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ORIGINAL ARTICLE

Effects of SARS-CoV-2 vaccination on the severity of COVID-19 infection in patients on chronic dialysis

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Abstract

Background COVID-19 is associated with increased morbidity and mortality in patients with end-stage kidney disease on dialysis. Efficacy of SARS-CoV-2 vaccination to prevent severe COVID-19 disease in end-stage kidney disease patients remains limited. We compared the incidence of COVID-19-related hospitalization and death in dialysis patients based on SARS-CoV-2 vaccine status.

Methods Retrospective study of adults on chronic dialysis within Mayo Clinic Dialysis System in the Midwest (USA) between April 1st, 2020 and October 31st, 2022, who had a laboratory test positive for SARS-CoV-2 by PCR. Incidence of both COVID-19-related hospitalization and death were compared between vaccinated and unvaccinated patients.

Results SARS-CoV-2 infection was identified in 309 patients, including 183 vaccinated and 126 unvaccinated. The incidence of death (11.1% vs 3.8%, $p=0.02$) and hospitalization (55.6% vs 23.5%, $p<0.001$) was significantly higher in unvaccinated compared to vaccinated patients. Age at infection, sex, Charlson comorbidity index, dialysis modality, and hospital stays did not differ between the two groups. The incidence of hospitalization was significantly higher in partially vaccinated (63.6% vs 20.9%, $p=0.004$) and unboosted (32% vs 16.4%, $p=0.04$) patients compared to fully vaccinated and boosted, respectively. Among the 21 patients who died in the whole cohort, 47.6% ($n=10$) died during the pre-vaccine period. The composite risk of death or hospitalization was lower among vaccinated patients after adjusting for age, sex and Charlson comorbidity index (OR 0.24, 95% CI 0.15–0.40).

Conclusions This study supports the use of SARS-CoV-2 vaccination to improve COVID-19 outcomes in patients on chronic dialysis.

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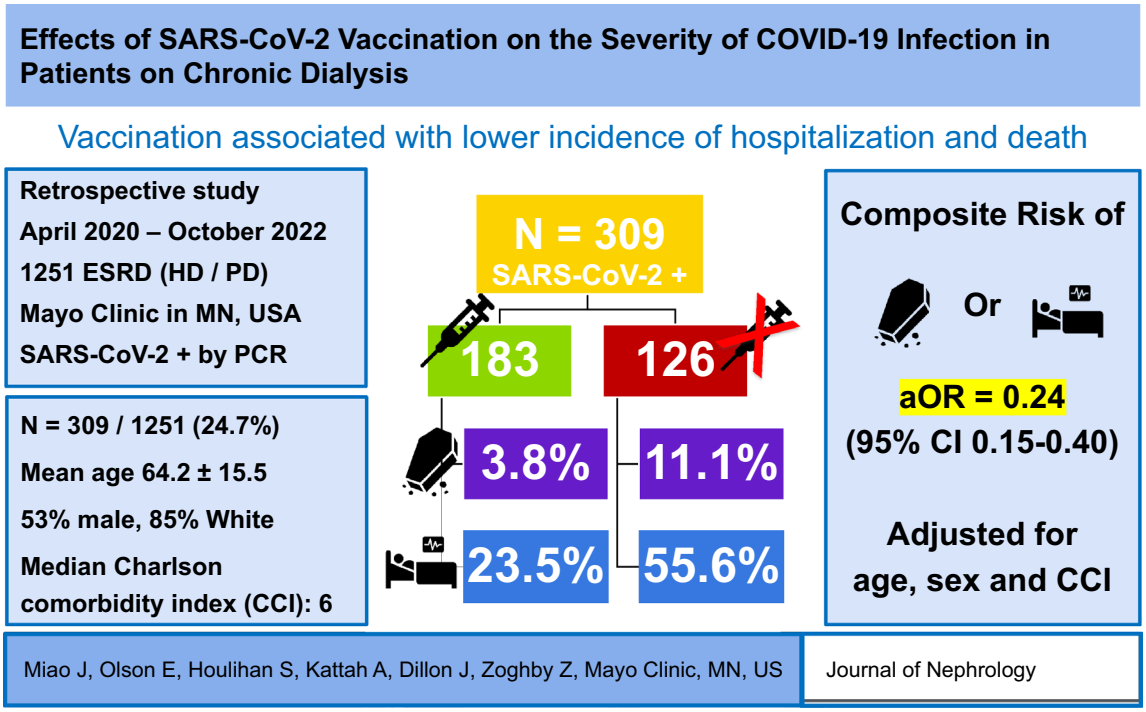
Graphical Abstract



Keywords SARS-CoV-2 · Vaccine · Dialysis · Death · Hospitalization

Introduction

COVID-19 disease caused by acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a systemic disease that may impact many organs including the kidneys. In patients with severe COVID-19, acute kidney injury, the development of chronic kidney disease (CKD), and the need for kidney replacement therapy occur more frequently compared to those with non-severe COVID-19 [1]. On the other hand, patients with impaired kidney function, particularly those with CKD stages G4-G5, those on chronic dialysis, and kidney transplant recipients are vulnerable to SARS-CoV-2 infection [2, 3]. The relative risk of COVID-19-associated mortality in patients with underlying kidney disease, including those on kidney replacement therapy, was reported to be three to fourfold higher compared to the general population [4–9]. Therefore, the availability of an effective and safe vaccine is important to prevent poor outcomes in these patients. Vaccination against other viruses is less effective in patients with severely impaired kidney function, likely caused by the immunosuppressive effect of uremic waste products [10]. The efficacy and safety of different types of SARS-CoV-2 vaccine have been demonstrated to be high in the general population [11–14]. Several studies have investigated the humoral or cellular responses to SARS-CoV-2 vaccination in patients on dialysis [15–18], but the results are inconsistent. Some studies showed that after vaccination, a significant portion of patients receiving maintenance dialysis developed dramatic antibody titers [19]. However, in comparison with a control group, antibody titers were found to be significantly lower in patients on dialysis [20]. Furthermore, evidence of the clinical efficacy of SARS-CoV-2 vaccine remains limited in these patients.

In this study, we aim to evaluate the incidence of severe COVID-19 outcomes (hospitalization and death) in dialysis patients based on their vaccination status and assess risk factors associated with these outcomes.

Methods

Patients

This retrospective study was approved by the Institutional Review Board (IRB 22-004841) of Mayo Clinic (Rochester, MN). We included all adults on maintenance dialysis (in-center and home dialysis, including peritoneal and hemodialysis) within the 12 dialysis centers (2 of them supporting home dialysis) of the Mayo Clinic Health System in the Midwest (Minnesota, Wisconsin and Iowa, USA) with

laboratory proven SARS-CoV-2 infection between April 1st, 2020 and October 31st, 2022. Patients who did not give research authorization were excluded.

The following information was collected from the electronic health record: age, race/ethnicity, sex, Charleston comorbidities index (CCI), dialysis modality (in-center vs home), hospital length of stay, death, SARS-CoV-2 vaccination status (unvaccinated, partially vaccinated, fully vaccinated, and boosted), vaccine type, and vaccination date. COVID-19 disease was diagnosed by positive PCR for SARS-CoV-2. For those with multiple COVID-19 infections, only the outcome of the first infection was analyzed. Partially, fully vaccinated or boosted were defined as receiving one, two or three doses of the vaccine (BNT162b2, Pfizer-BioNTech or m-RNA-1273, Moderna), respectively, at least 10 days prior to the SARS-CoV-2 infection [21]. Patients who received the Johnson COVID-19 vaccine (Ad26.COV2.S by Johnson & Johnson) were considered fully vaccinated 10 days after receiving one dose of the vaccine [21].

SARS-CoV-2 vaccination protocol

Our dialysis program complied with the United States public health authorities and followed the Center for Disease Control (CDC) recommendations to ensure SARS-CoV-2 vaccine was made available and offered to all patients. All our dialysis patients were educated by the dialysis staff and were recommended to receive the vaccine through the Mayo Clinic COVID-19 vaccination program or through community pharmacies offering the vaccine. In addition, all patients received a message on their patient portal to facilitate setting up a vaccination appointment at Mayo Clinic.

Outcomes

According to the World Health Organization (WHO) COVID-19 disease severity categorization, patients with severe or critical COVID-19 (pneumonia) require hospitalization or emergency interventions [22]. In this study, the two primary outcomes were the incidence of COVID-19-related hospitalizations and deaths during the study period. COVID-19-related hospitalization is defined as any patient admitted to the hospital within 14 days of a laboratory-confirmed diagnosis of SARS-CoV-2 infection [23]. COVID-19-related death is defined as a death primarily caused by SARS-CoV-2 infection [24]. The secondary outcome was the length of hospital stay.

Statistical analysis

The results are expressed as mean with standard deviation or median with the 25th and 75th percentile (Q1, Q3) for continuous data or as absolute numbers with percentages for discrete data. Statistical significance was determined by unpaired *t* test (two-tailed) and Fisher's exact (two-sided) test, respectively. The odds ratio (OR) and 95% confidence interval (CI) were presented for univariate analysis to assess risk of factors associated with the COVID-19 outcomes. In addition, a multivariate analysis was done to assess the effect of the vaccination status on the composite outcome of death or hospitalization, adjusted for age, sex and CCI. A composite outcome was used in the multivariate analysis because of the limited number of death events. All analyses were performed using JMP software, version 14.0 (SAS Institute Inc, Cary, NC). A p value of ≤ 0.05 was considered statistically significant.

Results

Characteristics and outcomes of dialysis patients with SARS-CoV-2 infection in the entire cohort

During the study period, 309 out of 1251 dialysis patients (24.7%) were infected by SARS-CoV-2 in all our centers. Among the infected patients, 275 (89%) had a single SARS-CoV-2 infection and 34 had multiple infections (33 patients had 2 infections, of whom, 2 were on home dialysis, and 1 patient on home dialysis had 3 infections).

As Table 1 shows, the average age at SARS-CoV-2 infection was 64.2 ± 15.5 years, 53% were male ($n = 165$), 85% white ($n = 262$), and the median CCI score was 6 (Q1, Q3:4, 8). Of the 309 patients, 6.8% ($n = 21$) died within a median of 14 days (Q1, Q3:9, 21.5) after SARS-CoV-2 infection, and 37% ($n = 113$) were hospitalized for a median of 5 days (Q1, Q3:4, 9). At the time of SARS-CoV-2 infection, 183 patients were vaccinated and 126 were not vaccinated. All patients were individually educated and advised to be vaccinated by the dialysis staff on multiple occasions. Unfortunately, many patients refused; overall, about 80% of all our dialysis patients were fully vaccinated as of December 31st, 2022. Among the vaccinated, 4% ($n = 7$) died compared to 11% ($n = 14$) of those who were unvaccinated ($p = 0.02$). The incidence of hospitalization was significantly lower in vaccinated compared to unvaccinated patients (24% vs 56%, $p < 0.001$). The length of hospitalization, age at infection, sex, race/ethnicity, dialysis modality (in-center vs home), and CCI score did not differ between the two groups.

The incidence of hospitalization was significantly higher in partially vaccinated (63.6% vs 20.9%, $p = 0.004$) and unboosted (32% vs 16.4%, $p = 0.04$) individuals compared to those fully vaccinated and boosted, respectively (Table 2). The death rate did not differ between fully and partially vaccinated as well as boosted and unboosted patients (Table 2). The incidence of hospitalization (23% vs 21.4%, $p > 0.99$)

Table 1 Characteristics and outcomes of chronic dialysis patients infected with SARS-CoV-2

	All ($n=309$)	Vaccinated ($n=183$)	Unvaccinated ($n=126$)	p value[a]
Age at infection, in years	64.2 ± 15.5	64.9 ± 14.9	63.3 ± 16.5	0.34
Male, *n* (%)	165 (53.4)	93 (50.8)	72 (57.1)	0.29
Race, *n* (%)				0.84
White	262 (84.8)	157 (85.8)	105 (83.3)	
Black	20 (6.5)	12 (6.6)	8 (6.4)	
Asian	21 (6.8)	10 (5.5)	11 (8.7)	
Not reported	6 (1.8)	4 (2.2)	2 (1.6)	
CCI, median score (Q1, Q3)	6 (4, 8)	6 (5, 8)	6 (4, 8)	0.66
Dialysis modality, *n* (%)[b]				
Home dialysis	31 (10)	18 (9.8)	13 (10.3)	> 0.99
In-center dialysis	278 (90)	165 (90.2)	113 (89.7)	
Hospitalized, *n* (%)	113 (36.6)	43 (23.5)	70 (55.6)	**< 0.001**
Median days (Q1, Q3)	5 (4, 9)	4 (4, 7)	6 (4, 11.3)	0.13
Re-hospitalized, *n* (%)[c]	10 (8.8)	3 (7)	7 (10)	0.09
Re-hospital stay, days (Q1, Q3)	4.5 (1.8, 6)	6 (6, 6)	4 (1, 5)	NA
Vaccination, *n* (%)				
Partially vaccinated	11 (3.6)[d]	11 (6)	NA	NA
Fully vaccinated	172 (55.7)[e]	172 (94)	NA	NA
Boosted	122 (39.5)[f]	122 (70.9)[g]	NA	NA
Death, *n* (%)	21 (6.8)	7 (3.8)	14 (11.1)	**0.02**
Time between infection and death, median days (Q1, Q3)	14 (9, 21.5)	10 (2, 19)	15 (9.8, 23.8)	0.59
Time between vaccination and infection, median days (Q1, Q3)	NA	356 (250, 500)	NA	NA

Values in bold are statistically significant

CCI Charlson comorbidity index, *Q1 and Q3* the 25th and 75th percentile, *NA* not applicable

[a]Determined by unpaired *t* test (two-tailed) or Fisher's exact (two-sided) test

[b]In-center dialysis: hemodialysis; home dialysis includes hemodialysis and peritoneal dialysis

[c]Percentage of admitted patients who returned to the hospital within the study period

[d]8 Pfizer and 3 Moderna. The percentage in the whole cohort

[e]114 Pfizer, 53 Moderna, and 5 J&J. The percentage in the whole cohort

[f]81 Pfizer, 36 Moderna and 5 J&J. The percentage in the whole cohort

[g]The percentage of booster in fully vaccinated patients

Table 2 Hospitalization and death among vaccinated patients based on vaccine type and status

	N	Hospitalization	p value[a]	Death	p value[a]
Fully vaccinated	172	36 (20.9%)	**0.004**	5 (2.9%)	0.06
Partially vaccinated	11	7 (63.6%)		2 (18.2%)	
Boosted	122	20 (16.4%)	**0.04**	4 (3.4%)	> 0.99
Unboosted	50	16 (32%)		1 (2%)	
BNT162b2[b] (Pfizer-Biotech NT)	122	28 (22.9%)	> 0.99	4 (3.3%)	0.51
m-RNA-1273 (Moderna)[b]	56	12 (21.4%)		3 (5.4%)	

Values in bold are statistically significant

[a]Determined by Fisher's exact (two-sided) test

[b]Only 5 patients received J&J. These patients were not included in the analysis

and death (3.3% vs 5.4%, $p=0.51$) did not differ between patients receiving the Pfizer-BioNTech or Moderna vaccine (Table 2).

Characteristics and outcomes of dialysis patients with SARS-CoV-2 infection based on the pandemic period

We performed a sub-analysis according to the periods of the COVID-19 pandemic. Period 1 was considered the "pre-vaccine" period between April 1st, 2020 and December 31st, 2020; period 2 (post vaccine and pre-delta SARS-CoV-2 variant) was defined as the period between January 1st, 2021 and August 31st, 2021, period 3 (delta variants) between September 1st, 2021 and February 28th, 2022, and period 4 (omicron) between March 31st, 2022 and October 31st, 2022.

Of 70 patients in period 1, 14% ($n=10$) died, and 61% ($n=43$) were hospitalized (Supplementary Table 1). Among the 21 patients who died in the entire cohort, 10 (47.6%) died in this period.

During period 2, which included 10 vaccinated and 21 unvaccinated patients (Supplementary Table 2), one patient died in each group (vaccinated, 10% vs unvaccinated, 5%, $p>0.99$), and the incidence of hospitalization was similar (vaccinated, 70% vs unvaccinated, 43%, $p=0.25$). The median duration between vaccination and SARS-CoV-2 infection was only 23 days (Q1, Q3:17.8, 121.8) in this period.

Period 3 had a total of 118 patients, including 91 vaccinated and 27 unvaccinated (Supplementary Table 3). During period 3, the incidence of hospitalization was significantly lower in vaccinated compared to unvaccinated patients (19.8% vs 51.9%, $p=0.002$). The incidence of COVID-19-related death in vaccinated patients was 2.2% compared to 11.1% in those unvaccinated, although the difference was not statistically significant ($p=0.08$). The median duration between vaccination and SARS-CoV-2 infection was 282 days (Q1, Q3:220, 343).

During period 4, that included 82 vaccinated and 8 unvaccinated patients (Supplementary Table 4), 4 patients with age ranging between 77 to 83 years died in the vaccinated group, and no patients died in the unvaccinated group. Of the 4 patients who died in the vaccinated group, 3 were fully vaccinated and boosted, and 1 was partially vaccinated. All 4 patients had high CCI scores (5, 6, 8 and 9, respectively). The incidence of hospitalization in vaccinated patients was 22% compared to 50% in those unvaccinated, although the difference was not statistically significant ($p=0.09$). However, the readmission rate in the vaccinated group was significantly lower (5.6% vs 50%, $p=0.02$) compared to the unvaccinated group. Additionally, the median duration between vaccination and SARS-CoV-2 infection was 504 days (Q1, Q3: 471, 565).

Factors associated with COVID-19 outcomes among dialysis patients with SARS-CoV-2 infection

We performed a univariate analysis to evaluate the association between several comorbidities and serious COVID-19 outcomes in dialysis patients with SARS-CoV-2 infection (Table 3). Chronic obstructive pulmonary disease was associated with death related to COVID-19 (OR 3.66; 95% CI 1.42–9.12; $p=0.01$). Higher CCI score (OR 1.17; 95% CI

Table 3 Factors associated with COVID-19 outcomes among dialysis patients infected with SARS-CoV-2

	Death		Hospitalization	
	Odds Ratio (95% CI)[a]	*p* values	Odds Ratio (95% CI)[a]	*p* values
Age at infection (years)[b]	1.02 (0.99–1.05)	0.16	1.01 (0.99–1.02)	0.33
Male (vs female)	0.96 (0.39–2.36)	0.92	1.3 (0.82–2.08)	0.27
CCI score[b]	1.16 (0.94–1.44)	0.18	**1.17** (1.05–1.32)	**0.01**
CAD/MI	1.18 (0.47–2.87)	0.72	**1.87** (1.16–3.00)	**0.01**
Heart failure	1.06 (0.43–2.61)	0.91	1.49 (0.94–2.39)	0.09
PVD	0.95 (0.22–2.96)	0.94	**1.92** (1.02–3.63)	**0.04**
Stroke	1.49 (0.33–4.74)	0.56	1.05 (0.48–2.20)	0.91
COPD	**3.66** (1.42–9.12)	**0.01**	1.28 (0.71–2.29)	0.41
Diabetes	0.86 (0.35–2.17)	0.74	**1.67** (1.04–2.74)	**0.04**
Hypertension	1.46 (0.40–9.36)	0.61	0.84 (0.43–1.69)	0.62
Vaccination	**0.32** (0.12–0.79)	**0.01**	**0.25** (0.15–0.39)	**<0.001**

Values in bold are statistically significant

CCI Charlson comorbidity index, *CAD/MI* coronary artery disease/Myocardial infarction, *PVD* peripheral vascular disease, *COPD* chronic obstructive pulmonary disease

[a]Odds ratios with 95% CIs and *p* values calculated using a logistic regression model

[b]Odds ratios for continuous variables are per unit change in regression

1.05–1.32; $p=0.01$) was associated with a higher likelihood of hospitalization. Specifically, a history of peripheral vascular disease (OR 1.92; 95% CI 1.02–3.63; $p=0.04$), coronary artery disease (OR 1.87; 95% CI 1.16–3; $p=0.01$), and diabetes (OR 1.67; 95% CI 1.04–2.74; $p=0.04$) were the strongest risk factors for hospitalization. Most notably, vaccination was significantly associated with a lower risk of COVID-19-related death (OR 0.32; 95% CI 0.12–0.79; $p=0.01$) and hospitalization (OR 0.25; 95% CI 0.15–0.39; $p<0.001$). After adjusting for age, sex and CCI, vaccination was associated with lower risk of hospitalization or death (composite outcome) with an OR of 0.24 (95% CI 0.15–0.40; $p<0.001$).

Discussion

In this study, among patients on chronic dialysis with COVID-19 disease, SARS-CoV-2 vaccination was associated with a 68% (95% CI 21–88%) lower mortality and 75% (95% CI 61–85%) lower rate of hospitalization compared to those unvaccinated despite having similar baseline characteristics and comorbidities. Furthermore, a multivariate analysis adjusted by age, sex and CCI showed that the composite outcome (hospitalization or death) was decreased by 76% in the vaccinated group relative to the unvaccinated. Our data suggest a significant protection of SARS-CoV-2 vaccination from severe disease in a population that is particularly vulnerable to COVID-19 though the length of hospital stay did not differ between the two groups. Previous studies from Scotland have reported SARS-CoV-2 vaccine efficacy against symptomatic infection in the range of 61–87% in patients on dialysis [25]. Our study also shows that hospitalization rate was significantly lower in fully vaccinated and boosted patients. A recent study reported that BNT162b2 vaccine booster was effective in increasing anti-SARS-CoV-2 spike protein S1 IgG titers in patients undergoing hemodialysis to the same level as the general population [26]. As such, these data highlight the importance of full vaccination and boosting in dialysis patients.

Currently, studies about the clinical efficacy of vaccination in dialysis patients with SARS-CoV-2 infection are limited. A study from the US with over 12,000 hemodialysis patients showed that the subsequent risk of symptomatic COVID-19 was significantly lower (hazard ratio, 0.22; 95% CI 0.13–0.35) in those receiving BNT162b2 compared with a matched unvaccinated cohort [27]. More recently, a multicenter study by Ashby et al. of 1323 hemodialysis patients with SARS-CoV-2 infection in the United Kingdom between December 1st, 2020 and September 26th, 2021 reported significant protection from severe disease after a two-dose vaccination schedule, with a 75% (95% CI 56–86%) lower hospitalization rate and an 88% (95% CI 70–95%) lower risk of death compared to unvaccinated individuals [28]. This is consistent with the effect of vaccination observed in our study. The overall incidence of hospitalization reported by Ashby et al. was similar to our cohort (vaccinated 29% vs 24% and unvaccinated 42% vs 56%, respectively). Similarly, the mortality in their unvaccinated group was 14% compared to 11% in our cohort although the mortality in the vaccinated group was higher in their cohort (9%) compared to our cohort (4%). This may be related to different patient characteristics, the pandemic period and the type of vaccine received. Our cohort included patients from April 1st, 2020 to October 31st, 2022 with 4 different periods, while the study by Ashby et al. only covered patients between December 2020 and September 2021. Also, in the study by Ashby et al. more than half of the cohort received the AZD1222 vaccine (AstraZeneca), while the rest received BNT162b2 (Pfizer-Biotech NT). In our study, most patients received either the BNT162b2 (Pfizer-Biotech NT, $n=122$) or the m-RNA-1273 (Moderna, $n=56$) vaccine, and the incidence of hospitalization and death did not differ between patients receiving the BNT162b2 or the m-RNA-1273 vaccines. However, the incidence of hospitalization was significantly lower in the fully vaccinated and boosted patients compared to partially vaccinated and unboosted patients. This suggests the importance for dialysis patients to receive the full SARS-CoV-2 vaccination series as well as the booster shot.

We also performed sub-analysis according to the different periods of the COVID-19 pandemic. The pre-vaccination period was notable for a high incidence of hospitalizations (61%) and COVID-19-related death (14%), with 48% of all deaths in the entire cohort occurring during this period. Similarly, a study showed that after 1 year of follow-up, 35.7% (20 of 56) of hemodialysis patients infected by SARS-CoV-2 during the first pandemic wave between March and May 2020 died, 6 (11%) during the initial admission and 14 (25%) in the following months, mainly within the first 3 months after diagnosis [8].

During the post-vaccine/pre-delta variant period, the incidence of hospitalizations was still high even in vaccinated patients (70%), possibly due to the short period between vaccination and SARS-CoV-2 infection (median 23 days, Q1, Q3:17.8, 121.8). The incidence of COVID-19-related mortality was not significantly different between vaccinated and unvaccinated patients (10% vs 5%). However, the overall mortality of 6% in this period was remarkably lower than the 14% seen in the pre-vaccine period. While this may have been related to the vaccination, new therapeutic options became available during this time.

During the delta variant period, vaccination was associated with decreased incidence of hospitalization compared to unvaccinated (20% vs 52%). Mortality was also lower (2% vs 11%) in vaccinated compared to unvaccinated although the difference was not significant likely due to the small number

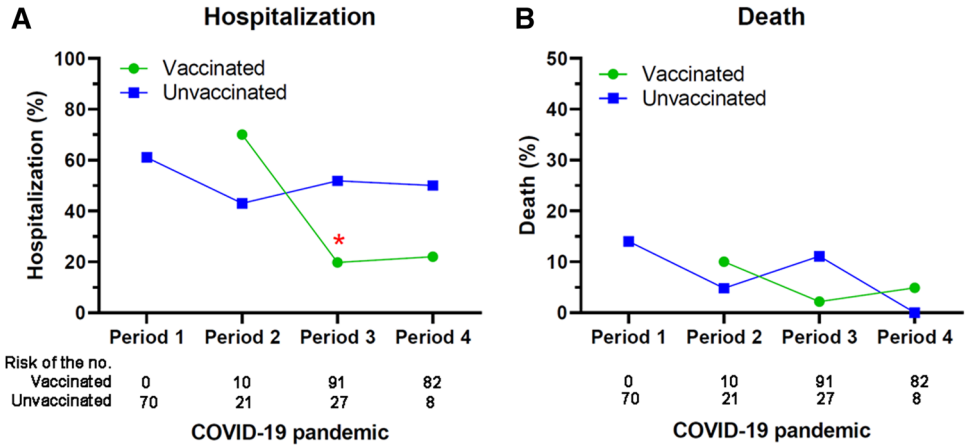


Fig. 1 Trend of death and hospitalization rates in vaccinated and unvaccinated patients on chronic dialysis. Period 1: pre-vaccine period between April 1st, 2020 and December 31st, 2020; period 2: post vaccine and pre-delta SARS-CoV-2 variant between January 1st, 2021 and August 31st, 2021; period 3: delta variants between September 1st, 2021 and February 28th, 2022; period 4: omicron variants between March 31st, 2022 and October 31st, 2022. *a significant difference of hospitalization incidence between vaccinated and unvaccinated patients in period 3

of deaths. Similarly, a recent study reported that during this period full vaccination significantly decreased the mortality rate (6.7% vs 11.1%, $p=0.004$) compared to unvaccinated hemodialysis patients [29]. Of note, our study shows that the median period between vaccination and SARS-CoV-2 infection was 283 days (Q1, Q3:220, 343), suggesting that vaccination has a long-term protective role. The persistent effectiveness was also observed in other studies showing that 75% of cases in the late SARS-CoV-2 infection group occurred more than 4 months after their second dose [30]. In another study, prior SARS-CoV-2 infection was seen to provide strong protection against re-infection up to 18 months later [28].

During the omicron variant period, hospitalization did not differ between the vaccinated and unvaccinated groups, but readmission rate was significantly lower in the vaccinated group. Overall, a notable, decreased incidence of death and hospitalization was observed in vaccinated patients compared to unvaccinated patients (Fig. 1). Four patients died in the vaccinated group during the omicron period, likely associated with older age and high CCI score. In one study of hemodialysis patients, age ≥ 65 years, immunosuppression, diabetes, cardiac, pulmonary, neurologic, and liver disease were associated with higher risks for severe COVID-19 outcomes (i.e., respiratory failure, intensive care unit hospitalization, or death), and all patients with severe COVID-19 outcomes after primary vaccination had at least one of these risk factors [31]. Another study on hemodialysis patients with COVID-19 infections showed that 30% of patients died from vascular causes and 40% from respiratory causes [8]. In our study, the only risk factor associated with death was a history of chronic obstructive pulmonary disease, while patients with higher CCI scores, particularly those with history of peripheral vascular disease, diabetes and coronary artery disease/myocardial infarction were at higher risk for hospitalization. Although substantially protected compared with unvaccinated patients, our data suggest that vaccinated dialysis patients remain at high risk for mortality (6.8%) and hospitalizations (37%) compared to individuals without kidney disease [32]. These findings suggest that dialysis patients should take precautions to reduce exposure and receive proven effective therapies to reduce the risk for severe COVID-19-associated outcomes.

This study includes patients from the early period of the COVID-19 pandemic until October 31st, 2022, but has several limitations. It is a single institution, observational study with a majority of Caucasian persons in a region limited to the Midwest of the USA; therefore, the results should be interpreted accordingly. The sample size also limits our statistical power to analyze the outcomes during each period of the pandemic and likely explains the lack of difference observed for certain outcomes within the subgroups. Also, we did not have data on antibody titers after vaccination.

In summary, our data suggest that vaccination decreases the severity of COVID-19 outcomes in dialysis patients with SARS-CoV-2 infection. These results provide additional support for promoting and prioritizing vaccination in this vulnerable population.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40620-023-01617-9.

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Availability of data and materials Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest None.

Ethical statement This study was approved by the Institutional Review Board of Mayo Clinic (IRB 22-004841; Rochester, MN), and conducted in compliance with the approved protocols, good clinical practice guidelines, and all applicable regulatory requirements.

Informed consent Patients who did not give research authorization to use their medical data were excluded.

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