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Breakthrough COVID-19 cases despite prophylaxis with 150 mg of tixagevimab and 150 mg of cilgavimab in kidney transplant recipients

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Abstract
The cilgavimab–tixagevimab combination retains a partial in vitro neutralizing activity against the current SARS-CoV-2 variants of concern (omicron BA.1, BA.1.1, and BA.2). Here, we examined whether preexposure prophylaxis with cilgavimab–tixagevimab can effectively protect kidney transplant recipients (KTRs) against the omicron variant. Of the 416 KTRs who received intramuscular prophylactic injections of 150 mg tixagevimab and 150 mg cilgavimab, 39 (9.4%) developed COVID-19. With the exception of one case, all patients were symptomatic. Hospitalization and admission to an intensive care unit were required for 14 (35.9%) and three patients (7.7%), respectively. Two KTRs died of COVID-19-related acute respiratory distress syndrome. SARS-CoV-2 sequencing was carried out in 15 cases (BA.1, n = 5; BA.1.1, n = 9; BA.2, n = 1). Viral neutralizing activity of the serum against the BA.1 variant was negative in the 12 tested patients, suggesting that this prophylactic strategy does not provide sufficient protection against this variant of concern. In summary, preexposure prophylaxis with cilgavimab–tixagevimab at the dose of 150 mg of each antibody does not adequately protect KTRs against omicron. Further clarification of the optimal dosing can assist in our understanding of how best to harness its protective potential.

KEYWORDS
clinical research/practice, infection and infectious agents—viral, infection and infectious agents—viral: SARS-CoV-2/COVID-19, infectious disease, solid organ transplantation

1 | INTRODUCTION
Transplant recipients are at high risk of COVID-19-related death.1 Currently, the serum SARS-CoV-2 neutralizing capacity is considered the most reliable correlate of protection in this vulnerable population.2 However, due to therapeutic immunosuppression, a significant fraction of transplant recipients fail to mount a protective antibody response despite reinforced

Abbreviations: BAU, binding arbitrary units; COVID-19, coronavirus disease 2019; FDA, Food and Drug Administration; KTRs, kidney transplant recipients; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

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### Table 1: General characteristics of kidney transplant recipients (n = 39) who developed COVID-19 after preexposure prophylaxis with tixagevimab and cilgavimab

| Patient # | Sex | Age (y) | Time elapsed from KT (y) | eGFR (ml/min/1.73m²) | Cardiovascular disease | Diabetes | Hypertension | BMI | History of rejection | CNI | MMF/MPA | Steroids | inTOR | Belatacept | Rituximab |
|-----------|-----|---------|--------------------------|-----------------------|------------------------|----------|--------------|-----|-----------------------|-----|---------|----------|-------|-----------|----------|
| 2         | M   | 72.3    | 1.1                      | 33                    | 0                      | 0        | 1            | 27.4 | 0                     | 0   | 1       | 1        | 0     | 0         | 0        |
| 3         | F   | 60.1    | 4.6                      | 35                    | 0                      | 1        | 1            | 19   | 1                     | TAC | 1       | 0        | 0     | 0         | 0        |
| 35        | M   | 57.5    | 0.19                     | 71                    | 0                      | 0        | 1            | 26.5 | 0                     | TAC | 1       | 1        | 0     | 0         | 0        |
| 7         | M   | 60.2    | 1.5                      | 50                    | 0                      | 1        | 1            | 27.1 | 0                     | TAC | 1       | 1        | 0     | 0         | 0        |
| 34        | F   | 56.2    | 13.3                     | 45                    | 0                      | 0        | 1            | 29.1 | 0                     | CSA | 1       | 0        | 0     | 0         | 0        |
| 13        | M   | 73.4    | 0.24                     | 35                    | 1                      | 0        | 1            | 29   | 0                     | TAC | 1       | 1        | 0     | 0         | 0        |
| 30        | F   | 71.6    | 1.1                      | 24                    | 0                      | 0        | 1            | 29.6 | 0                     | 0   | 1       | 1        | 0     | 0         | 0        |
| 33        | M   | 79.6    | 1.4                      | 19                    | 1                      | 0        | 1            | 24.1 | 0                     | TAC | 0       | 1        | 0     | 0         | 0        |
| 36        | M   | 75.4    | 7.4                      | 28                    | 1                      | 1        | 1            | 24.3 | 0                     | TAC | 1       | 1        | 0     | 0         | 0        |
| 18        | M   | 74.6    | 4.4                      | 36                    | 1                      | 0        | 0            | 24.9 | 1                     | 0   | 1       | 1        | 0     | 0         | 0        |
| 21        | M   | 62.0    | 10.6                     | 60                    | 1                      | 1        | 0            | 31.3 | 0                     | TAC | 1       | 1        | 0     | 0         | 0        |
| 22        | M   | 67.9    | 2.6                      | 26                    | 1                      | 1        | 1            | 21.7 | 0                     | 0   | 1       | 1        | 0     | 0         | 0        |
| 23        | M   | 68.9    | 2.8                      | 14                    | 1                      | 1        | 1            | 34.1 | 0                     | CSA | 0       | 1        | 0     | 0         | 0        |
| 24        | F   | 74.3    | 8.7                      | 18                    | 1                      | 1        | 1            | 29.2 | 1                     | CSA | 1       | 1        | 0     | 0         | 0        |

Note: Orange background: hospitalized patients; yellow background: symptomatic patients managed out of hospital; white background: asymptomatic patient.

Abbreviations: BMI, body mass index; CNI, calcineurin inhibitor; CSA, cyclosporine; d, days; eGFR, estimated glomerular filtration rate; F, female; HA, hospital admission; ICU, intensive care unit; KT, kidney transplantation; M, male; MMF, mycophenolate mofetil; MPA, mycophenolic acid; mTOR, mammalian target of rapamycin; NA, not available; TAC, tacrolimus; y, years.

*Patients who did not receive casirivimab–imdevimab prior to cilgavimab–tixagevimab; **Patients who received casirivimab–imdevimab prior to cilgavimab–tixagevimab (uninterpretable anti-RBD IgG levels).
| T depleting therapy | Number of vaccine doses | Time from last dose vaccine injection to COVID-19 (d) | Time from tixagevimab-cilgavimab injection to COVID-19(d) | Upper respiratory symptoms | Fever, headache, myalgia, chills | Lower respiratory symptoms | HA | ICU | Death | Variant | IgG RBD (BAU/mL) | Neutralizing capacity against Omicron |
|---------------------|------------------------|-------------------------------------------------------|-------------------------------------------------------------|---------------------------|-------------------------------|-----------------------------|-----|-----|------|---------|----------------|----------------------------------|
| 0                   | 3                      | 28                                                    | 160                                                         | No                        | Yes                           | Yes                          | Yes | Yes | Yes  | Yes     | BA1.1                      | Negative                         |
| NA                  | 3                      | 138                                                   | 263                                                         | 5                         | Yes                           | No                           | No  | No  | No   | No      | 2771**                   | Negative                         |
| 1                   | 4                      | 71                                                    | 214                                                         | 35                        | No                             | Yes                          | No  | No  | No   | No      | 2785                      | Negative                         |
| 0                   | 2                      | 229                                                   | 62                                                          | Yes                       | Yes                           | No                           | No  | No  | Yes  | No      | 522                       | Positive                         |
| 0                   | 3                      | 141                                                   | 30                                                          | No                        | Yes                           | No                           | Yes | No  | No   | No      | 1775                      | Negative                         |
| 0                   | 3                      | 28                                                    | 222                                                         | 28                        | Yes                           | Yes                          | No  | Yes | Yes  | Yes     | BA1.1                      | Positive                         |
| 0                   | 3                      | 28                                                    | 273                                                         | 16                        | Yes                           | Yes                          | No  | No  | No   | No      | 2458                      | Negative                         |
| 0                   | 3                      | 51                                                    | 252                                                         | 32                        | No                             | Yes                          | Yes | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 3                      | 26                                                    | 306                                                         | 42                        | Yes                           | Yes                          | No  | No  | No   | No      | 9442**                   | Negative                         |
| 1                   | 3                      | 41                                                    | 152                                                         | 26                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 2                      | 51                                                    | 351                                                         | 36                        | No                             | Yes                          | Yes | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | 62                                                    | 190                                                         | 22                        | No                             | Yes                          | Yes | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 2                      | *                                                     | 327                                                         | 5                         | No                             | Yes                          | Yes | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 3                      | 57                                                    | 276                                                         | 10                        | No                             | Yes                          | Yes | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | 84                                                    | 265                                                         | 18                        | Yes                           | Yes                          | No  | No  | No   | No      | 10932**                  | Negative                         |
| 1                   | 3                      | *                                                     | 257                                                         | 5                         | No                             | Yes                          | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 4                      | 51                                                    | 207                                                         | 9                         | Yes                           | Yes                          | No  | No  | No   | No      | 1790                      | Negative                         |
| 1                   | 3                      | 33                                                    | 228                                                         | 12                        | Yes                           | No                           | No  | No  | No   | No      | 6800**                   | Negative                         |
| 1                   | 3                      | 23                                                    | 291                                                         | 37                        | Yes                           | Yes                          | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 3                      | 108                                                   | 265                                                         | 36                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 3                      | 63                                                    | 201                                                         | 12                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| NA                  | 4                      | *                                                     | 167                                                         | 21                        | Yes                           | Yes                          | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 4                      | *                                                     | 49                                                          | 5                         | Yes                           | Yes                          | No  | No  | No   | No      | 3420                      | Negative                         |
| 0                   | 3                      | 225                                                   | 6                                                           | Yes                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | 28                                                    | 243                                                         | 12                        | Yes                           | Yes                          | No  | No  | No   | No      | 1581                      | Negative                         |
| 1                   | 3                      | *                                                     | 321                                                         | 40                        | No                             | Yes                          | No  | No  | No   | No      | 3570**                   | Negative                         |
| 1                   | 3                      | *                                                     | 302                                                         | 22                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | *                                                     | 314                                                         | 47                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | *                                                     | 93                                                          | 9                         | Yes                           | Yes                          | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | 69                                                    | 295                                                         | 32                        | Yes                           | Yes                          | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 4                      | *                                                     | 201                                                         | 12                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 2                      | 41                                                    | 222                                                         | 4                         | No                             | Yes                          | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 3                      | 56                                                    | 288                                                         | 46                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 1                   | 3                      | 77                                                    | 259                                                         | 20                        | No                             | Yes                          | No  | No  | No   | No      | BA2.1                      | Negative                         |
| 1                   | 2                      | 30                                                    | 230                                                         | 34                        | Yes                           | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
| 0                   | 3                      | *                                                     | 82                                                          | 6                         | No                             | No                           | No  | No  | No   | No      | BA1.1                      | Negative                         |
vaccination schemes.\textsuperscript{3,4} In this scenario, the use of anti-SARS-CoV-2 monoclonal antibodies for preexposure prophylaxis has recently gained traction. The casirivimab–imdevimab combination has been shown to confer satisfactory protection against the delta variant.\textsuperscript{5,6} However, both casirivimab–imdevimab and other antibodies have limited neutralizing activity against the current variants of concern (omicron sublineages BA.1, BA.1.1 and BA.2). In contrast, the cilgavimab–tixagevimab combination retains a partial in vitro neutralizing activity against omicron.\textsuperscript{7–9} Based on these data, health authorities have authorized the use of cilgavimab–tixagevimab for preexposure prophylaxis in immunocompromised patients with a weak anti-SARS-CoV-2 antibody response after vaccination. However, the amount of clinical protection provided by this strategy remains poorly understood as clinical trials on cilgavimab–tixagevimab were undertaken before the emergence of omicron.\textsuperscript{10} In this study, we report a case series of kidney transplant recipients (KTRs) who developed the omicron infection despite preexposure cilgavimab–tixagevimab administration.

2 | PATIENTS AND METHODS

2.1 | Study population

All procedures and visits occurred at the Strasbourg and Lyon University Hospitals (France). Intramuscular gluteal prophylactic injections of 150mg tixagevimab and 150mg cilgavimab were offered as of December 28, 2021. This dosage was in accordance to the Food and Drug Administration (FDA) and European Medicines Agency regulations at the time of conduction of the study. All KTRs who showed a weak serological response to SARS-CoV-2 mRNA vaccines—defined by the French health authorities as an antibody titer below 264 BAU/ml—were eligible to receive cilgavimab–tixagevimab.\textsuperscript{11,12} Patients who had already received the casirivimab–imdevimab combination (i.e., non-responders to vaccination with an antibody titer below 1 BAU/ml) were not excluded since these antibodies are not protective against the omicron variant and its sublineages.

The date of last follow-up was March 13, 2022. The diagnosis of COVID-19 was based on RT-PCR of nasopharyngeal swabs and genome sequencing was performed when suitable samples were available. The anti-receptor-binding domain (RBD) IgG response and neutralizing activity against the omicron BA.1 variant were assessed within the first 30 days after cilgavimab–tixagevimab injection and no later than the first 7 days after the onset of COVID-19.

2.2 | SARS-CoV-2 serological assessment

Anti-RBD IgG antibodies were detected by a chemiluminescence technique using the SARS-CoV-2 IgG II Quant commercial assay (Abbott Architect). A titer above 7.1 BAU per ml (50 arbitrary units per ml) was defined as a positive cutoff. The clinical sensitivity and specificity of this test are 98.3% (90.6%–100.0%) and 99.5%, respectively.\textsuperscript{13} The indication to perform serologic screening was identical in all kidney transplant recipients followed in our outpatient clinic, that is, at 1 month after the last vaccine dose (M1), followed by M3 and M6. Serology assessments were also undertaken on the day of preexposure prophylaxis with monoclonal antibodies and 1 month thereafter.

2.3 | Neutralizing antibody assessment

Neutralizing antibody titers were measured with an in-house viral pseudoparticle-based assay, as previously described.\textsuperscript{2} In brief, serum samples were sequentially diluted (from 1:40 to 1:1280) and incubated with BA.1 variant spike-pseudotyped lentiviral particles for 1 h at 37°C. Subsequently, this solution (100μl) was added to 60%–80% confluent HEK293T-ACE2 cells (kindly provided by the O. Schwartz Laboratory, Institut Pasteur) seeded in 96-well plates. After 72h, the Bright-Glo luciferase assay substrate (Promega) was added to each well and the luminescence was measured by a luminescence counter MicroBetaTriLux 1450LSC (Perkin Elmer). Results were expressed as the log\textsubscript{10} of the sample dilutions that yielded 50% inhibition of pseudoparticle infectivity (log\textsubscript{10} IC50). The neutralization efficiency—expressed as the log\textsubscript{10} of the median half-maximal effective dilution (ED50)—was calculated using GraphPad Prism 9.3.1 (GraphPad Inc.). Sera were considered positive if they were able to neutralize more than 50% SARS-CoV-2 pseudovirus at a 1:40 dilution.

2.4 | Statistical analysis

Continuous data are presented as medians and interquartile ranges (IQRs) and differences were analyzed using the non-parametric Mann–Whitney U test. Categorical variables are expressed as counts and percentages and their analysis was conducted with the Fisher’s exact test. All calculations were performed using GraphPad Prism 9.3.1 (GraphPad Inc.), with all tests two-sided at a 5% level of significance.

3 | RESULTS

Of the 416 KTRs who received prophylactic injections of cilgavimab–tixagevimab, 39 (9.4%) developed COVID-19 (Table 1). The patient characteristics are summarized in Table 2. They were mainly men (n = 23, 59%) with a median age of 60.1 years (IQR: 52.3–71.9 years). Most of them were treated with calcineurin inhibitors (n = 31, 84%), mycophenolate mofetil/mycophenolic acid (n = 37, 95%), and steroids (n = 37, 95%). Only one patient was treated with T-depleting therapies; however, none received

| Table 1: Characteristics of the study population.

| Characteristic | Number | Percentage |
|----------------|--------|------------|
| Gender | Male | 23 | 59% |
| Age (years) | Median | 60.1 | IQR: 52.3–71.9 |
| Treatment | Calcineurin inhibitors | 31 | 84% |
| | Mycophenolate mofetil/mycophenolic acid | 37 | 95% |
| | Steroids | 37 | 95% |

| Table 2: Outcome of the serological and neutralizing antibody assessments.

| Assessment | Number | Percentage |
|----------------|--------|------------|
| Neutralizing antibody titer | 39 | 9.4% |
| Serology | 39 | 9.4% |
rituximab during the previous year. In addition, none of them had a previous history of symptomatic COVID-19. All had been previously vaccinated against SARS-CoV-2 with an mRNA-based vaccine (22 with the mRNA-1273 vaccine, 15 with the BNT162b2 vaccine, and 2 with both) but failed to develop a protective humoral response. Three were vaccinated before transplantation and the remaining 36 thereafter. The time interval between the last vaccine dose and the serology measurement ranged from 39 days to 322 days. The time interval from the receipt of the most recent vaccine dose to COVID-19 infection ranged from 49 days to 351 days. From August 17, 2022, to December 22, 2022, a total of 25 patients were treated with casirivimab–imdevimab.

### Table 2: General characteristics of the study patients according to the hospitalization status

| Characteristic                      | Total cohort (n = 39) | Not hospitalized (n = 25) | Hospitalized (n = 14) | p   |
|------------------------------------|----------------------|--------------------------|-----------------------|-----|
| Age (years)                        | 60.1 [52.3; 71.9]    | 56.0 [49.0; 63.4]        | 70.2 [60.7; 74.1]     | <.01|
| Male                               | 23 (59%)             | 13 (52%)                 | 10 (71%)              | .24 |
| BMI (kg/m²)                        | 27.4 [22.6; 30.0]    | 27.4 [22; 30.7]          | 27.2 [24.5; 29.2]     | .9  |
| eGFR (ml/min/1.73m²) median        | 46.0 [32.0; 58.5]    | 51.0 [36.6; 59.0]        | 34.0 [24.5; 42.8]     | <.01|
| Cardiovascular disease             | 15 (38%)             | 7 (28%)                  | 8 (57%)               | .073|
| Diabetes                           | 16 (41%)             | 10 (40%)                 | 6 (43%)               | .86 |
| Hypertension                       | 34 (87%)             | 22 (88%)                 | 12 (86%)              | 1   |
| Time elapsed from KT (years)       | 2.90 [1.50; 6.05]    | 3.17 [1.60; 4.80]        | 2.30 [1.18; 6.70]     | .37 |
| History of rejection               | 13 (33%)             | 10 (40%)                 | 3 (21%)               | .3  |
| Number of vaccine doses            |                     |                          |                       |     |
| 2                                  | 6 (15%)              | 3 (12%)                  | 3 (21%)               | .87 |
| 3                                  | 27 (69%)             | 18 (72%)                 | 9 (64%)               | -   |
| 4                                  | 6 (15%)              | 4 (16%)                  | 2 (14%)               | -   |
| T depleting therapy at induction   | 19 (51%)             | 15 (62%)                 | 4 (31%)               | .065|
| CNI                                |                      |                          |                       |     |
| Tacrolimus                         | 26 (67%)             | 19 (76%)                 | 7 (50%)               | .31 |
| Cyclosporine                       | 5 (13%)              | 2 (8%)                   | 3 (21%)               | -   |
| No                                 | 8 (21%)              | 4 (16%)                  | 4 (29%)               | -   |
| MMF/MPA                            | 37 (95%)             | 25 (100%)                | 12 (86%)              | .12 |
| mTOR inhibitor                     | 0                    | 0                        | 0                     |     |
| Belatacept                         | 8 (21%)              | 4 (16%)                  | 4 (29%)               | .42 |
| Steroids                           | 35 (90%)             | 23 (92%)                 | 12 (86%)              | .61 |
| SARS-CoV-2 variant                 |                      |                          |                       |     |
| BA1.1                              | 9 (60%)              | 5 (71%)                  | 4 (50%)               | .28 |
| BA.1                               | 5 (33%)              | 1 (14%)                  | 4 (50%)               | -   |
| BA.2                               | 1 (6.7%)             | 1 (14%)                  | 0 (0%)                | -   |
| Time elapsed from tixagevimab-cilgavimab injection (days) | 20.0 [9.50; 34.5]    | 12.0 [6.00; 32.0]        | 29.0 [17.5; 35.8]     | .04 |
| ICU                                | 3 (7.7%)             | 0 (0%)                   | 3 (21%)               | .04 |
| Death                              | 2 (5.1%)             | 0 (0%)                   | 2 (14%)               | .12 |

Note: Data are expressed as median (interquartile range) or n (%).

Abbreviations: BMI, body mass index; CNI, calcineurin inhibitor; eGFR, estimated glomerular filtration rate; ICU, intensive care unit; MMF, mycophenolate mofetil; MPA, mycophenolic acid; mTOR, mammalian target of rapamycin.
p < .01), and a longer time elapsed from cilgavimab–tixagevimab injection (median: 29 days vs. 12 days, respectively, p = .04, Table 2). SARS-CoV-2 sequencing was carried out in 15 cases (BA.1, n = 5; BA.1.1, n = 9; BA.2, n = 1). Viral neutralizing activity of the serum was negative in the 12 tested patients (five hospitalized patients and seven managed in an outpatient setting), suggesting that this prophylaxis strategy does not provide sufficient protection against this SARS-CoV-2 variant of concern. Five patients had anti-RBD IgG titers <3500 BAU/mL. In the remaining seven patients, preexisting casirivimab–imdevimab administration did not allow interpreting anti-RBD IgG levels.

4 | DISCUSSION AND CONCLUSIONS

In this study, we describe the occurrence of severe omicron infections despite prophylactic administration of cilgavimab–tixagevimab. Notably, two study participants died of COVID-19. Previous investigations have shown that the BA.1.1 subvariant is characterized by a higher in vitro resistance to cilgavimab–tixagevimab compared with the BA.1 variant.8,9 The former genotype was predominant in our cohort, which can at least in part explain the disappointing level of protection observed in these patients. However, this issue is unlikely to be the only explanation for our findings; accordingly, we also observed that none of the sera collected after administration of cilgavimab–tixagevimab was able to neutralize the BA.1 variant in vitro. These results suggest that intramuscular injections of a combination of 150 mg tixagevimab and 150 mg cilgavimab might not be sufficient to elicit protective levels of circulating anti-RBD antibodies. Our data are in accordance with those obtained in a cohort of 63 KTRs who did not develop COVID-19;14 in this sample, only 9.5% of all participants was able to neutralize the omicron variant 1 month after cilgavimab–tixagevimab administration. This percentage was markedly lower than that observed in patients who had been previously infected with SARS-CoV-2 (71%; 10/14).14

Our clinical findings confirm recent FDA recommendations, derived from in vitro models, underlining the necessity to increase the dose of cilgavimab–tixagevimab.9 However, the European Medicines Agency is still recommending a dose of 150 mg for each antibody. Information on the effectiveness of higher antibody doses would have been interesting; however, as an increased dosage is not currently recommended, we are unable to provide these data. Further pharmacokinetic studies are warranted to determine the optimal dose of cilgavimab–tixagevimab for primary prophylaxis of COVID-19. Additional research is also required to investigate whether an increased tixagevimab–cilgavimab dosage would be sufficient to protect immunocompromised patients against the omicron variant and its sublineages. Under these circumstances, KTRs should be advised to maintain strict sanitary protection measures and receive booster doses.

DISCLOSURE

Sophie Caillard and Olivier Thaunat received consulting fees from Astra Zeneca. All other authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data supporting the findings from this study are available from the corresponding author upon reasonable request.

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