SARS-CoV-2 Infection in Ivory Coast: A Serosurveillance Survey among Gold Mine Workers

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Abstract. Of the 107 million COVID-19 cases worldwide, less than 2 million have been reported in African countries. The aim of this study was to evaluate the seroprevalence of SARS-CoV-2 infection in Ivory Coast mine workers. From July 15 to October 13, 2020, a voluntary serological test campaign was conducted in 3 sites: two gold mines, and the headquarters in Abidjan. Rapid tests to detect IgG and IgM on capillary blood were performed. To identify independent sociodemographic characteristics associated with a higher SARS-CoV-2 seroprevalence rate, a multivariate logistic regression analysis was performed. A total of 1,687 subjects were tested; 91% were male ($n = 1,536$), and the mean age was 37 years. The overall seroprevalence was 25.1% ($n = 422$), ranging between 13.6% (11.2–16.1%), 34.4% (31.1–37.7%), and 34.7% (26.2–43.2%) in mine A, in mine B, and in Abidjan, respectively. Among the 422 seropositive subjects, 74 reported mild symptoms in the three previous months and one was hospitalized for severe COVID-19 infection. SARS-CoV-2 seroprevalence is high in both gold miners and administrative staff working in Ivory Coast. The burden of infection in West Africa has probably been underestimated till now.

COVID-19 represents an unprecedented international public health challenge responsible for significant morbidity and mortality. In March 2020, the WHO officially declared the COVID-19 pandemic. As of February 10, 2021, (SARS-CoV-2) caused 2,360,000 deaths of more than 107 million cases reported worldwide. Unfortunately, these numbers continue to increase every day.[1]

Officially, according to the latest February 7, 2021 WHO report, COVID-19 cases in Africa were 2,761,000 and COVID-19–related deaths were 65,736.[2]

Considering the daily increase in the number of COVID-19 cases all around the world, it appears that Africa is controlling the epidemic spread better than Europe, the United States, or South America. Catastrophic scenarios about potentially devastating effect of COVID-19 in Africa have fortunately not yet occurred. The reasons are multiple and not always clearly established.[3] Some authors argue that this epidemic reached Africa a few weeks after European and African leaders adopted preventive measures, thanks to acquired knowledge of what was happening in Europe, having probably learned important lessons from previous major outbreaks, like 2014 Ebola virus disease in West Africa. In addition, many parts of Africa are still isolated and not linked to significant tourism and international business-related traffic. However, according to recent data, SARS-CoV-2 serological positivity in South Africa appears to be so high that it approaches the herd immunity threshold (i.e., more than 60%).[4] Did SARS-CoV-2 infection largely and silently spread in Africa, or did factors such as environment, younger population, climate, and policies limit the penetration of the virus in most African countries? In this report, we present the results of a COVID-19 serological testing campaign conducted in Ivory Coast among employees of a gold mining company using a reliable rapid point-of-care antibody test.

The objective of this testing campaign was to sensitize and protect employees and their families, particularly when a recent SARS-CoV-2 infection was diagnosed.

SUBJECTS AND METHODS

The serological screening based on voluntary testing was conducted in the period between July 15 and October 13 in two mines and in the Abidjan headquarter mines A and B, located, respectively, at 500 km and 200 km northwest from the economic capital of the country (Abidjan). Three-thousand three hundred eighty people are currently working in these three sites, including the Abidjan headquarters. Of these 3,380 workers, 1,360 are direct employees and 2,020 are subcontractor's employees of different companies. Direct employees working in the mines live on site in a rather confined place, whereas the subcontractor's employees come back home in their villages/towns every day. Administrative staff and other workers located in Abidjan headquarters are mainly exposed to COVID-19 in their daily activities in contact with the Ivorian urban population of Abidjan.

All employees were informed about the objectives of the campaign and were invited to participate. No clinical criteria were required to be tested. Tests were performed at the different work sites by healthcare personnel according to the manufacturers' instructions after a 2-hour training session. For each participant, written informed consent was obtained. Test result was provided within 15 minutes. Each time a test is carried out, a data sheet is filled out including socio-professional characteristics, including age, gender, nationality, place of residence, and employment. Each completed form is entered into an Excel database, and photographs of positive assay results were saved.

A standardized questionnaire was filled for each subject, including age, gender, working status, and previous symptoms potentially related to a SARS-CoV-2 infection in the previous 5 months (i.e., fever, dyspnea, cough, flu-like syndrome, and anosmia/ageusia).

POINT-OF-CARE USED TEST

The COVID-PRESTO® SARS-CoV-2 IgG/IgM antibody test kit (AAZ LMB, Boulogne Billancourt, France) is a lateral flow

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immune-chromatographic assay targeting antibodies specific to the SARS-CoV-2 N-protein. It has been manufactured and marketed by AAZ-LMB and already approved by French authorities. This rapid diagnostic test (RDT) uses antihuman IgM antibodies (test line IgM), antihuman IgG antibodies (test line IgG), and rabbit IgG (control line C) immobilized on a nitrocellulose strip. The conjugate (recombinant SARS-CoV-2 antigens labeled with colloidal gold) is also integrated into the strip. When a specimen is well placed in the sample and the assay buffer is added, the IgM and IgG antibodies, if present, bind to the SARS-CoV-2 conjugates, forming an antigen–antibodies complex. This complex migrates through a nitrocellulose membrane by capillary action. When the complex meets the line of the corresponding immobilized antibodies (antihuman IgM and/or antihuman IgG), the complex is trapped and forms a burgundy-colored band confirming test result. Results must be read within 10 minutes by two independent operators. When the control line is the only one present, the sample is negative. If the control line does not appear, the test is invalid and should be repeated with a new cassette. The sensitivity of COVID-PRESTO test ranged from 10% for patients having experienced their first symptoms from 0 to 5 days earlier to 100% in patients whose symptoms occurred more than 15 days earlier.[5]

STATISTICAL ANALYSIS

Data were collected on an Excel spreadsheet. Data were categorized by mine site, gender, age, and working characteristics (i.e., direct employees versus subcontractor's employees). Qualitative and quantitative variables including the proportion of seropositivity were reported in percentage and a 95% CI. Multivariate logistic regression was used to determine the relationship between demographics characteristics and seropositivity to SARS-CoV-2. A P-value of less than 0.05 was regarded as statistically significant. Only statistically significant variables were introduced in the multivariate model. Analysis was carried out using R studio software.

ETHICAL CONSIDERATIONS

The GISPE Research and Ethical Committee approved the survey on May 15, 2020 (N° EC-GISPE014). Potential participants were informed about the campaign purpose and procedures.

RESULTS

Among the 3,380 employees, a total of 1,687 subjects (49.9%) were included in the study. Based on volunteering testing, only subjects who participate in the screening procedure were analyzed. One thousand five hundred thirty-five were males and 151 were females. The mean age was 37 (18–66) years; 1,566 employees (92.7%) worked in the mine sites and 121 (7.3%) in Abidjan. Among mining workers, 845 were direct employees living night and day in the compound (587 in mine A and 258 in mine B), and 718 were subcontractor's employees of other companies working in the mine during the day but coming back to village after work (213 in mine A and 501 in mine B). One thousand four hundred fifty-eight workers were native from Ivory Coast (86.4%), 143 from another African country (8.5%), and the remaining 87 (5.1%)

TABLE 1
Sociodemographic characteristics of the study population

Characteristics	Overall	Ity	Agbaou	Abidjan	P-value
N	1,687	803	763	121	
Gender ratio (M/F)	10.2	14.1	10.1	3.17	< 0.001
Mean age (SD) (years)	38 (8.6)	36 (8.3)	37 (8.7)	39 (9.7)	0.001
< 36	805	400	359	46	
36–49	733	338	336	59	NS
≥ 50	149	65	68	16	
Employee's status					
Direct employees	848	587	258	3	
Subcontractors	721	213	505	3	< 0.001
Administrative staff	118	3		115	

NS = not significant or $P > 0.05$.

came from 12 worldwide countries (details in Table 1). Subjects working in Abidjan were significantly older (63% older than 36 years), and the proportion of male workers was half compared with mine sites.

Among the 1,687 people included in the study, 422 had a positive serological test (either IgG and/or IgM). Overall, seroprevalence was 25.1%, and prevalence rates were similar when stratified by age or gender. According to the different working sites, seroprevalence was 34.4%, 34.7%, and 13.6% in mine A, Abidjan headquarters, and mine B, respectively. The seroprevalence rate was significantly lower in subcontractors' workers than in those living full time in the mines. Ivory Coast natives had the highest prevalence rate (26.5% [24.3–28.8%]). Conversely, people coming from countries outside Africa were less likely to be SARS-CoV-2 seropositive (details in Table 2).

Among the 422 seropositive subjects, only one had previously been hospitalized for suspected COVID-19. Eighteen additional subjects had mild symptoms and were diagnosed by a positive real-time reverse transcription–PCR (RT-PCR) test. Among the 404 remaining subjects, 74 reported mild nonspecific symptoms that may or may not be attributable to a SARS-CoV-2 infection, particularly in a tropical setting, but were not tested at the time of symptoms.

No data are available on those who were not yet tested at the time of analysis. Some were in vacation, some were not volunteers, and some were not available for any reason on the days of the screening procedure. Then, it was not possible to make any comparison between those tested and those not tested.

DISCUSSION

The current epidemiological study conducted on a specific African population reports SARS-CoV-2 seroprevalence as high as 35% in gold mining workers as well as in administrative staff living in Abidjan. This high seroprevalence rate was reached before July 2020, and it remained stable after the first pandemic wave, between July and October 2020. This silent outbreak was not previously detected because most cases were asymptomatic.

From March to December 1, 2020, Ivory Coast reported 21,250 SARS-CoV-2 infections and 127 COVID-19–related deaths, suggesting that only 0.084% of Ivory Coast's 25 million inhabitants had been infected.[2] Official available data do not reflect the burden of infection but may reflect the emerging part of the iceberg. To our knowledge, there are very few published studies evaluating SARS-CoV-2 seroprevalence in

TABLE 2
SARS-CoV-2 seroprevalence rates, odds ratios, and 95% CI according to sociodemographic characteristics plus adjusted odds ratio (logistic model)

| | | Univariate | | | Multivariate | |
	N	Prevalence [95% CI]	OR	P-value	aOR (95% CI)	P-value
Gender						
Female	151	25.2% [18.2–32.1%]	1.01 [0.94–1.09]		0.88 [0.58–1.3]	NS
Male	1,536	25% [22.8–27.2%]	0.99 [0.92–1.07]	NS	1	
Age (years)						
≤ 35	805	24.8% [21.9–27.8%]	0.98 [0.96–1.01]		1	
36–49	733	25.2% [22.1–28.4%]	1.02 [1–1.05]		1.04 [0.82–1.33]	NS
≥ 50	149	24.8% [17.9–31.8%]	0.99 [0.92–1.07]	NS	1.18 [0.75–1.82]	NS
Employees status						
Direct employees	848	33.3% [30.1–36.4%]	2.49 [2.4–2.56]		2.33 [1.8–3.1]	0.001
Subcontractors	721	13.7% [11.2–16.2%]	0.32 [0.3–0.33]	< 0.001	1	
Administrative staff	118	34.7% [26.2–43.3%]	1.66 [1.53–1.8]		1.58 [0.34–6.8]	NS
Country of origin						
Ivory Coast	1,458	26.5% [24.3–28.8%]	2 [1.86–2.15]		3.5 [1.9–7]	0.001
African other	143	16.1% [10.1–22.1%]	0.55 [0.5–0.6]	0.001	1.8 [0.9–4.2]	NS
Non-African	86	14% [6.6–21.3%]	0.47 [0.4–0.57]		1	
Location						
Mine A	803	34.4% [31.1–37.7%]	2.65 [2.58–2.72]		2.54 [1.9–3.35]	< 0.001
Mine B	763	13.6% [11.2–16.1%]	0.3 [0.3–0.3]	< 0.001	1	
Abidjan	121	34.7% [26.2–43.2%]	1.66 [1.53–1.8]		3.5 [0.8–16.4]	NS

OR = odds ratio.

African countries. In Togo, among 955 participants from five different sectors, the prevalence rate was 0.9% (95% CI: 0.4–1.8%).[6] In a study conducted in Kenya from April to June 2020 on 3,174 blood donors' samples, seroprevalence was 5.2% (95% CI: 3.7–7.1%).[7] In two small populations of household contacts and healthcare workers in Nigeria, seroprevalence rates were to 25.4% and 45%, respectively.[8,9] Among the available preprint or published studies, seroprevalence was evaluated using RDTs in three studies, ELISA in three studies, and Clinical Laboratory Improvement Amendments in one study.[6–12] A recent study aiming to detect the persistence of SARS-CoV-2 antibodies 3–4 months after the onset of symptoms in healthcare workers at the Strasbourg University hospital reported that ELISA serological test has a 59% sensitivity and Biosynex RDT a 85% sensitivity compared with the S-flow reference test developed by the French National Reference Center for SARS-CoV-2 infection (Pasteur Institute, Paris, France).[13] The RDT used in our study showed high sensitivity even more than 21 days after the onset of symptoms, as well as a 100% specificity in a study carried out independently from the manufacturer.[14] Hence, seroprevalence rates from studies using ELISA tests must be cautiously interpreted as they may underestimate the real data.

In our study, 14–35% of workers were SARS-CoV-2 seropositive, despite having no symptoms or at least no severe disease. These data appear to be quite different than those observed in the rest of the world, but similar results have already been described in Ibadan, Nigeria, in healthcare workers who are much more exposed to the infection than mine workers.[9] A high level of seropositivity was found in both mining workers and administrative staff living in the economic capital. In mine A, as people live together, a cluster phenomenon may have occurred, explaining the difference in seroprevalence with mine B, which was more confined during the first wave with limited circulation between mine B and Abidjan. Subjects living in mine B had the same life

habits as the African population living in Abidjan. Therefore, we can expect that this similar seroprevalence reflects the real one in Abidjan.

In mine B, subcontractors' workers constitute 67% of the working population compared with 29% in mine A. As subcontractors' worker do not live full time in the mine, the lower seroprevalence of this population could reflect a lower prevalence in rural areas of the country.

In the capital, seropositivity was 34.7% among the 121 subjects working in the administrative staff in Abidjan and having no contact with gold mines. These data could reflect the high SARS-CoV-2 seroprevalence in the general population living in Abidjan.

Nevertheless, the most surprising results of the current study are the low percentage of symptomatic cases and mortality rate. Some authors speculate that African SARS-CoV-2 seroprevalence data could be related to a younger population, a favorable climate, and possible preexisting immunity due to previous exposure to other coronaviruses.[14] In our study, the mean age was 37 years, and there was no increase in symptom incidence or hospitalization according to age range. Lipsitch et al.[15] explored four models of cross-reactive immunity. Implications for individuals based on the reduction of lung burden model are a reduction in the magnitude and duration of symptomatic/clinical disease without change in the upper respiratory tract SARS-CoV-2 viral load. This model could explain low clinical expression despite high prevalence rates in the population studied.

Relatively stable prevalence rates observed between July and September may indicate that the SARS-CoV-2 outbreak occurred as early as March or April as in Europe, mainly not to say exclusively from imported cases, and spread silently but rapidly across the country. The plateau observed since July could be related either to complete travel restrictions, to the end of the first epidemic wave as in Europe, to the nationwide control of the SARS-CoV-2 circulation, or may reflect other phenomena including preexisting immunity,

genetic factors, or other unexplained factors in the remaining population.

This study has some limitations. First, the included population is not representative of the general Ivoirian population, although subjects living in Abidjan have presumably similar habits to those of the Abidjan's population. Furthermore, the voluntary test may have selected people thinking to be more exposed to the virus, for example, people who previously had mild symptoms or had household contacts of a confirmed SARS-CoV-2 case. Being an operational protocol, screening was based on employee volunteering. There was therefore no refusal to be screened, but on the contrary, there was broad support. Third, even if COVID-PRESTO has an excellent diagnostic performance, diagnostic sensitivity decreases a few months after the infection, compared with the reference test S-Flow, and may therefore have underestimated the real seroprevalence.

In conclusion, the high SARS-CoV-2 prevalence rate among mining workers recruited for this study confirms a higher proportion of asymptomatic cases than that observed in Europe, South America, or the United States till now. Herd immunity could be achieved in Africa much easier than expected without generating a dramatic health crisis.

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