Immunogenicity of The BNT162b2 mRNA COVID-19 Vaccine in Patients With Primary Brain Tumors: A Prospective Cohort Study

Amir Massarweh

Davidoff Cancer Center, Rabin Medical Center

Roi Tschernichovsky (✉ rtscher@gmail.com)

Rabin Medical Center Davidoff Center <https://orcid.org/0000-0002-3539-1940>

Amos Stemmer

Department of Oncology, Sheba Medical Center

Alexandra Benouaich-Amiel

Davidoff Cancer Center, Rabin Medical Center

Tali Siegal

Davidoff Cancer Center, Rabin Medical Center

Noa Eliakim-Raz

Beilinson Hospital, Rabin Medical Center

Salomon M. Stemmer

Davidoff Cancer Center, Rabin Medical Center

Shlomit Yust-Katz

Davidoff Cancer Center, Rabin Medical Center

Research Article

Keywords: Glioma, Covid-19, Vaccine, mRNA, BNT162b2

Posted Date: October 22nd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-986572/v1>

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Version of Record: A version of this preprint was published at Journal of Neuro-Oncology on January 12th, 2022. See the published version at <https://doi.org/10.1007/s11060-021-03911-7>.

Abstract

Purpose

Immunogenicity of Covid-19 vaccines may be negatively impacted by anti-cancer treatment. The management of primary brain tumor (PBT) patients routinely includes temozolomide and steroids, which are immune-suppressive. In this study, we aimed to determine the rate of seropositivity in PBT patients following receipt of two doses of the BNT162b2 vaccine.

Methods

We prospectively evaluated IgG antibody levels against SARS-CoV-2 spike protein in 17 PBT patients following two doses of the BNT162b2 mRNA vaccine. IgG levels were collected at two time points: T1 - after a median of 44 days from the second vaccine dose and T2 - after a median of 130 days from the second dose. Titers were compared against a group of healthy controls (HC) comprised of patients' family members/caregivers.

Results

At T1, 88.2% (15/17) of PBT patients achieved seroconversion, compared with 100% (12/12) of HCs. Median IgG titer was significantly lower in the PBT group compared to the HC group (1,908 AU/mL vs 8,198 AU/mL, respectively; $p=0.002$). At T2, 80% (12/15) of PBT achieved seroconversion, compared to 100% (10/10) of the HCs. Median IgG titer remained significantly lower in the PBT group (410 vs 1687; $p=0.002$). All three PBT patients who failed to seroconvert at T2 had been treated with corticosteroids during vaccination. In a univariate analysis, steroid use was negatively associated with antibody titer.

Conclusion

Most PBT patients achieve seroconversion after receiving the BNT162b2 vaccine, but with lower IgG titer compared to HCs. Steroid use during the vaccination period is associated with lower titer.

Introduction

More than 18 months after the first reported cases of Covid-19, the global community is still struggling to curb the pandemic. Vaccines for the prevention of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection are at the heart of this effort, with more than 4 billion doses administered globally as of August 2021^{1,2}.

At the time of the initial vaccine rollouts, there was scarce data regarding efficacy in the oncology space. Patients with cancer were under-represented in the original phase III trials leading up to the approval of

the BNT126b2 (Pfizer), mRNA-1273 (Moderna) and Ad26.COV2.S (Janssen) vaccines, and efficacy was not analyzed separately for this patient subgroup^{3,4,5}.

More recently, there have been reports indicating that the immunogenicity of the mRNA vaccine is attenuated in cancer patients, most notably in patients with hematological cancer actively receiving treatment^{6,7,8,9,10,11}. In solid cancer patients, seroconversion rates appear to lag behind those of healthy controls over the two-dose schedule, and are accompanied by consistently lower IgG antibody titers^{11,12}. Importantly, titers are differentially impacted by different anti-neoplastic treatment modalities^{10,11}.

Given that immunogenicity seems to vary by anti-cancer treatment type, primary brain tumor patients and gliomas in particular are potentially at high risk for a sub-optimal response to vaccination. The treatment of glioma patients is multi-faceted and typically includes maximal surgical resection for operable patients, followed by post-operative radiation therapy. Temozolomide (TMZ) is administered in the adjuvant setting for low grade gliomas while concurrent and adjuvant temozolomide is routinely used in high grade tumors. Temozolomide, an alkylating agent, is known to cause hematological toxicity to a significant degree, including lymphopenia and neutropenia, which might hinder the humoral response to the vaccine^{13,14,15}. Further contributing to immunosuppression in glioma patients is the frequent administration of glucocorticoids, commonly prescribed to reduce cerebral edema and alleviate the associated neurological symptoms¹⁶. There is very limited data on the use of steroids and its impact on Covid-19 vaccine efficacy^{17,18}. Still, under the caveat of limited data, the updated Center for Disease Control (CDC) guidelines single out receipt of prednisone in a dose greater than 20mg/day for more than 14 days as a putative risk factor for a reduced response to vaccination¹⁹.

So far, only a handful of primary brain tumor cases were included in the pan-cancer studies evaluating immunogenicity of Covid-19 vaccines in cancer patients^{7,8,9,10}. Furthermore, brain tumor patients' respective treatment modalities and their impact on seroconversion rates were not assessed. In this study, we aimed to shed further light on this pressing issue by using a brain tumor-only cohort of patients which have undergone a two-dose vaccination schedule with the BNT162b2 mRNA vaccine.

Materials & Methods

Study Population

The study population comprises a nested cohort of consecutive primary brain tumor (PBT) patients, derived from a larger pan-cancer cohort recently reported on by our group⁸.

The original cohort included adult patients (>18 years of age) with a histologically - confirmed diagnosis of solid malignancy, who were undergoing active anti-neoplastic treatment, had previously received 2 doses of the BNT162b2 mRNA Covid-19 vaccine, and were at least 30 days following the second ("boost") vaccination dose at the time of accrual. Of 102 cancer patients in the original cohort, 9 patients were diagnosed with a primary brain tumor. In the present cohort, the subset of brain tumor patients was

expanded to include a total of 17 cases. Treatment received by each patient were recorded at accrual (surgery, radiotherapy, temozolomide, bevacizumab, steroids, others).

The healthy control (HC) group was assembled from each cancer patient's respective family members/caregiver who accompanied him/her to the treatment center and had received 2 doses of BNT162b2. Exclusion criteria for both groups included history of prior Covid-19 infection (based on a positive polymerase chain reaction [PCR] test), active hematological cancer and pregnancy. Additional exclusion criteria for the control group included immune deficiency, active receipt of immunosuppressant therapy of any kind, and active other malignancy of any kind.

Determination of serological status

Blood samples were extracted from all participants at two separate time points. The first sample ("T1") was drawn at least 37 days after the second vaccine dose, between March 1st 2021 and June 10th 2021. The second sample ("T2") was drawn at least two months after the first sample, between May 18th 2021 and July 22nd 2021.

Serological status was determined using IgG antibodies level against the SARS-CoV-2 spike receptor-binding domain, quantified using a chemiluminescent microparticle immunoassay (by Abbott®). An antibody level of 50 AU/mL or higher was considered positive for successful seroconversion²⁰.

Statistical Analysis

Univariate and multivariable analyses were performed by fitting a generalized linear model on the log of IgG values at T2 and included age and days after vaccination as continuous variables, and sex, treatments (except for the study drug), and steroid use at vaccination as categorical variables. The Spearman correlation method was used to assess the correlation between the IgG values and the number of days after vaccination. The difference in IgG values between patients and controls was evaluated using the Wilcoxon rank sum test. A *P* value <.05 was considered significant. Statistical analysis was performed using R, version 4.0.2 (R Foundation).

Ethics Statement

The study was approved by the Rabin Medical Center Ethics Committee and all patients as well as HC provided informed consent.

Results

Characteristics of study population

A total of 17 PBT patients and 12 HCs were included in the study (see Table1). The PBT group comprised 11 male patients, with a median age of 65 (58-71). In the HC group, 2 participants were male and the median age was 58 (48-69). Most patients in the PBT group had a glioma diagnosis (glioblastoma multiforme=13, anaplastic astrocytoma=2, oligodendroglioma=1). A single patient with a non-glioma

diagnosis (atypical meningioma) was included based on having been treated with bevacizumab, a drug commonly prescribed for glioma in the second-line setting.

Table 1
Study Population

	PBT (n=17)	HC (n=12)
Age (median [IQR])	65 (58-71)	58 (48-69)
Sex n (%)		
male	11 (65%)	2 (17%)
Female	6 (35%)	10 (83%)
Diagnosis n (%)		
Glioblastoma	13 (76%)	n/a
Anaplastic astrocytoma	2 (12%)	n/a
Oligodendroglioma	1 (6%)	n/a
Atypical meningioma	1 (6%)	n/a
Treatment components in the three months prior to vaccination		
Radiation	5(27%)	n/a
Temozolomide	11(65%)	n/a
Bevacizumab	4 (23%)	n/a
Clinical trial drug	1 (6%)	n/a
Surgery	2 (12%)	n/a
Corticosteroids at time of vaccination	8/17 (47%)	n/a
Corticosteroid (Dexamethasone) dosage (mean mg [range])	0.5 (0-16)	n/a
IQR = Interquartile range		

Eleven patients received TMZ and four patients received bevacizumab within three months prior to vaccination. Eight patients were under systemic glucocorticoid treatment at the time of vaccination.

Serological outcome

At timepoint T1, the median elapsed time in days from the 2nd vaccination dose was 44 (37-53) for the PBT group and 44 (34 -51) for the HC group (p=0.8) [see **Table 2**]. At this timepoint, 88.2% (15/17) of PBT patients achieved seroconversion, compared with 100% (12/12) of HCs. Median IgG titer levels were

significantly lower in the PBT group compared to the HC group (1,908 AU/mL vs 8,198 AU/mL, respectively; $p=0.002$) [see **Table 2, Fig. 1**]

Table 2: Serological Status

Brain Tumor Patients	Control	p-value	
Timepoint T1			
Days post-vaccination (median [IQR])	44 (37-53)	44 (34 -51)	0.8
Seroconversion Rate (%)	88.2% (15/17)	100% (12/12)	
IgG Titer Values (AU/mL) (median [IQR])	1,908 (471 - 4,387)	8,198 (4,515 - 12,377)	0.002
Timepoint T2			
Days post-vaccination (median [IQR])	130 (126 -138)	134 (126 -140)	>0.9
Seroconversion Rate (%)	80% (12/15)	100%(12/12)	
IgG Titer Values (AU/mL) (median [IQR])	410 (138 - 770)	1,687 (937 - 2,326)	0.002

IQR: interquartile range

At T2, the median elapsed time in days from 2nd vaccination was 130 (126-138) and 134 (126-140) for the PBT and HC groups, respectively. IgG levels were available for 10 out of 12 patients in the HC group, with a seroconversion rate of 100% (10/10). In the PBT group, IgG level were available for 15 out of 17 patients, with a seroconversion rate of 80% (12/15). Two PBT patients who were seronegative at T1 remained so at T2. One PBT patient who successfully seroconverted at T1 (IgG level of 189 AU/mL) reverted back to a negative status at T2 (IgG level of 42 AU/mL). Median IgG titers remained significantly lower in the PBT group (410 vs 1687; $p=0.002$) [see **Fig. 1**].

Analysis of IgG levels as a function of time elapsed from 2nd vaccination at T2 revealed significant inverse correlations for both groups (see **Fig. 2**).

Steroid treatment at the time of vaccination

Notably, all three PBT patients who failed to achieve seroconversion at T2 had been treated with corticosteroids at the time of vaccination, with two patients out of the three receiving high dose dexamethasone (10 mg and 16 mg, respectively). Of the PBT patients who successfully seroconverted at T2, four patients were under steroid treatment, however all four were treated with low doses (between 0.5 and 4 mg).

Congruently, in a univariate analysis at timepoint T2, corticosteroid use was negatively associated with diminished IgG titers. The association was not significant in a multivariable analysis. Male sex was

positively associated with IgG titers. No additional putative risk factors for diminished titers were identified (see Table 3).

Table 3: Univariate & Multivariable Analysis at Timepoint T2

Characteristic	Univariate analysis			Multivariate analysis		
	Beta	95% CI	p-value	Beta	95% CI	p-value
Age	-0.03	-0.08, 0.03	0.3	0.01	-0.03, 0.05	0.6
Sex						
Female	-	-		-	-	
Male	1.5	0.22, 2.8	0.039	1.7	0.91, 2.5	0.014
Treatments						
Bevacizumab	-	-		-	-	
Surgery	1.6	-0.92, 4.1	0.2	1.0	-1.2, 3.2	0.4
Temozolomide	-0.36	-2.2, 1.4	0.7	-0.2	-0.93, 0.54	0.6
Elapsed time from vaccination (days)	-0.03	-0.06, 0.01	0.2	-0.01	-0.02, 0.01	0.5
Steroid treatment at vaccination						
No	-	-		-	-	
Yes	-1.9	-3.0, -0.82	0.005	-1.1	-1.9, -0.25	0.063
Diagnosis						
Anaplastic Astrocytoma	-	-		-	-	
Atypical Meningioma	0.22	-3.2, 3.7	>0.9	2.4	0.51, 4.2	0.066
Glioblastoma Multiforme	-1.3	-3.4, 0.91	0.3	0.37	-1.1, 1.9	0.7
Oligodendroglioma	0.67	-2.8, 4.1	0.7	0.08	-1.4, 1.5	>0.9

Discussion

To our knowledge, this is the largest reported cohort of PBT patients assessed for serological status following two doses of the BNT162b2 mRNA Covid-19 vaccine. Eighty percent of PBT patients in our

study seroconverted followings a two-dose vaccination schedule, which is a lower rate than was previously recorded in pan-cancer cohorts, including from our group ^{11,12}. As with the previous pan-cancer cohorts, median IgG titers in the PBT group were significantly lower compared with HCs, and remained lower upwards of 4 months post-vaccination.

The reduced immunogenicity observed in the PBT cohort should be interpreted with caution. First, while there is an agreed-upon laboratory IgG value above which a person is considered to have successfully seroconverted, the threshold required for actual real-life clinical protection against infection (a “protective threshold”) has not been established²¹. In addition, whether or not lower IgG titers in seroconverted individuals necessarily confer greater risk of infection is also unclear. Early data does indicate, however, that breakthrough infections are correlated with lower peak levels of both neutralizing and S- specific IgG antibodies. This was recently demonstrated in a study from Israel conducted among vaccinated healthcare personnel²².

All three PBT patients who failed to successfully seroconvert at T2 were under daily corticosteroid treatment during the vaccination schedule, with two patients receiving high-dose dexamethasone. Indeed, a negative association between steroid treatment and IgG titers was confirmed in a univariate analysis. Interestingly, while four PBT patients who successfully seroconverted were also treated with steroids, none required dosing above 4 mg, suggesting that the level of impairment exerted by steroids on vaccine immunogenicity may be dose dependent.

In contrast to our findings regarding steroids, there was no demonstrable association between receipt of TMZ in the peri-vaccination period and subsequent IgG titer levels. TMZ is known to induce lymphopenia which is driven primarily by selective CD4+ T-Cell Depletion^{15,23}. Therefore, any impairment to vaccine response exerted by TMZ would presumably be mediated through reduced CD4+ counts. In our study, longitudinal CD4 counts across the vaccination schedule were not routinely obtained, precluding a correlation analysis to be performed between CD4+ levels and humoral response. A relevant extrapolation could be made from the limited published data on vaccinated persons with HIV. Frater and colleagues recently reported safety and efficacy outcomes for a subset of 54 HIV-positive patients included in the phase II/III study of the ChAdOx1 nCoV-19 vaccine (Astra-Zeneca)²⁴. In the study, all participants were on active anti-retroviral therapy, had undetectable HIV viral load, and the median CD4 counts at enrollment were 694 cells/ μ L. The authors found no difference in the magnitude or durability of anti-spike IgG response between HIV-positive and HIV-negative participants, and there was no correlation between CD4 counts and the level of IgG response at day 56 following the prime vaccination (first dose).

Our study suffers from several limitations. Primarily, small sample sizes in both groups prohibit making robust conclusions regarding vaccine immunogenicity in PBT patients. Secondly, the groups were not matched by age and sex – the proportion of males in the PBTs was higher, as was the median age. Lastly, cellular immunity measures - which are of relevance in patients receiving lymphocyte-modulating treatment, were not assessed.

Notwithstanding the above limitations, our findings do point to a reduced vaccine response in PBT patients compared with healthy controls, as evidenced by a lower rate of successful seroconversion, as well as reduced IgG levels over a prolonged follow-up period. Both of these effects might be mediated by chronic steroid use throughout the vaccination schedule. In light of our findings, it appears prudent to minimize corticosteroid treatment for PBT patients during the peri-vaccination period to the lowest-possible dose required to control edema-related symptoms. In addition, PBT patients should be strongly considered for receipt of a third (“booster”) vaccination dose. Alternatively, IgG titer levels may be serially monitored following the two-dose schedule to single out the subset of PBTs patients who serve to benefit from a booster dose.

Like many other facets of oncology care, the treatment of neuro-oncology patients has been severely disrupted by the pandemic²⁵. Minimizing infection risk should be a high priority especially in patients with high - grade glioma, who typically harbor multiple risk factors for severe infection including older age, continuous immunosuppression, and reduced mobility secondary to neurological damage.

Declarations

Funding: No funding source to declare

Competing Interests: the authors declare that they have no financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

Authorship:

Substantial contribution to conception and design: N.E.R., S.M.S., S.Y.K

Acquisition of data: A.M., A.B.A, S.M.S, S.Y.K

Analysis and interpretation of data: A.M., R.T., A.S., N.E.R., S.M.M., S.Y.K.

Drafting of article: R.T., A.S., N.E.R, S.M.S., S.Y.K

Critical revision of article: RT, S.M.S., S.Y.K

Final approval of version to be published: N.E.R, S.M.S, S.Y.K, R.T.

Manuscript body word count: 2,040

Data Availability Statement: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

Figure 1: IgG Titer Levels

1A: IgG Titer levels at T1 (Control: n=12; Patient:n=17)

1B: IgG Titer levels at T2 (Control: n=10; Patient: n=15)

Figure 1

See image above for figure legend

Figure 2: IgG Titer Levels versus Time Elapsed in Days from Second Vaccination Dose

2A: Patient
2B: Controls

Figure 2

See image above for figure legend