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Neutralizing antibody responses against SARS-CoV-2 in patients with plasma cell disorders who are on active treatment after two doses of mRNA vaccination

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Abstract

Many patients with plasma cell disorder (PCD) on active treatment with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) require hospitalization, with an increased mortality rate over healthy adults. The FDA approved two mRNA vaccines against SARS-CoV-2: BNT162b2 and mRNA-1273. To assess the efficacy of vaccination in patients with PCD, retrospectively, we identified all patients on active treatment. A total of 149 patients were included. Neutralizing antibodies (NAbs) levels against SARS-CoV-2 adequate, intermediate, and no response were observed in 42%, 32%, and 26%, respectively. Low NAbs were seen in patients on daratumumab combinations or anti-BCMA therapy, low lymphocytes, and low IgG levels. Twenty-three (15%) patients have SARS CoV-2, while 8% required hospitalization, majority of these patients had intermediate or no response based on NAbs levels. Therefore, checking NAbs may be clinically helpful in identifying patients' responses. Further prospective studies should ascertain the value of a third vaccine dose in this population.

KEYWORDS
mRNA vaccine, multiple myeloma, plasma cell disorder, SARS-CoV-2

1 | INTRODUCTION

The severe acute respiratory syndrome coronavirus 2 (SARS CoV-2) changed how we delivered health care in 2021. SARS CoV-2 was declared a pandemic by World Health Organization on March 11, 2020.[1] The clinical spectrum of active infection ranges from asymptomatic carriers to a severe and life-threatening disease course in up to 5%–10% of patients.[2] Two mRNA vaccines against SARS CoV-2: BNT162b2 and mRNA-1273 were approved under an emergency use authorization (EUA) by the Food and Drug Administration (FDA) due to the high efficacy in preventing SARS CoV-2- in addition to the safety in December 2020.[3–5] The first mRNA vaccines for SARS CoV-2 (mRNA-1273 and BNT162b2) consist of mRNA encoding prefusion-stabilized SARSCoV-2 spike ectodomain packaged in a lipid nanoparticle.[6,7]

The risk of severe disease presentation, complications, and worse outcomes is higher amongst patients with hematological malignancies than the general population, and the risk of death amongst hospitalized patients is as high as 39%.[8–10] Patients with multiple myeloma (MM) are at increased risk of infections due to their immunocompromised state, older age, and comorbidities. SARS CoV-2 causes moderate to severe acute respiratory

dysfunction in 77% of MM patients and leads to critical condition in 8% of them, while >80% of MM patients whom SARS CoV-2 infects require hospitalization with a mortality rate of 33% of hospitalized MM patients with SARS CoV-2.[9,11–13]

This retrospective study evaluated the antibody responses to the two mRNA vaccines against SARS CoV-2, mRNA-1273, and BNT162b2 in all patients with plasma cell disorders (PCD), including MM AL-amyloidosis, and smoldering myeloma (SMM) who are on active treatment, at one institution.

2 | PATIENTS AND METHODS

Retrospectively, we collected data from patients with plasma cell disorder (PCD) who were on active treatment between January 2021 and February 2022. We included for this analysis: (1) presence of plasma cell disorder (multiple myeloma smoldering myeloma and AL amyloidosis) on active treatment (active treatment was defined as PCD- specific active treatment in the last 30 days, including patients who received CAR-T cell within 6 months); (2) Patients who received two doses of either mRNA vaccines against SARS CoV-2: BNT162b2 & mRNA-1273; and (3) Patients with measured neutralizing antibodies (NAbs) against SARS CoV-2 after 30 days from the second dose of the vaccine. Our study excluded: (1) patients who were partially vaccinated of either mRNA vaccines against SARS-CoV-2; and (2) patients who received Ad26.COV2.

The NAbs levels after 30 days from the second vaccine dose were evaluated. Blood samples were drawn early in 2021, from February 1 to February 20, 2022.

NAbs against SARS CoV-2 were measured as units/ml (U/ml) (normal reference value is >250 U/ml). The NAbs levels were grouped into full response (≥250 U/ml), intermediate response (between 250 U/ml and ≥50 U/ml), and no response (<50 U/ml).[14] Per institutional protocol, all patients on active treatment are screened using RT-PCR for SARS CoV-2 through nasopharyngeal swap every 4 weeks regardless of their symptoms or vaccine status. Descriptive statistics were utilized in data analysis for patient characteristics, type of treatment, disease response status, uninvolved immunoglobulin (Ig) level, and other comorbidities. In addition, univariate and multivariate analyses were performed to identify patients at higher risk of inadequate vaccination response (<250 U/ml).

Fisher's exact or chi-square tests were used to analyze contingency tables. The distribution of nonparametric independent variables was compared by the Wilcoxon rank-sum test. To identify the difference between group means for continuous variables, comparisons were performed with analysis of variance (ANOVA). Factors with a p value less than 0.1 were included in a forward and backward stepwise model selection. Odds ratios are presented with their 95% confidence intervals. Statistical significance was designated at the conventional two-tailed α level of .05 using R statistical software.

TABLE 1 Patients characteristics with PCD who received mRNA vaccine

Characteristics	No. of patients (%)
Gender, male: female	76: 73
Age, years, median (range)	69 (40–95)
Race, no of patients (%)	
Caucasian	121 (81%)
African American	25 (17%)
Hispanic	3 (2%)
PCD, no. of patients (%)	
Multiple myeloma	131 (88%)
AL Amyloidosis	13 (9%)
Smoldering myeloma	5 (3%)
Paraprotein type, no. of patients (%)	
IgG	84 (57%)
Non-IgG	33 (22%)
Light chain	32 (21%)
Therapy type; no. of patients (%)	
IMiD	29 (20%)
PI	11 (7%)
IMiD/PI	8 (5%)
IMiD/PI/steroids	11 (7%)
Daratumumab	23 (16%)
Dara/PI/dexamethasone	22 (15%)
Dara/IMiD/dexamethasone	27 (18%)
BCMA-targeted therapy	14 (11%)
Other	2 (1%)
Previous autologous SCT	104 (70%)
Median number of lines of therapy (range)	2 (1–13)

Abbreviations: BCMA, B- cell maturation agent (belantamab, CAR-T, BiTE, BCMA MoA); Dara, daratumumab; IMiD, immunomodulatory agent (thalidomide, lenalidomide, pomalidomide); PCD, plasma cell disorder; PI, protesome inhibitor (bortezomib, carfilzomib, ixazomib); SCT, stem cell transplant.

3 | RESULTS

3.1 | Baseline characteristics of PCD patients

We identified 149 patients, including 49% females with a median age of 69 (40–95) years. The characteristics of the patients with PCD are described in Table 1.

Among them, 131 patients were myeloma, 10 (8%) patients were newly diagnosed on induction therapy, 46 (35%) patients were on maintenance therapy, and 75 (57%) patients had relapsed/refractory multiple myeloma (RRMM) who had ongoing treatment. Median lines of therapy (LOT) for the whole myeloma group ($n = 131$) were 2 (1–13) lines, while for those with RRMM ($n = 75$) the median LOT was 4 (2–13) lines. Sixty-six (51%) patients received monotherapy while 65 (49%) patients received combination therapy, while

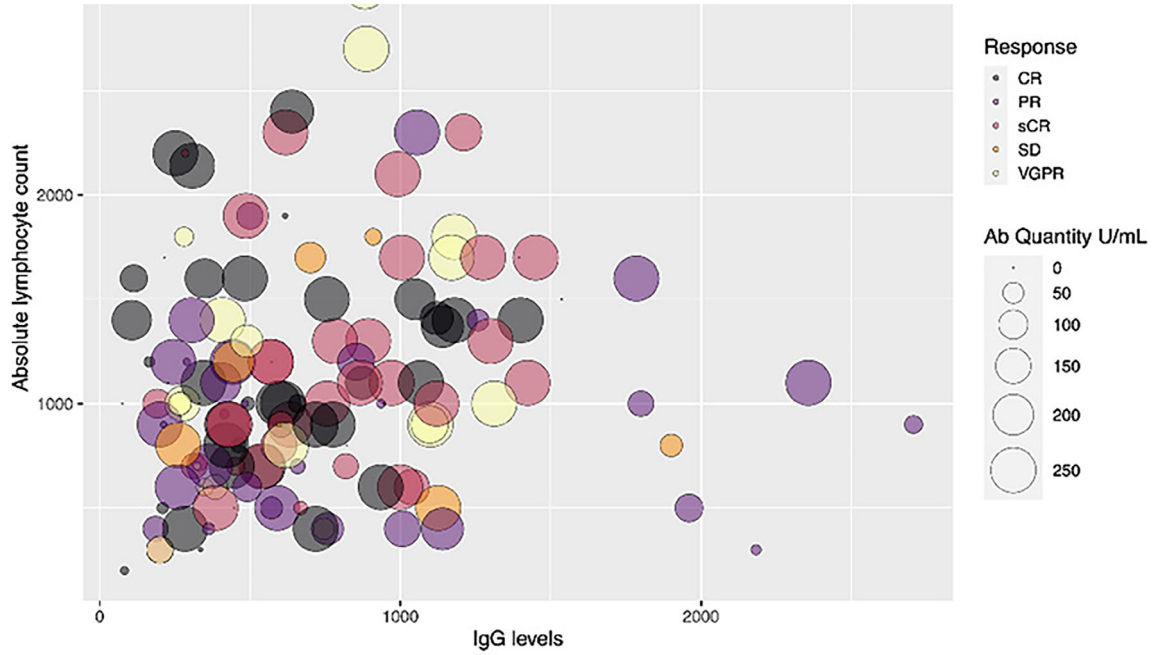

FIGURE 1 Bubble plot showing the relationship between absolute lymphocyte count (ALC), IgG levels, myeloma status, and the level of antibody response to vaccination

TABLE 2 Percentage of NAbs responders and non-responders in PCD patients

	NAbs adequate response, *n* (%)	NAbs intermediate response, *n* (%)	NAbs non-responders, *n* (%)
All PCD patients ($n = 149$)	63 (42%)	47 (32%)	39 (26%)
MM ($n = 131$)	57 (44%)	42 (32%)	32 (24%)
AL-amyloidosis ($n = 13$)	4 (31%)	3 (23%)	6 (46%)
SMM ($n = 5$)	2 (40%)	2 (40%)	1 (20%)

Abbreviations: MM, multiple myeloma; NAbs, neutralizing antibodies; PCD, plasma cell disorder; SMM, smoldering multiple myeloma.

101 (77%) patients underwent high-dose chemotherapy followed by autologous stem cell transplant. A total of 122 (93%) patients showed an overall response rate of at least partial response or better, while only six (7%) patients showed stable disease to treatment per IMWG response criteria. Ten (8%) patients were previously infected with SARS CoV-2 prior to vaccination.

Thirteen patients were identified with AL-amyloidosis in this study, four (31%) patients were newly diagnosed on induction therapy, three (23%) patients were on maintenance therapy, and six (46%) patients had relapsed AL-amyloidosis who had ongoing treatment. Median LOT for AL-amyloidosis sub-group ($n = 13$) were 2 (1–2) lines. Eight (62%) patients received monotherapy, eight (38%) received combination therapy, while three (23%) underwent high-dose chemotherapy followed by autologous stem cell transplant. All patients showed an overall response rate of at least partial response or hematological response or better. One patient was previously infected with SARS CoV-2 prior vaccination. We included five patients diagnosed with high-risk smoldering myeloma receiving active treatment per active clinical trials. One patient (20%) was on induction therapy, while four (80%) patients were on maintenance therapy. All patients showed an overall response of at least partial response or better.

3.2 | Humoral response in PCD patients

We categorized the patients on many factors, including age, gender, race, performance status, other comorbidities (congestive heart failure, renal failure), type of plasma cell disorder, immunoglobulin levels, response status, and the type of anti-myeloma treatment. The relation between myeloma response, ALC, IgG levels, and antibodies response after vaccination is summarized in Figure 1. NAbs levels were evaluated in 149 patients who were either treated with monotherapy or combination therapy. The median time between the second dose of the vaccine and testing for NAbs was 104 (30–196) days. Only 63 patients (42%) developed an adequate response, 47 patients (32%) had an intermediate response, while 39 (26%) did not respond to the vaccine. Table 2 demonstrates the NAbs levels amongst all PCD subtypes.

TABLE 3 Type of treatment for NAbs responders and non-responders

	NAbs adequate response, *n* (%)	NAbs partial response, *n* (%)	NAbs non-responders, *n* (%)
IMiDs ($n = 29$)	18 (62%)	8 (28%)	3 (10%)
PI ($n = 11$)	10 (91%)	0	1 (9%)
IMiD + PI ($n = 8$)	7 (88%)	1 (12%)	0
IMiD + PI + Dex ($n = 11$)	3 (27%)	3 (27%)	5 (46%)
Daratumumab ($n = 23$)	8 (35%)	9 (39%)	6 (26%)
Dara + PI+ Dex ($n = 22$)	8 (36%)	7 (32%)	7 (32%)
Dara + IMiD + Dex ($n = 27$)	6 (23%)	12 (44%)	9 (33%)
BCMA-targeted therapy[a] ($n = 16$)	3 (19%)	5 (31%)	8 (50%)
Others[b] ($n = 2$)	0	0	2 (100%)
Any monotherapy ($n = 75$)	38 (51%)	22 (29%)	15 (20%)
Any combination therapy ($n = 74$)	25 (34%)	23 (31%)	26 (35%)
Daratumumab-based therapy ($n = 72$)	22 (31%)	28 (31%)	22 (31%)
IMiD-based therapy ($n = 79$)	34 (43%)	24 (30%)	21 (27%)
PI-based therapy ($n = 56$)	29 (52%)	11 (19%)	16 (29%)
Any combination therapy with dexamethasone ($n = 66$)	18 (28%)	22 (33%)	26 (39%)

Abbreviations: IMiD, immunomodulatory agent (thalidomide, lenalidomide, pomalidomide); NAbs, neutralizing antibodies; PI, protesome inhibitor (bortezomib, carfilzomib, ixazomib).

[a]BCMA-targeted therapy: includes belantamab, BCMA MoAb, BiTE, CAR-T.

[b]Elotuzumab-based therapy.

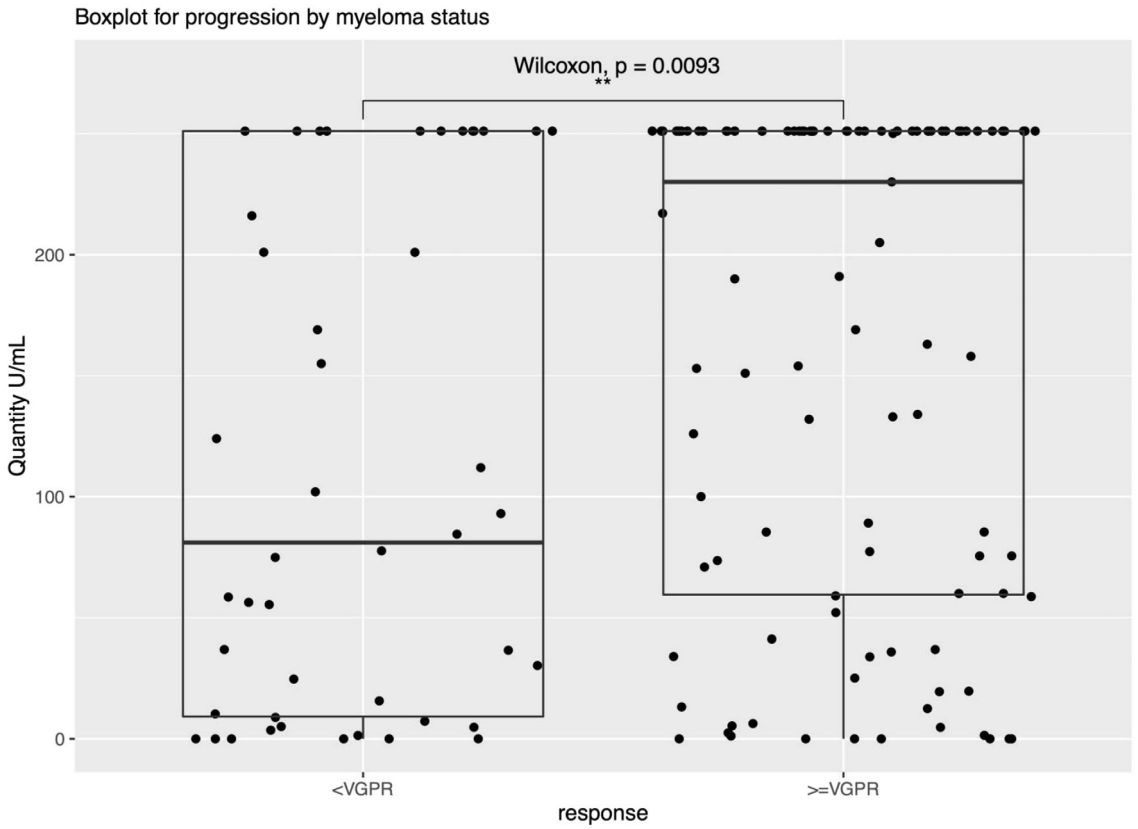

FIGURE 2 Boxplot for antibody response based on myeloma response to therapy

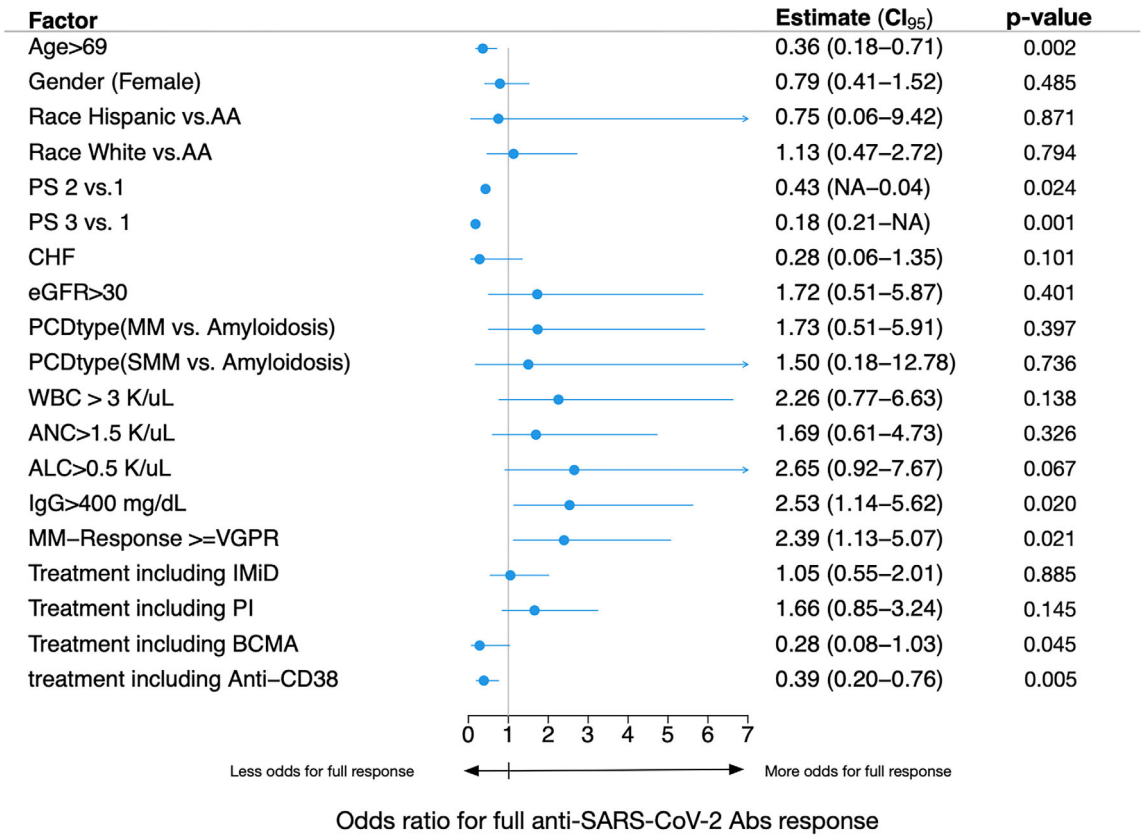

FIGURE 3 The odds ratio for full antibodies responses to vaccination

Twenty-three (15%) patients developed SARS CoV-2 post-vaccine. Eleven (48%) of 23 patients were NAbs levels non-responders, eight (35%) patients showed an adequate response, while four (17%) had intermediate response. None of these patients were infected with SARS CoV-2 prior vaccine. Eighteen (78%) of 23 patients who were infected were symptomatic (fever, shortness of breath, congestions, cough, headache, and fatigue). The median time between second vaccine and the date of SARS CoV-2 infection was 9 (3–12) months. For those who were symptomatic, 8 of 18 (45%) NAbs levels were non-responders, 6 of 18 (33%) patients showed an adequate response, and 4 of 18 (22%) patients had an intermediate response. Eighteen patients received different treatment for SARS CoV-2, 8 of 18 (44%) received casirivimab and imdevimab, 7 of 18 (39%) received remdesivir and dexamethasone, while 3 of 18 (17%) received sotrovimab.

Only 8 of 149 (5%) patients who were fully vaccinated required hospitalization due to SARS CoV-2 infection, two patients were admitted to the intensive care unit; unfortunately, one patient (0.7%) died due to complications from SARS CoV-2. For those who were hospitalized, four of eight (50%) NAbs levels were non-responders, three of eight (38%) patients showed an intermediate response or adequate response, while one of eight (12%) patients had adequate response.

Eleven (7%) patients who were previously infected with SARS CoV-2 prior to the vaccine showed that 10 (91%) patients had an adequate response of NAbs levels versus one (9%) patient who showed no NAbs response.

3.3 | Correlation between the efficacy of SARS CoV-2 vaccine and the type of treatment for PCD patients

We analyzed Nabs response in relation to type of treatment (Table 3). Patients who received monotherapy ($n = 40$) versus combination therapy ($n = 109$), showed that those with NAbs adequate response (70% vs. 32%; $p < .005$), partial response (20% vs. 33%; $p = .14$), and no response (10% vs. 37%; $p = .037$). Patients who received daratumumab-based therapy, whether monotherapy ($n = 24$) or in combination therapy ($n = 48$), showed that those with NAbs had an adequate response (33% vs. 29%), intermediate response (41% vs. 37%), and no response (26% vs. 32%). Treatment with BCMA (B-cell maturation antigen) targeted therapy that includes: Belantamab, BCMA/CAR-T, BCMA BiTE (bispecific T-cell engager), and other BCMA-targeted Ab were included in this study ($n = 16$), four of these patients received combination therapy. Patients on BCMA-targeted therapy showed NAbs with an adequate response, intermediate response, and no response reported in 19%, 31%, and 50%, respectively.

3.4 | Predictive factors for NAbs production

There were no significant differences regarding NAbs levels between myeloma and AL-amyloidosis and smoldering myeloma patients. No correlations were identified between gender, race, performance status, prior lines of therapy. However, patients with a very good partial response or better are more likely to have a full antibodies response ($p = .009$; Figure 2).

While treatment with IMiD-based regimen was associated with higher odds for full NAbs levels, treatment with BCMA-targeted or anti-CD38-based regimen was associated with a lower odd of mounting full NAbs response ($p < .005$; Figure 3). The median eGFR, IgG, and absolute lymphocyte counts were higher for patients with full antibody responses than for patients with a suboptimal response.

In a forward stepwise selection model on patients with complete data ($n = 140$), younger age, higher eGFR, higher IgG levels, higher ALC, higher performance status, and treatment without daratumumab or BCMA-based therapy were associated with higher antibody responses.

4 | DISCUSSION

Patients with MM are at increased risk of infections secondary to their immunocompromised state, secondary to continuous treatment, older age, *hypogammaglobulinemia*, and comorbidities.[11] Our data indicate that vaccination with the mRNA-1273 and BNT162b2 leads to lower production of NAbs against SARS CoV-2 in PCD patients on active treatment. This retrospective study demonstrated that only 42% of patients with PCD on active treatment would achieve NAbs adequate response, while 32% demonstrated an intermediate response and 26% showed no response. The strongest predictive factors for poor humoral responses are daratumumab-based or anti-BCMA therapy, low lymphocytes, and low IgG levels at the time of vaccination.

This finding is consistent with a previous study showing that the suboptimal humoral response of PCD patients to vaccines can be attributed to impaired function of immune cells in the marrow microenvironment characterized by dysfunction of effector cells, loss of antigen presentation, and expansion of immunosuppressive cells.[14] Also, other studies showed that patients with multiple myeloma with active disease, on treatment, or immunoparesis had inadequate serological responses after vaccination.[14,15]

Our results confirm previously published data. Terpos et al.[16] eloquently demonstrated that, at the time of vaccination, treatment with either anti-CD38 (Mabs) or BCMA-based and lymphopenia were independent prognostic factors for suboptimal antibody response following vaccination. Memory B-cell and T-cell responses might be significantly compromised in patients with PCD. Antitumoral treatments are known to aggravate further immunosuppression, impairing T-cell and antibody function and production.[17–19]

The efficacy of the BNT162b2 and mRNA-1273 against SARS CoV-2 in healthy adults has been clearly demonstrated.[3,4] A high but variable mortality (27%–57%) in SARS CoV-2 hospitalized patients with PCD was reported by the International Myeloma Society. Our data suggested that 23 of 149 (15%) patients with PCD who were fully vaccinated with either mRNA-1273 or BNT162b2 developed symptomatic/asymptomatic SARS CoV-2 infection. Most of the patients (65%) who had SARS CoV-2 infection showed NAbs levels with intermediate or no response, indicating the possibility of a correlation of humoral response to the severity of the infection. Although 8 of 149 (5%) patients required hospitalization, the majority of them (88%) had either intermediate or no response.

Patients treated with daratumumab-based therapy (monotherapy or combination therapy), BCMA-targeted therapy, or any combination therapy with dexamethasone showed a decrease in the humoral response.

Our study has many limitations. First, this is a single-center retrospective study with a relatively moderate sample size by default. In addition, data collection was done through a chart review and is partly dependent on information obtained from treating physicians' documentation and did not monitor T-cell immunity to the vaccination. Finally, this data reflect results from an academic medical center that might not reflect the current vaccination response elsewhere.

5 | CONCLUSION

After both mRNA vaccines (mRNA-1273 and BNT162b2), the Ab response is lower in patients with PCD getting active treatment than in the general population. NAbs are especially low for patients on daratumumab combinations or anti-BCMA therapy, low lymphocytes, and low IgG levels at the time of vaccination. Some PCD (26%) may not develop NAbs despite vaccination or previous SARS CoV-2 infection. Therefore, checking NAbs may be clinically useful in identifying patients' responses, due to possibly increased risk of SARS-CoV-2 infection and might benefit from a booster vaccine or prophylactic treatment. Further prospective studies should ascertain the value of a third vaccine dose in this population.

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CONFLICTS OF INTEREST

Joseph McGuirk reports the following conflicts: Novartis: research funding; Fresenius Biotech: research funding; Astellas: research funding; Bellicum Pharmaceuticals: research funding; Kite Pharmaceuticals: honoraria, membership on an entity's Board of Directors or advisory committees, research funding, Speakers Bureau; Gamida Cell: research funding; Pluristem Ltd: research funding; Articulate Science LLC:

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DATA AVAILABILITY STATEMENT

The data sources from which the results of this study were generated can be shared if requested.

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REFERENCES

1. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19—March 11 2020. Accessed March, 2022. https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020.
2. Gavriatopoulou M, Korompoki E, Fotiou D, et al. Organ-specific manifestations of COVID-19 infection. *Clin Exp Med*. 2020;20:493-506.
3. Polack FP, Thomas SJ, Kitchin N. Safety and efficacy of the BNT162b2 mRNA COVID-19 vaccine. *N Engl J Med*. 2020;383:2603-2615.
4. El Sahly HM, Baden LR, Essink B, et al. Efficacy of the mRNA-1273 SARS-CoV-2 vaccine at completion of blinded phase. *N Engl J Med*. 2021;385(19):1774-1785. doi:10.1056/NEJMoa2113017
5. Accessed March, 2022. https://www.fda.gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/covid-19-vaccines
6. Corbett KS, Edwards DK, Leist SR, et al. SARS-CoV-2 mRNA vaccine design enabled by prototype pathogen preparedness. *Nature*. 2020;586:567-571.
7. Walsh EE, Frenck RW Jr, Falsey AR, et al. Safety and immunogenicity of two RNA-based Covid-19 vaccine candidates. *N Engl J Med*. 2020;383:2439-2450.
8. Yang K, Sheng Y, Huang C, et al. Clinical characteristics, outcomes, and risk factors for mortality in patients with cancer and COVID-19 in Hubei, China: a multicentre, retrospective, cohort study. *Lancet Oncol*. 2020;21:904-913.
9. Chari A, Samur MK, Martinez-Lopez J, et al. Clinical features associated with COVID-19 outcome in multiple myeloma: first results from the international myeloma society data set. *Blood*. 2020;136:3033-3040.
10. Vijenthira A, Gong IY, Fox TA, et al. Outcomes of patients with hematologic malignancies and COVID-19: a systematic review and meta-analysis of 3377 patients. *Blood*. 2020;136:2881-2892.
11. Dumontet C, Hulin C, Dimopoulos MA, et al. A predictive model for risk of early grade ≥ 3 infection in patients with multiple myeloma not eligible for transplant: analysis of the FIRST trial. *Leukemia*. 2018;32(6):1404-1413. doi:10.1038/s41375-018-0133-x
12. Martínez-López J, Mateos MV, Encinas C, et al. Multiple myeloma and SARS-CoV-2 infection: clinical characteristics and prognostic factors of inpatient mortality. *Blood Cancer J*. 2020;10(10):103. doi:10.1038/s41408-020-00372-5
13. Engelhardt M, Shoumariyeh K, Rösner A, et al. Clinical characteristics and outcome of multiple myeloma patients with concomitant COVID-19 at comprehensive cancer centers in Germany. *Haematologica*. 2020;105(12):2872-2878. doi:10.3324/haematol.2020.262758
14. Stampfer SD, Goldwater MS, Jew S, et al. Response to mRNA vaccination for COVID-19 among patients with multiple myeloma. *Leukemia*. 2021;35:3534-3541. doi:10.1038/s41375-021-01354-7
15. Bird S, Panopoulou A, Shea RL. Response to first vaccination against SARS-CoV-2 in patients with multiple myeloma. *Lancet Haematol*. 2021;8:e389-e392.
16. Terpos E, Gavriatopoulou M, Ntanasis-Stathopoulos I, et al. The neutralizing antibody response post COVID-19 vaccination in patients with myeloma is highly dependent on the type of anti-myeloma treatment. *Blood Cancer J*. 2021;11(8):138. doi:10.1038/s41408-021-00530-3
17. Leone P, Solimando AG, Malerba E, et al. Actors on the scene: immune cells in the myeloma niche. *Front Oncol*. 2020;10:599098. doi:10.3389/fonc.2020.599098
18. Nakamura K, Smyth MJ, Martinet L. Cancer immunoediting and immune dysregulation in multiple myeloma. *Blood*. 2020;136(24):2731-2740. doi:10.1182/blood.2020006540
19. Nahi H, Chrobok M, Gran C, et al. Infectious complications and NK cell depletion following daratumumab treatment of multiple myeloma. *PLoS One*. 2019;14(2):e0211927.

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