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Rapid antibody testing for SARS-CoV-2 vaccine response in pediatric healthcare workers



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ABSTRACT

Background: The durability of the immune response to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccination remains unknown. The objective of this study was to evaluate a rapid SARS-CoV-2 lgM/lgG antibody detection kit as a qualitative screen for the humoral response to vaccination.

Methods: Study participants (n = 125) included pediatric healthcare workers (HCWs) who had received two doses of BNT162b2 or mRNA-1273. Participants were tested on study entry (March 12, 2021 to April 9, 2021). The mean number of days post second dose was 22 (range 17–36). Participants were tested for IgM/IgG antibodies to the SARS-CoV-2 spike protein with the RightSign COVID-19 IgG/IgM Rapid Test Cassette. ELISA/competitive inhibition ELISA (CI-ELISA) were subsequently run to assess for the neutralization effect and SARS-CoV-2 anti-nucleocapsid IgM/IgG antibodies.

Results: Overall, 98.4% of participants were IgG-positive and 0.8% were IgM-positive on rapid Right-Sign testing. Of those with IgG-positive results, 100% were anti-spike protein IgG-positive on CI-ELISA; none of those who tested IgG-negative via the rapid test were IgG-positive on CI-ELISA. All HCWs who tested RightSign positive demonstrated neutralizing capability on CI-ELISA. Overall, 1.6% demonstrated anti-nucleocapsid IgM antibodies and 5.6% demonstrated anti-nucleocapsid IgG antibodies.

Conclusions: The strong agreement between the rapid RightSign IgG results and confirmatory CI-ELISA testing suggests that this test may be used to assess for positive, and neutralizing, antibody responses to SARS-CoV-2 mRNA vaccination.

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1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic and the responses enacted to limit its devastation have profoundly impacted almost all aspects of society. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccinations have the potential to not only reduce the morbidity and mortality associated with COVID-19, but also to precipitate a return to 'normal' life. In phase 2/3 trials, two doses of mRNA-1273 demonstrated 94% efficacy in preventing COVID-19, and BNT162b2 has been shown to be 95% effective in preventing COVID-19; both vaccines induce antibodies to the SARS-CoV-2 spike protein (Baden et al., 2021; Polack, 2021). However, the antibody response to vaccines can be highly variable, and it is unknown how or whether the antibody response profile to SARS-CoV-2 vaccines will change over time, and if these changes will be clinically significant (Zimmermann and Curtis, 2019). To date, several studies have examined the SARS-CoV-2 mRNA vaccine immune response in relatively small cohorts (Sahin et al., 2020; Wang et al., 2021; Widge et al., 2021). These studies have all relied on ELISA, and in many cases on flow cytometry as well, which is

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likely not sustainable or practical for fast, inexpensive, and largescale testing.

The primary objective of this study was to evaluate the use of a rapid and relatively inexpensive SARS-CoV-2 IgM/IgG antibody detection kit, RightSign COVID-19 IgG/IgM Rapid Test Cassette, as a qualitative screening tool for determining the humoral immune response to SARS-CoV-2 vaccination by comparison to a competitive inhibition ELISA. Neutralizing antibodies, formed as a result of vaccination or natural infection, are key measures of protection, and while direct measurement of SARS-CoV-2 neutralizing antibodies is complicated due to biosafety laboratory restrictions, surrogate neutralization tests have been shown to be acceptable alternatives (Addetia et al., 2020; Favresse et al., 2021; Huang et al., 2020; Tan et al., 2020; Valcourt et al., 2021). The secondary objective of this study was to evaluate, through ELISA testing, the seroprevalence of SARS-CoV-2 anti-nucleocapsid antibodies in a pediatric healthcare worker (HCW) population to assess for historical coronavirus infection. A cohort of pediatric HCWs was chosen, as they are exposed to a variety of respiratory viruses more common in the pediatric population, including coronaviruses circulating prior to SARS-CoV-2.

2. Methods

2.1. Study design

Pediatric HCWs involved in direct patient contact care or working in close proximity to patient-care areas at this institution were invited to participate in the study during the period from March 12 through April 9, 2021. The study participants (n = 125) were \geq 18 years of age and included physicians, physician assistants, nurse practitioners, nurses, aides, medical technicians, and additional clinical staff. All HCWs who participated in the study had received two doses of either BNT162b2 or mRNA-1273 vaccine, with receipt of the second dose 17-36 days prior to study enrollment. Any individual who had previously tested positive for SARS-CoV-2 via a reverse transcriptase PCR (RT-PCR) or any other antigen or antibody diagnostic test was excluded from the study. The average prevalence of positive COVID-19 testing for our county over a 14day period during the study was 0.0034% (Orange County Health Care Agency, 2021). During the study, the county cumulative total number of cases was 250 431 since tracking began, representing 7.9% of the total county population. During the study period, the alpha, epsilon, and gamma variants made up more than 73% of COVID-19 cases in California, and the delta variant accounted for <2.1% of cases (California Department of Public Health, 2021). The study was approved by the Institutional Review Board and signed informed consent was obtained from all study participants.

2.2. Serological testing

Blood samples were obtained on the day of consent. All samples were tested with the Hangzhou Biotest Biotech RightSign COVID-19 IgG/IgM Rapid Test Cassette, which was issued an Emergency Use Authorization by the US Food and Drug Administration on June 4, 2020 (U.S. Food & Drug Administration F 2021) IgG analysis performed by the manufacturer showed that the RightSign kit has a 93.3% sensitivity to anti-spike IgG for 30 samples tested and a 100% specificity to anti-spike IgG for 80 samples tested. All fingerstick sampling and antibody testing related to the study were performed by trained personnel according to the manufacturer's instructions. Consensus between two blinded research team members was needed to declare a positive result; this methodology was used to ensure accuracy and assess ease of use. All serum/plasma samples were stored at 4°C prior to analysis.

2.3. ELISA

The SARS-CoV-2 Surrogate Virus Neutralization ELISA (Gen-Script, Piscataway, NJ, USA), a competitive inhibition assay, was used to detect neutralizing IgG antibodies targeting the viral spike (S) protein receptor binding domain. This assay utilizes the purified receptor binding domain (RBD) from the SARS CoV-2 spike (S) protein to test plasma for the presence of patient antibodies that would block binding of specific viral binding spike protein (spike RBD) to its host receptor, ACE2. Using a horseradish peroxidaseconjugated recombinant SARS-CoV-2 RBD binding fragment and an ELISA plate coated with its target protein (the human ACE2 receptor protein, hACE2), test plasma is measured for its ability to block this protein-protein interaction between the HRP-linked RBD (HRP-RBD) and hACE2, thus inhibiting binding of a viral protein used for cell entry and propagation. This assay has been shown to be effective in detecting neutralizing antibodies when compared to a plaque reduction neutralization test, and has shown a significant correlation with specific known positive samples (95% confidence interval 87-100%) and specific negative samples (95% confidence interval 95.8-100%) (Tan et al., 2020). Each assay that is run requires titering of positive and negative controls provided in the kit, to determine the actual optical density (OD) level that sets the limits to call a plasma positive or negative for antibody directed against the SARS-Co-V2 RBD. The cutoff of 30% inhibition was determined to confirm the presence of anti-SARS-CoV-2 antibodies based on the studies performed by Tan et al. using the World Health Organization guidelines, and in comparison to parallel assays (Tan et al., 2020).

SARS-CoV2- IgG and IgM antibodies specific to the SARS-CoV-2 nucleocapsid protein were detected with ELISA kits (Epitope Diagnostics Inc., San Diego, CA, USA), which were run according to the manufacturer's instructions. Samples were tested in duplicate. Positive and negative cutoff values for IgG and IgM were determined according to the package insert for each assay. Values greater than the cutoff were considered positive. Manufacturing specifications/inserts for RightSign and all ELISAs may be found in the **Supplementary Material**.

2.4. Statistical methods

To measure the concordance between RightSign IgG screening and CI-ELISA-based screening, McNemar's Chi-square test of concordance was utilized to identify any significant levels of discord. To supplement these results with a measurement of the strength of agreement between tests, Cohen's Kappa was used to measure the strength of agreement. In the event of perfect concordance between screening methods, McNemar's Chi-square would produce a not applicable (NA) value. This NA occurs as a result of 0 values in both the false-positive and false-negative quadrants of a 2 $\,\times\,$ 2 table.

3. Results

All study participants (n = 125) had received two doses of either BNT162b2 or mRNA-1273 vaccine; 113 had received BNT162b2 and 12 had received mRNA-1273. At the time of enrollment in the study, the range of days post second vaccine was 17–36, and the average was 22.1 (Table 1). Participant demographics are described in **Supplementary Material** Table S1.

There was 100% agreement between study team members regarding the reading of rapid antibody test results. Of the total 125 participants, 123 (98.4%) tested positive for IgG to the spike protein RBD on the RightSign rapid antibody test, and one patient (0.8%) tested IgM-positive. Of those with positive RightSign IgG results, 100% were IgG-positive on confirmatory anti-spike IgG Cl-

Table 1

Results of serological testing

Patient number	RightSign rapid AB test	CI-ELISA		SARS-CoV-2 nucleocapsid ELISA		Vaccine type	Days since second vaccine dose
		IgG (+/-)	% inhibition	IgG (+/-)	IgM (+/-)		
1	IgG+/IgM-	Positive	94.58%	Negative	Negative	BNT162b2	21
2	IgG+/IgM-	Positive	83.93%	Negative	Negative	BNT162b2	18
3	IgG+/IgM-	Positive	59.75%	Negative	Negative	BNT162b2	20
4	IgG+/IgM-	Positive	79.50%	Negative	Negative	BNT162b2	21
5	IgG+/IgM-	Positive	97.18%	Negative	Negative	BNT162b2	20
6	IgG+/IgM-	Positive	50.98%	Negative	Positive	BNT162b2	20
/ 8	IgG+/IgM-	Positive	98.11%	Negative	Negative	BNT162D2 BNT162b2	25
9	IgG+/IgM-	Positive	90.42% 89.94%	Positive	Negative	BNT162b2	24
10	IgG+/IgM-	Positive	90.27%	Negative	Negative	BNT162b2	20
11	Negative ^a	Negative	10.27%	Negative	Negative	BNT162b2	21
12	IgG+/IgM-	Positive	94.26%	Negative	Negative	BNT162b2	19
13	IgG+/IgM-	Positive	94.97%	Negative	Negative	BNT162b2	19
14	IgG+/IgM-	Positive	96.43%	Negative	Negative	BNT162b2	20
15	lgG+/lgM-	Positive	97.06%	Negative	Negative	BNT162b2	25
10	IgG+/IgM-	Positive	83.76%	Negative	Negative	BINT 162D2	19
17	IgG + /IgM -	Positive	90.94%	Negative	Negative	BNT162b2	20
19	IgG+/IgM+	Positive	86 70%	Negative	Negative	BNT162b2	18
20	IgG+/IgM-	Positive	96.82%	Negative	Negative	BNT162b2	19
21	IgG+/IgM-	Positive	85.20%	Negative	Negative	BNT162b2	21
22	IgG+/IgM-	Positive	94.88%	Negative	Negative	BNT162b2	22
23	IgG+/IgM-	Positive	92.79%	Negative	Negative	BNT162b2	21
24	IgG+/IgM-	Positive	85.38%	Negative	Negative	BNT162b2	19
25	IgG+/IgM-	Positive	96.68%	Negative	Negative	BNT162b2	19
26	IgG+/IgM-	Positive	91.08%	Negative	Negative	BNT162b2	19
27	IgG+/IgM-	Positive	94.37%	Negative	Negative	BNT162b2	20
28	lgG+/lgM-	Positive	93.51%	Negative	Negative	BNT162b2	20
29	IgG+/IgM-	Positive	87.17%	Negative	Negative	BINT 162D2	19
30	IgG+/IgM-	Positive	95.88%	Negative	Negative	BINT 162D2	17
32	IgG+/IgM-	Positive	9 5. 42% 88.67%	Negative	Negative	BNT162b2	22
33	IgG+/IgM-	Positive	91 54%	Negative	Negative	BNT162b2	22
34	IgG+/IgM-	Positive	91.04%	Negative	Negative	BNT162b2	20
35	IgG+/IgM-	Positive	94.82%	Negative	Negative	BNT162b2	23
36	IgG+/IgM-	Positive	90.61%	Negative	Negative	BNT162b2	20
37	IgG+/IgM-	Positive	94.79%	Negative	Negative	BNT162b2	21
38	IgG+/IgM-	Positive	95.80%	Positive	Negative	BNT162b2	20
39	IgG+/IgM-	Positive	92.23%	Negative	Negative	BNT162b2	21
40	IgG+/IgM-	Positive	96.36%	Negative	Negative	BNT162b2	21
41	IgG+/IgM-	Positive	97.03%	Negative	Negative	BNT162b2	20
42	IgG+/IgM-	Positive	96.88%	Negative	Negative	BINT 162D2	33
43	IgG+/IgM-	Positive	94.00%	Negative	Negative	BNT162b2	20
45	IgG+/IgM-	Positive	85 78%	Negative	Negative	BNT162b2	25
46	IgG+/IgM-	Positive	94.11%	Positive	Negative	BNT162b2	23
47	IgG+/IgM-	Positive	96.05%	Negative	Negative	BNT162b2	20
48	IgG+/IgM-	Positive	83.93%	Negative	Negative	BNT162b2	19
49	IgG+/IgM-	Positive	96.01%	Negative	Negative	BNT162b2	19
50	IgG+/IgM-	Positive	97.22%	Negative	Negative	BNT162b2	20
51	IgG+/IgM-	Positive	97.35%	Negative	Negative	mRNA-1273	29
52	Negative [Au?3]	Negative	15.98%	Negative	Negative	BNT162b2	22
53	lgG+/lgM-	Positive	96.20%	Negative	Negative	BNT162b2	21
54	IgG+/IgM-	Positive	96.97%	Negative	Negative	BNT162b2	29
55 56	IgG+/IgM-	Positive	95.09%	Desitivo	Negative	BINT 162D2	21
57	IgG+/IgM-	Positive	90.33% 87 79%	Negative	Negative	BNT162b2	17
58	IgG+/IgM-	Positive	95 77%	Negative	Negative	BNT162b2	27
59	IgG+/IgM-	Positive	95.16%	Negative	Negative	BNT162b2	22
60	IgG+/IgM-	Positive	96.39%	Negative	Negative	BNT162b2	21
61	IgG+/IgM-	Positive	95.35%	Negative	Negative	BNT162b2	27
62	IgG+/IgM-	Positive	93.43%	Negative	Negative	BNT162b2	21
63	IgG+/IgM-	Positive	97.71%	Negative	Negative	mRNA-1273	33
64	IgG+/IgM-	Positive	89.29%	Negative	Negative	BNT162b2	20
65	IgG+/IgM-	Positive	96.43%	Negative	Negative	BNT162b2	24
66	lgG+/lgM-	Positive	92.16%	Negative	Negative	BNT162b2	21
67	IgG+/IgM-	Positive	94.10%	Negative	Negative	BNT162b2	20
60 60	IgG+/IgM-	Positive	97.08%	Negative	Negative	BNT162b2	22
70	igG+/igivi-	Positive	90.90% 40.50%	Negative	Negativo	BINT 102D2 BNT16252	22
70	IgG+/IgM-	Positive	86.50%	Negative	Negative	BNT162b2	22
72	IgG+/IgM-	Positive	73.04%	Negative	Negative	BNT162b2	17
				-	-		

(continued on next page)

Table 1 (continued)

$ \frac{1}{160} \cdot 1$	Patient number	RightSign rapid AB test	CI-ELISA		SARS-CoV-2 nucleocapsid ELISA		Vaccine type	Days since second vaccine dose
74 194 94.863 Negative Negative BNT16D2 21 75 195/11/8M- Positive 95.783 Negative Negative BNT16D2 21 76 195/11/8M- Positive 95.783 Negative Negative BNT16D2 21 77 195/11/8M- Positive 94.483 Negative Negative BNT16D2 21 78 195/11/8M- Positive 95.313 Negative Negative BNT16D2 22 79 195/11/8M- Positive 95.313 Negative Negative BNT16D2 22 81 195/11/8M- Positive 95.323 Negative Negative BNT16D2 22 83 195/11/8M- Positive 92.333 Negative Negative BNT16D2 22 84 195/11/8M- Positive 92.333 Negative Negative BNT16D2 21 85 195/11/8M- Positive 92.333 Negative Negati			IgG (+/-)	% inhibition	IgG (+/-)	IgM (+/-)		
74 IgC+ (IgM- Positive 93.48% Negative N	73	IgG+/IgM-	Positive	94.86%	Negative	Negative	BNT162b2	21
75 1g.G. / 1g.M. Positive 95.783 Negative Negative BNT162b2 21 76 1g.G. / 1g.M. Positive 94.483 Negative Negative BNT162b2 21 77 1g.G. / 1g.M. Positive 95.913 Negative Negative BNT162b2 21 79 1g.G. / 1g.M. Positive 95.913 Negative Negative BNT162b2 21 81 1g.G. / 1g.M. Positive 95.323 Negative Negative BNT162b2 21 81 1g.G. / 1g.M. Positive 95.323 Negative Negative BNT162b2 21 82 1g.G. / 1g.M. Positive 92.333 Negative Negative BNT162b2 21 83 1g.G. / 1g.M. Positive 92.333 Negative Negative BNT162b2 21 84 1g.G. / 1g.M. Positive 92.333 Negative Negative BNT162b2 21 85 1g.G. / 1g.M. Positive </td <td>74</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>93.49%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>24</td>	74	IgG+/IgM-	Positive	93.49%	Negative	Negative	BNT162b2	24
76 IgG-IgM- IgG-IgM- Positive 96.12% Negative Negative Negative Negative NTTG2/2 BNT1G2/2 BNT	75	IgG+/IgM-	Positive	95.78%	Negative	Negative	BNT162b2	21
77 18 19 94.87 Negative Negative BNT162b2 21 78 18 19 16 10 21 79 18 16 16 10 21 79 18 16 16 10 21 81 18 16 16 10 21 81 18 16 16 10 21 21 82 18 16 16 10 10 22 21 83 18 16 16 10 10 10 10 21 21 84 18 16 16 16 16 10	76	IgG+/IgM-	Positive	96.12%	Negative	Negative	BNT162b2	21
7818/54-/18/M-Positive90.313NegativeNegativeNTT 62b2218018/54-/18/M-Positive93.32XNegativeNegativeNTT 62b2228118/54-/18/M-Positive93.32XNegativeNegativeNTT 62b2268218/54-/18/M-Positive95.89XNegativeNegativeNTT 62b2228418/54-/18/M-Positive97.93XNegativeNegativeNTT 62b2238418/54-/18/M-Positive97.93XNegativeNegativeNTT 62b2238518/54-/18/M-Positive96.13XNegativeNegativeNTT 62b2218618/54-/18/M-Positive87.37XNegativeNegativeNTT 62b2218718/54-/18/M-Positive97.31XNegativeNegativeNTT 62b2219018/54-/18/M-Positive97.31XNegativeNegativeNTT 62b2219118/54-/18/M-Positive97.31XNegativeNegativeNTT 62b2219218/54-/18/M-Positive97.31XNegativeNegativeNTT 62b2229318/54-/18/M-Positive97.31XNegativeNegativeNTT 62b2229418/54-/18/M-Positive97.31XNegativeNegativeNTT 62b2229518/54-/18/M-Positive97.31XNegativeNegativeNTT 62b22296 <td>77</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>94.48%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>21</td>	77	IgG+/IgM-	Positive	94.48%	Negative	Negative	BNT162b2	21
791919191919181910010112228119191933.22Negative </td <td>78</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>90.93%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>21</td>	78	IgG+/IgM-	Positive	90.93%	Negative	Negative	BNT162b2	21
80gC+/gM- GC+/gM-Positive9.32% 9.54%NegativeNegativeBNT162/22181gC+/gM- GC+/gM-Positive9.54% 9.64%NegativeNegativeBNT162/22182gC+/gM- GC+/gM-Positive9.23% 9.23%NegativeNegativeBNT162/22184gC+/gM- GC+/gM-Positive9.73% 9.613%NegativeNegativeBNT162/22185gC+/gM- GC+/gM-Positive8.73% 9.73%NegativeNegativeBNT162/22186gC+/gM- GC+/gM-Positive8.73% 9.73%NegativeNegativeBNT162/22187gC+/gM- GC+/gM-Positive8.73% 9.73%NegativeNBT162/2212188gC+/gM- GC+/gM-Positive8.73% 9.731%NegativeNegativeBNT162/22190gC+/gM- GC+/gM-Positive9.731% 9.731%NegativeNegativeBNT162/22191gC+/gM- GC+/gM-Positive9.317% 9.731%NegativeNegativeBNT162/22192gC+/gM- GC+/gM-Positive9.317% 9.731%NegativeNegativeBNT162/22194gC+/gM- GC+/gM-Positive9.315% 9.731%NegativeNegativeBNT162/22195gC+/gM- GC+/gM-Positive9.434% 9.731%NegativeNegativeBNT162/22196gC+/gM- GC+/gM-Positive9.435	79	IgG+/IgM-	Positive	95.91%	Negative	Negative	BNT162b2	22
81gGr-//gM-Positive9.59%NegativeNegativeRPTIG2/22682gGr-//gM-Positive9.03%NegativeNegativeRPTIG2/22183lgGr-//gM-Positive97.59%NegativeNegativeRPTIG2/22185lgGr-//gM-Positive97.59%NegativeNegativeRPTIG2/22186lgGr-//gM-Positive88.87%NegativeNegativeRPTIG2/22187lgGr-//gM-Positive82.37%NegativeNegativeRPTIG2/22188lgGr-//gM-Positive92.83%NegativeNegativeRPTIG2/22189lgGr-//gM-Positive92.83%NegativeNegativeRPTIG2/22191lgGr-//gM-Positive97.81%NegativeNegativeRPTIG2/22192lgGr-//gM-Positive97.15%NegativeNegativeRPTIG2/22193lgGr-//gM-Positive97.31%NegativeNegativeRPTIG2/22194lgGr-//gM-Positive97.31%NegativeNegativeRPTIG2/22195lgGr-//gM-Positive97.31%NegativeNegativeRPTIG2/22196lgGr-//gM-Positive97.31%NegativeNegativeRPTIG2/22197lgGr-//gM-Positive97.31%NegativeNegativeRPTIG2/22198lgGr-//gM-Positive<	80	IgG+/IgM-	Positive	93.32%	Negative	Negative	BNT162b2	21
82upd-rlgM- upd-rlgM-Positive PositiveProgrative PositivePNTIC2D2 POSITIVE2183Upd-rlgM- upd-rlgM-Positive Positive95.13% POSITIVENegative NegativePNTIC2D2 RDTIC2D22384Upd-rlgM- upd-rlgM-Positive Positive96.13% POSITIVENegative PositivePNTIC2D2 POSITIVE2186Upd-rlgM- upd-rlgM-Positive POSITIVE87.29% POSITIVENegative PositivePNTIC2D2 POSITIVE2187Upd-rlgM- upd-rlgM-Positive POSITIVE97.31% POSITIVENegative Negative POSITIVEPNTIC2D2 POSITIVE2190Upd-rlgM- upd-rlgM-Positive POSITIVE97.31% POSITIVENegative Negative Negative POSITIVEPNTIC2D2 POSITIVE2191Upd-rlgM- upd-rlgM-Positive POSITIVE97.31% POSITIVE POSITIVENegative Negative Negative POSITIVEPNTIC2D2 POSITIVE2192Upd-rlgM- upd-rlgM-Positive POSITIVE97.31% POSITIVE POSITIVENegative Negative POSITIVE POSITIVEPNTIC2D2 POSITIVE POSITIVE POSITIVEPNTIC2D2 POSITIVE POSITIVE POSITIVE POSITIVEPNTIC2D2 POSITIVE POSITIVE POSITIVE POSITIVEPNTIC2D2 POSITIVE POSITIVE POSITIVE POSITIVEPNTIC2D2 POSITIVE POSITIVE POSITIVEPNTIC2D2 POSITIVE POSITIVE POSITIVE POSITIVEPOSITIVE POSITIVE POSITIVE POSITIVEPOSITIVE POSITIVE POSITIVE POSITIVEPOSITIVE POSITIVE POSITIVE PO	81	IgG+/IgM-	Positive	95.89%	Negative	Negative	BNT162b2	26
83igC+lgM- lgC+lgM- lgC+lgM-Positive Positive97.593Negative NegativeNPTIC2D2 Negative2285lgC+lgM- lgC+lgM-Positive Positive97.593Negative NegativeNRN-12733586lgC+lgM- lgC+lgM-Positive Positive87.872Negative NegativeNPTIC2D22187lgC+lgM- lgC+lgM-Positive Positive87.873Negative NegativeNPTIC2D22189lgC+lgM- lgC+lgM-Positive Positive97.813Negative NegativeNPTIC2D22191lgC+lgM- lgC+lgM-Positive Positive97.813Negative NegativeNPTIC2D22192lgC+lgM- lgC+lgM-Positive Positive97.413Negative NegativeNPTIC2D22193lgC+lgM- lgC+lgM-Positive Positive97.313Negative NegativeNPTIC2D22194lgC+lgM- lgC+lgM-Positive Positive97.313Negative NegativeNPTIC2D22195lgC+lgM- lgC+lgM-Positive Positive97.313Negative NegativeNPTIC2D22296lgC+lgM- lgC+lgM-Positive Positive97.313Negative NegativeNPTIC2D22297lgC+lgM- lgC+lgM-Positive Positive97.313Negative NegativeNPTIC2D22197lgC+lgM- lgC+lgM-Positive Positive97.353Negative NegativeNPTIC2D22298lgC+	82	IgG+/IgM-	Positive	60.69%	Negative	Negative	BNT162b2	21
84 IgC+/IgM- Positive 95.75% Negative Negative NRTIC2D2 23 85 IgC+/IgM- Positive 88.87% Negative Negative NRTIC2D2 21 86 IgC+/IgM- Positive 87.27% Negative Negative NRTIC2D2 21 87 IgC+/IgM- Positive 87.27% Negative Negative NRTIC2D2 21 88 IgC+/IgM- Positive 95.37% Negative Negative NRTIC2D2 21 91 IgC+/IgM- Positive 97.31% Negative Negative NRTIC2D2 21 92 IgC+/IgM- Positive 97.31% Negative Negative NRTIC2D2 21 93 IgC+/IgM- Positive 97.31% Negative Negative NRTIC2D2 22 94 IgC+/IgM- Positive 97.31% Negative Negative NRTIC2D2 22 95 IgC+/IgM- Positive 93.17%	83	IgG+/IgM-	Positive	92.93%	Negative	Negative	BNT162b2	22
85 IgC+/IgM- Positive 96-13% Negative Negative Negative NRNA-1273 25 86 IgC+/IgM- Positive 872.9% Negative Negative BNT162b2 21 87 IgC+/IgM- Positive 872.9% Negative Negative BNT162b2 21 89 IgC+/IgM- Positive 872.9% Negative Negative BNT162b2 21 90 IgC-/IgM- Positive 97.06% Negative Negative BNT162b2 21 91 IgC+/IgM- Positive 95.3% Negative Negative BNT162b2 21 94 IgC+/IgM- Positive 95.3% Negative Negative BNT162b2 21 95 IgC+/IgM- Positive 95.1% Negative Negative BNT162b2 21 96 IgC+/IgM- Positive 95.1% Negative Negative BNT162b2 21 97 IgC+/IgM- Positive 9	84	IgG+/IgM-	Positive	97.59%	Negative	Negative	BNT162b2	23
86 IgC+/IgM- Positive 88.87% Negative Negative BNT162b2 21 87 IgC+/IgM- Positive 92.83% Negative Negative BNT162b2 21 88 IgC+/IgM- Positive 97.81% Negative Negative BNT162b2 21 90 IgC+/IgM- Positive 97.06% Negative Negative BNT162b2 21 91 IgC+/IgM- Positive 97.06% Negative Negative BNT162b2 21 92 IgC+/IgM- Positive 95.74% Negative Negative BNT162b2 21 93 IgC+/IgM- Positive 93.17% Negative Negative BNT162b2 21 94 IgC+/IgM- Positive 93.17% Negative Negative BNT162b2 21 95 IgC+/IgM- Positive 93.17% Negative Negative BNT162b2 21 96 IgC+/IgM- Positive 93.17%	85	IgG+/IgM-	Positive	96.13%	Negative	Negative	mRNA-1273	35
87 IgG-//IgM- Positive 97.29% Negative Negative BNT162b2 21 88 IgG-//IgM- Positive 95.33% Negative Negative BNT162b2 21 89 IgG-//IgM- Positive 95.37% Negative Negative BNT162b2 26 91 IgG-//IgM- Positive 97.06% Negative Negative BNT162b2 21 93 IgG-//IgM- Positive 97.31% Negative Negative BNT162b2 21 94 IgG-//IgM- Positive 97.31% Negative Negative BNT162b2 21 95 IgG-//IgM- Positive 97.31% Negative Negative BNT162b2 22 96 IgG-//IgM- Positive 99.90 Positive Negative Negative BNT162b2 20 99 IgG-//IgM- Positive 94.95% Negative Negative BNT162b2 20 91 IgG-//IgM- Positive	86	IgG+/IgM-	Positive	88.87%	Negative	Negative	BNT162b2	21
88 IgG-//IgM- Positive 92.83% Negative Negative BNT162b2 21 90 IgG-//IgM- Positive 97.81% Negative Negative BNT162b2 26 91 IgG+//IgM- Positive 97.81% Negative Negative BNT162b2 21 93 IgG-//IgM- Positive 95.33% Negative Negative BNT162b2 21 94 IgG-//IgM- Positive 95.13% Negative Negative BNT162b2 22 95 IgG-//IgM- Positive 93.17% Negative Negative BNT162b2 22 96 IgG-//IgM- Positive 93.17% Negative Negative BNT162b2 22 97 IgG-//IgM- Positive 95.99% Positive Negative Negative BNT162b2 23 100 IgG-//IgM- Positive 94.95% Negative Negative BNT162b2 21 101 IgG-//IgM- Posititve <td>87</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>87.29%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>21</td>	87	IgG+/IgM-	Positive	87.29%	Negative	Negative	BNT162b2	21
89IgC+/IgM-Positive85.97%NegativeNegativeBNT162b22190IgC+/IgM-Positive97.06%NegativeNegativeBNT162b22691IgC+/IgM-Positive95.33%NegativeNegativeBNT162b22193IgC+/IgM-Positive95.74%NegativeNegativeBNT162b22194IgC+/IgM-Positive97.31%NegativeNegativeBNT162b22195IgC+/IgM-Positive97.31%NegativeNegativeBNT162b22296IgC+/IgM-Positive93.15%NegativeNegativeBNT162b22297IgC+/IgM-Positive95.99%PositiveNegativeNegativeBNT162b22298IgC+/IgM-Positive94.94%NegativeNegativeBNT162b221100IgC+/IgM-Positive84.92%NegativeNegativeBNT162b221101IgC+/IgM-Positive94.95%NegativeNegativeBNT162b221102IgC+/IgM-Positive93.35%NegativeNegativeBNT162b221103IgC+/IgM-Positive93.35%NegativeNegativeBNT162b221104IgC+/IgM-Positive93.35%NegativeNegativeBNT162b222105IgC+/IgM-Positive93.35%NegativeNegativeBNT162b222104IgC+/IgM-<	88	IgG+/IgM-	Positive	92.83%	Negative	Negative	BNT162b2	21
90igC+/lgM- igC+/lgM-Positive97.81% 97.06%Negative NegativeNegative NegativemRN-12732691igC+/lgM- igG+/lgM-Positive95.33% 95.33%Negative NegativemRN-12732693igC+/lgM- igG+/lgM-Positive95.74% 95.74%Negative NegativemRN-12732694igG+/lgM- igG+/lgM-Positive93.17% 95.15%Negative NegativeNegative NegativemRN-12732695igG+/lgM- igG+/lgM-Positive93.15% 95.95%Negative PositiveNegative NegativeNegative 80T162b22297igG+/lgM- igG+/lgM-Positive94.14% 94.92%Negative NegativeNegative 80T162b22098igG+/lgM- igG+/lgM-Positive94.93% 94.93%Negative NegativeNEgative 80T162b221100igG+/lgM- igG+/lgM-Positive94.95% 94.93%Negative NegativeNEgative 80T162b221101igG+/lgM- igG+/lgM-Positive95.33% 94.93%Negative NegativeNEgative 80T162b221102igG+/lgM- igG+/lgM-Positive94.95% 94.93%Negative NegativeNEgative 80T162b221103igG+/lgM- igG+/lgM-Positive97.38% 94.93%Negative NegativeNEgative 80T162b222104igG+/lgM- igG+/lgM-Positive97.38% 94.93%Negative NegativeNEgative 80T162b222 <tr< td=""><td>89</td><td>IgG+/IgM-</td><td>Positive</td><td>85.97%</td><td>Negative</td><td>Negative</td><td>BNT162b2</td><td>21</td></tr<>	89	IgG+/IgM-	Positive	85.97%	Negative	Negative	BNT162b2	21
91IgC+/IgM-Positive97.06%NegativeNegativeNegativeBNTI62D22193IgC+/IgM-Positive95.74%NegativeNegativeBNT162D22194IgC+/IgM-Positive97.31%NegativeNegativeBNT162D22195IgC+/IgM-Positive93.17%NegativeNegativeBNT162D22296IgC+/IgM-Positive93.15%NegativeNegativeBNT162D22297IgC+/IgM-Positive95.85%NegativeNegativeBNT162D22298IgC+/IgM-Positive84.92%NegativeNegativeBNT162D223100IgC+/IgM-Positive94.95%NegativeNegativeBNT162D221111IgC+/IgM-Positive94.95%NegativeNegativeBNT162D221102IgC+/IgM-Positive94.95%NegativeNegativeBNT162D221103IgC+/IgM-Positive93.35%NegativeNegativeBNT162D221104IgC+/IgM-Positive93.35%NegativeNegativeBNT162D222105IgC+/IgM-Positive93.84%NegativeNegativeBNT162D222106IgC+/IgM-Positive95.75%NegativeNegativeBNT162D222107IgC+/IgM-Positive95.75%NegativeNegativeBNT162D222108IgC+/IgM- <td>90</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>97.81%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>36</td>	90	IgG+/IgM-	Positive	97.81%	Negative	Negative	BNT162b2	36
92IgC+/IgM-Positive95.33%NegativeNegativeBNT162b22193IgC+/IgM-Positive97.31%NegativeNegativeBNT162b22194IgC+/IgM-Positive93.17%NegativeNegativeBNT162b22195IgC+/IgM-Positive93.17%NegativeNegativeBNT162b22297IgC+/IgM-Positive96.99%PositiveNegativeBNT162b22298IgC+/IgM-Positive96.99%PositiveNegativeBNT162b22099IgC+/IgM-Positive94.14%NegativeNegativeBNT162b221101IgC+/IgM-Positive94.95%NegativeNegativeBNT162b220102IgC+/IgM-Positive94.95%NegativeNegativeBNT162b221103IgC+/IgM-Positive95.35%NegativeNegativeBNT162b221104IgC+/IgM-Positive97.38%NegativeNegativeBNT162b221105IgC+/IgM-Positive97.38%NegativeNegativeBNT162b222106IgC+/IgM-Positive97.38%NegativeNegativeBNT162b222107IgC+/IgM-Positive97.59%NegativeNegativeBNT162b222108IgC+/IgM-Positive97.59%NegativeNegativeBNT162b222109IgC+/IgM-Positive <td>91</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>97.06%</td> <td>Negative</td> <td>Negative</td> <td>mRNA-1273</td> <td>26</td>	91	IgG+/IgM-	Positive	97.06%	Negative	Negative	mRNA-1273	26
93IgC+/IgM-Positive95.74%NegativeNegativeRNT162b22194IgC+/IgM-Positive93.17%NegativeNegativeBNT162b22195IgC+/IgM-Positive93.17%NegativeNegativeBNT162b22296IgC+/IgM-Positive93.15%NegativeNegativeBNT162b22297IgC+/IgM-Positive95.69%PositiveNegativeBNT162b22298IgC+/IgM-Positive94.14%NegativeNegativeBNT162b22099IgC+/IgM-Positive94.95%NegativeNegativeBNT162b221101IgC+/IgM-Positive94.95%NegativeNegativeBNT162b221102IgC+/IgM-Positive93.35%NegativeNegativeBNT162b221103IgC+/IgM-Positive93.35%NegativeNegativeBNT162b221104IgC+/IgM-Positive93.35%NegativeNegativeBNT162b221105IgC+/IgM-Positive95.75%NegativeNegativeBNT162b222106IgC+/IgM-Positive95.75%NegativeNegativeBNT162b222107IgC+/IgM-Positive91.57%NegativeNegativeBNT162b221108IgC+/IgM-Positive95.75%NegativeNegativeBNT162b222109IgC+/IgM-Positive <td>92</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>95.33%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>21</td>	92	IgG+/IgM-	Positive	95.33%	Negative	Negative	BNT162b2	21
941gC+/[gM-Positive97.31%NegativeNegativemRNA-127326951gC+/[gM-Positive93.17%NegativeNegativeBNT162b.221961gC+/[gM-Positive96.99%PositiveNegativeBNT162b.222971gC-/[gM-Positive96.99%PositiveNegativeBNT162b.222981gC-/[gM-Positive94.14%NegativeNegativeBNT162b.2211001gC-/[gM-Positive94.14%NegativeNegativeBNT162b.2211011gC-/[gM-Positive94.95%NegativeNegativeBNT162b.2211021gC-/[gM-Positive94.95%NegativeNegativeBNT162b.2211031gC-/[gM-Positive97.38%NegativeNegativeBNT162b.2231041gG-/[gM-Positive97.38%NegativeNegativeBNT162b.2241051gC-/[gM-Positive97.38%NegativeNegativeBNT162b.2241061gC-/[gM-Positive97.59%NegativeNegativeBNT162b.2221081gC-/[gM-Positive97.59%NegativeNegativeBNT162b.2241171gC-/[gM-Positive97.59%NegativeNegativeBNT162b.2241181gC-/[gM-Positive97.58%NegativeNegativeBNT162b.2241191gC-/[gM- <td>93</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>95.74%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>21</td>	93	IgG+/IgM-	Positive	95.74%	Negative	Negative	BNT162b2	21
95IgC+/IgM-Positive93.17%NegativeNegativeBNT162b22196IgC+/IgM-Positive93.15%NegativeNegativeBNT162b22297IgC+/IgM-Positive96.99%PositiveNegativeBNT162b22298IgC+/IgM-Positive85.88%NegativeNegativeBNT162b22399IgC+/IgM-Positive94.14%NegativePogativeBNT162b223100IgC+/IgM-Positive94.55%NegativeNegativeBNT162b221101IgC+/IgM-Positive94.55%NegativeNegativeBNT162b221102IgC+/IgM-Positive93.55%NegativeNegativeBNT162b221103IgC-/IgM-Positive93.55%NegativeNegativeBNT162b222104IgC-/IgM-Positive96.15%NegativeNegativeBNT162b224105IgG+/IgM-Positive96.75%NegativeNegativeBNT162b224107IgC-/IgM-Positive91.57%NegativeNegativeBNT162b222108IgG-/IgM-Positive94.58%NegativeNegativeBNT162b224117IgG-/IgM-Positive97.59%NegativeNegativeBNT162b224118IgG-/IgM-Positive94.58%NegativeNegativeBNT162b224119IgG-/IgM-Positive </td <td>94</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>97.31%</td> <td>Negative</td> <td>Negative</td> <td>mRNA-1273</td> <td>26</td>	94	IgG+/IgM-	Positive	97.31%	Negative	Negative	mRNA-1273	26
96 $ gC_+ /gM$ Positive93.15%NegativeNegativeBNT162b22297 $ gC_+ /gM$ Positive96.99%PositiveNegativeBNT162b22098 $ gC_+ /gM$ Positive94.14%NegativeNegativeBNT162b22099 $ gC_+ /gM$ Positive94.14%NegativeNegativeBNT162b221100 $ gC_+ /gM$ Positive94.95%NegativeNegativeBNT162b221101 $ gC_+ /gM$ Positive94.55%NegativeNegativeBNT162b221103 $ gC_+ /gM$ Positive93.35%NegativeNegativeBNT162b221104 $ gC_+ /gM$ Positive97.38%NegativeNegativeBNT162b222106 $ gC_+ /gM$ Positive93.84%NegativeNegativeBNT162b224107 $ gC_+ /gM$ Positive91.57%NegativeNegativeBNT162b222106 $ gC_+ /gM$ Positive97.59%NegativeNegativeBNT162b222111 $ gC_+ /gM$ Positive97.59%NegativeNegativeBNT162b224111 $ gC_+ /gM$ Positive97.59%NegativeNegativeBNT162b221111 $ gC_+ /gM$ Positive97.59%NegativeNegativeBNT162b221111 $ gC_+ /gM$ Positive94.38%NegativeNegativeBNT162b2 <td< td=""><td>95</td><td>IgG+/IgM-</td><td>Positive</td><td>93.17%</td><td>Negative</td><td>Negative</td><td>BNT162b2</td><td>21</td></td<>	95	IgG+/IgM-	Positive	93.17%	Negative	Negative	BNT162b2	21
97IgC+/IgM-Positive96.99%PositiveNegativeNegativeBNT162b22298IgC+/IgM-Positive85.88%NegativeNegativeBNT162b233100IgC+/IgM-Positive94.44%NegativeNegativeBNT162b221101IgC+/IgM-Positive94.95%NegativeNegativeBNT162b220102IgC+/IgM-Positive94.95%NegativeNegativeBNT162b221103IgC+/IgM-Positive93.35%NegativeNegativeBNT162b228104IgC+/IgM-Positive97.35%NegativeNegativeBNT162b224105IgC+/IgM-Positive93.64%NegativeNegativeBNT162b224106IgC+/IgM-Positive93.7%NegativeNegativeBNT162b224107IgC+/IgM-Positive91.57%NegativeNegativeBNT162b222108IgC+/IgM-Positive94.33%NegativeNegativemRNA-127328119IgC+/IgM-Positive94.43%NegativeNegativeBNT162b222110IgC+/IgM-Positive94.7%NegativeNegativeBNT162b222111IgC+/IgM-Positive94.3%NegativeNegativeBNT162b222111IgC+/IgM-Positive94.8%NegativeNegativeBNT162b222111IgC+/IgM- </td <td>96</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>93.15%</td> <td>Negative</td> <td>Negative</td> <td>BNT162b2</td> <td>22</td>	96	IgG+/IgM-	Positive	93.15%	Negative	Negative	BNT162b2	22
98IgC+/IgM-Positive95.88%NegativeNegativeBNT162b22099IgC+/IgM-Positive94.14%NegativePositiveBNT162b221100IgC+/IgM-Positive84.92%NegativeNegativeBNT162b221101IgC+/IgM-Positive94.95%NegativeNegativeBNT162b221102IgC+/IgM-Positive93.35%NegativeNegativeBNT162b218103IgC+/IgM-Positive93.35%NegativeNegativeBNT162b220105IgC+/IgM-Positive96.15%NegativeNegativeBNT162b220106IgC+/IgM-Positive96.79%NegativeNegativeBNT162b224107IgC+/IgM-Positive96.79%NegativeNegativeBNT162b222108IgC+/IgM-Positive97.59%NegativeNegativeBNT162b222109IgC+/IgM-Positive97.59%NegativeNegativeBNT162b224111IgC+/IgM-Positive94.3%NegativeNegativeBNT162b224112IgC+/IgM-Positive94.3%NegativeNegativeBNT162b224111IgC+/IgM-Positive94.3%NegativeNegativeBNT162b224112IgC+/IgM-Positive94.3%NegativeNegativeBNT162b224113IgC+/IgM-Positive <td>97</td> <td>IgG+/IgM-</td> <td>Positive</td> <td>96.99%</td> <td>Positive</td> <td>Negative</td> <td>BNT162b2</td> <td>22</td>	97	IgG+/IgM-	Positive	96.99%	Positive	Negative	BNT162b2	22
99IgG+/IgM-Positive94.14%NegativePositiveBNT162b233100IgG-/IgM-Positive84.92%NegativeNegativeBNT162b221101IgG-/IgM-Positive94.95%NegativeNegativeBNT162b220102IgG-/IgM-Positive94.95%NegativeNegativeBNT162b221103IgG-/IgM-Positive93.35%NegativeNegativeBNT162b218104IgG-/IgM-Positive97.35%NegativeNegativeBNT162b224105IgG-/IgM-Positive96.15%NegativeNegativeBNT162b224106IgG-/IgM-Positive96.15%NegativeNegativeBNT162b224107IgG-/IgM-Positive96.15%NegativeNegativeBNT162b222108IgG-/IgM-Positive97.5%PositiveNegativemRNA-127328109IgG-/IgM-Positive96.3%NegativeNegativeBNT162b221110IgG-/IgM-Positive94.98%NegativeNegativeBNT162b221111IgG-/IgM-Positive94.98%NegativeNegativeBNT162b224112IgG-/IgM-Positive94.98%NegativeNegativeBNT162b221111IgG-/IgM-Positive94.98%NegativeNegativeBNT162b222112IgG-/IgM-Positiv	98	IgG+/IgM-	Positive	85.88%	Negative	Negative	BNT162b2	20
100IgG+/IgM-Positive84.92%NegativeNegativeBNT162b221101IgG+/IgM-Positive94.95%NegativeNegativeBNT162b220102IgG+/IgM-Positive96.15%NegativeNegativeBNT162b221103IgG+/IgM-Positive93.35%NegativeNegativeBNT162b218104IgG+/IgM-Positive97.38%NegativeNegativemRNA-127328105IgG+/IgM-Positive91.65%NegativeNegativeBNT162b224106IgG+/IgM-Positive95.7%PositiveNegativemRNA-127328108IgG+/IgM-Positive91.57%NegativeNegativemRNA-127322109IgG+/IgM-Positive97.5%NegativeNegativemRNA-127322110IgG+/IgM-Positive94.3%NegativeNegativeBNT162b224111IgG+/IgM-Positive94.3%NegativeNegativeBNT162b221111IgG+/IgM-Positive94.17%NegativeNegativeBNT162b224112IgG+/IgM-Positive94.17%NegativeNegativeBNT162b221113IgG+/IgM-Positive94.17%NegativeNegativeBNT162b222114IgG+/IgM-Positive95.6%NegativeNegativeBNT162b222115IgG+/IgM-Positi	99	IgG+/IgM-	Positive	94.14%	Negative	Positive	BNT162b2	33
101IgG+/IgM-Positive94.95%NegativeNegativeBNT162b220102IgG+/IgM-Positive96.15%NegativeNegativeBNT162b221103IgG+/IgM-Positive97.38%NegativeNegativeBNT162b228104IgG+/IgM-Positive97.38%NegativeNegativeBNT162b220106IgG+/IgM-Positive96.15%NegativeNegativeBNT162b224107IgG+/IgM-Positive96.79%PositiveNegativeNRNA-127328108IgG+/IgM-Positive91.57%NegativeNegativeBNT162b222109IgG+/IgM-Positive91.57%NegativeNegativeBNT162b221110IgG+/IgM-Positive94.43%NegativeNegativeBNT162b222111IgG+/IgM-Positive94.43%NegativeNegativeBNT162b224112IgG+/IgM-Positive94.83%NegativeNegativeBNT162b224113IgG+/IgM-Positive94.83%NegativeNegativeBNT162b224114IgG+/IgM-Positive94.83%NegativeNegativeBNT162b224115IgG+/IgM-Positive94.63%NegativeNegativeBNT162b224116IgG+/IgM-Positive94.63%NegativeNegativeBNT162b222117IgG+/IgM-Posi	100	IgG+/IgM-	Positive	84.92%	Negative	Negative	BNT162b2	21
102IgC+/IgM-Positive96.15%NegativeNegativeBNT162b221103IgC+/IgM-Positive93.35%NegativeNegativeBNT162b218104IgC+/IgM-Positive97.38%NegativeNegativeBNT162b220105IgC+/IgM-Positive96.15%NegativeNegativeBNT162b224106IgC+/IgM-Positive93.84%NegativeNegativeBNT162b224107IgC+/IgM-Positive91.57%NegativeNegativeBNT162b222108IgC+/IgM-Positive91.57%NegativeNegativeBNT162b222109IgC+/IgM-Positive94.33%NegativeNegativeBNT162b221111IgC+/IgM-Positive94.43%NegativeNegativeBNT162b224112IgC+/IgM-Positive94.17%NegativeNegativeBNT162b224113IgC+/IgM-Positive94.17%NegativeNegativeBNT162b224114IgC+/IgM-Positive95.56%NegativeNegativeBNT162b224115IgC+/IgM-Positive93.26%NegativeNegativeBNT162b222116IgC+/IgM-Positive93.26%NegativeNegativeBNT162b222117IgC+/IgM-Positive92.68%NegativeNegativeBNT162b222118IgC+/IgM-Posit	101	IgG+/IgM-	Positive	94.95%	Negative	Negative	BNT162b2	20
103IgG+/IgM-Positive93.35%NegativeNegativeBNT162b218104IgG+/IgM-Positive97.38%NegativeNegativemRNA-127328105IgG+/IgM-Positive96.15%NegativeNegativeBNT162b220106IgG+/IgM-Positive93.84%NegativeNegativeBNT162b224107IgG-/IgM-Positive91.57%NegativeNegativeBNT162b222108IgG+/IgM-Positive91.57%NegativeNegativeBNT162b222109IgG+/IgM-Positive97.59%NegativeNegativeBNT162b224110IgG+/IgM-Positive94.33%NegativeNegativeBNT162b222111IgG-/IgM-Positive94.33%NegativeNegativeBNT162b224112IgG-/IgM-Positive94.98%NegativeNegativeBNT162b224113IgG-/IgM-Positive94.17%NegativeNegativemRNA-127328114IgG-/IgM-Positive97.58%NegativeNegativeBNT162b220115IgG-/IgM-Positive93.26%NegativeNegativeBNT162b222116IgG-/IgM-Positive92.68%NegativeNegativeBNT162b222117IgG-/IgM-Positive93.02%NegativeNegativeBNT162b222118IgG-/IgM-Pos	102	IgG+/IgM-	Positive	96.15%	Negative	Negative	BNT162b2	21
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	125	IgG+/IgM-	Positive	97.00%	Negative	Negative	mRNA-1273	29

AB, antibody; CI-ELISA, competitive inhibition ELISA; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

^a Immunocompromised participant.

ELISA testing. No participant who tested IgG-negative via Right-Sign was positive on anti-spike IgG CI-ELISA testing. Table 1 shows the IgG/IgM RightSign results and the anti-spike IgG CI-ELISA results. All those testing IgG-positive via the RightSign test kit demonstrated antibody neutralizing capability, including 117 patients (93.6%) who demonstrated greater than 80% inhibition. The ELISA results for IgM and IgG to the nucleocapsid were as follows: two patients (1.6%) had anti-nucleocapsid IgM antibodies and seven patients (5.6%) had anti-nucleocapsid IgG antibodies (Table 1). Cohen's Kappa demonstrated excellent agreement between RightSign IgG results and confirmatory CI-ELISA results (Cohen's Kappa = 1.00). McNemar's Chi-square showed perfect agreement between RightSign and CI-ELISA.

4. Discussion

In this study, we sought to evaluate the use of a rapid qualitative antibody test to screen for a vaccine-mediated SARS-CoV-2 antibody response. It was found that IgG RightSign results correlated directly with confirmatory CI-ELISA testing. Positive IgG serology, 98.4%, was consistent with previous studies investigating the immunogenicity of both vaccines involved in this study. In phase 1 trials of mRNA-1273, Jackson et al. demonstrated IgG titers and a positive neutralization response in all participants (Jackson et al., 2020). Walsh et al. showed in phase 1 trials that, after a second dose of BNT162b2, even older adults demonstrated neutralizing geometric mean titers that were similar or greater to those found in SARS-CoV-2 convalescent serum (Walsh et al., 2020).

In many countries, HCWs were among the first to be vaccinated, and several larger studies have explored the vaccine-mediated antibody responses in this population. Abu Jabal et al. investigated the antibody response to one dose of BNT162b2 at 21 days postvaccination in 514 HCWs, and found that 92% had anti-spike IgG antibodies (Jabal et al., 2020) Angyal et al. examined the T-cell and antibody response in 237 HCWs after one and two vaccine doses of BNT162b2, and demonstrated a robust immune response to vaccination; 99% mounted higher anti-spike IgG antibody responses than previously infected unvaccinated individuals (Angyal et al., 2021). However, it appears that there have been no studies examining the SARS-CoV-2 mRNA vaccine-mediated immune response in pediatric HCWs. This population is relatively unique in that, similar to schoolteachers, they are likely to be more frequently exposed to coronaviruses than the general population. This is of particular interest, as Ng et al. demonstrated that samples taken from 21 of 48 children in the age range 1-16 years, with no history of SARS-CoV-2 infection (samples were taken from 2011 to 2018), had detectable levels of IgG antibodies that reacted with the SARS-CoV-2 spike protein, as compared to one of 43 young adults (age range 17-25 years) (Ng et al., 2020).

However, very few participants in this study showed evidence of SARS-CoV-2 anti-nucleocapsid IgM or IgG. There were nine individuals with positive serology for SARS-CoV-2 anti-nucleocapsid antibodies, seven IgG-positive and two IgM-positive, none were IgG-positive/IgM-positive. Given the conserved nature of the nucleocapsid, IgG-positive results may represent historical infection with other coronaviruses or SARS-CoV-2 (despite attempts to exclude individuals with a positive history of COVID-19). It is more difficult to interpret the IgM-positive results, as both participants testing positive for anti-nucleocapsid IgM were negative for antispike IgM antibodies on rapid RightSign testing. Although the overall nucleocapsid results correlate with previous work done at this institution using the Abbott Architect IgG anti-nucleocapsid assay prior to vaccination, it is somewhat surprising, as both the spike protein and the nucleocapsid protein appear to be somewhat conserved (Der et al., 2020; Huang et al., 2021). The clinical implications of this finding, especially regarding historical coronavirus infection leading to the potential for an amplified vaccine response in the pediatric HCW population, remain unclear.

A limitation of this study was that pediatric HCWs were not compared to non-pediatric HCWs, which prevented comparison to a population potentially less frequently exposed to coronaviruses. As the percent inhibition was calculated rather than geometric mean titers or geometric mean concentrations, it was also not possible to directly contrast these results to those of previous studies. In addition, the generalizability of the results may be limited due to the small percentage of participants who received the mRNA-1273 vaccine. Future research may also include investigating how the vaccine-mediated immune response changes over time.

In summary, the strong agreement between the RightSign IgG results and confirmatory CI-ELISA testing suggests that this pointof-care test can be used to screen for positive, and neutralizing, antibody responses at 17–36 days post-SARS-CoV-2 mRNA vaccination. This may allow for rapid and relatively inexpensive documentation and monitoring of the individual immune response, including evaluating the need for booster vaccination, as well as aiding in large-scale immune surveillance.

Author	queries			
[Note: The text has undergone minor rephrasing throughout.]				
[Au?1]	Abbreviations must be given in full at first use. Please provide abbreviation ACE2 in full.			
[Au?2]	"Each assay that is run requires <u>titering</u> of positive and negative controls" Should this be "the titration"?			
[Au?3]	Table 1: Should footnote 'a' also be included here?			

Ethical approval

Informed consent was obtained for experimentation on human subjects. This study was approved by the Institutional Review Board.

Conflict of interest

All authors have no conflicts of interest to disclose.

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This study was supported by CHOC Children's Hospital. Dr Theodore Heyming and Terence Sanger are supported by this organization. Aprille Tongol, Kellie Bacon, and Bryan Lara are supported by CHOC Children's Research Institute. We also wish to acknowledge Karen Imfeld, Senior Scientist in the Hematology Advanced Diagnostic Laboratory, who established and provided oversight of all of the immune assays other than RightSign at CHOC.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2021.09.065.

References

- Addetia A, Crawford KHD, Dingens A, Zhu H, Roychoudhury P, Huang ML, et al. Neutralizing antibodies correlate with protection from SARS-CoV-2 in humans during a fishery vessel outbreak with a high attack rate. J Clin Microbiol 2020;58. doi:10.1128/JCM.02107-20.
- Angyal A, Longet S, Moore S, Payne RP, Harding A, Tipton T, et al. T-Cell and Antibody Responses to First BNT162b2 Vaccine Dose in Previously SARS-CoV-2-Infected and Infection-Naive UK Healthcare Workers: A Multicentre, Prospective, Observational Cohort Study. SSRN Electron J 2021. doi:10.2139/ssrn.3812375.
- Baden LR, El Sahly HM, Essink B, Kotloff K, Frey S, Novak R, et al. Efficacy and Safety of the mRNA-1273 SARS-CoV-2 Vaccine. N Engl J Med 2021. doi:10.1056/nejmoa2035389.
- California Department of Public Health. Track Var 2021. https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/COVID-Variants.aspx (accessed September 15, 2021).
- Favresse J, Gillot C, Di Chiaro L, Eucher C, Elsen M, Van Eeckhoudt S, et al. Neutralizing antibodies in covid-19 patients and vaccine recipients after two doses of bnt162b2. Viruses 2021;13. doi:10.3390/v13071364.
- Huang AT, Garcia-Carreras B, Hitchings MDT, Yang B, Katzelnick LC, Rattigan SM, et al. A systematic review of antibody mediated immunity to coronaviruses: kinetics, correlates of protection, and association with severity. Nat Commun 2020;11. doi:10.1038/s41467-020-18450-4.
- Huang Y, Nguyen AW, Hsieh C-L, Silva R, Olaluwoye OS, Wilen RE, et al. Identification of a conserved neutralizing epitope present on spike proteins from all highly pathogenic coronaviruses. BioRxiv 2021.
 Jabal KA, Ben-Amram H, Beiruti K, Batheesh Y, Sussan C, Zarka S, et al. Impact
- Jabal KA, Ben-Amram H, Beiruti K, Batheesh Y, Sussan C, Zarka S, et al. Impact of age, ethnicity, sex and prior infection status on immunogenicity following a single dose of the BNT162b2 MRNA COVID-19 vaccine. Israel: Real-world evidence from healthcare workers; 2020 Decemberto January 2021. Eurosurveillance 2021.
- Jackson LA, Anderson EJ, Rouphael NG, Roberts PC, Makhene M, Coler RN, et al. An mRNA Vaccine against SARS-CoV-2 Preliminary Report. N Engl J Med 2020. doi:10.1056/nejmoa2022483.

- Der Li Y, WY Chi, Su JH, Ferrall L, Hung CF, Wu TC. Coronavirus vaccine development: from SARS and MERS to COVID-19. J Biomed Sci 2020. doi:10.1186/s12929-020-00695-2.
- Ng KW, Faulkner N, Cornish GH, Rosa A, Harvey R, Hussain S, et al. Preexisting and de novo humoral immunity to SARS-CoV-2 in humans. Science 2020(80-). doi:10.1126/science.abe1107.
- Orange County Health Care Agency. COVID-19 Case Counts Test Fig 2021; 2021 https://occovid19.ochealthinfo.com/coronavirus-in-oc (accessed September 15.
- Polack F. Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine. N Engl J Med 2021. doi:<u>10.1056/nejmc2036242</u>.
- Sahin U, Muik A, Derhovanessian E, Vogler I, Kranz LM, Vormehr M, et al. COVID-19 vaccine BNT162b1 elicits human antibody and TH1 T cell responses. Nature 2020. doi:10.1038/s41586-020-2814-7.
- Tan CW, Chia WN, Qin X, Liu P, Chen MIC, Tiu C, et al. A SARS-CoV-2 surrogate virus neutralization test based on antibody-mediated blockage of ACE2-spike protein-protein interaction. Nat Biotechnol 2020;38. doi:10.1038/s41587-020-0631-z.
- U.S. Food & Drug Administration F. EUA, RightSign COVID-19 IgG/IgM Rapid Test Cassette 2020; 2021 https://www.fda.gov/media/138657/download (accessed January 3.
- Valcourt EJ, Manguiat K, Robinson A, Chen JCY, Dimitrova K, Philipson C, et al. Evaluation of a commercially-available surrogate virus neutralization test for severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). Diagn Microbiol Infect Dis 2021;99. doi:10.1016/j.diagmicrobio.2020.115294.
- Walsh EE, Frenck RW, Falsey AR, Kitchin N, Absalon J, Gurtman A, et al. Safety and Immunogenicity of Two RNA-Based Covid-19 Vaccine Candidates. N Engl J Med 2020. doi:10.1056/nejmoa2027906.
- Wang Z, Schmidt F, Finkin S, Schaefer-Babajew D, Cipolla M, Gaebler C, et al. mRNA vaccine-elicited antibodies to SARS-CoV-2 and circulating variants. Nature 2021.
- Widge AT, Rouphael NG, Jackson LA, Anderson EJ, Roberts PC, Makhene M, et al. Durability of Responses after SARS-CoV-2 mRNA-1273 Vaccination. N Engl J Med 2021. doi:10.1056/nejmc2032195.
- Zimmermann P, Curtis N. Factors that influence the immune response to vaccination. Clin Microbiol Rev 2019. doi:10.1128/CMR.00084-18.