Humoral Response after SARS-CoV-2 mRNA Vaccination in a Cohort of Hemodialysis Patients and Kidney Transplant Recipients

Clément Danthu,1,2 Sébastien Hantz,2,3 Arthur Dahlem,1 Marion Duval,1 Bacary Ba,1 Manon Guibbert,3 Zhour El Ouafi,1 Séverine Ponsard,1 Inasaf Berrahal,1 Jean-Michel Achard,1 Frédérique Bocquentin,1 Vincent Allot,1 Jean-Philippe Rerolle,1 Sophie Alain,2,3 and Fatouma Touré1,4

1 Department of Nephrology, Dialysis and Transplantation, Hospital University of Limoges, Limoges, France
2 UMR Institut National de la Santé et de la Recherche Médicale 1092, RESINFIT, Limoges, France
3 Department of Virology, Hospital University of Limoges, Limoges, France
4 UMR Centre National de la Recherche Scientifique 7276, Institut National de la Santé et de la Recherche Médicale U1262, Limoges, France

ABSTRACT

Background Kidney transplant recipients and patients receiving hemodialysis are immunocompromised populations that are prioritized for COVID-19 vaccination but were excluded from clinical trials of SARS-CoV-2 mRNA vaccines. Antibody titers and rates of seroconversion after vaccination are lower among patients with CKD and those taking immunosuppressants compared with controls. Data are lacking regarding their humoral response to vaccination to prevent COVID-19.

Methods This investigation of early serological response after COVID-19 vaccination with the Pfizer/BioNTech (BNT162b2) mRNA vaccine included 78 patients undergoing hemodialysis, 74 kidney transplant recipients, and seven healthy controls. We recorded data from the medical file for various clinical parameters, including response to hepatitis B vaccination, and measured antibody titers against SARS-CoV-2 at 0, 14, 28, 36, and 58 days after the first injection.

Results In controls, we detected antibodies at a positive level (>13 arbitrary units per ml; AU/ml) at day 14 postinjection, which increased progressively to peak at day 36 (1082 AU/ml; interquartile range [IQR], 735.0–1662.0). Patients undergoing hemodialysis had lower titers that peaked at day 58 (276 AU/ml; IQR, 83.4–526.0). We detected a positive antibody level in only three transplant recipients at day 36. In patients on hemodialysis, those aged <75 years had a higher antibody response versus those aged ≥75 years, and serum albumin and Kt/V were positively correlated with serological response (P<0.04 and P<0.0, respectively); nonresponders to HBV vaccine had the lowest anti–SARS-CoV-2 antibody titers.

Conclusions Our results suggest that the postvaccination humoral response is strongly inhibited by immunosuppressant therapy in kidney transplant recipients, and is reduced by the uremic condition in patients undergoing hemodialysis.

JASN 32: 2153–2158, 2021. doi: https://doi.org/10.1681/ASN.2021040490

Kidney transplant recipients and patients on hemodialysis are immunocompromised populations that are prioritized for coronavirus disease 2019 (COVID-19) vaccination.1 Both these groups were excluded from studies of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) mRNA vaccines.2–4 It is well established that patients with CKD and those taking immunosuppressants have lower antibody titers and lower rates of seroconversion after vaccination, compared with healthy controls.5,6 Indeed, this lower postvaccine response led to the adaptation of hepatitis B and influenza immunization schedules.5,7,8 For the COVID-19 vaccine, data are scarce on the postvaccine response in immunocompromised patients. In this study, we analyzed the kinetics of serological response after anti–COVID-19 vaccination with the Pfizer/BioNTech (BNT162b2) mRNA vaccine (Comirnaty) in patients of our nephrology unit.

METHODS

Patients

Patients were recruited among those undergoing hemodialysis in our Nephrology unit, and from kidney transplant recipients of our nephrology unit. Patients receiving treatment with immunosuppressants were excluded from studies of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) mRNA vaccines.2–4 It is well established that patients with CKD and those taking immunosuppressants have lower antibody titers and lower rates of seroconversion after vaccination, compared with healthy controls.5,6 Indeed, this lower postvaccine response led to the adaptation of hepatitis B and influenza immunization schedules.5,7,8 For the COVID-19 vaccine, data are scarce on the postvaccine response in immunocompromised patients. In this study, we analyzed the kinetics of serological response after anti–COVID-19 vaccination with the Pfizer/BioNTech (BNT162b2) mRNA vaccine (Comirnaty) in patients of our nephrology unit.

Received April 11, 2021. Accepted May 14, 2021

C.D. and S.H. contributed equally to this study.

Published online ahead of print. Publication date available at www.jasn.org.

Correspondence: Prof. Fatouma Touré, Department of Nephrology, Transplantation and Dialysis, Hospital University of Limoges, CHU Dupuytren 2, 16 rue du Professeur Descotes 87000 Limoges and UMR CNRS 7276, Inserm U1262, Controle de la Réponse Immune et Lymphoproliférations, 2, rue du Professeur Descotes, 87025 Limoges. Email: Fatouma.Toure@chu-limoges.fr

Copyright © 2021 by the American Society of Nephrology.

JASN 32: 2153–2158, 2021 ISSN : 1533-3450/1046-2153 2153
recipients who were followed in our center. The control group constituted members of the medical staff, vaccinated between February and March 2021, and included in the institutional postvaccine follow-up program.

Patients and healthy subjects included in the study received two doses (30 μg each) of the Pfizer/BioNTech (BNT162b2) Comirnaty vaccine, 28 days apart, according to the recommendations of French National Health Authority (Haute Autorité de Santé),² between February 2, 2021, and March 15, 2021. None of the subjects included had a prior PCR–confirmed diagnosis of COVID-19. For each patient, the following clinical parameters were recorded from the medical file: age, sex, body mass index (BMI), primary kidney disease, cardiovascular comorbidities, response to hepatitis B vaccination, renal function, lymphocyte count, gammaglobulin level, and antibody titer level against SARS-CoV-2 at days 0, 14, 28, 36, and 58 after the first injection. Specific data regarding transplantation or hemodialysis were also collected for each subgroup of patients: date of transplantation, induction therapy, immunosuppressant treatment, Kt/V, type of dialysis, and duration of dialysis. The study was approved by the French commission for data privacy under 2210609609/(V0).

Anti–SARS-CoV-2 Antibody Response
All patients were tested for anti-N antibodies (Abbott Alinity SARS-CoV-2 IgG, Chicago, IL, USA) on the day of the first injection, and at each timepoint during follow-up, to eliminate past SARS-CoV-2 infection, or infection occurring during the vaccination program.

The anti–SARS-CoV-2 antibody response against the spike protein was assessed at 14, 28, 36, and 58 days postinjection using the LIAISON SARS-CoV-2 TrimericS IgG (DiaSorin, Saluggia, Italy), with titers >13 arbitrary units per ml (AU/ml) considered as positive (detection range 1.85–800 AU/ml; positive agreement 98.7%; negative agreement 99.5%). Values >800 were diluted to 1:20 to obtain the exact value. Antibodies detected over the threshold of 13 AU/ml are considered as neutralizing antibodies according to the manufacturer’s data. Both tests are on the basis of chemiluminescence microparticle immunoassay and were performed according to the manufacturer’s instructions. We performed additional analyses to focus on the antibody response at day 36, reported in the literature to be the timepoint associated with the highest antibody level in the general population.³,⁴

Statistical Analysis
Qualitative variables are described as number and percentage. Quantitative variables are described as median and interquartile ranges (IQR), or means and standard deviation. For comparisons, the chi-squared, Fisher’s exact, Mann–Whitney, or Wilcoxon tests were used according to their conditions of application. Correlations were investigated using Pearson’s correlation coefficient between the main outcome (antibody titers >13 AU/ml) and each of the following quantitative variables: age, BMI, Kt/V, albuminemia, anti-Hepatitis B surface antibodies (anti-HBs), lymphocyte count, and total IgG. Finally, because reduced postvaccine humoral response is a common feature of patients with ESKD, for each patient we analyzed the link between previous humoral response to hepatitis B virus (HBV) vaccine and response to the Pfizer-BNT162b2 anti–COVID-19 vaccine. To this end, patients undergoing hemodialysis were categorized into three groups, depending on the titers of anti-HBs: patients with no detection of anti-HBs antibodies were considered nonresponders to the HBV vaccine; patients with a titer of antibodies between 10 mili-international units per milliliter (mIU/ml) and 200 mIU/ml were considered mild responders (intermediate); and patients with anti-HBs >200 mIU/ml were considered as high responders. Humoral response to anti–COVID-19 vaccination was compared across HBV responder groups. Statistical analysis was performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and GraphPad Prism version 9.1.

RESULTS
Description of the Study Population
The baseline characteristics of the population are detailed in Table 1. In the kidney transplant recipient group, average age was 64.8±11.5 years, 38.9% were women, and mean time since transplantation was 6.42±7.8 years. The maintenance immunosuppressant regimen included calcineurin inhibitors (87%), corticosteroids (45.4%), antimitabolites (82.4%), m-Tor inhibitors (10.4%), and belatacept (2.6%). The antimitabolites used were mycophenolate mofetil (85.2%), mycophenolic acid (11.5%), and azathioprine (3.3%). Mean GFR was 44.5±18.5 ml/min, as estimated by the CKD Epidemiology Collaboration equation. All patients in the hemodialysis group were undergoing hemodialysis in the University Hospital of Limoges; mean age was 73.5±12.8 years, 40.2% were women, and the mean duration of dialysis was 5.1±6.3 years. Subjects in the control group were aged 51.6±6.8 years, and 42% were women (Table 1).

Kinetics of Humoral Response
The anti–SARS-CoV-2 antibody response against the spike protein was analyzed at
14, 28, 36, and 58 days postinjection, in each group. In the control group, antibodies were detected at a positive level (≥13 AU/ml) starting at day 14 postinjection, and increased progressively to peak at day 36. The median antibody titer in the control group was: 59 AU/ml (IQR, 26.5–216.5) at day 14, 1082 AU/ml (IQR 735.0–1662) at day 36, and 925 AU/ml (IQR 637–3624.5) at day 58 (Figure 1).

Patients undergoing hemodialysis had a similar pattern of response, but at a lower magnitude, with greater heterogeneity and a longer time to maximal response, which was reached at day 58.

In this group, median antibody titer was 4.0 AU/ml (IQR, 1.85–12.2) at day 14; 6.6 AU/ml (IQR 2.1–19.0) at day 36; and 276 AU/ml (IQR 83.4–526.0) at day 58.

A positive antibody level was detected in only three kidney transplant recipients at day 36. These three patients had immunosuppressant regimens comprising cyclosporine monotherapy.

### Intensity of Humoral Response

We then focused on the antibody response at day 36, reported to be the timepoint associated with the highest antibody level in the general population (Table 2). At day 36, 100% of the control group had responded to the vaccine, with an antibody titer higher than the positivity threshold. The proportion of responders (as defined by the threshold of 13 AU/ml) in the hemodialysis group was not statistically different from that of the control group (81% versus 100%)

### Table 1. Baseline characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Transplant Recipients (n=74)</th>
<th>Patients on Hemodialysis (n=78)</th>
<th>Control Group (n=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>64.8±11.5</td>
<td>73.5±12.8</td>
<td>51.6±6.8</td>
</tr>
<tr>
<td>Females, n (%)</td>
<td>30 (38.9)</td>
<td>32 (41)</td>
<td>3 (42)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>26.7±5.8</td>
<td>26.8±5</td>
<td>24.1±1.2</td>
</tr>
<tr>
<td>First transplantation, n (%)</td>
<td>66 (85.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean time since transplantation, yrs</td>
<td>6.42±7.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean duration of dialysis, yrs</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary kidney disease, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glomerular</td>
<td>24 (32.4)</td>
<td>5 (6)</td>
<td></td>
</tr>
<tr>
<td>Vascular</td>
<td>8 (10.8)</td>
<td>21 (26.9)</td>
<td></td>
</tr>
<tr>
<td>Intestinal</td>
<td>5 (6.7)</td>
<td>6 (7.6)</td>
<td></td>
</tr>
<tr>
<td>Polycystic kidney disease</td>
<td>13 (17.5)</td>
<td>8 (10)</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>6 (8.1)</td>
<td>20 (26.9)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>18 (24.3)</td>
<td>18 (24.3)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>27</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>HIV</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>14</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Cirrhosis</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>History of cancer</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Anti HBS-Ab</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative &lt;10</td>
<td>25</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Intermediate: 10–200</td>
<td>26</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>High: &gt;200</td>
<td>23</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Albumin level, g/dl</td>
<td>4.07±0.37</td>
<td>3.54±0.47</td>
<td></td>
</tr>
<tr>
<td>Lymphocyte count, x10⁹/mm³</td>
<td>1.630±1250</td>
<td>1.200±600</td>
<td></td>
</tr>
<tr>
<td>Total Ig level, g/l</td>
<td>7.58±4.7</td>
<td>8.1±3.8</td>
<td></td>
</tr>
<tr>
<td>Immunosuppressant regimen, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Induction therapy</td>
<td>77 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antithymocyte serum/basiliximab</td>
<td>27 (35.1)/49 (64.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcineurin inhibitors</td>
<td>68 (91.8)</td>
<td>1 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Belatacept</td>
<td>2 (2.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Everolimus</td>
<td>8 (10.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antimetabolite</td>
<td>61 (82.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mycophenolate mofetil</td>
<td>52 (85.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mycophenolic acid</td>
<td>7 (11.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azathioprine</td>
<td>2 (3.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steroids</td>
<td>34 (45.9)</td>
<td>3 (3.7)</td>
<td></td>
</tr>
<tr>
<td>Rituximab</td>
<td>—</td>
<td>2 (2.5)</td>
<td></td>
</tr>
<tr>
<td>Type of dialysis HD/HDF, n/n</td>
<td>—</td>
<td>66/12</td>
<td></td>
</tr>
<tr>
<td>Mean Kt/V</td>
<td>—</td>
<td>1.3±0.2</td>
<td></td>
</tr>
</tbody>
</table>

HBS-Ab, hepatitis B surface antibodies; HD, hemodialysis; HDF, hemodiafiltration.
However, the median antibody level in the control group was significantly higher than in the hemodialysis group: 1082 AU/ml (IQR, 293–5500) for controls versus 114 AU/ml (IQR, 15–1482) for patients on hemodialysis, \( P<0.0001 \).

Factors Associated with Humoral Response on Patients on Hemodialysis

We investigated the factors associated with the antibody titer in the hemodialysis group. We did not find any significant relation between diabetes, sex, or BMI, and antibody production. However, we observed higher antibody production in patients aged <75 years compared with those aged ≥75, suggesting that antibody response was associated with age: 115 AU/ml (IQR, 1.85–1482) versus 60 AU/ml (IQR, 1.85–526) \( P<0.03 \). In addition, serum albumin and Kt/V were also positively correlated with serological response, \( P<0.04 \) and \( P<0.02 \), respectively.

Association between Humoral Response to Hepatitis B Virus Vaccine and Humoral Response to SARS-CoV-2 Vaccine

Comparison with the humoral response to anti–COVID-19 vaccination according to prior response to HBV vaccination showed that the median titer of anti SARS-CoV-2 antibodies differed between these three groups of patients (Table 3). Indeed, nonresponders to HBV vaccine had the lowest SARS-CoV-2 antibody titers (36 AU/ml; IQR, 1.85–526), whereas patients with intermediate and high levels of anti-HBs had significantly higher SARS-CoV-2 antibody titers: 113 AU/ml (IQR, 1.85–1482) for the intermediate group (\( P=0.02 \)) and 209 AU/ml (IQR, 9.06–565) (\( P=0.03 \)) for the high HBV response group (Table 3).

\[ \text{DISCUSSION} \]

In this study, we describe the kinetics of humoral response after Pfizer BNT162b2, Comirnaya vaccination in kidney transplant recipients, patients undergoing hemodialysis, and healthy controls. To the best of our knowledge, this is the first study to compare postvaccine humoral response of subgroups of patients with CKD. Our results confirm previous reports of lower antibody responses among patients who are transplanted and highlight novel findings for the pattern of response in patients on hemodialysis, because we found that nonresponders to the HBV vaccine were less likely to develop humoral response after the COVID-19 vaccine. This finding is of particular interest not only for clinical care, but also as an avenue for future research, focusing on common pathophysiological mechanisms linking HBV and SARS-CoV-2 humoral response.

Kidney transplant recipients in our study were younger, and had a satisfactory renal function (44.5±18.5 ml/min), but we found a significantly lower

### Table 2. Postvaccine serological response at 36 days after the first injection

<table>
<thead>
<tr>
<th>Variable</th>
<th>Kidney Transplant Recipients (n=72)</th>
<th>Patients on Hemodialysis (n=75)</th>
<th>Healthy Controls (n=7)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of total study population</td>
<td>46.8</td>
<td>48.7</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Responders, n (% of the group)</td>
<td>3 (4.1)</td>
<td>59 (85.5)</td>
<td>7 (100)</td>
<td>( P&lt;0.001 ) (KTR versus HD) ( P&lt;0.001 ) (KTR versus Control) ( P=0.38 ) (HD versus Control) ( P&lt;0.0001 )</td>
</tr>
<tr>
<td>SARS-CoV-2 Antibody level, AU/ml median (Q1–Q4)</td>
<td>NA</td>
<td>114 (15–1488)</td>
<td>(293–5500)</td>
<td></td>
</tr>
</tbody>
</table>

KTR, kidney transplant recipients; HD, hemodialysis; Contr., controls; NA, not applicable (low number of responders).
humoral response in this group, with only 4.3% found to be responders at 36 days after the first injection. Patients in the hemodialysis group were older, and had lower residual renal function compared with the kidney transplant recipients. However, despite these differences, 85.5% were found to be responders in the hemodialysis group. This suggests that, rather than age or CKD condition, the immunosuppressant therapy may be a critical factor implicated in this lack of humoral response.

Our study is in line with recent published reports describing lower humoral response in kidney transplant recipients. For example, Boyarsky and colleagues reported an immunization rate of 54% in a population of solid organ transplant recipients, whereas publications from Benotmane et al. and Grupper et al. respectively observed that 48% and 37.5% of kidney transplant recipients mounted a humoral response after two doses of mRNA vaccine.10–12 Hence, our results are markedly different, with a lower immunization rate. We hypothesize that the presence of several factors associated with poor humoral response could account for this discrepancy. First, our transplant recipients were older than previous published cohorts, by at least 5 years on average.10–12 Second, the effect of mycophenolate mofetil–based immunosuppressant regimens has been reported10–12 and most of our patients were treated with a combination of antirejection drugs, including mycophenolate mofetil. Lastly, our vaccination protocol was homogeneous, with the use of only one mRNA vaccine, Pfizer BNT162B2, but recent reports suggest the Moderna vaccine leads to higher immunization rates.10,13

Taken together, our data and recent reports in the literature argue for a revision of the vaccination protocol in kidney transplant recipients, the type of vaccine, number of injections, and doses should be redefined in light of these recent findings.

In this report, we describe for the first time the profile of humoral response to the Pfizer BNT162B2 Comirnaty vaccine in patients undergoing hemodialysis. We found that antibody production in this population had a pattern similar to that of healthy subjects, with a similar rate of responders at day 36. However, humoral response in patients on hemodialysis was delayed, heterogeneous, and of lower intensity, as assessed by the antibody level. Lower humoral response in patients on hemodialysis has recently been reported,14 and our results are in agreement. In addition, we found that the humoral response of the hemodialysis population was correlated with age, serum albumin, and Kt/ V. These factors are well established as being associated with immune status and therefore, able to influence humoral response in the general population, particularly in uremic subjects.6,7

A finding of interest in our study is the link between the humoral response to the Pfizer BNT162B2 Comirnaty vaccine, and previous response to hepatitis B vaccination. Patients who were nonresponders to HBV vaccine were those who also displayed the lowest level of anti–SARS-CoV-2 antibodies, suggesting similar mechanisms are involved in the failure to mount an immune response to these two vaccines.15–17 Taken together, these findings suggest the humoral response to the Pfizer BNT162B2 Comirnaty vaccine in patients undergoing hemodialysis is guided by factors related to the uremic condition, leading to delayed humoral response of lower magnitude.

Furthermore, our results suggest response to the vaccine could be predicted for each patient by analyzing the level of anti-HBs, reflecting the magnitude of the humoral response to HBV vaccine. This could help us to personalize the anti–COVID-19 vaccination protocol.

Our study has several limitations, including its single-center and retrospective design. However, the strengths of our study include the comparison of two populations with CKD, and the precise and dynamic analysis of humoral response.

Our results suggest that (1) immunosuppressant therapy in kidney transplant recipients is a key factor inhibiting their humoral response to the Pfizer BNT162B2 vaccine; and (2) humoral response in patients undergoing hemodialysis is regulated by factors related to the uremic condition, leading to a significant number of responders but with a delayed response, of lower magnitude. Interestingly, the levels of antibodies detected with the LIAISON SARS-CoV-2 TrimericS IgG ELISA assay were shown to be correlated with SARS-CoV-2 neutralizing antibodies,18,19 suggesting that low titer of anti–SARS-CoV-2 may still be efficient in neutralizing the virus. Further studies are warranted to determine whether the humoral response obtained in the

---

### Table 3. Post–COVID-19 vaccine serological response according to titers of anti-HBs antibody in patients undergoing hemodialysis

<table>
<thead>
<tr>
<th>Immune Response to Vaccine</th>
<th>Anti HBs-Ab</th>
<th>Anti HBs-Ab</th>
<th>Anti HBs-Ab</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative &lt;10 mIU/ml (n=40)</td>
<td>Intermediate: 10–200 mIU/ml (n=26)</td>
<td>High: &gt;200 mIU/ml (n=12)</td>
</tr>
<tr>
<td>Titer of anti-SARS-CoV-2 antibody (AU/ml)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative versus intermediate P=0.02</td>
<td></td>
<td></td>
<td>P=0.295, intermediate versus high</td>
</tr>
<tr>
<td>Negative versus high P=0.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 (1.85–526)</td>
<td>113.5 (1.85–1482)</td>
<td>209 (9.06–565)</td>
<td></td>
</tr>
</tbody>
</table>
hemodialysis group is sufficient to confer efficient protection against COVID-19 disease.

DISCLOSURES

B. Ba reports speakers bureau from SOSENEPH; and reports having other interests/relationships with SOSENEPH. F. Touré reports receiving honoraria from Astellas, Baxter, and Fresenius; and being a scientific advisor of Fresenius. S. Alain reports receiving research funding from BioMerieux, Merck, MSD, and Sanofi Pasteur Takeda, and Shire. All remaining authors have nothing to disclose.

FUNDING

None.

ACKNOWLEDGMENTS

The authors would like to thank Ms. Celine Boche, Ms. Estelle Depenne, and Ms. Karelle Reineix, for their investment in the vaccination program of our patients. We also would like to thank all of the medical staff and all of the nurses involved in the institutional vaccination program for hemodialized and kidney transplant recipients. We would like to thank Ms. El Hamel Chahrazed, Ms. Florence Laforet, and Ms. Elodie Bec for their help in collecting the data for this study. Lastly, we thank Dissior for supplying the SARS-CoV-2 Trimerics IgG assay. S. Alain, F. Bocquentin, C. Danthu, S. Hantz, J. P. Rerolle, and F. Toure designed the study; A. Dahlam, C. Danthu, S. Hantz, and S. Ponsiard collected the data; S. Alain, B. Ba, F. Bocquentin, A. Dahlam, C. Danthu, S. Hantz, Z. E. Ouafi, J. P. Rerolle, and F. Toure analyzed the data; S. Alain, C. Danthu, S. Hantz, and F. Toure wrote the manuscript; and all authors approved the manuscript.

REFERENCES


