Assessment of COVID-19 vaccines in building immunity response through the measurement of anti-spike protein antibodies

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Abstract. The ongoing COVID-19 crisis, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has led to illness and loss of life. The primary strategy to change the course of the pandemic is, through vaccination, against SARS-CoV-2. The present cross-sectional study aimed to assess the effectiveness of Sinopharm and AstraZeneca COVID-19 vaccines through an assessment of anti-spike protein antibodies. The rate of antibody response was measured by detecting anti-spike and neutralizing antibodies against SARS-CoV-2 after administering two doses of the vaccines. These antibodies are pivotal indicators of the immune response elicited by vaccines, providing crucial insight into their protective efficacy. The objective was to evaluate the response of the host to the vaccine and determine the necessity of booster doses by examining the longevity and variability of antibody responses post-vaccination. To achieve this, serum and plasma samples were collected from 197 patients that tested positive for SARS-CoV-2, and anti-spike protein antibody levels were measured at 1 month after receiving the second doses of either of the aforementioned vaccines. The samples were analyzed using the Elecsys anti-SARS-CoV-2 S assay on the cobas e411 analyzer, a quantitative test that detects antibodies to the SARS-CoV-2 spike protein receptor binding domain, with results of ≥0.8 U/ml considered positive. The results revealed that 92% of the participants tested positive for anti-spike proteins, with the AstraZeneca vaccine demonstrating a better response (95.45%; 42 out of 44) compared with the Sinopharm vaccine (89,54%; 137 out of 153), exhibiting positive results for anti-spike antibodies (>0.8 U/ml).

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Introduction

Since the COVID-19 pandemic began in 2019 due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), nations have faced major challenges. COVID-19 infection typically begins with flu-like symptoms, and can be asymptomatic or progress from mild to severe (1,2). The infection is characterized by marked inflammation. Studies have shown an association between blood count parameters and COVID-19 infection, with the neutrophil/lymphocyte ratio (3) and platelet/lymphocyte ratio linked to infection (4).

Despite extensive research into diagnosis, treatment and vaccines (5), it remains difficult to fight the virus effectively. The number of rapid and accurate tests is not sufficient, case identification is not always effective, and the human defense mechanism against the virus is still not fully understood. However, scientists have rapidly developed multiple vaccines (5). The origins of vaccination trace back to the late 18th century with development of the smallpox vaccine by Edward Jenner (6). Jenner's groundbreaking research utilized the cowpox virus to confer immunity against smallpox, marking the inaugural successful endeavor in immunization against a targeted disease (6). Since then, progress in vaccine development has continued to evolve. Advancements, such as attenuated viral strains adapted for *in vitro* growth have facilitated the creation of vaccines for diseases, such as polio, measles, rubella, mumps and varicella (7). Vaccine development has employed several approaches which include the following: i) Assortment which involves mixing RNA segments from different viruses to create vaccines for influenza and rotavirus; ii) inactivation, which involves the use of heat or chemicals to prepare vaccines that contain non-infectious viruses or bacteria; iii) protein-based, which involves utilizing purified proteins as antigens to trigger an immune response; iv) genetic engineering, which involves inserting genes encoding protective antigens into viral or bacterial carriers,

innovating vaccine development. During the COVID-19 pandemic, various vaccines with varying approaches have been developed, such as: i) mRNA vaccines, which include BNT162b2 (Pfizer) and mRNA-1273 (Moderna); these vaccines use mRNA to make cells produce a specific protein found in COVID-19, triggering an immune response (8). ii) Viral vector vaccines, which include vaccines, such as AZD1222 (Oxford/AstraZeneca) which use harmless viruses known as adenoviruses as carriers to carry a specific piece of DNA into cells (9). This DNA contains instructions for creating proteins associated with COVID-19, which stimulates the immune system. Inactivated vaccines, including CoronaVac by Sinovac and Covaxin by Bharat Biotech, employ inactivated forms of COVID-19 (10). Additionally, certain vaccines, such as NVX-CoV2373 by Novavax use specific protein subunits derived from COVID-19 (11). Each vaccine employs a distinct approach to bolster immunity against the virus. However, all of these vaccines focus on the COVID-19 spike protein (12). This protein facilitates viral entry into host cells by binding to angiotensin-converting enzyme 2. Antibodies that specifically target the spike protein have exhibited effective antiviral activity and are associated with potential immunity (13).

Since the introduction of the initial COVID-19 vaccine, ~4.9 billion individuals worldwide have received vaccination. In Morocco, the vaccination campaign commenced on January 29, 2021, initially utilizing the AstraZeneca and Sinopharm vaccines only. Subsequently, Janssen by Johnson & Johnson and Pfizer-BioNTech vaccines were administered. However, Moderna vaccine uptake has been limited. Presently, ~23.5 million individuals in Morocco are fully vaccinated, constituting 65% of the country's population (14). The original COVID-19 vaccine, sold under the name Vaxzevria, was withdrawn from the market by AstraZeneca in 2024, as it caused fatal blood clots and low platelet counts, also known as thrombosis-thrombocytopenia syndrome (15).

The Sinopharm vaccine contains inactive viral particles, while AstraZeneca uses a modified adenovirus to deliver the genetic material. The time-dynamic differences in the anti-spike antibody response between Sinopharm and AstraZeneca vaccines may depend on a number of key factors (the timing of antibody production after vaccination, term immunity, patient clinicopathological factors influencing antibody response, etc.) (16,17).

The present study aimed to examine the efficacy of two vaccines, those by Sinopharm and AstraZeneca in generating long-term immunity against SARS-CoV-2, through the evaluation of factors such as age, sex, previous COVID-19 infections and subsequent infections affecting the immune response to these vaccines. By examining these parameters, the present study aimed to determine the extent to which these vaccines establish and maintain protective immunity against COVID-19.

Subjects and methods

Study population. The present study took place from July, 2021 to July, 2022, spanning the period from the end of the second wave to the end of the fourth wave of COVID-19 in Morocco. A total of 197 individuals between the ages of 18 and 80 years volunteered to participate in the study. In total, 44 individuals received the AstraZeneca vaccine, while 153 individuals received the Sinopharm vaccine. At 1 month after the second dose of the vaccine, blood samples were collected from the Analyses Laboratory Anoual in Casablanca, Morocco, to measure the levels of anti-spike antibodies. Individuals with pre-existing medical conditions, serious allergic reactions to vaccines, pregnant females, and those receiving cancer treatments, radiation therapy, or immune-suppressing medications were excluded from the study.

The research began in July, 2021 with preliminary work that involved the secondary analysis of anonymized data, for which formal ethics approval was not initially required. As the project evolved to include primary data collection, an ethics approval waiver was proactively obtained in March, 2022 to ensure compliance with institutional standards. Following this approval waiver, the experimental phase began by analyzing samples that had been stored in the Analyses Laboratory Anoual in Casablanca since July 2021, as well as collecting new samples. This schedule reflects the study period described in the study, capturing both the preliminary analysis of existing samples and the subsequent collection of new data. Verbal consent was obtained from participants due to several factors, including the illiteracy of some patients and the preference of other patients for oral consent rather than written documentation.

Viral RNA extraction. The Genrui 48 automated platform was used to isolate RNA from nasopharyngeal and pharyngeal swabs using the Genrui nucleic acid extraction assay (Genrui Biotech Inc.), according to the manufacturer's guidelines. The extracted RNA samples were then stored at -80˚C until analysis.

Reverse transcription-quantitative PCR (RT-qPCR). The GeneFinder™ COVID-19 Plus RealAmp kit (OSANG Healthcare Co., Ltd.) was used for RT-PCR according to the instructions provided with the kit (EUA-OSANG-gene-ifu, REF IFMR-45). Thus, RT-PCR was carried out in a total volume of 20 μl, containing 15 μl of the GeneFinder™ COVID-19 Plus RealAmp master mixture (containing 10 μl of COVID-19 Plus Reaction mixture and 5 μl of COVID-19 Plus Probe mixture), and 5 μl of RNA extracted from patient samples, using the croBEE® Real-Time PCR System (18). The reaction mixture was incubated at 50˚C for 20 min, followed by a pre-denaturation at 95˚C for 5 min, then 45 cycles of denaturation at 95˚C for 15 sec and annealing at 58˚C for 60 sec. The human housekeeping gene RNAse P was used for the internal control for normalizing gene expression. The primer sequences for the ORF1ab target and RNAse P are proprietary and confidential to OSANG Healthcare Co., Ltd., the kit's manufacturer, and therefore cannot be disclosed. The relative expression level of SARS-CoV-2 was calculated using the $2^{-\Delta\Delta Cq}$ value, based on the threshold cycle (Cq) method (19).

Measurement of antibodies. Blood samples were tested for antibodies against SARS-CoV-2 using the Elecsys anti-SARS-CoV-2 S assay (Roche Diagnostics), which runs on the Cobas e411 system from Roche Diagnostics. This test measures antibodies that bind to a specific part of the spike protein of the virus. It uses a technique known as

Table I. General clinical characteristics of the subjects included in the present study.

Parameters	AstraZeneca (n=44)	Sinopharm (n=153)	No. of subjects (%)
Age, years			
<40	9	44	53 (27)
40-60	22	60	82 (42)
>60	13	49	62 (31)
Sex			
Female	22	79	101 (51)
Male	22	74	96 (49)
Vaccine			
Sinopharm	-	-	153 (78)
AstraZeneca	-	-	44 (22)
Vaccine response			
High response	26	63	89 (45)
Average response	10	13	23 (11)
Low response	7	62	69 (36)
No response	1	15	16 (8.1)
History of COVID-19 infection			
No	27	91	118 (59,89)
Yes	17	62	79 (40.10)
Post-vaccination infection			
No	28	105	133 (67.51)
During the first 6 months	5	27	32 (16.24)
After 6 months	11	21	32 (16.24)

electrochemiluminescence to detect the antibodies, and it is designed to quantify their levels. The test can detect antibody concentrations ranging from 0.40 to 250 U/ml, and it can be diluted 1:10 to measure concentrations up to 2,500 U/ml. Concentrations <0.80 U/ml are considered negative, while concentrations at or above ≥0.80 U/ml are classified as positive (20).

Statistical analysis. Statistical data were processed using IBM SPSS Statistics 28.0 software for Windows. The analysis of the association between the response to the vaccines and data from COVID-19-infected patients was performed using the Chi-squared test or Fisher's exact test (when one of the theoretical numbers was ≤5). A P-value ≤0.05 was considered to indicate a statistically significant difference.

Results

The present study included 197 participants with an average age of 52.6 years, ranging from 18 to 80 years. The age breakdown revealed that 27% of the subjects were <40 years of age, 42% were between 40 and 60 years of age, and 31% were >60 years of age. As regards the type of vaccine received, the majority (78%) received two doses of the Sinopharm vaccine, while the remaining 22% were vaccinated with the AstraZeneca vaccine (Table I).

After completing the second dose of vaccination, at the 14-day mark, the levels of antibodies against the spike protein of the virus were measured. The majority of the participants (92%) had detectable levels (>0.8 U/ml) of these antibodies (181 out of 197 subjecdts). Of these, 45% had high antibody responses (>200 U/ml), 11% had intermediate responses (>100 U/ml), 36% had low responses (<100 U/ml), and 8.1% had no detectable antibody response (Table I).

At 1 year following vaccination, 67.51% of the study subjects remained fully protected and had not been ill, 16% of the subjects had been ill within the first 6 months, and 16% of the subjects had been ill after the first 6 months (Table I).

A statistical analysis found no clear association between age, sex, or previous COVID-19 infection and the effectiveness of the AstraZeneca vaccine. However, there was a noticeable trend in the response based on age. Younger patients (<40 years of age) had a higher response rate (88%) compared to those aged 40-60 years (59.1%) and those >60 years of age (38.5%). However, these differences were not statistically significant (P=0.31; Table II).

By contrast, a notable association was detected between the response to the Sinopharm vaccine and age. A high response rate was noted in 43 and 49% of cases in the age group <40 years and in the age group between 40-60 years, respectively, compared to 31% in cases >60 years of age (P=0.018; Table III). However, no significant associations were found between the response to the Sinopharm vaccine and sex (P=0.22) or a history of COVID-19 infection (P=0.48; Table III).

When comparing the two vaccines, there was no noticeable difference in the immune response based on sex or

Table II. Association between the clinical features of subjects and the response to the AstraZeneca vaccine.

Parameter	High response (n=26) (%)	Low response (n=10) (%)	Average response (n=7) (%)	No response (n=1) (%)	P-value
Age, years					
<40	8 (88.9)	1 (11.1)	0 (0)	0 (0)	0.31
40-60	13 (59.1)	4 (18.18)	5 (22.73)	0 (0)	
>60	5 (38.5)	5 (38.5)	2 (15.38)	1 (7.7)	
Sex					
Female	12 (55)	5 (23)	4 (18)	1 (4)	0.999
Male	14 (64)	5 (23)	3 (13)	0 (0)	
History of COVID-19 infection					
No	14 (52)	9 (33)	3 (11)	1 (4)	0.23
Yes	12 (70)	1 (6)	4 (24)	0 (0)	

Table III. Association between the clinical features of subjects and the response to the Sinopharm vaccine.

Parameter	High response (n=63) (%)	Average response (n=13) (%)	Low response (n=62) (%)	No response (n=15) (%)	P-value
Age, years					
<40	19 (43)	4 (9)	12 (27)	9 (21)	0.018[a]
40-60	29 (49)	3(4)	26 (44)	2 (3)	
>60	15 (31)	6 (12)	24 (49)	4 (8)	
Sex					
Female	38 (48)	4 (5)	31 (39)	6 (8)	0.22
Male	25 (34)	9 (12)	31 (42)	9 (12)	
History of COVID-19 infection					
No	33 (36)	8 (9)	40 (44)	10 (11)	0.48
Yes	30 (48)	5 (8)	22 (36)	5 (8)	

[a]Indicates a significant difference (P<0.05).

previous COVID-19 infection. However, older individuals had a significantly improved response to both vaccines (P=0.01). Furthermore, the type of vaccine influenced the response. Those who received the AstraZeneca vaccine had a higher response rate (59.09%) compared to those who received the Sinopharm vaccine (41.17%) (P=0.02; Table IV).

Following vaccination, 67% of individuals who developed a strong response to the vaccine never contracted the virus, while 24% of the subjects were infected with COVID-19 after 6 months. Among those who developed a weak or no response to the vaccine, 69% did not contract the virus. As regards the type of vaccine, the populations vaccinated with the Sinopharm and AstraZeneca vaccines exhibited similar results in the statistical analysis. These results indicate that there is no significant difference to conclude that post-vaccination infection is directly related to the type of vaccine or the vaccine response (Table V).

Thus, although the AstraZeneca vaccine may induce a higher antibody response, this does not necessarily translate into a significant difference in terms of overall protection against post-vaccinal infection, particularly when assessing severe forms of the disease.

Discussion

The recent and devastating COVID-19 pandemic was caused by SARS-CoV-2 that emerged in Wuhan, China in 2019 and spread globally at a rapid rate, creating a major health emergency with widespread infections and deaths (21,22). International studies have been conducted to evaluate the effectiveness of vaccines (23). They compare vaccinated and unvaccinated individuals, including a placebo group, to assess the effectiveness of the vaccines in different populations. It is also important to examine the impact of the vaccine on

Table IV. Association between the clinical features of subjects and the response to both the AstraZeneca and Sinopharm vaccines.

Parameter	High response (n=89) (%)	Average response (n=20) (%)	Low response (n=72) (%)	No response (n=16) (%)	Total	P-value
Age, years						
40-60	42 (51)	8 (10)	30 (37)	2 (2)		0.01[a]
>60	20 (32)	8 (13)	29 (47)	5 (8)		
<40	27 (51)	4 (8)	13 (23)	9 (18)		
Sex						
Female	50 (49)	8 (8)	36 (36)	7 (7)		0.52
Male	39 (41)	12 (13)	36 (37)	9 (9)		
History of COVID-19 infection						
No	47 (40)	11 (9)	49 (42)	11 (9)		0.21
Yes	42 (53)	9 (11)	23 (29)	5 (7)		
Vaccine						
Sinopharm	63 (41)	13 (9)	62 (40)	15 (10)	153	0.02[a]
AstraZeneca	26 (59)	7 (16)	10 (23)	1 (2)	44	

[a]Indicates a significant difference (P<0.05).

Table V. Association between the clinical features of subjects and post-infection with COVID-19 following vaccination with the AstraZeneca and Sinopharm vaccines.

Parameter	No post-vaccination infection (n=133) (%)	During 6 months (n=32) (%)	After 6 months (n=32) (%)	P-value
Age, years				
40-60	54 (66)	13 (7)	15 (18)	0.84
>60	42 (68)	12 (19)	8 (13)	
<40	37 (70)	7	9	
Sex				
Female	76 (75)	15 (15)	10 (10)	0.027[a]
Male	57 (59)	17 (18)	22 (23)	
History of COVID-19 infection				
No	118 (89)	0 (0)	0 (0)	<0.001[a]
Yes	15 (11)	32 (100)	32 (100)	
Vaccine				
Sinopharm	105 (69)	27 (17)	21 (14)	0.16
AstraZeneca	28 (64)	5 (11)	11 (25)	
Response				
High response	60 (67)	8 (9)	21 (24)	0.034[a]
Low response	50 (69)	16 (23)	6 (8)	
Average response	12 (60)	4 (20)	4 (20)	
No response	11 (69)	4 (25)	1 (6)	

[a]Indicates a significant difference (P<0.05).

transmission by studying how effectively it prevents infections in individuals who have not been vaccinated and how it reduces the contagiousness of vaccinated individuals who do become infected (24,25). Studies have also investigated the duration of protection provided by various COVID-19 vaccines, including the BNT162b2 mRNA (Pfizer-BioNTech) vaccine, demonstrating its high effectiveness for at least 6 months after the second dose (8,26). The Sinopharm (BBIBP-CorV) and

AstraZeneca (Vaxzevria) vaccines lead to antibody production at 10-14 days after the first dose, with a peak at 1-2 weeks after the second dose. For Sinopharm, antibodies can be monitored for up to 6 months following vaccination, although their level gradually declines. As regards AstraZeneca, antibodies often remain detectable beyond 6 months, with persistence reaching 9 to 12 months (26,27).

Measuring both antibody-based (humoral) and cell-based (cellular) immune responses is crucial for evaluating the effectiveness of a vaccine. Humoral responses focus on measuring the levels of neutralizing antibodies, which block virus infectivity by preventing it from entering cells. Assessing virus-specific T-cells also provides information about vaccine effectiveness, as previously mentioned by Martin *et al* (28). Seroconversion studies track post-vaccination antibody development by detecting their presence in blood of vaccinated individuals (29).

The present study evaluated the effectiveness of two vaccines, Sinopharm and AstraZeneca, in protecting against SARS-CoV-2. Antibody levels in subjects who had received two doses of either vaccine were measured 14 days after the second dose. Factors such as age and sex affecting the immune response to these vaccines were examined. In addition, the impact of previous COVID-19 infection on the vaccine-induced immune response was examined. Finally, vaccine efficacy was assessed by examining the incidence of infection after vaccination. To achieve these objectives, 197 participants were enrolled in the present study; of these, 44 subjects received the AstraZeneca vaccine and 153 subjects the Sinopharm vaccine. The levels of antibodies targeting the spike protein were determined using a newly developed serological assay from Roche Diagnostics (30).

Among those vaccinated with the Sinopharm vaccine (153 subjects), 138 subjects (>90%) had antibodies against the virus. This is similar to the rate reported in the Sinopharm vaccination program (>95%). For AstraZeneca, ~98% (42 out of 44 subjects) had antibodies against the virus. This is in line with the rate reported in the Oxford University Hospitals study (>97%) (31).

The age and sex of an individual can significantly affect the administration and effectiveness of vaccines. Age-related factors include the development of the immune system, differences in exposure to disease-causing agents, and varying susceptibility to certain illnesses (29). The immune responses of infants, young children and the elderly can be influenced by age-based changes in B-cell and T-cell functionality. Indeed, sex exerts a considerable influence on shaping immune responses, given the interplay of hormonal and genetic factors that can result in variations between males and females. Females typically display more robust immune responses, characterized by higher antibody production and enhanced activation of immune cells (32-34). These differences in immune function between the sexes may contribute to variances in susceptibility to infections and responses to vaccination (35). The present study demonstrated that age plays a significant role in the effectiveness of vaccines. Among participants <60 years of age, 51% had a strong response compared to only 32% of older participants (P=0.01). The response rate also decreased gradually as the age of the subjects increased. As regards sex, there was a slight difference in the response rates between females and males. Females had a slightly higher response to the vaccines (49%) compared to males (41%). Younger subjects (<40 years of age) generally had higher immune responses to the AstraZeneca and Sinopharm vaccines. As regards the AstraZeneca vaccine, this response decreased with age (88% for those <40 years of age, 59.1% for those aged 40-60 years, and 38.5% for those >60 years of age). For the Sinopharm vaccine, the response rate was 43.14% for those <40 years of age, 49.15% for those aged 40-60 years, and 30.6% for those >60 years of age. This pattern is consistent with the findings of other studies that demonstrate that age and sex can affect vaccine responses, specifically for both the AstraZeneca and Sinopharm vaccines; these studies have demonstrated a significant decline in vaccine effectiveness with increasing age, while the effect of sex on response rates varies moderately (31,36).

Out of 118 individuals who had never previously been infected with COVID-19, 10% (i.e., 11) exhibited no immune response after the injections. By contrast, of the 79 subjects who had been previously infected with COVID-19, only 5 subjects (or <7%) did not develop an immune response. This slight difference suggests that individuals who have been previously infected with COVID-19 are more likely to develop an immune response following vaccination. This indicates that vaccination may be particularly beneficial for individuals with a history of COVID-19 infection. As in the previous study by El-Ghitany *et al* (37), the findings of the present study suggest that individuals who have been infected with COVID-19 prior to being vaccinated are more likely (97.8%) to test positive for anti-spike protein antibodies than those who have not been previously infected (77.3%) (data not shown). Vaccine efficacy was also examined by examining those who contracted infections even after following the two-dose vaccination schedule. Among the 197 participants, 165 (84%) did not become infected for the first 6 months after receiving the vaccine. Even after 1 year, 133 individuals (67%) were still protected against infection. This indicates that the vaccine is highly effective at preventing infections for a long period of time. During the same period as that in the present study, Boshra *et al* (38) conducted a similar study and found similar outcomes. They observed that after 6 months of vaccination, ~82.2% of the individuals remained unaffected by the virus. Notably, their study recorded a 73% protection rate among those who received the Sinopharm vaccine and a 91.7% protection rate among those who received the AstraZeneca vaccine. The results of the present are in accordance with previous findings, indicating the effectiveness of the Sinopharm and AstraZeneca vaccines. At 6 months following vaccination, a slightly lower, yet still substantial, protection rate of 82% (126 out of 153 subjects) was observed for the Sinopharm and 89% (39 out of 44 subjects) for the AstraZeneca vaccines. This further demonstrates the ability of both vaccines to prevent infections beyond the initial 6-month period. The present study found that the AstraZeneca vaccine consistently produced better results than the Sinopharm vaccine. This difference is likely due to the mechanisms through which the vaccines produce their effect. The AstraZeneca vaccine uses a weakened chimpanzee virus to carry genetic material into the body, which triggers the production of potent antibodies (38). The Sinopharm vaccine, on the other hand, uses a completely inactivated virus that cannot replicate in the body, which stimulates multiple

immune responses (39). Moreover, differences in protection rates between the AstraZeneca and Sinopharm vaccines may reflect differences in the way these vaccines induce inflammation and, consequently, the strength and duration of the immune response. Although both vaccines are effective in producing anti-spike protein antibodies, the AstraZeneca vaccine, with its ability to produce potent antibodies, may be linked to a more rapid and stronger initial inflammatory response, leading to longer-lasting immunity than the Sinopharm vaccine, which, while effective, may exhibit a slower increase and steeper decline over time (40).

However, one of the limitations of the present cross-sectional study is the exclusion of individuals with pre-existing medical conditions, such as those undergoing cancer treatments, or those suffering from severe allergies or immunosuppression. Additionally, the levels of anti-spike protein antibodies prior to the second vaccination were not determined, which could have provided valuable insight into the baseline immunity of participants. This exclusion was necessary to preserve the integrity of the study; however, it limited the generalizability of the findings to the whole population. Future studies are thus required to include a more diverse patient population to assess the association between antibody production, longevity and various health conditions.

In addition, an extension of the present study to other vaccines is planned to assess their efficacy, allowing for a comparison of the principles and techniques of antiviral vaccine production with the corresponding response of the immune system. This comparative analysis could provide valuable insight into optimizing vaccine design and improving overall immunization strategies.

In conclusion, the present study sheds light on how the Sinopharm and AstraZeneca vaccines generate immunity against SARS-CoV-2. The majority of vaccinated individuals developed antibodies, suggesting that the vaccines effectively stimulate an immune defense. While age and sex slightly affect the immune response, younger individuals generally tend to have a stronger response. The present study thus demonstrates that individuals who have contracted COVID-19 prior to being vaccinated have a stronger immune response. This suggests that vaccination is crucial for everyone, even those already infected, as it helps to protect the population as a whole. However, further studies are warranted to determine the duration of this enhanced immune response and its efficacy against new variants of the virus.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

MN was involved in the conception and design of the study, collected patient data, participated in the analysis and interpretation of results, and contributed to the preparation of the initial draft of the manuscript. RB contributed to the conception and design of the study and was involved in the analysis and interpretation of the results. MSSAEK participated in the analysis and interpretation of the results. FZEA was responsible for the collection of patient data, and helped prepare the initial draft of the manuscript. KAT was involved in the analysis and interpretation of the results, as well as in reviewing and editing the main text of the manuscript. MME supervised the study, ensuring its direction and integrity, and contributed to the conception and design of the study and the final editorial changes of the manuscript. MN and MME confirm the authenticity of the raw data. All authors have reviewed and approved the final version of the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics approval and consent to participate

The research began in July, 2021 with preliminary work that involved the secondary analysis of anonymized data, for which formal ethics approval was not initially required. As the project evolved to include primary data collection, an ethics approval waiver was proactively obtained in March, 2022 to ensure compliance with institutional standards. Following this approval waiver, the experimental phase began by analyzing samples that had been stored in the Analyses Laboratory Anoual in Casablanca since July 2021, as well as collecting new samples. This schedule reflects the study period described in the study, capturing both the preliminary analysis of existing samples and the subsequent collection of new data. Verbal consent was obtained from participants due to several factors, including the illiteracy of some patients and the preference of other patients for oral consent rather than written documentation.

Patient consent for publication

Not applicable.

Competition interests

The authors declare that they have no competing interests.

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