IJBPAS, December, Special Issue, 2021, 10(12): 632-639
ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)
'A Bridge Between Laboratory and Reader'
www.ijbpas.com

Sars-Cov-2 seroprevalence among HIV patients under ART in Morocco, during the Covid-19 pandemic

IMANE BELBACHA[1,2*], OUAFA BENNANI[1], RAJAE MENGAD[1], MOHAMED ETTANJAOUI[1], KHADIJA HAJOUTT[3], RAJAE BENSGHIR[4], KAMAL FILALI MARHOUM[4], ELMIR ELHARTI[1], KHALID SADKI[2,5], HICHAM OUMZIL[1,6]

1: National Reference Laboratory for HIV, Virology Department, National Institute of Hygiene, Rabat Morocco

2: Laboratory of Human Pathologies Biology, Faculty of Sciences, Mohammed V University, Rabat, Morocco.

3: National Center for Blood Transfusion, Immuno-hematology Unit, Rabat, Morocco.

4: Infectious Diseases Service, the University Hospital IBN ROCHD, Casablanca. Morocco

5: Fundamental Sciences Department, Faculty of Dental Medecine, Mohamed-V University of Rabat

6: Microbiology RPU, Faculty of Medicine and Pharmacy, Mohamed V University, Rabat, Morocco

***Corresponding Author: Dr. Imane Belbacha; E Mail: imanbelbacha@yahoo.fr, Imane_belbacha@um5.ac.ma**

Received 20th Aug. 2021; Revised 24th Sept. 2021; Accepted 30th Oct. 2021; Available online 1st Dec. 2021

https://doi.org/10.31032/IJBPAS/2021/10.12.2060

ABSTRACT

SARS-Cov-2 or the severe acute respiratory syndrome Coronavirus 2, since its appearance in December 2019 in Wuhan City of China, it has not stopped creating disasters in different countries of the world. It has warranted an epidemic outburst of respiratory disease called as Covid-19 by the WHO. To curb the spread of the epidemic, Morocco has put in place drastic measures especially regarding vulnerable groups such as HIV positive-patients receiving antiretroviral therapy (ART). Molecular techniques are considered as the gold standard for the acute SARS-Cov-2 infection diagnosis but serological tests have the potential to verify how much the individual has been exposed to the virus. For the present study, we report a seroprevalence of SARS-Cov-2 specific antibodies among a total of 204 HIV-1 patients admitted for immuno-virological monitoring in the INH in Rabat and 200 healthy Moroccans adults recruited from the National Center for Blood Transfusion in Rabat. Serum samples were tested for IgG antibodies against SARS-Cov-2 nucleoprotein using Architect/Abbott. SARS-Cov-2 seroreactivity was significantly lower in HIV-1 subjects 7.35% compared to that found in healthy controls 19%. Seroprevalences results highlight an amount of circulating neutralising antibodies among our groups. Serological testing is useful for the identification of asymptomatic infection of SARS-Cov-2. Further serosurveys among other populations and in other regions are under process to inform the public of the Covid-19 epidemic variations in all of the country.

Key words: SARS-Cov-2, HIV, seroprevalence

INTRODUCTION

Since March 2020, Sars-Cov-2 infection rapidly spread around the world and was declared a significant public health emergency of International Concern by the World Health Organization (WHO) (1). As for 20 December 2021, globally more than 275 101 377 confirmed cases of COVID-19 causing 5 372 600 deaths (https://worldometers.info/coronavirus/). In Morocco, Sars-Cov-2 imported first case was reported in February 27, 2020 (2). Since the onset of

the pandemic worldwide and with the appearance of new positive cases, Morocco adopted large-scale drastic measures in order to preserve the Moroccan population (3). People living with HIV (PLWH) may be at heightened risk for severe physical health illness from the SARS-Cov-2 compared to general population (4)(5). Thus, in light of this pandemic, the Ministry of Health through care and monitoring centers for PLWH, provided to this vulnerable population the antiretroviral treatment (ART) which can cover the 6 months of confinement in order to reduce their mobility and the risk of becoming infected with SARS-Cov-2. During that period, a very limited data on COVID-19 in PLWH under ART was available. Globally until now, only few cohorts studies have been published addressing the issue regarding whether PLWH might be at an increased risk of severe COVID-19(6). The diagnosis of COVID-19 was usually based on viral RNA test by RT-PCR, real-time reverse transcription-polymerase chain reaction assay among suspected cases with SARS-Cov-2 infection symptoms(7). Although it's qualified as a gold standard test, RT-PCR appears to be sensitive to the assay method and can not be adopted as sole diagnostic method in surveillance because of its inability to detect past infection (8). Given that, seroprevalence studies could be used to better estimate previous and active infection in both symptomatic and asymptomatic individuals (9). SARS-Cov-2 is newly emerging virus, almost all patients infected with COVID-19 develop detectable IgG and IgM antibodies within several weeks of symptom onset(10). The antibody response induced can be measured by serological assays which are, comparing to PCR, advantageous with faster turn-around-time and less workload (11)(12). To contribute to the emerging data regarding the prevalence of SARS-Cov-2 seroprevalence/COVID-19 in Morocco, we conducted a prospective cross-sectional study among two cohorts of individuals. We performed anti-nucleocapsid IgG testing on plasma samples from 204 HIV-1 PLWH and 200 healthy donors who donated blood from April to August 2021 at Center for blood Transfusion in Rabat, capital of Morocco.

MATERIALS AND METHODS

Study subjects

A total of 204 PLWH and 200 healthy individuals were recruited from April to August 2021 just before the second wave of SARS-Cov-2, which occurred in Morocco at the end of July. PLWH are part of the active line of patients under monitoring in the Infectious Diseases service in the University Hospital IBN Rochd in Casablanca and their Immuno-virological monitoring is carried out in National Reference Laboratory of HIV (NRLV) in the National Institute of Hygiene (INH) in Rabat. The Healthy individuals were recruited from the National Center for Blood Transfusion in Rabat during the performance of the SARS-Cov-2 seroprevalence study among blood donors in the RABAT-SALE-KENITRA region in collaboration with INH. The immuno-virological status for the PLWH was assessed by TCD4 lymphocyte count and the HIV-1 Viral Load then a part of their plasma is intended for SARS-Cov-2 serology. Donor blood samples are collected in EDTA anti-cogulated blood and labelled at the National Center for Blood Transfusion and sent to the laboratory (LNRV) twice a week for the detection of IgG antibodies against SARS-Cov-2. A written informed consent was obtained from each participant and the study was approved by the Ethical Committee of the Faculty of Medicine and pharmacy, University Mohamed V, Rabat, Morocco (approval N°72/16).

Detection of Sars-Cov-2 antibodies

In the LNRV, blood samples from primary tubes are centrifuged and the plasma collected. Sars-Cov-2 antibodies were detected in the plasma using chemiluminescent microparticle immunoassay for the qualitative detection of IgG antibodies against SARS-Cov-2 nucleoprotein (SARS-Cov-2 IgG for use with ARCHITECT; Abbott Laboratories, Finisklin Business Park, Ireland; reference 6R86-22). The nucleocapsid protein used in Architect IgG assay has an increased sensitivity compared to the spike protein (13)(14). Many point-of-care rapid test applied directly to fingerpick blood were available for use but we choose this immunoassay after evaluating several high-performance serological kits at the INH. According to the manufacturer, the amount of IgG antibodies to Sars-Cov-2 is determined by comparing its chemiluminescent relative light unit (RLU) to the calibrator RLU (index S/C)(15). Referring to the product technical documentation, Abbott Architect SARS-Cov-2 showed a satisfactory performance with a very high specificity. The sensitivity neighbor 100% after 14 days from COVID-19 symptom onset and the specificity is of 99.6% using RT-PCR as the gold standard. The Architect platform requires a minimum of 100 µl of plasma.

Data analysis

PLWH and healthy blood donors demographic and disease informations (sex, age, TCD4 and VL) were summarized using descriptive analysis. To establish

the correlates of SARS-Cov-2 seroprevalence with age, gender and HIV we used logistic regression model (logit). Comparisons were assessed using comparison of proportions test. P-value<0.05 was considered as statistical significant and 95% confidence interval (CI) was used, as appropriate, to report the estimates. All analysis was done on statistical package for social science SPSS (version 25).

RESULT

A total of 404 individuals were included in this study, 204 PLWH and 200 healthy blood donors. Their demographic and biological data are shown in (Table 1).The viral load average have not been considered because some of PLWH samples addressed for biological monitoring in NRLV during the study period were tested only for TCD4 count. The mean age for PLWH was 37.69 years and 35.24 years for the healthy individuals. All PLWH were under ART, their median CD4 cell count was 434.49 cell/µl and their viral loads ranging between 0-1 491 390.

All subjects enrolled were investigated for IgG antibodies against SARS-Cov-2 nucleocapsid using the Abbott Architect platform. Overall, SARS-Cov-2-specific IgG antibodies were detected in 15 plasma samples of PLWH and in 38 healthy blood donors resulting in a seroprevalence of 7.35% and 19 % respectively (Table 2)(figure 1). With statistical comparison of proportions test, we found that the difference between the two proportions at the 95% level [-0.05; -0.18] was significant thus the prevalence of SARS-Cov-2 among PLWH was significantly lower than that found in healthy blood donors ($p<0.05$). 7.35% and 19% reflected a high positivity in supporting the evidence of increase in infection spread in both groups. .

Of note, in both PLWH and healthy individuals, the gender ratio was respectively 1.17 and 0.80 (male/female). There was a difference in seroprevalences found between females and males. Indeed, SARS-Cov-2 seroprevalence was higher among females than males in both PLWH (4.90% *vs* 2.45%) and healthy blood donors (11% *vs* 8 %). Although this result drew attention, statistical analysis showed that there was no significant difference between the two proportions at the 95% level [-0.09; 0.13]. These findings suggest that females individuals could have higher rates of confirmed cases of SARS-Cov-2 compared with males individuals. The same, there was no significant association between the different age of seropositive and seronegative participants and COVID-19 prevalence, CI 95% [0.98; 1.03]; $p=0.44$.

Table 1. Demographic data of HIV patients and Healthy blood donors.		
Subject	HIV patients	Healthy blood donors
Number	204	200
Females	94 (46.07%)	111 (55.50%)
Males	110 (53.92%)	89 (44.50%)
Mean age	37.69 (18-56)	35.24 (19-58)
CD4 count(cells/µl)	434.49 (6-1510)	
Viral Load (copies/ml)	Indetectable-1 491 390	

Table 2. Laboratory outcomes of SARS-Cov-2 positive antibodies among HIV-1 patients and Healthy blood donors		
Subject	Positive	Negative
HIV patients	15/204 (7.35%)	189/204 (92.64%)
Healthy blood donors	38/200 (19 %)	162/200 (81%)

Fig 1: Study groups having COVID-19 antibodies

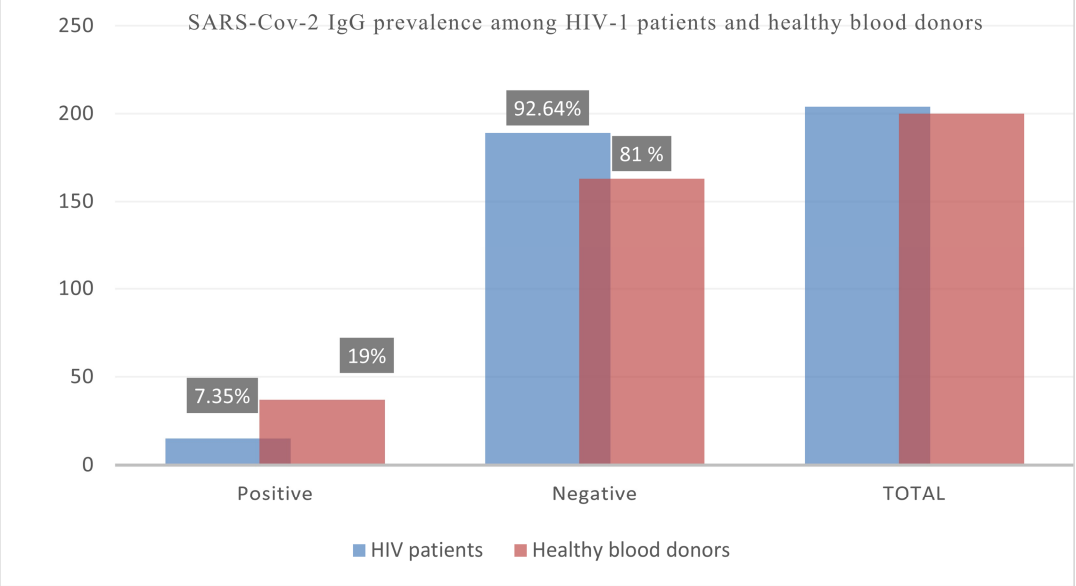

Table 3: SARS-Cov-2 seroprevalences in Healthy blood donors in different populations.

	pop											
	Present study	**Italy** *L. Valenti et al. 2021*	**Pakistan** A. Younas et al. 2020	**Saudi Arabia** *A. Banjar et al. 2020*	**Canada** S. Saeed et al. 2021	**Brazil** L. Filho et al. 2020	**Denmark** C. Erikstrup et al. 2021	**Austria** A. Siller et al. 2021	**France** P. Gallian et al. 2020	**Jordan** Z. Elnasser et al. 2021	**South Africa** W. Sykes et al. 2021	**Kenya** S. Uyoga et al. 2021
The study period	**April to August 2021**	24 February to 8 April 2020	May to July 2020	20 to 25 May 2020	9 May to 21 Juin 2020	14 to 27 April 2020	6 April to 3 May 2020	8 June to 4 September 2020	March to April 2020	September 2020 to March 2021	January 2021	30 April to 16 June 2020
Number of blood donors	**200**	789	380	837	74 642	2857	20 640	5345	998	1000	4858	3098
SARS-COv-2 IgG prevalence	**18.5%**	5.2%	21.4% to 37.7%	1.4%	0.7%	4%	1.7%	3.1%	2.7%	14.5%	2.2% to 2.8%	5.6%

DISCUSSION

Since the first case COVID-19 was reported on 2 March 2020, SARS-Cov-2 was confirmed to have spread in Morocco. Like many countries, the rapid propagation of SARS-Cov-2 has created unprecedented challenges to health systems, in fact, an extensive disruptions occurred on several Public Health Programs including HIV services (16). People living with HIV (PLWH), considered as immunocompromised subjects, might be at an increased risk of SARS-Cov-2 especially those with comorbidities, lower CD4 cell counts or unsuppressed HIV RNA viral load (17) (18). In order to reduce the impact of Sars-Cov-2 in PLWH and keeping them safe from the contamination, the Moroccan Ministry of Health has deployed several measures based on availing antiretroviral treatment, HIV testing and prevention actions. The present study was conducted relatively after the first SARS-Cov-2 pandemic wave in late 2020 and before the second wave, which was happened in Summer 2021. It was carried out after the National seroprevalence study for the benefit of blood donors and Health Professionals Workers in Morocco (data not yet published). The identification of SARS-Cov-2 seroprevalence through samples of health blood donors has been currently encouraged by WHO who recommend that individuals must not present any symptom (cough, fever, flu) and not be exposed to a confirmed COVID-19 patient, otherwise a temporary deferral for 28 days is recommended until eligibility for blood donation (19). Consequently, this kind of seroprevalence can give an estimate of circulation of the SARS-Co-2 in healthy individuals, providing a real actual disease burden in population at the time of the study (20).

204 PLWH and 200 healthy donors were consecutively enrolled, they were investigated for IgG antibodies against SARS-Cov-2 nucleocapsid using the Abbott Architect platform. The IgG are predictive for neutralizing activity with high positive percent agreement and their presence might provide a more accurate estimate of SARS-Cov-2 because they are likely to persist for a longer period of time after the viral infection is cleared (21). The findings from this seroprevalence indicate a higher prevalence of IgG antibodies against SARS-Cov-2 surrounding 19% among Moroccan healthy donors and 7.35% among PLWH. Given that anti-nucleocapsid antibodies are not thought to be directly neutralizing, our results suggest that detection of anti-nucleocapsid IgG antibodies may be indicative of a productive and humoral immune response (22). Based on the number of confirmed positive cases (n=15) in 204 PLWH, the seroprevalence of SARS-Cov-2 was important (7.35%) but compared to that found among general population (19%) at the corresponding period, appears to be significantly lower (approximately more than two times lower). Both PLWH and healthy individuals seemed to be similarly affected by SARS-Cov-2 and the virus IgG positivity confirm evidence of an increased spread of infection and

support the idea of high number of asymptomatic carriers of COVID-19 in our groups.

The prevalence of SARS-Cov-2 in PLWH has not been widely investigated. Here we report the study of *D. Kaddu et al*. 2021, who found a low seroprevalence of SARS-Cov-2 (1.85%=11/594) in PLWH in Germany (from 1 April to 30 June 2020), moreover *Lombardi et al*. 2021, reported an IgG carriage rate around 0.72% (8/1106, 95% CI [0.37-1.42]) among PLWH in Italy (study done from 1 March to 30 November 2020). Through these reported prevalences in PLWH and with comparison with our one (7.35%), we noticed that the positivity rate of serological tests increased over time especially after the second wave of the pandemic in line with an increase of immunization (9). Despite no definitive evidence that PLWH are at higher risk of contracting COVID-19, the physical distancing guidelines that they were confronted with, only exacerbated the high levels of isolation that they already face (23). In this study we were not able to measure neutralizing antibodies but just providing an indication about previous exposure, however, it is still yet unclear whether IgG levels detected in PLWH are protective, how long such protects lasts and how they provide the required effect for preventing new infections (24).

A higher prevalence of 19% in healthy blood donors highlights the proportion of the population that had been infected with SARS-Cov-2. Due to the ongoing dynamic of increasing seroprevalence rates, our study reflects the circumstances of the time period in which it was done. We summarized in a comparative table (table 3) the different seroprevalences of COVID-19 studied in different populations and in several durations since the apparition of the pandemic.

Note that published seroprevalence studies have been used different immunoassays and divergent methods of sampling. Our prevalence was in line with reports from blood donors from Pakistan (ranging between 21.4% and 37.7%)(20) and Jordan (14.5%)(25) but generally the studies which were carried out after the initial epidemic peak or between the two waves showed low prevalences in blood donors such in San Francisco (0.1%) (22), Saudi Arabia (1.4%) (26), Denmark (1.7%) (27), Canada (0.7%)(28), France and Netherlands (2.7%)(29)(30), and many others countries. Low prevalence suggest a limited circulation of the virus in the blood donors community. SARS-Cov-2 infection was also more widespread in the Dutch donor population (5.9%)(31), in Kenya (5.6%)(32), Milan (5.2%)(33), Brazil (4%)(34), and in many parts of England (35).

In both PLWH and healthy individuals, the gender ratio was respectively 1.17 and 0.80 (male/female). Through our study, SARS-Cov-2 seroprevalence was higher among females than males in both PLWH (4.90% *vs* 2.45%) and healthy blood donors (11% *vs* 8%) but statistically, there was no significant difference between the two proportions at the 95% level [-0.09; 0.13]. This finding was similar to that reported by *P. Gallian et al*. 2020 in France who found a similar seroprevalence values in males and females (2.82% *vs* 2.69%) and were in agreement with the findings of *Slot et al.* 2020 in Dutch blood donors who reported that the prevalence of antibodies to SARS-Cov-2 was not different for men and women (2.70% *vs* 2.73%) (36). On the other hand, in three serosurveys studies held in China based on the health population, females found having a significant higher seroprevalence than males because they have more risk for being exposed to the virus especially when caring for sick family members and could develop more asymptomatic infections (21)(37)(38).

SARS-Cov-2 serological surveillance is fundamental to effectively monitor the spread of the COVID-19 epidemic and support the government in making informed decisions (28). It's a critical approach to assess the prevalence of COVID-19 and estimate herd immunity in a population. The serosurveillance of the virus may help to understand in both vulnerable (PLWH) and general population, the epidemiology of the SARS-Cov-2 outbreak, its contagiousness and the host's immune response. Of course, the precautions adopted, such as proper social distance, wearing mask and frequent hand hygiene before an effective vaccination had reduced the rate of contamination but in no case stopped the chain of transmission. Hence, there is an urgent need to understand deeply the active interplay between the SARS-Cov-2 and the host immune response in order to validate the best therapeutic interventions and then to reduce the severity of infection.

CONCLUSION

Our study was performed before the second wave of the coronovirus in Morocco. The 19% and 7.35% seroprevalences among respectively healthy blood donors and PLWH demonstrates a presence of potential antibody-mediated immunity to SARS-Cov-2 at the time of the study. Our findings showed

that with high-quality serological assays we can assess the immunity in a population and measure the protective antibody titers of SARS-Cov-2 post exposure/upon vaccination. To the best of our knowledge, it's the first study carried out among PLWH in Morocco during the COVID-19 pandemic. Further evaluations are certainly needed in this vulnerable community to analyze cohorts with several immuno-virological profiles**.** To inform the public health and the public policy of the Covid-19 epidemic variations in all of the country, serosurveys among other populations and in other regions are under process to identify local epidemics so that targeted interventions are implemented.

Conflict of interest

The authors declare no conflict of interest

Acknowledgements

This work was supported By National Institute of Hygiene, in Rabat, Morocco with collaboration with the National Center for Blood Transfusion and University Hospital IBN Rochd in Casablanca. The authors would like to acknowledge each participant involving in this study and all the staff from health blood bank and Hospital IBN Rochd from Casablanca for their invaluable help and commitment.

References

1. Burki TK. Coronavirus in China. Lancet Respir Med. 2020;8(3):238.
2. Badaoui B, Sadki K, Talbi C, Salah D, Tazi L. Genetic diversity and genomic epidemiology of SARS-CoV-2 in Morocco. 2020;(January).
3. Hadrya F, Soulaymani A, Hattimy F El. Space-time COVID-19 monitoring in Morocco. 2020;35(Supp 2):1–7.
4. CDC. Coronavirus Disease 2019 (COVID-19) in People with HIV. 2019;2019:2019–21.
5. Shiau S, Krause KD, Valera P, Swaminathan S, Halkitis PN. The Burden of COVID-19 in People Living with HIV: A Syndemic Perspective. AIDS Behav [Internet]. 2020;24(8):2244–9. Available from: https://doi.org/10.1007/s10461-020-02871-9
6. Kaddu-Mulindwa D, Keuser L, Lesan V, Rissland J, Smola S, Werdecker V, *et al*. IgG seroprevalence of COVID-19 among people living with HIV or at high risk of HIV in south-west Germany: A seroprevalence study. HIV Med. 2021;(May):1–6.
7. Lai CC, Wang JH, Hsueh PR. Population-based seroprevalence surveys of anti-SARS-CoV-2 antibody: An up-to-date review. Int J Infect Dis [Internet]. 2020;101:314–22. Available from: https://doi.org/10.1016/j.ijid.2020.10.011
8. Lai AL, Millet JK, Daniel S, Freed JH, Whittaker GR. The important role of serology for COVID-19 control. Lancet. 2020;395(April):1315.
9. Lombardi F, Ricci R, Belmonti S, Fabbiani M, Borghetti A, Baldin G, *et al*. Seroprevalence of sars-cov-2 antibodies in hiv-infected patients in rome, italy during the covid-19 outbreak. Diagnostics. 2021;11(7).
10. To KKW, Tsang OTY, Leung WS, Tam AR, Wu TC, Lung DC, *et al*. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. Lancet Infect Dis [Internet]. 2020;20(5):565–74. Available from: http://dx.doi.org/10.1016/S1473-3099(20)30196-1
11. Zhao J, Yuan Q, Wang H, Liu W, Liao X, Su Y, *et al*. Antibody Responses to SARS-CoV-2 in Patients with Novel Coronavirus Disease 2019. Clin Infect Dis. 2020;71(16):2027–34.
12. Krammer F, Simon V. Serology assays to manage COVID-19. Science. 2020;368(6495):1060–1.
13. Burbelo PD, Riedo FX, Morishima C, Rawlings S, Smith D, Das S, *et al*. Sensitivity in detection of antibodies to nucleocapsid and spike proteins of severe acute respiratory syndrome coronavirus 2 in patients with coronavirus disease 2019. J Infect Dis. 2020;222(Xx Xxxx):206–13.
14. Liu W, Liu L, Kou G, Zheng Y, Ding Y, Ni W, *et al*. Evaluation of nucleocapsid and spike protein-based enzyme-linked immunosorbent assays for detecting antibodies against SARS-CoV-2. J Clin Microbiol. 2020;58(6):1–7.
15. Pollán M, Pérez-Gómez B, Pastor-Barriuso R, Oteo J, Hernán MA, Pérez-Olmeda M, *et al*. Prevalence of SARS-CoV-2 in Spain (ENE-COVID): a nationwide, population-based seroepidemiological study. Lancet. 2020;396(10250):535–44.
16. Tiffany G. Harris, Edward Jaszi,Matthew R, Carlos A, Maria Lucia Mendes Furtado, Bunaparte Nijirazana, Ndayizeye Aimé GLE. Effects of the COVID-19 Pandemic on HIV Services: Findings from 11 Sub-Saharan African Countries. Clin Infect Dis. 2021;1–41.
17. Vizcarra P, Pérez-Elías MJ, Quereda C, Moreno A, Vivancos MJ, Dronda F, *et al*. Description of COVID-19 in HIV-infected individuals: a single-centre, prospective cohort. Lancet HIV. 2020;7(8):e554–64.
18. Zhu F, Cao Y, Xu S, Zhou M. Reply to Comments on "Co-infection of SARS-CoV-2 and

HIV in a patient in Wuhan city, China." J Med Virol [Internet]. 2020;92(9):1417–8. Available from: http://dx.doi.org/10.1002/jmv.25838

19. Almalki S, Asseri M, Khawaji Y, Alqurashi R, Badawi M. Awareness about Coronavirus (COVID-19) and challenges for blood services among potential blood donors Saud. Transfus Apher Sci. 2020;(January).

20. Younas A, Waheed S, Khawaja S, Imam M. Seroprevalence of SARS-CoV-2 antibodies among healthy blood donors in Karachi, Pakistan. 2020;(January).

21. Xu X, Sun J, Nie S, Li H, Kong Y, Liang M, *et al*. Seroprevalence of immunoglobulin M and G antibodies against SARS-CoV-2 in China. Nat Med [Internet]. 2020;26(8):1193–5. Available from: http://dx.doi.org/10.1038/s41591-020-0949-6

22. Ng DL, Goldgof GM, Shy BR, Levine AG, Balcerek J, Bapat SP, *et al*. SARS-CoV-2 seroprevalence and neutralizing activity in donor and patient blood. Nat Commun. 2020;11(1):1–7.

23. Prabhu S, Poongulali S, Kumarasamy N. Impact of COVID-19 on people living with HIV: A review. J Virus Erad [Internet]. 2020;6(4):100019. Available from: https://doi.org/10.1016/j.jve.2020.100019

24. Jiang S, Hillyer C, Du L. Neutralizing Antibodies against SARS-CoV-2 and Other Human Coronaviruses. Trends Immunol. 2020;41(6):545.

25. Elnasser Z, Obeidat H, Amarin Z, Alrabadi N, Jaradat A, Alomarat D, *et al*. Prevalence of COVID-19 among blood donors The Jordan University of Science and Technology experience. Medicine (Baltimore). 2021;100(41):e27537.

26. Banjar A, Al-taw JA, Alruwaily A, Alserehi H. Seroprevalence of antibodies to SARS-CoV-2 among blood donors in the early months of the pandemic in Saudi Arabia. Int J Infect Dis. 2020;(January).

27. Erikstrup C, Hother CE, Pedersen OBV, Mølbak K, Skov RL, Holm DK, *et al*. Estimation of SARS-CoV-2 Infection Fatality Rate by Real-time Antibody Screening of Blood Donors. Clin Infect Dis. 2021;72(2):249–53.

28. Saeed S, Drews SJ, Osmond L, Brien SFO. SARS-CoV-2 seroprevalence among blood donors after the first COVID-19 wave in Canada. 2021;(November 2020):862–72.

29. Gallian P, Pastorino B, Morel P, Chiaroni J, Ninove L, Lamballerie X De. Lower prevalence of antibodies neutralizing SARS-Cov-2 in group O French blood donors. Antiviral Res. 2020;(January).

30. Slot E, Hogema BM, Molier M, Karregat JHM, Zaaijer HL, Reusken CBEM, *et al*. Low SARS-CoV-2 seroprevalence in blood donors in the early COVID-19 epidemic in the Netherlands. 2020;1–7.

31. van den Hurk K, Merz EM, Prinsze FJ, Spekman MLC, Quee FA, Ramondt S, *et al*. Low awareness of past SARS-CoV-2 infection in healthy plasma donors. Cell Reports Med [Internet]. 2021;2(3):100222. Available from: https://doi.org/10.1016/j.xcrm.2021.100222

32. Ng W, Rombo C, Yegon C, Kithi K, Odhiambo E, Rotich T, *et al*. Seroprevalence of anti – SARS-CoV-2 IgG antibodies in Kenyan blood donors. 2021;82(January):79–82.

33. Valenti L, Bergna A, Pelusi S, Facciotti F, Lai A, Tarkowski M, *et al*. SARS-CoV-2 seroprevalence trends in healthy blood donors during the COVID-19 outbreak in Milan. Blood Transfus. 2021;19(3):181–9.

34. Luiz Amorim Filho, Landmann C, Ii S. Seroprevalence of anti-SARS-CoV-2 among blood donors in Rio de Janeiro , Brazil. 2020;1–10.

35. Public Health England. Weekly Coronavirus Disease 2019 (COVID - 19) Surveillance Report: 23rd April 2020 (week 17). Summ COVID-19 Surveill Syst [Internet]. 2020;2019:1–26. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/880925/COVID19_Epidemiological_Summary_w17.pdf

36. Slot E, Hogema B, Reusken C, Reimerink J, Molier M, Karregat J, *et al*. Herd immunity is not a realistic exit strategy during a COVID-19 outbreak. 2020;1–15.

37. Liu A, Li Y, Wan Z, Wang W, Lei X, Lv Y. Seropositive Prevalence of Antibodies against SARS-CoV-2 in Wuhan, China. JAMA Netw Open. 2020;3(10):2020–2.

38. Chang L, Hou W, Zhao L, Zhang Y, Wang Y, Wu L, *et al*. The prevalence of antibodies to SARS-CoV-2 among blood donors in China. 2021;1–10.