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Article

Surveillance of SARS-CoV-2 in Healthcare Workers before and after COVID-19 Vaccination: A Cohort Study in a Primary Care Unit of Brazil

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Abstract: Introduction: Healthcare workers (HCW) are at higher risk of SARS-CoV-2 infection. Viral surveillance for early detection of COVID-19 is a critical strategy to understand the infection dynamics in this population and to prevent transmission. The study examines SARS-CoV-2 infection and reinfection among HCW vaccinated against COVID-19 who are employed at a primary health care unit serving a disenfranchised community of Brazil. **Methods:** The study was conducted in Cidade Estrutural, Federal District of Brazil, between February and October 2021. Participants were interviewed and provided samples. A prospective open cohort study was used to analyze the frequency of SARS-CoV-2 infection and reinfection. Nasopharyngeal and peripheral blood samples were collected from workers presenting with flu-like symptoms and subjected to RT-qPCR and serological testing (IgM and IgG chemiluminescence). The frequencies of infection and reinfection (RT-qPCR positive results 90 days after the infection) were calculated along with their respective confidence intervals (95%CI). **Results:** Of the 128 workers, 61 (47.65%; CI: 39.19-56.25) reported probable SARS-CoV-2 infection before vaccination. Of these, 50 (39.06%; CI: 31.04-47.71) had SARS-CoV-2 infection after vaccination, confirmed by molecular tests. Reinfection was identified in seven workers (14.00%; CI: 6.95-26.18), based on the 90-day interval between results. The serological data from the 128 workers during the cohort indicated that 68 had IgG antibodies (53.12%; CI: 44.5-61.5) and 46 had IgM antibodies (35.93%; CI: 28.14-44.54) against SARS-CoV-2. SARS-CoV-2 infection was common in community health workers (CHW, 56%), registered nurses (50%), and licensed practice nurses (33%). Following the COVID-19 vaccination, the percentage of infections among CHW decreased from 47.83% to 4.35%. **Conclusion:** These results demonstrate that (i) approximately 40% of the workers were infected with SARS-CoV-2 in 2021 and (ii) reinfections confirmed by RT-qPCR occurred in 14% of the HCW after vaccination. The results provide valuable insights into the circulation of SARS-CoV-2 among HCW in a primary care unit serving a minoritized community.

Keywords: monitoring; seroprevalence; SARS-CoV-2; COVID-19

1. Introduction

The COVID-19 pandemic caused by SARS-CoV-2 has led to more than 700 million cases and 7 million deaths worldwide. Despite the pandemic being declared over, new cases of COVID-19 continue to be reported [1]. Healthcare workers (HCW) working in primary care are on the front lines of the COVID-19 response and still face a high risk of infection due to frequent and close interactions with infected patients. The safety of these workers is crucial not only for their own well-being, but

also for preventing transmission to uninfected patients and avoiding healthcare system backlog caused by absenteeism [2].

The surveillance of SARS-CoV-2 among HCW is essential for monitoring their health, understanding the dynamics of transmission, and evaluating their importance as a sentinel group for detecting virus variant shifts. Efficient monitoring of SARS-CoV-2 infections can help prevent high rates of COVID-19 and is crucial for identifying vulnerable groups and reducing the virus's spread within healthcare facilities. [3]. Despite COVID-19 vaccination having a strong protective effect against reinfection, the risk of SARS-CoV-2 infection persists among HCW. Reinfections can occur in fully vaccinated workers, but with reduced severity and mortality [4,5].

Several factors have been identified as potential risk factors for SARS-CoV-2 transmission among HCW, such as job role, work environment, use of personal protective equipment, vaccination status, and concurrent community and household exposure. Studies showed substantial variability in prevalence of and risk factors for SARS-CoV-2 infection among HCW, attributed to different job roles, exposure to COVID-19 patients, and healthcare settings [6], although the risk of SARS-CoV-2 exposure for HCW is higher in the community rather than at their workplace [7]. HCW in the Global South may face limited resources and workforce shortages, leading to overworked staff and reduced quality of care. These challenges underscore the need for targeted support and resources to protect HCW in the Global South to ensure they can provide the highest quality of care during the pandemic. Monitoring infection and seroconversion among HCW is crucial in identifying at-risk individuals, assessing the effectiveness of protective measures, and implementing timely interventions to mitigate the spread of SARS-CoV-2.

This study aims to investigate SARS-CoV-2 infection and reinfection in HCW from a primary healthcare unit serving a disenfranchised community located in Cidade Estrutural (RA XXV SCIA/Estrutural, DF, Brazil). This city, on the outskirts of the capital of Brazil, Brasília, was home to Latin America's largest untreated refuse disposal site until its decommissioning in 2018 [8]. Our work describes the sociodemographic profile of the HCW, evaluates their frequency of infection, cases of reinfection, and post-infection IgM and IgG values in a prospective descriptive open cohort. The surveillance of SARS-CoV-2 in the healthcare workforce is a strategic approach for filling information gaps, understanding the behavior of the virus, and enabling early responses for the population.

2. Material and Methods

2.1. Study design, Settings, and Ethical Considerations

This research was a prospective analytical cohort study conducted between February and October 2021, with the staff of a primary healthcare unit (HU) at Cidade Estrutural (RA XXV SCIA/Estrutural, DF, Brazil) (Figure 1). Cidade Estrutural is characterized by considerable social challenges, where many residents face economic difficulties, inadequate housing conditions, and limited access to basic sanitation services. The city was home to the world's second-largest untreated refuse disposal site for decades, which was closed in 2018 [8].

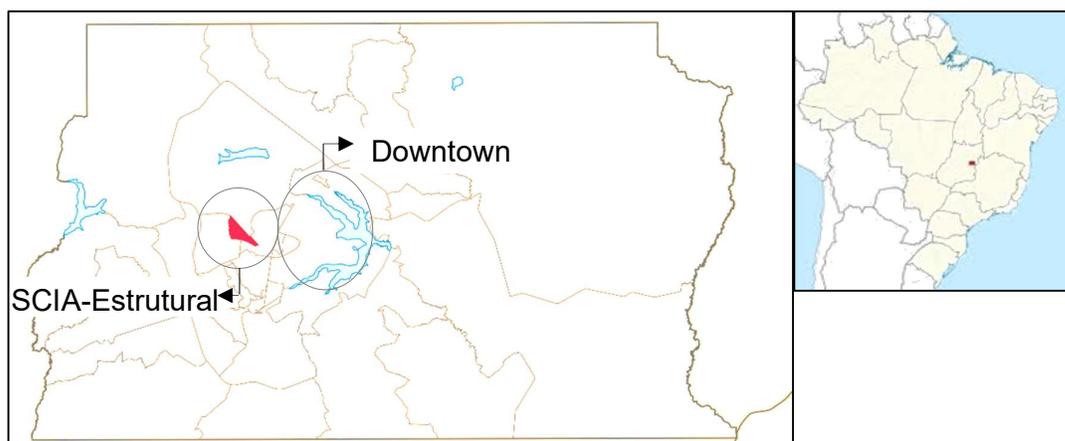


Figure 1. Study area: Location of the Health Unit in the Administrative Region of Cidade Estrutural in the Federal District, Brazil. Source: https://pt.wikipedia.org/wiki/Distrito_Federal_%28Brasil%29

This research was approved by the Committees for Ethics in Research of the Faculdade de Medicina of Universidade de Brasília (CEP-FM/UnB, CAEE 39866620.4.0000.5558) and of Fundação de Ensino e Pesquisa em Ciências da Saúde (FEPECS/SES/DF, CAAE 40557020.6.3001.5553). All HCW were invited to participate and signed an informed consent to participate in this study. This work was conducted in accordance with the Ethical Principles for Medical Research in Human Subjects (Declaration of Helsinki) and Brazilian regulations (Resolution 466/12 Conep/CNS/MS).

2.2. Selection of Participants

The target population was the team of 134 HCW at the HU in Cidade Estrutural. The healthcare team is responsible for providing primary care services for the population of Cidade Estrutural, including vaccinations, examinations, outpatient clinical care, schedule appointments, among other services. All HCW were invited to participate. The study included HCW who worked in the HU during the period studied that voluntarily signed the informed consent, agreed to provide biological samples (nasopharyngeal and venous blood), and answered a standardized questionnaire during the investigation. Participants were classified in three categorical groups: HCW who (i) had not yet received the first dose of the COVID-19 vaccine (Coronavac or AstraZeneca) for any reason; (ii) had received the first dose of any COVID-19 vaccine; or (iii) had received two doses of any COVID-19 vaccine. In all three cases, the biological material and primary data were collected in the period immediately preceding the scheduled vaccination date.

Participants were interviewed to obtain sociodemographic characteristics and had a venous blood sample collected every 30 ± 2 days from the initial sample collection (Figure 2). Data on adverse effects were recorded, and serological analysis was performed at the same intervals. The follow-up period lasted eight months, during which any workers reporting flu-like symptoms were tested for COVID-19 using RT-qPCR at any time.

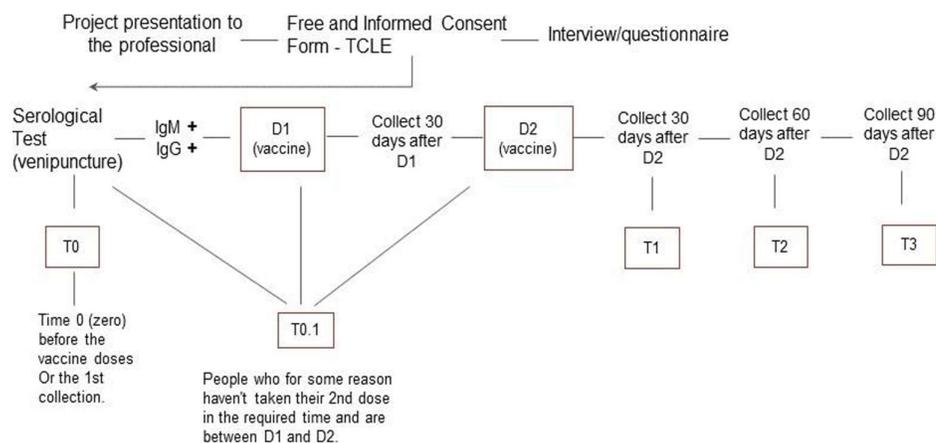


Figure 2. Flowchart depicting the sample collection scheme. Beginning on the day the participants received their first dose of the vaccine (D1), samples were collected, and interviews were conducted every 30 ± 2 days for a period of eight months. If the participant had previously received a jab, D2 was considered the start point. HWC presenting with flu-like symptoms were tested for COVID-19 by RTq-PCR.2.3.

2.3. Serological Analysis and SARS-CoV-2 Detection

A total of 240 venous blood samples (approximately 4 mL each) was collected over a period of eight months. The samples were centrifuged, and the serum was separated and stored at -80°C until analysis. The qualitative detection of IgM and IgG antibodies against SARS-CoV-2 was performed using chemiluminescence microparticle immunoassay technology [9]. The Abbott Architect Plus i2000SR was used to conduct tests for the detecting IgM against SARS-CoV-2 spike proteins (S) and IgG against SARS-CoV-2 nucleocapsid proteins (N). All tests were performed in accordance with the

manufacturer's instructions, including calibration and daily analysis of positive/negative controls, to meet the required quality criteria.

Molecular diagnosis was conducted on demand at the Hospital Universitário de Brasília (HUB) to assess infection and reinfection from nasopharyngeal samples collected between the third and tenth day of symptoms. The samples were analyzed by RT-qPCR using the Allplex SARS-CoV-2 Assay kit (Seegene) on Quantstudio 5 (Applied Biosystems), following the manufacturer's instructions [10]. Infection and reinfection criteria as based on RT-qPCR positive results.

2.4. Data Analysis

We assessed the frequency of infection and reinfection (positive results 90 days after an infection) among HCW according to their sociodemographic characteristics. The study analyzed the frequency of SARS-CoV-2 at nine time points, both before and after vaccination, to assess infection and reinfection. We used the Hmisc package in R 4.2.1 software, along with the RStudio 2023.03.1.446 [11] interface.

3. Results

3.1. Characterization of the Population

From, the 134 HCW employed at the HU, 128 participated in the study. Four HCW declined to participate in the study. Three workers chose not to receive the vaccine but agreed to be monitored. During the study period, seven workers withdrew, and 12 new workers joined the study. A total of 128 workers were sampled at various stages of the study. Of these, 27 were sampled before receiving the first dose of the vaccine, 109 before the second dose, 19 immediately after the second dose, and 99 on the 30th day (± 2) after the second dose. Four workers received the AstraZeneca vaccine, while the remaining workers (124) were vaccinated with CoronaVac. Most of the workers had completed college education, earned more than six minimum wages, and worked as nursing technicians or CHW (Table 1).

Table 1. Demographic characteristics and SARS-CoV-2 infection data of the HCW participating in the study according to age, race, education, income, and function.

Variables	Frequency n	Percent %	Infection (%)		
			Self-reported	Infection	Reinfection
Age					
< 24	5	3.9	0.0	20.0	0.0
25-34	15	11.7	46.7	46.7	13.0
35-44	48	37.5	52.1	47.9	8.0
45-54	46	35.9	52.2	34.8	7.0
55-64	14	10.9	35.7	21.4	0.0
Race					
Yellow	4	3.1	75.0	25.0	0.0
White	35	27.3	42.9	40.0	6.0
Mixed	72	56.3	50.0	40.3	7.0
Black	17	13.3	41.2	35.3	12.0
Education					
Elementary school	4	3.1	100	0.0	0.0
High school	24	18.7	75.0	80.0	20.0
Vocational education	4	3.1	50.0	50.0	0.0
College	100	78.1	45.0	61.8	20.0
Master's Degree	6	4.6	66.0	80.0	20.0

PhD	1	0.8	0.0	0.0	0.0
Income					
Up to US\$ 600.00	19	14.9	47.3	55.6	0.0
Up to US\$ 1200.00	20	15.6	35.0	40.0	15.0
Up to US\$ 1800.00	26	20.3	34.6	34.6	8.0
Up to US\$ 2400.00	26	20.3	57.7	42.3	8.0
> US\$ 2400.00	34	26.6	55.9	35.3	6.0
No answer	3	2.4	80.0	0.0	0.0
Profession					
Administrative worker	3	2.3	66.7	33.3	0.0
Community Health Workers	23	18	47.8	56.5	13.0
Manager	3	2.3	66.7	33.3	33.0
Oral health assistant	1	0.8	100	0.0	0.0
Pharmacist	1	0.8	100	0.0	0.0
Physiotherapist	2	1.6	100	0.0	0.0
Registered Nurse	18	14.1	50.0	50.0	0.0
Social worker	1	0.8	0.0	0.0	0.0
Speech therapist	1	0.8	100	100	0.0

(n) Total number of participants in the study. Self-reported: HCW reported that they had COVID-19. Infection: positive results for chemiluminescence or RT-qPCR. Reinfection: positive result 90 days after an infection.

3.2. SARS-CoV-2 Infections and Reinfections

Of the 128 workers, 61 self-reported probable SARS-CoV-2 infection (47.65%; CI: 39.19-56.25) before vaccination. A total of 50 (39.06%; CI: 31.04-47.71) HCW had SARS-CoV-2 infection after vaccination, confirmed by RT-qPCR. Reinfection was identified in seven HCWs (14.00%; CI: 6.95-26.18), based on a positive RT-qPCR result after 90 days of a previous positive RT-qPCR result. The serological data from 128 HCW indicated that 68 had IgG antibodies (53.12%; CI: 44.5-61.5) and 46 had IgM antibodies (35.93%; CI: 28.14-44.54) against SARS-CoV-2 proteins.

Infections occurred in all age, race, and educational groups (Table 1). No differences in infection were observed among the different income groups (Table 1). However, infections were identified in HCW from different professions, mostly in community health workers (CHWs, 56%), registered nurses (50%), and licensed practice nurses (33%) (Table 1). Following the vaccination, the percentage of infections among CHWs decreased, from 47.83% to 4.35%.

Table 2 presents the IgG and IgM values based on the time of measurement for both vaccinated and unvaccinated individuals. At the beginning of the study (T0), only 28 (22.05%) individuals had a positive IgG result before vaccination. At T1, 42 individuals who received the first dose of the vaccine tested positive for IgG (40.38%). The frequency of positive IgG gradually decreased in subsequent measurements (Table 2). A comparable pattern was observed for IgM, although to a lesser extent.

Table 2. Number of healthcare workers participating in the cohort that tested positive for IgG and IgM Sars-CoV-2 by time (T).

Time (T)*	IgG Positive	IgG Negative	IgM Positive	IgM Negative	n
T0	28	99	28	99	127
T0_1/	3	9	3	9	12
T1	42	62	26	80	101
T2	38	64	12	89	104
T3	25	68	7	86	93

T4	24	66	9	81	90
T5	16	65	9	71	81
T6	12	57	12	57	69
T7	10	49	9	50	59

(n) Total number of participants in the cohort. *Described in Figure 2.

4. Discussion

The study found that 50 (~40%) HCW in the HU located in Cidade Estrutural were infected with SARS-CoV-2 in 2021. CHW were the most infected group. The study also showed a low frequency of reinfection among these workers after vaccination. These results contribute to the understanding of SARS-CoV-2 infection dynamics among HCW of a HU serving a disenfranchised community of Brazil during the COVID-19 pandemic.

The study of HCW infection is fundamental to understanding transmission dynamics and suggesting prevention strategies. WHO [1] recommendation of testing and isolation of asymptomatic HCW infected with SARS-CoV-2 from health care settings was critical for controlling COVID-19 transmission. This also has a direct impact on the quality of care and the mental health of HCW, minimizing additional stress [12]. We found that approximately 40% of HCW were infected with SARS-CoV-2 in 2021. Studies reported that prior to the first dose of COVID-19 vaccination, SARS-CoV-2 infections varied between 7-58% among HCW, depending on the diagnostic method used [13–16]. It is worth noting that studies have demonstrated the effectiveness of combining serological methods with RT-qPCR to detect SARS-CoV-2, resulting in a more accurate diagnosis. In some suspected COVID-19 cases, when presenting with flu-like symptoms and having had close contact with confirmed cases, patients have tested negative twice by RT-qPCR but positive for SARS-CoV-2-specific IgM and IgG antibodies. These findings suggest a promising strategy for the prevention or rapid control of future cases [17]. During the postvaccination, SARS-CoV-2 infections was reduced among HCW, varying between 0.5-9% [18,19], values slightly lower than those showed in our study. Surveillance based on accurate diagnostic methods allows for the prevention and management of COVID-19 symptoms, which can help prevent serious outcomes for HCW, including death [13].

We detected SARS-CoV-2 infections in workers from over 18 different healthcare roles, with the majority being CHW (56%). Association between job role and SARS-CoV-2 infection was found among healthcare personnel [6], although the risk of SARS-CoV-2 exposure for HCW was more likely to have occurred in the community and/or their households rather than at their workplace [7]. The higher occurrence of SARS-CoV-2 infections in CHW may be linked to their direct contact with the community and visits to households, where transmission is occurring. Notably, a seroprevalence of 24% was observed in certain areas of the Federal District of Brazil during the pandemic [20].

Our results show the dynamics of seroconversion in vaccinated individuals, indicating a positive immune response to the vaccine over time, with an initial increase at T1 and effective maintenance through T7. This analysis highlights the effectiveness of the vaccines in producing a detectable immune response in HCW, as observed in other studies [18,19,21,22]. After vaccination, participants who had a previous, self-reported SARS-CoV-2 infection had higher antibody levels than those who did not self-report a previous infection. This correlation between post-vaccination antibody levels and previous infection has been observed in other studies [23]. The effectiveness of the COVID-19 vaccine in HCW was high, even against the Omicron variant (e.g. [24]). Reduction in COVID-19 cases in HCW was observed in many studies [18,19,21,22]. For example, a reduction of 62% in new cases of COVID-19 among HCW seven weeks after vaccination was observed, demonstrating the effectiveness of the vaccines [21].

COVID-19 infection among HCW is a significant public health challenge that requires the implementation of more effective protective measures. A system where hospital-based occupational health services were adapted to offer a monitoring program with daily evaluations and treatment options for HCW with SARS-CoV-2 has shown significant results. Of the 4,814 professionals enrolled, only 2% were hospitalized, and there were six deaths. The tracked professionals had lower rates of comorbidities, hospitalization, and mortality, indicating that this surveillance approach may be feasible [25].

The study was conducted during a government-declared state of emergency, which, in conjunction with a global shortage of supplies, caused delays in the arrival of diagnostic kits. As a result, there were frequent delays in the return of results, leading some participants to seek diagnostics in the private sector. Another limitation is related to the kit used during diagnosis, as we used a qualitative method available at the beginning of the cohort. It was not possible to measure the level of antibodies after exposure. Overcoming these challenges is critical to ensure the effectiveness of the study and its effective contribution to pandemic control and the formulation of more effective and comprehensive health strategies in the future.

Surveillance offers the prospect of monitoring and follow-up, providing timely and effective health responses to health systems, populations, and governments. Incorporating routine surveillance as a public health policy could prevent future barriers to conducting research projects. COVID-19 surveillance can provide an epidemiologic perspective for controlling virus transmission. Public health surveillance by community health workers is critical, especially in disenfranchised settings. HCW play essential roles, including contact tracing and patient visits, in controlling infectious diseases such as HIV/AIDS, malaria, tuberculosis, Ebola, and COVID-19. Despite the challenges HCW face, such as unfavorable psychosocial conditions, insufficient training and resources, investment in their well-being at work and infrastructure can significantly improve their work and the quality of public health surveillance [26,27].

5. Conclusion

Our results demonstrate that: (i) approximately 40% of the HCWs were infected with SARS-CoV-2 after vaccination, primarily CHWs, and (ii) reinfections occurred in 14% of the HCW. The results provide valuable insights into the circulation of SARS-CoV-2 among HCWs in a primary care unit attending an unserved community of the capital of Brazil during the COVID-19 pandemic. In addition, the study indicates that some HCW were still infected even after complete immunization. This finding is consistent with previous studies that have also shown a decline in vaccine effectiveness over time, highlighting the need for revaccination.

List of abbreviations

COVID-19: Coronavirus disease of 2019;
CHW: Community health workers
HUB: Brasília University Hospital;
HCW: Health care workers
HU: primary health unit
IEQ: Enzyme immunoassay of chemiluminescence;
95% CI: 95% confidence interval;
IgG: Immunoglobulin G;
IgM: Immunoglobulin M;
RA: Administrative Region;
RT-PCR: Reverse transcriptase reaction followed by polymerase chain reaction;
SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2;
SCIA: Complementary Industry and Supply Sector;
UnB: University of Brasília;

Ethical approval and consent to participate: The research was approved by the Research Ethics Committee (CEP), under protocol number: 39866620.4.0000.5558 and approved by the Research Ethics Committee of the Faculty of Medicine (CEP/FM) of the University of Brasília. We also obtained permission from the Federal District Health Department (SES/DF), with the management of the health unit, to carry out the research at the Estrutural Basic Health Unit. Authorization for the collection of data, serological samples and swabs was assessed and accepted by the UBS manager. The health professionals who agreed to take part in the research signed the Informed Consent Form (ICF).

Consent for publication: All volunteers signed informed consent that the data will be disclosed to interested authorities and in reports, scientific articles and other educational dissemination.

Data availability: The data collected and analyzed for this study is available from the corresponding author upon reasonable request.

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Competitive interests: The authors declare that they have no conflicting interests.

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