Original Article

Positive Rate of Serology and RT-PCR for COVID-19 among Community Residents and Healthcare Workers in Wuhan, China

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SUMMARY: This study aimed to evaluate the infection rate of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) among different populations in Wuhan, China. This cross-sectional survey-based study examined the results of SARS-CoV-2-specific serological tests and RT-PCR tests for 4,454 community residents and 4,614 healthcare workers performed from May 15 to May 29, 2020. The healthcare workers were classified as administrative and logistical staff ($n = 1,378$), non-first-line healthcare workers ($n = 2,630$), or first-line healthcare workers ($n = 606$) according to their frequency of contact with coronavirus disease (COVID-19) patients. The positive rates of SARS-CoV-2-specific IgG, IgM, and RNA were 2.9%, 0.4%, and 0.1% for the community residents and 3.3%, 0.6%, and 0.2% for the healthcare workers, respectively. There were no statistically significant differences between the rates of the two groups. Spearman's correlation analysis showed that the frequency of contact with COVID-19 patients negatively correlated with the positive rates of RT-PCR ($r_s = -0.036$, $P = 0.016$), but did not significantly correlate with the positive rates of IgM ($r_s = -0.006$, $P = 0.698$) or IgG ($r_s = 0.017$, $P = 0.239$). There was no statistically significant difference between the SARS-CoV-2-specific IgG, IgM, or RNA positive rates of the community residents and those of the healthcare workers. The positive rate of SARS-CoV-2 RNA was lower for the first-line healthcare workers than for the non-first-line healthcare workers and the administrative and logistical staff.

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread rapidly and caused a global pandemic of coronavirus disease (COVID-19). China was one of the first and most affected countries during the global outbreak. As of August 4, 2020, a total of 84,491 confirmed COVID-19 cases and 4,634 deaths due to COVID-19 in China had been reported (1). Among these, 50,343 confirmed cases and 3,869 deaths occurred in Wuhan (2). Although the current COVID-19 outbreak in China is effectively under control, some individuals, especially those who were asymptomatic

or experienced mild symptoms, may have not visited a clinic or an emergency room and thus failed to receive a diagnosis. This would have greatly undermined the prevention and control of the spread of the disease in China (3).

Real-time reverse transcriptase polymerase chain reaction (real-time RT-PCR) is a relatively simple, effective, and sensitive method for detecting viral RNA (4,5). In addition, serological testing can be used to detect IgM and IgG antibodies against SARS-CoV-2 (6). The IgG antibody can remain in convalescent COVID-19 patients up to 6 months after symptom onset (7). A recent study used host serological responses to estimate the cumulative infection prevalence of SARS-CoV-2 in China from March 9 to April 10, 2020. The results revealed that the seropositive prevalence rate was 3.8% in 714 healthcare workers, 3.8% in 346 hotel workers, and 3.2% in 219 members of healthcare workers' families in Wuhan (8). Mass viral RNA testing and serological testing can accurately evaluate SARS-CoV-2 infection in a population and help us understand the epidemiology of SARS-CoV-2 infection, the infectivity of SARS-CoV-2, and immunity to SARS-CoV-2. We analyzed the results of SARS-CoV-2-specific serological tests and RT-PCR tests of 4,454

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Table 1. Protection measures according to frequency of contact with COVID-19 patients

Healthcare group	Personal protective equipment
Administrative and logistical staff	Surgical mask and work clothes
Non-first-line healthcare workers	Work clothes, disposable hat, N95 respirators, single use gloves, and isolation gown if necessary
First-line healthcare workers	Work clothes, disposable hat, N95 respirators, single use gloves, single use waterproof protective clothing, and face shield or protective goggles

Table 2. Demographic characteristics and positive rates of serology and real-time RT-PCR tests in different populations

	Community residents <i>n</i> = 4,454 (%)	Healthcare workers <i>n</i> = 4,614 (%)	χ^2	<i>P</i> value	Odds Ratio (95%CI)
Male	2,220 (49.8)	1,371 (29.7)	383.904	<0.0001	–
Median age (years, $\pm$ SD)	36.89 ($\pm$ 10.811)	36.86 ($\pm$ 10.644)	–0.119	0.905 ¹⁾	–
IgG+	127 (2.9)	154 (3.3)	1.785	0.182	0.850 (0.670, 1.079)
IgM+	19 (0.4)	27 (0.6)	1.129	0.288	0.728 (0.404, 1.311)
RNA+	3 (0.1)	9 (0.2)	2.797	0.094	0.345 (0.093, 1.275)

¹⁾: *t*-test.

SD, standard deviation; CI, confidence interval.

community residents and 4,614 healthcare workers in Wuhan performed from May 15 to May 29, 2020. The findings showed the differences, or lack thereof, between SARS-CoV-2 infection in the community residents and the healthcare workers in Wuhan.

MATERIALS AND METHODS

Data collection: From May 15 to May 29, 2020, we enrolled for our study 4,454 community residents in Wuhan and 4,614 healthcare workers from a tertiary hospital located in Wuhan. Demographic data, including age, sex, and job title, were collected for each participant. According to their frequency of contact with COVID-19 patients, healthcare workers were classified as (i) administrative and logistical staff who were not in daily contact with patients, (ii) non-first-line healthcare workers who were in daily contact with non-COVID-19 patients, or (iii) first-line healthcare workers who were in daily contact with known COVID-19 patients or suspected patients in the fever clinic, designated wards, or intensive care units. The local protocols for infection prevention and control were developed and approved by experts from the infection control unit, following the World Health Organization (WHO) guidelines (Table 1). This study was approved by the Ethics Committee of Renmin Hospital of Wuhan University (No. WDRY2020-K073) and was exempt from the requirement of obtaining informed consent.

Laboratory measurements: We collected blood samples from each participant for SARS-CoV-2-specific serological tests and nasopharyngeal swabs for viral genome detection. Anti-SARS-CoV-2 IgG and IgM antibodies were detected using a diagnostic kit for IgM/

IgG antibodies against SARS-CoV-2 following the manufacturer's instructions (Colloidal Gold Method; Livzon Diagnostics Inc., Zhuhai, China). The presence of SARS-CoV-2 RNA in nasopharyngeal swab samples was determined via real-time RT-PCR assay using the Chinese Control and Prevention (China CDC) recommended kit (DAAN Gene Co., Ltd., Sun Yat-sen University, Guangzhou, China).

Statistical analysis: The statistical software package IBM SPSS Statistics 20.0 (IBM, Chicago, IL, USA) was used for statistical analysis. Continuous variables were expressed as mean $\pm$ standard deviation (SD) and categorical variables were expressed as counts (%). The statistical differences between the serology and RT-PCR results of the community residents and the healthcare workers were evaluated using the χ^2 test. The statistical differences between the serology and RT-PCR results of the different groups of healthcare workers were assessed using Spearman's correlation analysis. Statistical significance was defined as $P < 0.05$.

RESULTS

A total of 4,454 community residents and 4,614 healthcare workers were enrolled in this study. The demographics of the participants are presented in Table 2. There was a statistically significant difference between the two groups with respect to sex ($\chi^2 = 383.904$, $P < 0.0001$), but no significant difference with respect to age ($t = -0.119$, $P = 0.905$). The positive rates for SARS-CoV-2 IgG antibodies, IgM antibodies, and RNA were 2.9%, 0.4%, and 0.1% for the community residents and 3.3%, 0.6%, and 0.2% for the healthcare workers, respectively. There was no significant

Table 3. The results of serology and RT-PCR in different exposure groups of healthcare workers

Healthcare workers	Administrative and logistical staff workers <i>n</i> = 1,378 (%)	Non-first-line healthcare workers <i>n</i> = 2,630 (%)	First-line healthcare workers <i>n</i> = 606 (%)	<i>r_s</i>	<i>P</i> value
IgG+ (%)	43 (3.1)	84 (3.2)	27 (4.5)	0.017	0.239
IgM+ (%)	8 (0.6)	17 (0.6)	2 (0.3)	-0.006	0.698
RNA+ (%)	6 (0.4)	3 (0.1)	0 (0.0)	-0.036	0.016

difference between the positive rates of the community residents and those of the healthcare workers. Table 3 compares the positive rates of SARS-CoV-2 IgG antibodies, IgM antibodies, and RNA for the different groups of healthcare workers. The positive rates were 3.1%, 0.6%, and 0.4% for the administrative and logistical staff; 3.2%, 0.6%, and 0.1% for the non-first-line healthcare workers; and 4.5%, 0.3%, and 0% for the first-line healthcare workers, respectively. Spearman's correlation analysis showed that the apparent frequency of contact with COVID-19 patients negatively correlated with the positive rates of SARS-CoV-2 RNA ($r_s = -0.036$, $P = 0.016$) but did not significantly correlate with IgM ($r_s = -0.006$, $P = 0.698$) or IgG ($r_s = 0.017$, $P = 0.239$).

Twelve study participants (3 community residents and 9 healthcare workers) had positive results for SARS-CoV-2 RNA. Among them, 1 participant was also IgM positive and IgG positive, 6 participants were IgM negative and IgG positive, and 5 participants were IgM negative and IgG negative. A total of 259 participants were negative for RNA but positive for IgG or IgM antibodies, with 27 of them IgM positive and IgG positive.

DISCUSSION

SARS-CoV-2 has been shown to have greater transmissibility than SARS-CoV and MERS-CoV (9). The surge in new cases of COVID-19 placed healthcare workers under tremendous pressure in the early stages of the pandemic, especially in the epicenter, Wuhan (10). Healthcare workers were at a high risk of nosocomial infection. In a Wuhan-specific retrospective study, 59.1% of 110 healthcare workers with COVID-19 were thought to have been infected via contact with COVID-19 patients and 10.9% via contact with colleagues (11). Data from the municipal Notifiable Disease Report System show that there were 32 583 laboratory-confirmed COVID-19 cases, including 1496 healthcare workers, in Wuhan from December 8, 2019, to March 8, 2020 (12). By April 3, a total of 23 healthcare workers had died from COVID-19 in China, 18 of whom were from Wuhan (13).

The Chinese government has been working to improve prevention and control programs to curb outbreaks and save lives. With increased awareness of the need for personal protection, intensive training in infection control procedures, and rapid provision of medical assistance, SARS-CoV-2 infections among healthcare workers in Wuhan have gradually decreased. Our results showed that while the positive rates of IgG,

IgM, and RNA were slightly higher in the healthcare worker participants than in the community resident participants, these differences were not statistically significant (Table 2). The observed positive rates of IgG, IgM, and RNA among the healthcare workers were 3.3%, 0.6%, and 0.2%, respectively. Similarly, Xu et al. (8) reported that the positive rates of IgG, IgM, and RNA in 714 healthcare workers were 3.8%, 0.8%, and 0.7%, respectively.

Our study also found that the positive rate of SARS-CoV-2 RNA was higher in the non-first-line healthcare workers and nonclinical staff than in the first-line healthcare workers (Table 3), in agreement with the findings of previous studies. Hou et al. (14) showed that the seropositivity for SARS-CoV-2 antibodies (IgG, IgM, or both IgG and IgM) in healthcare workers in nonisolation medical areas (5.4%) and nonmedical areas (4.4%) in Wuhan was greater than that in healthcare workers in isolation areas (3.4%). Lai et al. (11) also found a greater infection rate in non-first-line healthcare workers than in first-line healthcare workers from Tongji Hospital in Wuhan (1.4% [93 of 6,574] vs. 0.5% [17 of 3,110]). One possible explanation for this finding is that the first-line healthcare workers were provided better personal protective equipment and more intensive training on infection control procedures than were the non-first-line healthcare workers and nonclinical staff. Therefore, it is vitally important that proper training on infection control and the use of personal protective equipment be increased for healthcare workers in both non-COVID-19 wards and nonclinical departments.

Mass screening of both symptomatic and asymptomatic healthcare workers can help guide infection prevention and control to reduce or prevent nosocomial transmission of SARS-CoV-2 (15). The mass screening reported here was a proactive approach for ensuring a safer medical environment and keeping the hospital operating normally during the pandemic (16).

The WHO recommended RT-PCR as the primary method for SARS-CoV-2 detection (17). In our study, 12 participants were positive for SARS-CoV-2 RNA. Among these 12 participants, only 1 was IgM positive and IgG positive. Interestingly, 6 of the 12 were IgM negative and IgG positive. We suspected that the IgM antibody level decreased to undetectable levels because of the long interval between infection and detection. Five participants were IgM negative and IgG negative, probably because there was not enough time to generate IgM and IgG antibodies (18,19). In this study, 259 cases were negative for RNA but IgG positive or IgM positive; 27 were both IgM and IgG

positive. One possible explanation for this is that the viral load decreased over time. Indeed, a previous study showed that the detectability of RNA decreased from 66.7% (58/87) within the first week of onset to 45.5% (25/55) within 15 to 39 days of sample collection (20). Therefore, the combination of RT-PCR testing and serological testing may be a more reliable method for diagnosing SARS-CoV-2 infection (21–23).

Our study had several limitations. First, the exposure levels of the healthcare workers were not precisely estimated. Second, the sensitivity of the serological tests may have been affected by the wide range of time between the onset of the disease and sample collection. Third, because of the cross-sectional design of the study, the dynamics of antibody levels in infected individuals could not be evaluated. Future long-term follow-ups will be important for estimating the role of serological markers in epidemiological investigations of COVID-19.

In conclusion, there were no statistically significant differences between the SARS-CoV-2-specific IgG antibody, IgM antibody, or RNA levels of the healthcare workers and those of the community residents in Wuhan from May 19 to May 25, 2020. The positive rate of SARS-CoV-2 RNA was lower for the first-line healthcare workers than for the non-first-line healthcare workers and nonclinical staff. Thus, it is essential to establish and maintain vigilance against nosocomial transmission and infection, even in COVID-19 wards and nonclinical departments.

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Conflict of interest None to declare.

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