf of Korean Society of Nephrology Disaster Preparedness and Response Committee

Background: Patients with end-stage kidney disease (ESKD) are more susceptible to viral epidemics and are known to have higher incidence and death rates of coronavirus disease 2019 (COVID-19) compared to the general population. We determined COVID-19 incidence and mortality among chronic hemodialysis (HD), peritoneal dialysis (PD), and kidney transplantation (KT) patients in Korea.

Methods: We conducted a retrospective cohort study and data regarding Korean ESKD adults (aged ≥18 years) were obtained from the National Health Insurance Service of Korea from October 2020 to December 2021. We examined and compared the incidence of COVID-19–related infections and deaths among the patients receiving HD, PD, and KT.

Results: Of all ESKD patients, 85,018 (68.1%) were on HD, 8,399 (6.7%) on PD, and 31,343 (25.1%) on KT. The COVID-19 incidence was 1.3% for HD, 1.2% for PD, and 1.5% for KT. COVID-19 mortality was 16.3% for HD, 12.2% for PD, and 4.7% for KT. PD patients had a lower incidence of infection compared to HD patients (odds ratio [OR], 0.76; 95% confidence interval [CI], 0.60–0.93), but KT patients had a significantly higher risk of infection (OR, 1.28; 95% CI, 1.13–1.44). Compared with HD, the risk of COVID-19–related death was not different for PD patients but was significantly lower for KT patients (hazard ratio, 0.55; 95% CI, 0.35–0.88).

Conclusion: COVID-19 incidence was lower in PD patients than in HD patients, but mortality was not different between them. KT was associated with a higher risk of COVID-19 infection but lower mortality compared to HD.

Keywords: COVID-19, Renal dialysis, Kidney transplantation, Mortality, Peritoneal dialysis

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has significantly affected end-stage kidney disease (ESKD) patients. Compared with the general population, patients with ESKD are at increased risk of developing severe acute
respiratory syndrome coronavirus 2 (SARS-CoV-2) infection and complications because of higher rates of comorbidities such as cardiovascular disease and diabetes mellitus, advanced age, and compromised immune function [1,2].

Hemodialysis (HD) patients typically need to be transported to a dialysis center three times a week, which makes complete self-isolation impossible. Furthermore, dialysis units generally have a high patient density, increasing the risk of transmission of infectious diseases. In contrast, peritoneal dialysis (PD) treatments are performed at home, where patients are better physically isolated from the virus and are expected to have a lower risk of COVID-19 than in-center dialysis patients [3]. It is not yet clear whether there is a difference between HD and PD patients in COVID-19–related morbidity and mortality.

The Korean Society of Nephrology (KSN), based on Korea’s experience in responding to the respiratory syndrome of the Middle East [4,5], has formed a COVID-19 Task Force Team and developed clinical practice guidelines to prevent the transmission of COVID-19 in HD facilities [6]. However, the impact of applying these COVID-19 clinical guidelines on HD patients is still unknown.

In addition, kidney transplantation (KT) recipients are at increased risk for serious disease from COVID-19 and show higher mortality rates associated with COVID-19 compared with the general population [7]. Since the COVID-19 pandemic, incidence and mortality studies in ESKD populations have compared HD dialysis modalities to PD [8,9]. However, no studies have examined the incidence and mortality of COVID-19 in the three modalities of kidney replacement therapy, including KT.

We investigated the incidence of COVID-19–related infections and deaths among HD, PD, and KT patients in Korea and aimed to compare the risk of infection and mortality among the three modalities.

**Methods**

**Data source**

We conducted a nationwide population-based observational study using the Korea Disease Control and Prevention Agency-COVID-19 National Health Insurance Service (K- Cov-N) linkage database. K-COV-N contains data on all individuals diagnosed with COVID-19 in South Korea between October 8, 2020, and December 31, 2021. The cohort database has the following characteristics and includes: 1) healthcare services and insurance provided by the Korean government; 2) information obtained on patients diagnosed with COVID-19, including diagnosis date and COVID-19–related deaths; and 3) all patient-related data anonymized to ensure confidentiality.

**Study population and design**

We included patients aged 18 years and older in our analysis and excluded patients with HD or PD of less than 3 months. HD patients were defined as such if they met all the following criteria: 1) an International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10) code for chronic kidney disease (CKD)/ESKD or related conditions (N18, N181–N184, N189, N19, Z490, Z491, Z90, or Z905), 2) HD-related procedure code, and 3) a special exemption code (V001) used by the National Health Insurance System (NHIS) to provide financial assistance to HD patients. We defined PD as meeting all the following criteria: 1) an ICD-10 code for CKD/ESKD or related conditions, 2) a code of procedures related to PD, and 3) a special exemption code (V003) used by the NHIS to provide financial assistance to patients with PD. KT patients were defined as meeting all of the following criteria: 1) an ICD-10 code for CKD/ESKD or related conditions, 2) a KT surgery code (R3280), and 3) a special exemption code (V005) used by the NHIS to provide financial assistance to KT patients.

Information included baseline demographics (age and sex), region of residence (metropolitan vs. nonmetropolitan), medical aid recipients, vaccination status, and presence of comorbidities. Baseline comorbidities were defined as conditions diagnosed within 1 year before the index date using the following ICD-10 diagnosis codes. The status of COVID-19 vaccination was defined as the completion of the primary series of COVID-19 vaccines with BNT162b2 (Pfizer-BioNTech), mRNA-1273 (Moderna), ChAdOx1 nCoV-19 (AstraZeneca), NVX-CoV2373 (Novavax), or Ad26.COV2.S (Janssen/Johnson & Johnson) vaccines, or without a vaccine. Two doses represented the completion of the primary series and the Ad26.COV2.S vaccine was considered to have completed the primary series with a
single dose, as a second dose is not authorized. Because of the short duration of the vaccination, patients diagnosed with COVID-19 within 14 days after vaccination were considered unvaccinated.

The primary outcome was the first positive diagnosis of COVID-19 based on reverse transcriptase polymerase chain reaction analysis listed in the database. The secondary outcome was all-cause mortality within 28 days of the first diagnosis of COVID-19.

This work was performed according to the Declaration of Helsinki. K-COV-N was fully anonymized, and informed consent was waived by the Institutional Review Board of Hallym University Kangnam Sacred Heart Hospital (No. 2022-07-022).

Statistical analysis

Statistical analysis was performed by dividing subjects into three groups using the kidney replacement therapy method: HD, PD, and KT. The chi-square tests were used to compare categorical variables, and analysis of variance was used to compare continuous variables between groups. The risk of COVID-19 was calculated by multivariate-adjusted logistic regression based on age, sex, region of residence, medical aid recipients, vaccination status, and comorbidities (diabetes mellitus, hypertension, ischemic heart disease, heart failure, lung disease, liver disease, dementia, stroke, and cancer) to calculate adjusted odds ratio (OR) and 95% confidence interval (CI).

The Kaplan-Meier survival curves were used to compare the risk of death between groups. In the survival analysis of confirmed and nonconfirmed COVID-19 cases, groups were matched in a 1:3 ratio using propensity scores to minimize confounding factors that could affect the results. Propensity score matching was performed based on age, sex, region of residence, medical aid recipients, and vaccination status, and analyzed using the “MatchIt” package in R version 4.0.5 (R Foundation for Statistical Computing; https://www.R-project.org/). Comparisons of the risk of COVID-19 death from kidney replacement therapy were analyzed using Cox proportional hazards regression models. All statistical analyses were performed using R version 4.0.5. A p-value of less than 0.05 was considered statistically significant.

Results

Baseline characteristics according to kidney replacement therapy modalities

A total of 124,760 patients with ESKD were included in the analysis, with 85,018, 8,399, and 31,343 undergoing HD, PD, and KT, respectively. The baseline characteristics of the subjects according to the kidney replacement therapy method are shown in Table 1. Compared with the other groups, HD patients were older. They received more medical aid and comorbidities such as diabetes mellitus, hypertension, ischemic heart disease, heart failure, stroke, and dementia. COVID-19 vaccination rates were highest among KT patients, followed by HD and PD.

Incidence and mortality of COVID-19 in patients with hemodialysis, peritoneal dialysis, and kidney transplantation

During the study period, 1,140 of 85,018 HD patients (1.3%) were diagnosed with COVID-19 (Fig. 1A). Of the 1,140 HD patients diagnosed with COVID-19, 186 (16.3%) died within 28 days. During the same period, 9,388 of the 83,878 patients (11.2%) without COVID-19 died. After matching the propensity score (Supplementary Table 1, available online), survival analyses were performed for patients with HD with and without confirmed COVID-19 (Fig. 2A). The results showed that patients diagnosed with COVID-19 had a higher risk of death than patients without a diagnosis (p < 0.001).

Of the 8,399 patients with PD, 98 (1.2%) were diagnosed with COVID-19 during the study period (Fig. 1B). Twelve of the 98 PD patients (12.2%) diagnosed with COVID-19 died within 28 days. Of the 8,301 patients without COVID-19, 642 (7.7%) died during the same period. Survival analysis was performed in PD patients with and without confirmed COVID-19 after comparing the propensity score matching (Fig. 2B; Supplementary Table 2, available online). We found that patients with confirmed COVID-19 had a higher risk of death than those not diagnosed (p < 0.001).

Among 31,343 KT patients, 469 (1.5%) were confirmed to have COVID-19 during the study period (Fig. 1C). Of the 469 KT patients diagnosed with COVID-19, 22 (4.7%) died within 28 days. During the same period, 514 of the 30,874 patients (1.7%) who did not have COVID-19 died.
Table 1. Patient characteristics of ESKD patients stratified by kidney replacement therapy

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>HD</th>
<th>PD</th>
<th>KT</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>85,018</td>
<td>8,399</td>
<td>31,343</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>64.7 ± 13.3</td>
<td>56.2 ± 13.8</td>
<td>53.9 ± 12.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>50,604 (59.5)</td>
<td>4,842 (57.6)</td>
<td>18,684 (59.6)</td>
<td>0.003</td>
</tr>
<tr>
<td>Medical aid</td>
<td>17,943 (21.1)</td>
<td>1,217 (14.5)</td>
<td>3,226 (10.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Metropolitan area</td>
<td>40,847 (48.0)</td>
<td>4,178 (49.7)</td>
<td>15,843 (50.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vaccination</td>
<td>69,601 (81.9)</td>
<td>6,362 (75.7)</td>
<td>27,266 (87.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>50,234 (59.1)</td>
<td>2,679 (31.9)</td>
<td>11,496 (36.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>61,208 (72.0)</td>
<td>4,300 (51.2)</td>
<td>17,310 (55.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>16,919 (19.9)</td>
<td>895 (10.7)</td>
<td>1,893 (6.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart failure</td>
<td>9,017 (10.6)</td>
<td>607 (7.2)</td>
<td>928 (3.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stroke</td>
<td>3,834 (4.5)</td>
<td>249 (3.0)</td>
<td>331 (1.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lung disease</td>
<td>4,799 (5.6)</td>
<td>238 (2.8)</td>
<td>664 (2.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Liver disease</td>
<td>5,578 (6.6)</td>
<td>254 (3.0)</td>
<td>1,562 (5.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Malignancy</td>
<td>2,248 (2.6)</td>
<td>248 (3.0)</td>
<td>867 (2.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dementia</td>
<td>3,435 (4.0)</td>
<td>68 (0.8)</td>
<td>52 (0.2)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data are expressed as number only, mean ± standard deviation, or number (%).

ESKD, end-stage kidney disease; HD, hemodialysis; KT, kidney transplantation; PD, peritoneal dialysis.

of patients with and without COVID-19 was analyzed using propensity score matching (Fig. 2C; Supplementary Table 3, available online). Patients with confirmed COVID-19 had a higher risk of death than those without a diagnosis (p < 0.001).

Risk of COVID-19 incidence and mortality by kidney replacement therapy

Multivariate analysis showed that KT was associated with an increased risk of COVID-19 (OR, 1.27; 95% CI, 1.12–1.44; p < 0.001), while PD was associated with a decreased risk of infection (OR, 0.76; 95% CI, 0.60–0.95; p = 0.02) (Table 2).

We also performed a survival analysis to determine if there was a difference in mortality based on the modality of kidney replacement therapy in patients with COVID-19. There was no difference in mortality risk between patients with HD and PD, with a lower mortality rate in patients with KT (Fig. 3). A Cox proportional hazards model was used to identify the kidney replacement therapy method as a risk factor associated with patient mortality (Table 3). In the univariate analysis, KT was associated with decreased mortality compared with HD, while PD did not differ in mortality. Multivariate analysis also showed that KT was associated with lower mortality (hazard ratio, 0.56; 95% CI, 0.35–0.90; p = 0.02), whereas PD did not show a difference in mortality.

Discussion

We investigated SARS-CoV-2 infection rates and mortality among patients with maintenance HD, PD, and KT. The study found that KT patients had higher COVID-19 rates than HD patients, while PD patients had less COVID-19 than HD patients. All-cause mortality related to COVID-19 did not differ between patients with HD and PD, but KT patients had lower COVID-19 mortality than HD patients.

As the worst global pandemic in decades, COVID-19 has significantly impacted patients with ESKD. ESKD patients are especially vulnerable to severe COVID-19. Uremic conditions are associated with immunosuppressive immune dysfunction, which can contribute to the high prevalence of infection and immune activation, leading to inflammation in these patients [10].

However, it is unclear whether the incidence of COVID-19 in HD patients is higher than in the general population and it is often reported to be similar to the prevalence in the general population in a given geographic area. The Dialysis Outcomes and Practice Patterns Study (DOPPS) in 15 countries in Asia, Europe, and the Americas found that
Figure 1. Incidence of COVID-19 diagnosis and deaths among ESKD patients. (A) Hemodialysis (HD), (B) peritoneal dialysis (PD), and (C) kidney transplantation (KT).

COVID-19, coronavirus disease 2019; ESKD, end-stage kidney disease.

Figure 2. Kaplan-Meier curves for death among ESKD patients diagnosed with COVID-19. (A) Hemodialysis, (B) peritoneal dialysis, and (C) kidney transplantation.

COVID-19, coronavirus disease 2019; ESKD, end-stage kidney disease.
the impact of COVID-19 on dialysis care varied widely between countries [11]. The number of cases and deaths per population among dialysis patients varied more than 100 times between the participating countries, reflecting the burden on the general population. In the Ontario study, the number of new cases of SARS-CoV-2 infection in long-term dialysis patients and the general population was similar, with 33 and 27 cases per 100,000 population, respectively [12]. A United States study of 28,503 randomly selected patients from approximately 1,300 dialysis facilities found a SARS-CoV-2 seroprevalence of 9.3%, with an estimated seropositivity of 9.2% in the adult population of the United States at the same time [13]. Meanwhile, a nationwide cohort study in Thailand reported that the overall incidence of COVID-19 infection in patients with kidney replacement therapy (HD, PD, and KT) was 4% which is similar to the rate of 3.4% for the general population [14]. In this study, the COVID-19 infection rates for HD and PD patients were 1.3% and 1.2%, respectively, similar to the 1.22% infection rate for the general population in Korea reported by the Korea Disease Control and Prevention Agency [15]. This incidence could be underestimated due to the fact that some patients died at home, but the different national policy responses to COVID-19 in each country and different study periods and populations could explain this different incidence.

DOPPS found that mortality rates for dialysis patients in each country ranged from 10% to 30%, confirming the severity of COVID-19 [11]. In population-based studies, even after adjusting for demographic factors and comorbidities, dialysis patients had a 2- to 4-fold increase in mortality compared with the general population [16–18]. In large studies of dialysis patients diagnosed with COVID-19, the overall mortality rate was greater than 20% [18–20]. A study in Korea reported an overall hospital mortality rate of 22.4%, with an even higher rate of 64.7% for intensive care unit admissions [17]. In the United States, mortality among people with ESKD exceeded those of previous years because of additional deaths related to COVID-19 in 2020, with an estimated 9 to 13 deaths per 1,000 people with ESKD between February and August 2020 [21].

Table 2. Risk of COVID-19–related infections stratified by kidney replacement therapy among Korean ESKD patients, from October 2020 to December 2021

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Univariate OR (95% CI)</th>
<th>p-value</th>
<th>Multivariate OR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>1 (Reference)</td>
<td></td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>0.87 (0.70–1.06)</td>
<td>0.18</td>
<td>0.76 (0.61–0.93)</td>
<td>0.01</td>
</tr>
<tr>
<td>KT</td>
<td>1.12 (1.00–1.25)</td>
<td>0.04</td>
<td>1.28 (1.13–1.44)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI, confidence interval; COVID-19, coronavirus disease 2019; ESKD, end-stage kidney disease; HD, hemodialysis; KT, kidney transplantation; OR, odds ratio; PD, peritoneal dialysis.

aAdjusted for age, sex, region of residence, medical aid recipients, vaccination status, and comorbidities.

Table 3. Risk of COVID-19–related mortality stratified by kidney replacement therapy among Korean ESKD patients, from October 2020 to December 2021

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Univariate Hazard ratio (95% CI)</th>
<th>p-value</th>
<th>Multivariate Hazard ratio (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>1 (Reference)</td>
<td></td>
<td>1 (Reference)</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>0.72 (0.40–1.22)</td>
<td>0.28</td>
<td>1.19 (0.67–2.15)</td>
<td>0.57</td>
</tr>
<tr>
<td>KT</td>
<td>0.27 (0.17–0.42)</td>
<td>&lt;0.001</td>
<td>0.55 (0.35–0.88)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

CI, confidence interval; COVID-19, coronavirus disease 2019; ESKD, end-stage kidney disease; HD, hemodialysis; KT, kidney transplantation; PD, peritoneal dialysis.

aAdjusted for age, sex, region of residence, medical aid recipients, vaccination status, and comorbidities.

Figure 3. All-cause mortality among ESKD patients diagnosed with COVID-19 by kidney replacement therapy.

COVID-19, coronavirus disease 2019; ESKD, end-stage kidney disease; HD, hemodialysis; KT, kidney transplantation; PD, peritoneal dialysis.
placement therapy, and there are reports that in-center HD patients have a higher incidence of COVID-19 than home-dialysis patients [11,20–25]. A French national cohort study found that patients with HD in the center had approximately twice the risk of COVID-19 infection compared with patients with HD treated at home [20]. A Chinese study followed 818 patients with PD for 4 months and found that only eight patients (0.9%) were diagnosed with COVID-19, a much lower rate than the one reported for patients with HD at the center [23]. DOPPS results vary by country, but in general, HD patients in a center were more likely to be diagnosed with COVID-19 than dialysis patients at home (Belgium, 8.6% vs. 4.1%; Spain, 4.6% vs. 1.8%; and Italy, 3.6% vs. 1.4%) [11]. In a Brazilian study, the incidence of COVID-19 per 10,000 population was higher in the HD group, with 1,752.5 in the PD group and 2,423.5 in the HD group [24]. A survey by the Italian Society of Nephrology found that the incidence of COVID-19 was significantly higher in HD (3.55%) than in PD (1.38%) patients [25]. A recent COVID-19 surveillance report on renal centers in the United Kingdom found that cumulative COVID-19 cases were also higher in HD patients treated in centers than in HD patients treated at home (40.4% vs. 14.4%) [26]. The Thailand national cohort also showed that patients with HD had a higher chance of COVID-19 infection than those with PD [14]. Similarly to other studies, we found that the incidence of COVID-19 was lower in patients with PD than in patients with HD. Visiting the dialysis room 2–3 times a week and having contact with patients may explain these results.

The risk of COVID-19 in HD patients treated at home is lower than in those treated in centers, but it is uncertain whether there is a difference in mortality from COVID-19 depending on the dialysis modality. In the DOPPS results, the mortality rates at a center versus at-home dialysis varied by country [11]. A United States study examining the association between dialysis modality and COVID-19 outcomes found that home dialysis had a lower risk of diagnosis, hospitalization, and death from COVID-19 [27]. A COVID-19 surveillance report for renal centers in the United Kingdom also found that cumulative mortality from COVID-19 was higher in HD patients treated in centers than in HD patients treated at home (4.5% vs. 2.3%) [26]. However, the COVID-19 Registry of the Japan Society for Dialysis Therapy found that COVID-19 mortality was 7.6% in HD patients and 9.4% in patients with PD [28]. In a Brazilian study, mortality from COVID-19 was higher in the PD group (19.4% vs. 52.9%) [24]. A survey by the Italian Society of Nephrology found that COVID-19 mortality was significantly higher in HD (44.51%) than in PD patients (33.76%) [25]. In a Belgian registry study, the cumulative mortality rate among patients with ESKD diagnosed with SARS-CoV-2 infection was 29.6% in HD and 33% in PD [29]. There is evidence of differences in morbidity and mortality between hospital and home-dialysis patients, not only by region but also by the time of the COVID-19 outbreak. In a study in the United States, patients on dialysis in the center had higher incidence and mortality rates of COVID-19 than patients on dialysis at home during Phase 1 (February 22 to September 30, 2020), but no significant differences were observed during Phase 2 (October 1 to December 31, 2020) [30]. This study did not find significant differences in the risk of death from COVID-19 between HD and PD patients. In Thailand, HD patients tended to have a higher mortality rate compared with PD patients, but the difference was not significant [14]. Although the PD group was likelier to stay at home and maintain social distancing, age and comorbidities may have impacted patient mortality more than the dialysis modality.

Globally, the proportion of PD among patients with ESKD is very low compared with HD. COVID-19 infection rates among home-dialysis patients, including PD, were lower than for HD patients, and the COVID-19 pandemic highlighted the benefits of home-dialysis. Therefore, the COVID-19 pandemic has increased patient and provider interest in PD, and strategies are needed to increase PD use, including identifying PD candidates, evaluating eligibility, offering PD, and choosing patients for PD [31].

Immunocompromised patients, such as those with KT, are at increased risk of severe illness from COVID-19, but it is unclear if the risk of SARS-CoV-2 infection is higher in dialysis patients. In the DOPPS study, European KT patients had a COVID-19 infection rate of 0.9% to 2.7%, which was less than the 4.6% to 17.3% for HD patients. However, the mortality rate for COVID-19 patients with KT was 16.8% to 27.0%, which was not significantly different from 14.2% to 34.0% for patients with HD [11]. In a study that examined the population-level effects of COVID-19 in patients with ESKD in the United States, the adjusted relative mortality rate for the first half of 2020 compared with 2017 to 2019...
was 1.17 for dialysis patients and 1.30 for patients with KT [27]. A United Kingdom surveillance report found that the cumulative incidence of COVID-19 was lower in patients with KT compared with patients with HD (40.4% vs. 9.0%) [26]. The cumulative mortality rate from COVID-19 was also lower in patients with KT compared with patients with HD (4.5% vs. 1.0%) [26]. In this study, the COVID-19 infection rate was 1.5% in KT patients and 1.3% in HD patients, and multivariate analysis showed that the infection rate was significantly higher in KT patients compared with HD patients. The mortality rate for COVID-19 was 1.7% in KT patients and 11.2% in HD patients. Cox analysis showed that the mortality rate was significantly low in KT patients. KT patients were younger, had fewer comorbidities than HD patients, and had a lower mortality rate from COVID-19, even after adjusting for age, sex, and comorbidities.

While in-center HD patients are often more exposed to the community, following optimal protocols and guidelines can reduce infections in the center. KSN has published and frequently updates the COVID-19 response guidelines for nephrology clinicians providing HD care and advises all dialysis facilities to follow the recommendations in these guidelines. The COVID-19 infection rate among HD patients in Korea was 1.3%, which was not significantly different from the 1.2% infection rate in the general population during the same period. More research is needed to determine whether optimal protocols and guidelines can reduce infections in HD centers [6]. In this study, there was a difference in vaccination rate depending on the modality of kidney replacement therapy, and the vaccination rate was higher in that order for KT, HD, and PD patients. This result can be explained by the fact that KT patients are a group of patients taking immunosuppressants, and HD patients have a lot of contact with others while visiting the dialysis room. In some studies, the mortality rate decreased in ESKD patients following vaccination, but there were reports that the antibody formation rate was lower than that of the general population [32–34]. In this study, we mainly investigated the effects of COVID-19 according to modalities of kidney replacement therapy. Further analysis is needed to determine the impact of vaccine type and number of vaccinations on the prognosis of ESKD patients.

This study has some limitations that need to be addressed. Although the study included patients diagnosed with COVID-19 up to December 2021, most COVID-19 cases occurred after January 2022, when Omicron was predominant in Korea. However, the study is important because it was a nationwide cohort study and showed differences in COVID-19 infection rates and mortality among patients with ESKD. Second, even if COVID-19 is a mandatory reported disease, mildly ill and asymptomatic patients may not be tested for COVID-19. This may have contributed to an underestimation of their risk of COVID-19 infection. Third, this study did not include patients who were reinfected with COVID-19. Fourth, we could not evaluate medication use for COVID-19 treatment. Fifth, this study was conducted with data from the early stages of the pandemic, and the outcomes of COVID-19 are improving over time due to better management. Therefore, the results beyond the period of this study may differ, and additional longitudinal studies are needed, including the period of the outbreak of the Omicron variant.

In conclusion, the Incidence of COVID-19 was lower in PD patients than in HD patients, but mortality was not different. KT patients were associated with a higher risk of diagnosis of COVID-19 and lower mortality risk than HD patients. The COVID-19 pandemic challenges patients with ESKD more than ever. Home dialysis could be beneficial in mitigating the spread of infectious diseases such as COVID-19, and nephrologists must focus more on the outcomes of dialysis patients to reduce infections in HD centers with optimal protocols and guidelines.

**Conflicts of interest**

All authors have no conflicts of interest to declare.

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Data sharing statement

The data presented in this study are available from the corresponding author upon reasonable request.

Authors’ contributions

Conceptualization, Methodology: AJC, HCP, DHK, YKL
Data curation: AJC, YKL
Formal analysis: AJC, SAJ
Funding acquisition: YKL
Investigation: KDY, HEY, YGK
Writing–original draft: AJC, YKL
Writing–review & editing: HCP
All authors read and approved the final manuscript.

ORCID

AJin Cho, https://orcid.org/0000-0001-7097-7026
Seon A Jeong, https://orcid.org/0009-0009-1615-5983
Hayne Cho Park, https://orcid.org/0000-0002-1128-3750
Do Hyoung Kim, https://orcid.org/0000-0002-8664-8830
Kyung Don Yoo, https://orcid.org/0000-0001-6545-6517
Hye Eun Yoon, https://orcid.org/0000-0002-6347-7282
Yang Gyun Kim, https://orcid.org/0000-0002-3497-5514
Young-Ki Lee, https://orcid.org/0000-0003-3464-6144

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