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ORIGINAL ARTICLE

Infection

Humoral antibody response to the first dose of the ChAdOx1 nCoV-19 vaccine in Asian patients undergoing hemodialysis

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Abstract

Background and objectives: The immunogenicity of vaccines is known to be attenuated in patients with end-stage kidney disease due to uremia. Patients on dialysis were excluded from coronavirus disease 2019 (COVID-19) vaccine trials; thus, the effectiveness of vaccines for this population is unclear. The aim of this study was to explore whether Asian dialysis patients can effectively produce an immune response after being vaccinated with the first dose of the ChAdOx1 nCoV-19 vaccine.

Design setting, participants, and measurements: In this prospective cohort study, we included Asian hemodialysis patients who received the ChAdOx1 nCoV-19 vaccine. At 3 weeks after the first dose of vaccination, we assessed the

Wan-Chuan Tsai and Fang-Yeh Chu contributed equally to this study.

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humoral immune response by measuring anti-SARS-CoV-2 S antibody titers. The primary outcome was the seropositive rate following vaccination, defined as an antibody titer greater than or equal to 0.8 U/ml. Factors associated with seropositivity were explored in multivariate logistic regression analyses.

Results: In total, 434 participants were included. The mean age was 64 years, the mean dialysis vintage was 6 years, and 61% of the participants were men. At a mean time of 22 days from vaccination, 56% of the participants were seropositive. The vast majority (88%) had low antibody titers (< 15 U/ml). The multivariate logistic regression analyses showed that older age (every increase of 10 years, odds ratio [OR] 0.80, 95% CI 0.65–0.98, $p = 0.03$) was negatively associated with seropositivity and that higher Kt/V (every increase of 0.1, OR 1.14, 95% CI 1.01–1.28, $p = 0.03$) and higher serum albumin level (every increase of 0.1 g/dl, OR 1.09, 95% CI 1.02–1.18, $p = 0.02$) were positively associated with seropositivity.

Conclusions: In Asian hemodialysis patients, the seropositive rate was low, and most had low antibody titers after the first dose of the ChAdOx1 nCoV-19 vaccine. Younger age, better dialysis adequacy, and higher albumin levels were associated with seropositivity.

KEYWORDS
Asian, ChAdOx1 nCoV-19 vaccine, COVID-19, dialysis, humoral response, seropositive

INTRODUCTION

Vaccination is an effective preventive measure to ameliorate the impacts of coronavirus disease 2019 (COVID-19) on global health.[1] The deployment of vaccines against COVID-19 is of the highest priority for government agencies around the globe in the ongoing fight against the pandemic. Recent studies have established end-stage kidney disease (ESKD) to be among the most prevalent and important independent risk factors for severe COVID-19 and mortality.[2]

In the general population, the ChAdOx1 nCoV-19 (AZD1222) vaccine has been shown to be safe and highly effective in preventing severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, with efficacy up to 76% after the first dose.[3,4] However, vaccine efficacy and immunogenicity following vaccination in dialysis patients are generally lower due to a diminished immune response.[5,6] Moreover, prospective data on the effectiveness of currently available COVID-19 vaccines in dialysis patients are scarce, as this population was excluded from most studies.[7,8] Early reports on immunogenicity following vaccination in ESKD dialysis patients have begun to surface in the literature but are more limited, especially for ChAdOx1 nCoV-19, than those for mRNA vaccines, and to date, there is no study in the Asian population receiving dialysis.[9]

Due to the necessity of regular thrice weekly in-center hemodialysis in close proximity without being able to shelter in place, patients on hemodialysis are even more vulnerable to COVID-19, and nephrology societies have urged prioritization for this patient population.[10] In Taiwan, vaccines for hemodialysis patients received prioritized allocation. However, there has been a substantially inequitable global vaccine distribution, and the challenges of limited vaccine availability insurmountably remains in most countries, especially low- and middle-income countries.[11] Accordingly, some nations have opted to prioritize the increasing coverage of the first dose of COVID-19 vaccine rather than early completion of two doses in the high-risk population. Considering these abovementioned factors, the immunogenicity following the first dose of COVID-19 vaccination in the Asian population receiving dialysis is of high importance.

We designed a prospective observational cohort study among a large, single-center, hemodialysis patient group in an Asian population to evaluate the humoral antibody response following vaccination with the ChAdOx1 nCoV-19 vaccine. The preliminary findings regarding the humoral antibody response following the first dose vaccination are reported here. We also sought to determine clinical and laboratory factors associated with seropositivity following vaccination.

MATERIALS AND METHODS

Study population and design

This prospective observational study was conducted in a hemodialysis unit of a tertiary teaching hospital during June–July 2021. All subjects provided written informed consent to participate in this study, which was approved by the institutional review board at Far Eastern Memorial Hospital (FEMH-110101-E). Subjects were asked to participate if they met the following inclusion criteria (1) were aged older than 20 years, (2) had ESKD and had undergone hemodialysis, and (3) were vaccinated or willing to receive vaccination. All participants were vaccinated with the first dose of the ChAdOx1 nCoV-19 (AZD1222) vaccine. Our work followed the standards of the STROBE guidelines.[12]

Assessment of the humoral immune response to the vaccine

Nonfasting venous blood specimens were drawn prior to routine dialysis treatment to assess the humoral immune response to the vaccine. Approximately, 3 weeks after receiving the first dose of the ChAdOx1 nCoV-19 vaccine, all participants were tested for the presence of antibodies (including IgG) directed against the receptor-binding domain (RBD) of the SARS-CoV-2 spike (S) protein using the Elecsys Anti-SARS-CoV-2 S Assay (Roche Diagnostics). The participant was considered a responder if the test result was seropositive (i.e., the antibody titer value was greater than or equal to 0.8 U/ml). According to the manufacturer, this cutoff for the detection of anti-SARS-CoV-2 S antibodies gives a specificity of 99.98%, with a sensitivity of 98.8%. This cutoff has a strong correlation to a neutralization method with a positive predictive value of 96.3%. A cutoff of 15 U/ml further improved the positive predictive value to 99.1%, and thus, such a cutoff was used to define low antibody titer status in this study.

To distinguish the immune response due to naturally acquired COVID-19 from that due to vaccination, all participants were also tested for the presence of antibodies (including IgG) directed against the SARS-CoV-2 nucleocapsid (N) antigen using the Elecsys Anti-SARS-CoV-2 N Assay (Roche Diagnostics). According to the manufacturer, the test result was seropositive if the cutoff index (COI) was greater than or equal to 1.0, which gives a specificity of 99.8%, with a sensitivity of 99.5%. Throughout the study period, mandatory COVID-19 antigen rapid tests were routinely performed for early detection of asymptomatic patients on a weekly basis, and such data were collected to identify individuals who might have developed humoral immune response confounded by natural infection. We used the VTRUST COVID-19 Antigen Rapid Test (TaiDoc Technology Corporation, Taiwan) to detect SARS-CoV-2 nucleocapsid protein by using a lateral flow chromatographic immunoassay.

Data collection

The following clinical and laboratory data were collected through electronic medical records: age, sex, vintage, dry weight, cause of ESKD, history of parathyroidectomy, blood flow, dialysate flow, urea reduction ratio, Kt/V (Daugirdas formula), ferritin level, iron saturation, albumin level, white blood cell count, hemoglobin level, platelet count, blood urea nitrogen level, creatinine level, phosphate level, calcium level, intact parathyroid hormone, alanine transaminase level, aspartate transaminase level, alkaline phosphatase level, sodium level, potassium level, glucose level, total cholesterol level, triglyceride level, and types of medications.

Outcomes

The primary outcome measure was the rate of seropositivity for anti-SARS-CoV-2 S antibodies among the study participants. Responders were those who were seropositive, and nonresponders were those who were not. The secondary outcome measure was low antibody titer status (i.e., an antibody titer value of less than 15 U/ml). Clinical and laboratory factors associated with seropositivity were also explored.

Statistical analysis

Continuous measures were evaluated as the means (±SDs) or medians (first and third quartiles), and categorical variables were evaluated as counts and percentages. We classified the participants into responders and nonresponders according to seropositivity. For between-group comparisons, Student's t test was used for normally distributed variables, the Wilcoxon–Mann–Whitney test was used for non-normally distributed variables, and the chi-square test was used for categorical variables. Variables with statistical significance were included in the multivariate logistic regression analyses to explore factors associated with seropositivity. A two-sided P value less than 0.05 indicated statistical significance. There were no missing data or loss to follow-up in this cohort. All analyses were performed with SAS version 9.4 software (SAS Institute). Figure illustrations were performed with R software (version 4.0.5, R Foundation for Statistical Computing, Vienna, Austria).

TABLE 1 Characteristics of the study participants according to seropositivity

Characteristic	Overall ($n = 434$)	Responders ($n = 241$)	Nonresponders ($n = 193$)	p value
Age (years)	64 ± 12	61 ± 12	66 ± 12	<0.001
Dialysis vintage (years)	6.0 ± 5.9	5.9 ± 5.8	6.1 ± 5.9	0.64
Male sex (n, %)	264 (61)	152 (63)	112 (58)	0.29
Diabetes-related ESKD (n, %)	221 (51)	124 (51)	97 (50)	0.81
History of parathyroidectomy (n, %)	81 (19)	45 (19)	36 (19)	0.99
Use of intravenous iron agent (n, %)	130 (30)	73 (30)	57 (30)	0.86
Use of vitamin D analogs (n, %)	174 (40)	89 (37)	85 (44)	0.13
Use of antihypertensive drugs (n, %)	188 (43)	109 (45)	79 (41)	0.37
Dry weight (kg)	62.6 ± 12.7	63.6 ± 13.2	61.3 ± 12.1	0.06
Blood flow ≥300 ml/min (n, %)	102 (24)	71 (30)	31 (16)	0.001
Dialysate flow >500 ml/min (n, %)	55 (13)	38 (16)	17 (9)	0.03
Urea reduction ratio (%)	73 ± 4	73 ± 4	72 ± 4	0.08
Kt/V (Daugirdas formula)	1.52 ± 0.21	1.54 ± 0.23	1.50 ± 0.17	0.04
Ferritin (ng/ml)	372 (241, 522)	361 (230, 480)	405 (255, 571)	0.03
Iron saturation (%)	29 ± 13	29 ± 12	30 ± 14	0.33
Albumin (g/dl)	3.9 ± 0.4	4.0 ± 0.3	3.8 ± 0.4	<0.001
White blood cells (×1000/μl)	6.3 ± 1.9	6.5 ± 1.9	6.1 ± 1.9	0.01
Hemoglobin (g/dl)	11.3 ± 1.4	11.4 ± 1.2	11.1 ± 1.6	0.01
Platelets (×1000/μl)	191 ± 64	197 ± 67	183 ± 60	0.02
Blood urea nitrogen (mg/dl)	71 ± 18	71 ± 17	70 ± 20	0.6
Creatinine (mg/dl)	10.5 ± 2.2	11.0 ± 2.1	10.0 ± 2.2	<0.001
Phosphate (mg/dl)	4.6 ± 1.5	4.8 ± 1.5	4.5 ± 1.5	0.12
Calcium (mg/dl)	9.3 ± 0.7	9.3 ± 0.7	9.2 ± 0.8	0.39
Intact parathyroid hormone (pg/ml)	192 (84, 436)	181 (74, 431)	231 (91, 438)	0.82
Alanine transaminase (IU/L)	12 ± 15	10 ± 6	13 ± 21	0.05
Aspartate transaminase (IU/L)	15 ± 11	13 ± 5	17 ± 15	0.01
Alkaline phosphatase (IU/L)	86 ± 49	81 ± 45	91 ± 52	0.04
Sodium (mmol/L)	136 ± 3	136 ± 3	136 ± 3	0.56
Potassium (mmol/L)	4.3 ± 0.6	4.3 ± 0.6	4.3 ± 0.7	0.96
Glucose (mg/dl)	156 ± 76	160 ± 78	152 ± 74	0.28
Total cholesterol (mg/dl)	150 ± 40	153 ± 40	147 ± 39	0.09
Triglyceride (mg/dl)	176 ± 138	186 ± 152	165 ± 118	0.12
Anti-SARS-CoV-2 S antibody titer, mean (U/ml)	9.9 ± 36.5	17.8 ± 47.5	0.1 ± 0.3	<0.001
Anti-SARS-CoV-2 S antibody titer, median (U/ml)	1.1 (0.3, 5.4)	3.9 (1.9, 12.1)	0.3 (0.3, 0.3)	<0.001
Time from vaccination (days)	22 ± 2	22 ± 3	22 ± 2	0.11

Abbreviation: ESKD, end-stage kidney disease.

RESULTS

Characteristics of the study population

A total of 434 patients on hemodialysis were included in this study, and 431 of 434 (99.3%) patients were vaccinated during their routine dialysis sessions at our hemodialysis unit. All of them completed follow-up, so all data were analyzed. At baseline, there were no participants seropositive for antibodies directed against the SARS-CoV-2 N antigen, indicating no previous COVID-19 in our study cohort. During the follow-up

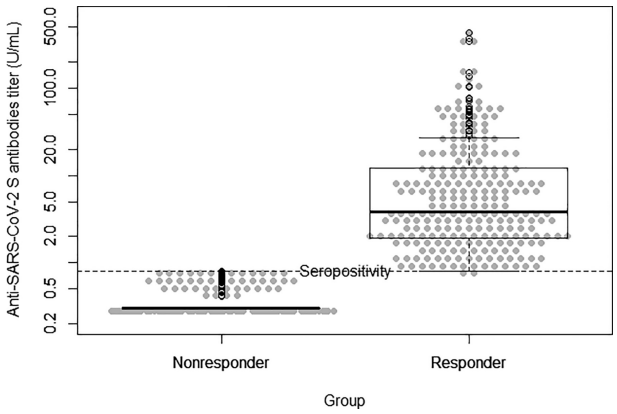

FIGURE 1 Comparison of anti-SARS-CoV-2 S antibody titers between responders and nonresponders. Each dot represents one participant's anti-SARS-CoV-2 S antibody titer value. The dotted horizontal line shows the threshold value for seropositivity, which was defined as an antibody titer of 0.8 U/ml. The responders had antibody titer values greater than or equal to 0.8 U/ml, and the nonresponders had antibody titer values less than 0.8 U/ml. In both groups, box plots of the antibody titer values are also illustrated. In the responder group, the top and bottom of the box indicate the interquartile range, the horizontal line within the box indicates the median, and the error bars represent the range between the minimal and maximal points. In the nonresponder group, values below the detection limit (<0.4 U/ml) are arbitrarily plotted as 0.3 U/ml, and the median, upper and lower quartiles and the minimal and maximal values are presented in the same location of the box plots as the solid horizontal line

period, there were no newly confirmed COVID-19 cases among our study participants, and the results from weekly COVID-19 antigen rapid tests also showed no participants with asymptomatic COVID-19. The baseline characteristics of the overall participants are provided in Table 1. The mean age was 64 years, the mean dialysis vintage was 6 years, and 61% of the participants were men. Of these, 51% of the participants had diabetes-related ESKD, 24% had blood flow ≥300 ml/min, and 14% had dialysate flow >500 ml/min. Their mean Kt/V was 1.52, serum albumin level was 3.9 g/dl, and hemoglobin level was 11.3 g/dl.

Only a minority ($n = 15$, 3.5%) of the study participants had conditions that could affect the humoral antibody response to vaccination, which is summarized in Table S1. These conditions included autoimmune disease ($n = 8$), liver transplant ($n = 2$), solid cancer ($n = 3$), and hematological disorder ($n = 2$). Among them, only two patients (one had breast cancer without chemotherapy and one had chronic myeloproliferative disorder with no medication) were seropositive.

Primary and secondary outcomes of the study population

At the mean time of 22 days after the first dose of immunization, 241 (55.5%) participants were seropositive for anti-SARS-CoV-2 S antibodies. The median (IQR) antibody titer was 1.1 (0.3, 5.4), and the mean titer (±SD) was 17.8 ± 47.5 U/ml. The vast majority (88%) of the participants had low antibody titers (<15 U/ml).

Comparisons of seropositivity between responders and nonresponders

Figure 1 shows the comparison of antibody titers for the responders and nonresponders. Table 1 shows the comparison of the baseline characteristics of the responders and nonresponders. As shown in Table 1, the factors associated with seropositivity were younger age (61 ± 12 years vs. 66 ± 12 years in responders and nonresponders, respectively, $p < 0.001$), blood flow ≥300 ml/min (30% vs. 16%, $p = 0.001$), dialysate flow >500 ml/min (16% vs. 9%, $p = 0.03$), higher Kt/V (1.54 ± 0.23 vs. 1.50 ± 0.17, $p = 0.04$), lower ferritin level (361 [IQR 230–480] vs. 405 [IQR 255–571] ng/ml, $p = 0.03$), higher albumin level (4.0 ± 0.3 vs. 3.8 ± 0.4 g/dl, $p < 0.001$), higher white blood cell count (6.5 ± 1.9 vs. 6.1 ± 1.9 × 1000/μl, $p = 0.01$), higher hemoglobin level (11.4 ± 1.2 vs. 11.1 ± 1.6 g/dl, $p = 0.01$), higher platelet count (197 ± 67 vs. 183 ± 60 × 1000/μl, $p = 0.02$), higher creatinine level (11.0 ± 2.1 vs. 10.0 ± 2.2 mg/dl, $p < 0.001$), lower aspartate transaminase level (13 ± 5 vs. 17 ± 15 IU/L, $p = 0.006$), and lower alkaline phosphatase level (81 ± 45 vs. 91 ± 52 IU/L, $p = 0.04$).

Other factors, such as sex, dry weight, diabetes-related ESKD, dialysis vintage, and the use of medications, including antihypertensive agents, vitamin D analogs, and intravenous iron agents, were not associated with seropositivity.

Factors associated with seropositivity in multivariate logistic regression analyses

Table 2 presents factors associated with the seropositivity of anti-SARS-CoV-2 S antibodies after the first dose of ChAdOx1 nCoV-19 vaccination in multivariate logistic regression analyses. After adjustment for all statistically significant variables from the univariate analyses in these multivariate analyses, only three factors remained significantly associated with seropositivity. These factors were age (odds ratio [OR] 0.80 with every increase of 10 years, 95% CI 0.65–0.98, $p = 0.03$), Kt/V (OR 1.14, every increase of 0.1, 95% CI 1.01–1.28, $p = 0.03$), and serum

TABLE 2 Factors associated with seropositivity after the first dose of ChAdOx1 nCoV-19 vaccination

Variables	Odds ratio[a]	95% CI	*p* value
Age (every increase of 10 years)	0.80	0.65–0.98	0.03
Kt/V (every increase of 0.1)	1.14	1.01–1.28	0.03
Albumin (every increase of 0.1 g/dl)	1.09	1.02–1.18	0.02
White blood cells (every increase of 1000/μl)	1.14	0.99–1.31	0.07
Alkaline phosphatase (every increase of 10 IU/l)	0.96	0.92–1.01	0.09
Male sex (female as reference)	0.81	0.48–1.36	0.42
Ferritin (every increase of 1 ng/ml)	0.99	0.99–1.00	0.24
Hemoglobin (every increase of 1 g/dl)	0.96	0.80–1.16	0.69
Platelet (every increase of 1000/μl)	1.00	0.99–1.00	0.92
Creatinine (every increase of 1 mg/dl)	1.08	0.96–1.23	0.22
Aspartate transaminase (every increase of 10 IU/L)	0.76	0.53–1.08	0.12
Blood flow ≥300 ml/min (<300 ml/min as reference)	1.32	0.71–2.45	0.38
Dialysate flow >500 ml/min (≤500 ml/min as reference)	1.07	0.50–2.28	0.87

Abbreviation: CI, confidence interval.

[a]All of the above variables were adjusted in the multivariate logistic regression analyses.

albumin level (OR 1.09, every increase of 0.1 g/dl, 95% CI 1.02–1.18, $p = 0.02$).

DISCUSSION

We conducted a large, single-center, prospective cohort study of 434 hemodialysis patients in an Asian population without prior COVID-19. The initial humoral antibody response following vaccination with a single dose of the ChAdOx1 nCoV-19 vaccine showed a low seropositivity rate, with only 56% of patients seropositive according to the anti-SARS-CoV-2 S antibody test at a mean time of 22 days. An attenuated immune response was found in most patients, with 88% having a low antibody titer (<15 U/ml). After adjusting for important clinical and laboratory parameters in the multivariate logistic regression analyses, we found three factors independently associated with the initial vaccine response, namely younger age, higher albumin level, and higher Kt/V. Our findings support that Asian ESKD patients on hemodialysis developed low and attenuated humoral immune responses to the first dose of the ChAdOx1 nCoV-19 vaccine, and thus, urgent and timely vaccination with the second dose is mandatory in these populations to yield better protection against COVID-19. More vulnerable patient groups, including those with older age, poor nutrition or chronic inflammation status and those with inadequate dialysis therapy, should be prioritized for immunization.

The urgency for vaccination in the in-center hemodialysis population is unique in that all patients have mandatory needs for dialysis (typically thrice weekly, 4 h/dialysis session). In Taiwan, hemodialysis patients were prioritized for COVID-19 vaccination along with other high-risk populations. Unfortunately, our study shows that almost half (44%) of patients on hemodialysis have no immune response to the first dose of vaccination. Further follow-up of antibody titers after full vaccination with the second dose and third "booster dose" will further clarify the antibody response in this population which is our ongoing project.

Although unsurprising, the low seropositivity rate in the ESKD population is in stark contrast to findings in healthy volunteers vaccinated with ChAdOx1 nCoV-19, for who peak levels of IgG were detectable at Day 14 and peaked at Day 28.[13] Similarly, in a cohort of health care workers, immunization with ChAdOx1 nCoV-19 resulted in 93.4% antibody seroconversion rate at 28–32 days in those previously uninfected with SARS-CoV-2.[14] Another study by Jeong and colleagues enrolling health care workers revealed a high rate of seropositivity (84.6%) at 11–28 days after the first dose of ChAdOx1 nCoV-19 when using the same Roche Assay as our study.[15]

Early findings regarding the response to the ChAdOx1 nCoV-19 and mRNA vaccines in ESRD patients, including those on hemodialysis, those on peritoneal dialysis and those with kidney transplantation, have begun to accumulate, with reports of variable response rates. Similar to the results in our study, low initial response after the first

vaccine dose was found in two studies,[16,17] with detectable antibody-positive rates of 70.6% for ChAdOx1 nCoV-19 and 81.8% for the Pfizer-BioNTech vaccine (BNT162b2)[16] at 28 days; an even lower positivity rate of 35% was found at 21 days with BNT162b2.[17] The attenuated response is further demonstrated in a small cohort study receiving the BNT162b2 vaccine, where a control group of health care workers was compared with hemodialysis patients and kidney transplant patients, and early on at Day 14, 100% of the control group already had detectable antibodies, whereas at Day 36, only 81% of hemodialysis and 4.1% of kidney transplant patients had detectable antibodies and with significantly attenuated levels.[18]

Such an attenuated immune response to the first dose of vaccine could be improved with the further COVID-19 immunization doses. A dialysis network study of antibody responses in hemodialysis patients to three different vaccines (BNT162b2, mRNA-1273/Moderna, and Ad26.COV2.S/Johnson&Johnson) showed combined detectable antibody levels at only a 35% rate at >14 days of the first dose of vaccination, with a modest increase to 77% at >14 days after complete vaccination, but with an attenuated response in up to 22.1% of participants, regardless of prior infection status.[19] Fortunately, positive antibody responses up to 90–96.4% have been reported after two doses.[20–22] However, a UK study showed that even with complete vaccination with ChAdOx1 nCoV-19, there were suboptimal levels of neutralizing antibodies against SARS-CoV-2 variants of concern,[23] which need to be investigated and correlated with further studies. In face of the new variants such as the recent Omicron surge since November 2021, government agencies around the world have also aggressively push for third dose "booster vaccination" to enhance protection against breakthrough infections and hospitalization.

The abovementioned studies show that ESKD patients on hemodialysis have delayed and attenuated humoral responses to the COVID-19 vaccines, which is comparable to our findings showing only 56% with positive antibody titers at 22 days after the first dose of the ChAdOx1 nCoV-19 vaccine. Some factors may differentiate individuals who will respond to vaccines. In our study, patients with younger age, higher albumin levels, and higher Kt/V were likely to be immunized, which is compatible with the findings of recent studies showing that older age and low albumin levels are associated with nonresponse or lower antibody titers.[16,19,21,22]

The possible explanations for the delayed and attenuated immunogenicity toward vaccination have been investigated in previous efforts to vaccinate the ESKD population, as the immune response to vaccines has been found to be diminished, with shorter attenuation periods in dialysis patients, as demonstrated for seasonal influenza virus vaccines and hepatitis B virus vaccines.[24,25] Disturbance in uremia impairs innate and adaptive immunity, including T lymphocytes, B lymphocytes, and dendritic cells.[26,27] The important factors that have been identified as risk factors for blunted vaccine antibody responses include hypoalbuminemia and chronic inflammation, uremic toxins, immunosuppression due to glomerulonephritis treatment, and prior or current kidney transplantation immunosuppressant use.[5,6]

Our study has several limitations. First, this is a single-center study with a homogenous Asian population and might not be representative of a wider population. However, the cohort was large, and our findings of delayed and attenuated responses to vaccines were comparable to those of previous studies, intentionally closing the knowledge gap in this field. Second, a neutralizing antibody test or T cell response to confirm a comprehensive picture of immunogenicity following vaccination was not available in our study. However, there is growing evidence that adequate antibody titers offer a higher level of protection, as a strong correlation has been found between anti-S antibody titers and neutralization antibody levels in many studies, and most studies have used antibody responses as a surrogate marker of the immune response following vaccination. Third, we could not completely exclude prior or recent COVID-19, which might enhance the immune response to vaccination. This possibility was unlikely because each participant in our cohort showed negative weekly antigen test results throughout the study follow-up and negative anti-SARS-CoV-2 N antibody tests, which were performed at the time of blood sampling.

In conclusion, the seropositive rate was low, with substantially low antibody titers after the first dose of the ChAdOx1 nCoV-19 vaccine in Asian hemodialysis patients. Younger age, better dialysis adequacy, and higher albumin levels were associated with seropositivity in hemodialysis patients. Further evaluation of immunogenicity response after two-dose vaccination in these patients is ongoing and can guide future policies.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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