ИНФЕКЦИОННЫЕ БОЛЕЗНИ
INFECTIOUS DISEASES

HIGH SEROPREVALENCE TO SARS-COV-2 AMONG HEALTHCARE AND NON-HEALTHCARE WORKERS OF THE OPHTHALMOLOGY CENTER

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ABSTRACT

Background. *The pandemic of COVID-19 raised safety concerns for healthcare workers while non-medical personnel were left unattended. Comparing the levels of seroprevalence to SARS-CoV-2 and vaccination in different employee groups will allows us to assess the risk of infection and develop a strategy to minimize the spread of infections in medical institutions in future.*

The aim. *To identify the level of seroprevalence to SARS-CoV-2 for seven groups of medical center workers.*

Methods. *The seroprevalence to SARS-CoV-2 was analyzed in 361 employees of the ophthalmology center in mid-2021. Data on the level of specific IgM and IgG antibodies were compared with questionnaire, including occupation data.*

Results. *Depending on occupation, workers were divided into seven groups. The average seroprevalence rate for all employees was 82.3 %, and the percentage of vaccinated employees was 27.4 %. The lowest level of seroprevalence was found in the group of maintenance staff (55.0 %) which is significantly lower ($p < 0.05$) than in the groups of doctors (84.4 %), nurses (85.6 %), administrative stuff (82.6 %) and cafeteria stuff (77.7 %). The seroprevalence rate for cleaning staff was 84.6 % and for pharmacy workers it was 80 %. The highest vaccination coverage was among doctors – 50.0 %, the lowest was among cafeteria and kitchen staff – 7.4 %.*

Discussion. *We believe the high seroprevalence is associated with asymptomatic spread of SARS-CoV-2.*

Conclusions. *High seroprevalence was among doctors and nurses, pharmacy workers, canteen workers, cleaners, as well as administration workers. Anti-epidemic measures for these groups will reduce the spread of infectious diseases and help retain staff during the seasonal increase in incidence.*

Key words: *SARS-CoV-2, seroprevalence, vaccination, healthcare workers, non-healthcare workers, IgM, IgG*

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ВЫСОКАЯ СЕРОПРЕВАЛЕНТНОСТЬ К SARS-COV-2 СРЕДИ МЕДИЦИНСКИХ И НЕМЕДИЦИНСКИХ РАБОТНИКОВ ОФТАЛЬМОЛОГИЧЕСКОГО ЦЕНТРА

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РЕЗЮМЕ

Обоснование. *Пандемия COVID-19 вызвала обеспокоенность по поводу безопасности медицинских работников, в то время как немедицинский персонал остался без должного внимания. Сравнение уровней серопревалентности к SARS-CoV-2 и вакцинации в разных группах сотрудников позволяет оценить риск заражения и разработать стратегию по минимизации распространения инфекций в медицинских учреждениях.*

Цель исследования. *Выявить риски заражения SARS-CoV-2 для всех групп работников медицинского центра.*

Методы. *В середине 2021 г. серопревалентность SARS-CoV-2 проанализировали у 361 сотрудника офтальмологического центра. Уровень специфических антител IgM и IgG сравнивали с данными, указанными в опроснике, включающем информацию о профессии.*

Результаты. *В зависимости от рода деятельности рабочие были разделены на 7 групп. Средний показатель серопревалентности среди всех сотрудников составил 82,3 %, а процент вакцинированных сотрудников – 27,42 %. Самый низкий уровень серопревалентности выявлен в группе обслуживающего персонала (55 %), что значительно ниже, чем в группах врачей (84,4 %), медсестёр (85,6 %), административного персонала (82,6 %) и работников столовой (77,7 %). Уровень серопревалентности среди уборщиков составил 84,6 %, а среди работников аптек – 80 %. Самый высокий охват вакцинацией был среди врачей (50 %), самый низкий – среди работников столовой (7,4 %).*

Обсуждение. *Мы считаем, что высокая заболеваемость связана с бессимптомным распространением SARS-CoV-2.*

Заключение. *Высокий риск заражения был у врачей и медсестёр, работников аптек, столовых, уборщиц, а также у работников администрации. Противоэпидемические мероприятия для этих групп позволят снизить распространение инфекционных заболеваний и помогут сохранить здоровье персонала в период сезонного роста заболеваемости.*

Ключевые слова: *SARS-Sov-2, серопревалентность, вакцинация, работники здравоохранения, сотрудники, не являющиеся работниками здравоохранения, IgM, IgG*

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INTRODUCTION

The COVID-19 pandemic, which began in China in late 2019, has been a major challenge for healthcare systems around the world. Medical personnel found themselves at an increased risk of infection due to numerous contacts associated with professional activities [1]. Infection of medical personnel occurred both as a result of contact with patients in infectious diseases departments of hospitals and through interaction with asymptomatic spreaders of infection when providing care not related to infectious diseases [2]. So, non-medical healthcare workers are also at increased risk of infection, as many of them also interact with large numbers of patients. Despite the fact that in non-infectious medical institutions, rules have been established prohibiting the admission of patients with signs of acute respiratory viral infection, patients with asymptomatic COVID-19 can infect staff and other patients, if the mandatory PCR test was done before the onset of asymptomatic disease. Factors influencing the level of seroprevalence in the group are low income, low education, and densely populated centers [3]. An analysis of similar factors was carried out in different countries of the world and the results differ significantly, because each country has its own specifics. Thus, in April 2021, among workers at a university hospital in Colombia, the overall seroprevalence was 35 % (35 % among medical personnel and 33 % among non-medical personnel) [4]. In 2020–2021 in Iran, the seroprevalence among healthcare workers at a children's hospital was 8.8 % of employees before vaccination, and 50 % after the second dose of the SARS-CoV-2 vaccine [5]. Seropositivity among North Carolinians by February 15, 2021, among health care workers and non-health care workers was 83 % and 49 %, respectively [6]. The seroprevalence study in 170 healthcare workers of infectious disease departments of the Arkhangelsk region providing medical care to COVID-19 patients in May 2021 revealed 91.2 % healthcare workers were seropositive to SARS-CoV-2 [7]. A study to assess seroprevalence to the SARS-CoV-2 virus among health care workers and workers at two industrial enterprises in Omsk was conducted at the end of 2020 [8]. Among medical workers, the proportion of people with a positive reaction to IgG was 73.1 %. In the control group, the proportion of seropositive people was 3.9 times less – 18.6 %.

Detection of SARS-CoV-2 in tears and conjunctival secretions of infected patients with conjunctivitis [9] has revealed a threat to ophthalmologists, as conjunctivitis can be the first symptom of COVID-19. Due to this feature, the incidence among ophthalmologists turned out to be high [10]. The prevalence of SARS-CoV-2 antibodies of workers of the Ophthalmic Unit of San Giuseppe Hospital was ranged from 4 to 8 % in the first and second wave, respectively [11]. Serum was tested for the qualitative presence of SARS-CoV-2 IgM and IgG antibodies and the difference between the frequency of SARS-CoV-2 positivity amongst team members and differences in the number of ambulatory visits was performed by the chi-square test. In our work we also used qualitative SARS-CoV-2 IgM and IgG antibodies test chi-square statistics.

By mid-2021, the first two waves of COVID-19 incidence ended in Novosibirsk and another rise began, associated with the arrival of the Delta variant in the region [12]. According to official data, by July 2021 in the Novosibirsk region (population 2.7 million people), 46,820 people have had an infection, which is only 1.7 % of the population of the Novosibirsk region [13]. Vaccination in risk groups, which included healthcare workers and people over 60 years of age, began at the end of 2020, after which the vaccine was available to everyone by mid-2021.

The Novosibirsk Branch of the S. Fyodorov Eye Microsurgery Federal State Institution provides surgical and other ophthalmological care. Patients with symptoms of acute respiratory viral infections (ARVI) are not allowed to undergo treatment. Both medical personnel (doctors, nurses) and non-medical workers (reception, cafeteria) work with patients. In addition, the center has specialists who maintain the building or are engaged in administrative work and do not have direct contact with patients. Compliance with anti-epidemic measures, such as wearing personal protective equipment (masks, gloves) and social distancing complied with current regulations.

Identifying the characteristics of SARS-CoV-2 seroprevalence among medical and non-medical workers using the example of an ophthalmology center can help formulate recommendations for protecting personnel of non-infectious healthcare institutions from infection during periods of increased risk of infectious diseases (influenza epidemics, seasonal rise of ARVI).

The aim of the study was to compare the seroprevalence level for SARS-CoV-2 infection among medical and non-medical staff of a non-COVID hospital during the second year of the new coronavirus infection pandemic.

MATERIALS AND METHODS

Blood sampling for analysis was carried out from July 5 to July 16, 2021. Voluntary informed consent was obtained from all 361 study participants. The study was approved by the Committee on Biomedical Ethics at the Federal Research Center of Fundamental and Translational Medicine (protocol No. 22-20).

All participants completed a short questionnaire and donated blood to determine the level of specific IgM and IgG antibodies to SARS-CoV-2. The questionnaire included full name, gender, age, whether they had COVID-19, whether they were vaccinated against SARS-CoV-2, and their occupation. The diagnosis of coronavirus infection was recorded verbally and was not confirmed by documents, so participants could be mistaken about the infection they had had. The vaccination was confirmed by documents.

Some study participants agreed to fill out an extended questionnaire, which included questions about gender, age, height, weight, vaccinations, occupation, lifestyle, comorbid conditions, and medications taken. Thus, 142 participants indicated their height and weight. Of the 361 participants, three did not indicate their occupation. De-

pending on the type of activity, workers were divided into 7 groups: doctors, nurses, administrative work, maintenance staff, cleaning stuff, cafeteria and kitchen stuff, and pharmacy.

Since our goal was to identify everyone who was infected with SARS-CoV-2 and could spread the infection, we determined not only IgG, which indicates a past infection, but also IgM, which indicates an early infectious process. The presence of specific IgM and IgG antibodies to SARS-CoV-2 was determined using qualitative reagent kits for the enzyme immunoassay detection of immunoglobulins of classes G and M to SARS-CoV-2 (the enzyme-linked immunosorbent assay (ELISA), "Vector-Best", Novosibirsk, Russia). All manipulations were carried out in accordance with the manufacturer's recommendations.

Initially, the presence of each type of antibody (IgM or IgG) was assessed separately. A negative result is up to 0.8, a positive result is above 1.1, a questionable result is from 0.8 to 1.1. Next, total antibodies were assessed for each study participant (IgM + IgG): seronegative – no antibody to SARS-CoV-2, seropositive – there is at least one type of antibodies to SARS-CoV-2. Questionable results were not included in the seroprevalence analysis. Anyone who received at least one dose of the SARS-CoV-2 vaccine was considered vaccinated. Statistical analysis was carried out using the online resource [14]. For measurement values that did not correspond to normal distribution, the significance of the difference was assessed using nonparametric statistical tests, including Pearson's chi-square (χ^2) test and Fisher's exact test. Confidence intervals were calculated using Epitools [15]. The proportion of positive results with 95 % Wilson confidence interval (95% CI) was used as a general characteristic of the immune layer in the corresponding institution.

RESULTS

The study included 285 women and 76 men. People aged 40 to 60 years predominated. Age distribution is shown in Table 1.

TABLE 1

THE NUMBER OF PARTICIPANTS OF DIFFERENT AGE

Age	Number
18–30 years	15
31–40 years	64
41–50 years	106
51–60 years	121
61–72 years	49

At the start of the study, 99 of 361 people had received at least one dose of the SARS-CoV-2 vaccine (27.4 %; 95% CI: 23.1–32.2). The average body mass index (BMI) among those who reported height and weight (142 participants) was 26.11 ± 0.837 kg/m^2.

Detection of specific IgM and IgG antibodies to SARS-CoV-2

By mid-2021, 286 employees of the S. Fyodorov Eye Microsurgery Federal State Institution (79.2 %; 95% CI: 74.7–83.1) already had antibodies to SARS-CoV-2 (Table 2). Of these, 83 were vaccinated (29.0 %; 95% CI: 24.1–34.5), and the rest received immunity as a result of the disease. Only 169 of them indicated in the questionnaire that they had suffered from COVID-19 (59.1 %; 95% CI: 53.3–64.6), six additionally reported that they required hospitalization (2.1 %; 95% CI: 1.0–4.5). The seroprevalence level among all S. Fyodorov Eye Microsurgery Federal State Institution employees, who indicated their profession, was 82.3 %. There was no difference in antibody to SARS-CoV-2 levels depending on age, gender, BMI, chronic diseases, comorbid conditions, and medications taken (χ^2 test).

We identified 61 seronegative S. Fyodorov Eye Microsurgery Federal State Institution employees (Table 2) (16.9 %; 95% CI: 13.4–21.1). It can be assumed that these people had not previously been vaccinated against SARS-CoV-2 and did not have COVID-19, but among them four were found who indicated that they had had COVID-19

TABLE 2

THE NUMBER OF EMPLOYEES OF THE CLINIC: SEROPOSITIVE/SERONEGATIVE TO SARS-COV-2, VACCINATED OR PREVIOUSLY HAD* COVID-19

Antibodies (IgM + IgG)	Total, *n*	Vaccinated, *n*	COVID-19, *n**
Seropositive	286	83	169
Seronegative	61	14	4
Questionable	14	2	4
Total	361	99	177

Note. * – according to questionnaires.

(6.6 %; 95% CI: 2.6–15.7) and 14 cases of absence of antibodies after vaccination (14.1 % of all vaccinated; 95% CI: 8.6–23.3). The absence of antibodies in six cases (6.1 %; 95% CI: 2.8–12.6) is explained by insufficient time elapsed after vaccination (less than 15 days). For three participants, 3.5 months, 5 months and 8 months had passed since vaccination; the rest 5 of 99 did not indicate the date of vaccination in the questionnaire.

Description of questionable results

The number of employees of the S. Fyodorov Eye Microsurgery Federal State Institution with different types of antibodies to SARS-CoV-2 is shown in Table 3.

A total of 52 study participants were identified with questionable results. Questionable IgG with positive IgM was detected in 2 study participants, one of them had COVID-19, the second one received the vaccine; questionable IgM with positive IgG was observed in 36 participants. All 38 were classified as seropositive (Table 2).

A questionable result, not supported by a positive one, was found in 14 people, among them: 2 people were vaccinated, 9 people had not previously COVID-19 and were not vaccinated, and 3 people had previously had COVID-19 but were not vaccinated. These individuals were excluded from the seroprevalence analysis.

According to questionnaires 202 or more had previously COVID-19, however, the course of the disease was not always in an obvious form. This is evidenced by the discrepancy between the status indicated in the questionnaire (had previously COVID-19/had not previously COVID-19) and the real immune status. The result of comparing the questionnaire data and the level of specific antibodies clearly demonstrate that a person cannot know for sure whether he or she has had previously COVID-19. Of the 12 people who doubted their answer to this question, 7 turned out to have antibodies (all are not vaccinated), and 5 – without antibodies (one is vaccinated), in addition, 56 people with antibodies indicated in the questionnaire that they were not sick and were not vaccinated, which means their coronavirus infection was mild or asymptomatic (of 106 not vaccinated and had not previously COVID-19, 52.8 %; 95% CI: 43.4–62.1). Thus, the answers to the question about previous COVID-19 cannot be considered reliable.

Four cases of absence of antibodies were found in people who indicated in the questionnaire that they had suffered from COVID-19. This may indicate both "self-diagnosis" and a fading of the immune response if too much time has passed since the illness. The possible extinction of the immune response is also indicated by the identification of three people in whom antibodies were not detected less than a year after vaccination, however, in most cases, antibodies persist for at least 480 days (Table 4).

TABLE 3

THE NUMBER OF EMPLOYEES OF THE S. FYODOROV EYE MICROSURGERY FEDERAL STATE INSTITUTION WITH DIFFERENT TYPES OF ANTIBODIES TO SARS-COV-2

IgM	IgG			
	Positive, *n*	Negative, *n*	Questionable, *n*	Total, *n*
Positive, *n*	103	13	2	118
Negative, *n*	132	61	3	196
Questionable, *n*	36	9	2	47
Total, *n*	271	83	7	361

TABLE 4

THE SEROPREVALENCE, THE NUMBER OF SEROPOSITIVE AND SERONEGATIVE PEOPLE AT DIFFERENT PERIODS FROM CONTACT WITH SARS-COV-2 (16 MONTHS, 103 PERSONS TESTED)

Days from contact*	Seropositive, *n*	Seronegative, *n*	Total, *n*	Seroprevalence, % (95% CI)
< 15	13	9	22	59.1 (38.7–76.7)
15–59	18	0	18	100.0 (82.4–100.0)
60–99	16	1	17	94.1 (73.0–99.0)
100–250	21	2	23	91.3 (48.3–79.6)
251–480	22	1	23	95.7 (79.0–99.2)

Note. * – in this table, the first day of exposure is considered to be either the first day of vaccine administration or the first day of COVID-19 illness, whichever comes first.

The persistence of high seroprevalence on days 251–480 after initial contact may be explained by the booster effect of repeated contact with the pathogen (vaccination, infection).

Seroprevalence to SARS-CoV-2 in different groups of employees of the S. Fyodorov Eye Microsurgery Federal State Institution

Since 358 people indicated their position in the questionnaire, we had the opportunity to study the impact of profession on the likelihood of becoming infected. We combined similar specialties for a more accurate analysis: a group of doctors, a group of nurses, administrative workers (with documents and on a computer), maintenance staff, cleaning stuff, pharmacy stuff and people working in a cafeteria and kitchen (Table 5).

The study involved 64 doctors working at the S. Fyodorov Eye Microsurgery Federal State Institution, including ophthalmologists, anesthesiologists-resuscitationist, and heads of the departments. Of the 43 ophthalmologists, only five do not have antibodies (one is not vaccinated); 22 managed to get vaccinated, of which 9 claim that they did not have COVID-19 before.

The percentage of vaccinated people among all the doctors turned out to be 50 % (64/344; 95 % CI: 73.6–91.3), which was significantly higher ($p < 0.05$) than in the groups "nurses", "administrative workers" and "cafeteria" (χ^2 tests respectively: 17.534, 7.087, 14.720). Among all the doctors, the most vaccinated were the heads of departments (66.7 %, 8/12; 95% CI: 39.1–86.2). Greater vaccination rate in this case can be explained by both medical education and the high responsibility of this group, which could lead to higher adherence to vaccination. We assume that ophthalmologists working with a large number of patients face to face have an increased risk of becoming infected compared to anesthesiologists and resuscitators at an ophthalmology center who constantly work in sterile rooms wearing a mask and gloves. The seroprevalence to SARS-CoV-2 among heads of departments was 75 %. The seroprevalence among all the doctors was 84.4 % (54/64; 95% CI: 74.6–91.3), which is significantly higher ($p < 0.05$) than in the maintenance staff group (χ^2 test 7.512).

Nurses, like doctors, often work in contact with infectious diseases. 146 nurses of the S. Fyodorov Eye Microsurgery Federal State Institution of various specializations took part in this study. The seroprevalence among all S. Fyodorov Eye Microsurgery Federal State Institution nurses was at the same level as that of doctors and amounted to 85.6 % (125/146; 95% CI: 79.0–90.4) which is significantly higher ($p < 0.05$) than in the maintenance staff group (χ^2 test 11.136). Of the 37 regular nurses, only 6 do not have antibodies, 9 are vaccinated. Operating room nurses and sister-hostess were the most committed to vaccination (33 % and 50 % vaccinated). Vaccination among all nurses was at the level of 21.2 % (31/146; 95% CI: 15.4–28.6) which is significantly lower ($p < 0.05$) than in the doctors' group (χ^2 test 17.534).

The group of administrative workers included people who work in offices in the same part of the clinic. Mainly they work on a computer with documents and work with people, but not in the same quantity as medical workers. The seroprevalence in this group did not differ significantly from doctors or nurses and was 82.6 % (57/69; 95% CI: 72.0–89.8) which is significantly higher ($p < 0.05$) than in the maintenance staff group (χ^2 test 6.556). Adherence to vaccination in this group was 27.5 % which is significantly lower ($p < 0.05$) than in the doctors' group (χ^2 test 7.087). The percentage of seropositive to SARS-CoV-2 chiefs, deputy directors or managers was the same as in the whole group.

TABLE 5

THE NUMBER AND PERCENTAGE OF S. FYODOROV EYE MICROSURGERY FEDERAL STATE INSTITUTION STAFF VACCINATED, SEROPOSITIVE OR SERONEGATIVE TO SARS-COV-2

Specialties	Total, *n*	Vaccinated, *n*	Seronegative, *n*	Seropositive, *n*	Seroprevalence, % (95% CI)	Vaccinated, % (95% CI)
Doctors	64	32	10	54	84.4 (73.6–91.3)	50 (38.1–61.9)
Nurses	146	31	21	125	85.6 (79.0–90.4)	21.2 (15.4–28.6)
Administrative workers	69	19	12	57	82.6 (72.0–89.8)	27.5 (18.4–39)
Maintenance staff	20	7	9	11	55.0 (34.2–74.2)	35.0 (18.1–56.7)
Cleaning	13	3	2	11	84.6 (84.6–95.7)	23.0 (8.2–50.3)
Cafeteria	27	2	6	21	77.8 (59.2–89.4)	7.4 (2.1–23.4)
Pharmacy	5	1	1	4	80.0 (37.6–96.4)	20.0 (3.6–62.4)
Total	344	95	61	283	82,3 %	27,6 %

The group of maintenance staff, which also included mechanics and drivers, was least susceptible to contact with SARS-CoV-2, because their work involves equipment and not contact with a large number of people. By mid-2021, the seroprevalence of SARS-CoV-2 in this group was only 55 % (11/20; 95% CI: 34.2–74.2), which was significantly lower ($p < 0.05$) than in the groups of "doctors", "nurses", "administrative work" (χ^2 tests, respectively: 7.512, 11.136, 6.556). Comparison of occupational subgroups showed that the lowest seroprevalence was among drivers (22 %). Out of 9 drivers, only two who were vaccinated and had antibodies, the rest had not COVID-19 before, were not vaccinated and did not had antibodies to SARS-CoV-2. Medical center drivers carry either their boss, thus contacting only one person, or cargo, some of them were on vacation due to a decrease in the amount of work during the lockdown period. Vaccination rate of all maintenance staff was 35 % (7/20; 95% CI: 18.1–56.7) which was significantly higher ($p < 0.05$) than in the cafeteria and kitchen group (χ^2 tests 5.650).

It also turned out that working in the fresh air (landscaping and cleaning the area) does not protect against SARS-CoV-2 infection – all three workers have antibodies, but according to the questionnaires they did not have COVID-19, therefore, they suffered it in an asymptomatic form.

The "cleaning" group was separated from maintenance staff or nurses, because has its own specifics of work. Cleaning personnel may be at risk of infection from contact with infected material. Although, with proper compliance with safety measures, these risks are quite low in the ophthalmology center, in contrast to specialized "COVID" hospitals. As we can see, the low infectious alertness among medical orderly is confirmed by the high seroprevalence in this group – 84.6 % (11/13; 95% CI: 84.6–95.7). The vaccination rate in this group was 23 % (3/13; 95% CI: 8.2–50.3).

As for kitchen and cafeteria workers, it can be assumed that bakers and cooks, as well as stockroom and cafeteria managers communicate less with visitors than waiters and cashiers; dishwashers are at increased risks, because they come into contact with dishes that may carry SARS-CoV-2.

It turned out that seroprevalence among kitchen and cafeteria workers was indeed lower among cooks (70 %) and higher among waiters and dishwashers (80 and 83.3 %), however, these differences were not significant. The average seroprevalence among kitchen and cafeteria workers was 77.8 % (21/27; 95% CI: 59.2–89.4). But the vaccination rate among them turned out to be the lowest among all groups and amounted to only 7.4 % (2/27; 95% CI: 2.1–23.4). It is significantly lower ($p < 0.05$) than in the doctors and maintenance staff groups (χ^2 tests: 14.720 and 5.650).

Another group with increased infectious risks is pharmacy staff. Of the five people, only the pharmacy manager did not have antibodies to SARS-CoV-2. The seroprevalence thus turned out to be at the level of doctors and amounted to 80 % (4/5; 95% CI: 37.6–96.4). Pharmacy staff vaccination rates were among the lowest (20 %, 1/5; 95% CI: 3.6–62.4), but no significant differences were found from other groups.

In Figure 1 we have combined all the information we received. The vaccination rate (pink), percentage of employees without antibodies to SARS-CoV-2 (blue) and percentage of employees with antibodies but not vaccinated (red) are shown for seven groups of S. Fyodorov Eye Microsurgery Federal State Institution staff.

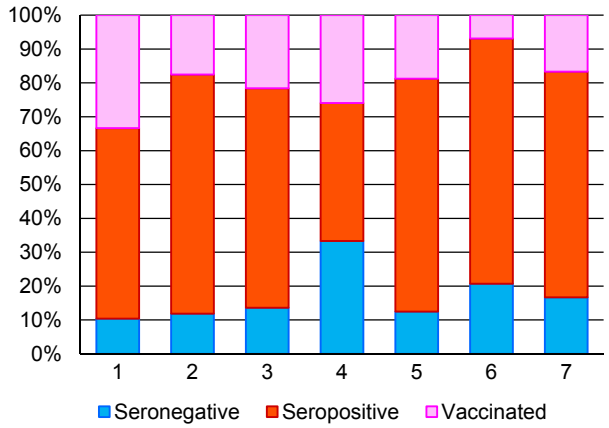

FIG. 1.

Percentage of seronegative (blue), seropositive not vaccinated (red) and seropositive vaccinated (pink) in different groups of ophthalmology center employees: 1 *– doctors (n = 64);* 2 *– nurses (n = 146);* 3 *– administrative workers (n = 69);* 4 *– maintenance staff (n = 20);* 5 *– cleaning (n = 13);* 6 *– cafeteria and kitchen (n = 27);* 7 *– pharmacy (n = 5)*

The group of doctors is distinguished by a significantly higher level of vaccination compared to the nurses, administration and cafeteria and kitchen groups and a significantly higher seroprevalence compared to the group of maintenance staff ($p < 0.05$). The group of maintenance staff has a significantly lower ($p < 0.05$) seroprevalence compared to the groups of doctors, nurses and administration, and has a significantly higher ($p < 0.05$) level of vaccination compared to the cafeteria and kitchen group.

DISCUSSION

Our results are in good agreement with earlier works showing the appearance of neutralizing antibodies to SARS-CoV-2 within the first two weeks of the onset of illness or vaccination [16], then they peak after a month, and begin to decline three months after the onset of symptoms [17]. However, in our work we show that in most employees of the ophthalmology center, antibodies persist much longer than described in the first works on the dynamics of antibodies in COVID-19. We suggest it may be explained by the fact that at the beginning of the pandemic, the number of infected carriers of SARS-CoV-2 in the population was small, quarantine measures were in force eve-

rywhere, and a person who had recovered from the disease had a low probability of encountering the virus again. In addition, there was no vaccination capable of renewing fading immunity.

The incidence of COVID-19 showed a higher risk of infection for healthcare workers [1, 18, 19]. Several studies have shown a high seroprevalence in healthcare workers, which is in good agreement with our results [1, 4, 5, 18–21]. Healthcare workers whose job was in contact with patients had a higher percentage of SARS-CoV-2 infection when compared with those not in direct contact, also being a health care worker was significantly associated with getting a positive COVID-19 PCR result [22]. The wide variation in seroprevalence values in different medical organizations may indicate different levels of effectiveness of anti-epidemic measures [1, 6, 20, 21]. By mid-2021, mass vaccination began, quarantine restrictions were relaxed, and there were more asymptomatic carriers in the population due to an increase in the total number of cases [2].

Unlike most people, healthcare workers are more often in contact with patients, so we suggest they have constant additional immunization. Thus, by constantly being immunized in contact with numerous patients, even if they do not have obvious symptoms of ARVI, doctors may retain antibodies against SARS-CoV-2 longer.

When processing personal data and matching them with serological results, we noticed that the patient may be mistaken both about the absence and presence of diseases or their previous conditions. Taking an anamnesis in most cases includes interviewing the patient, but the reliability of such information may be low even if the patient does not intend to deceive the doctor. It is important to take this into account and, if possible, use more objective criteria, such as PCR or antibody test for assessing immunity to infectious diseases.

Measures to protect medical and non-medical personnel must consider all risk factors [19]. The formation of a serological response in healthcare workers is an important criterion for assessing the risks of SARS-CoV-2 and other infection [20]. In early 2020, WHO launched a prospective study and validated a protocol to evaluate potential risk factors for COVID-19 among healthcare workers in a health care facility caring for patients with confirmed COVID-19 [23]. As we show in our study, non-health care workers of the clinic and health care workers not involved in COVID-19 care also have increased probability of contact with a virus carrier. Although the risk of becoming infected in an ophthalmology center with proper safety measures should have been quite low, unlike specialized "COVID" hospitals, the seroprevalence to SARS-CoV-2 among doctors, nurses, cleaning, cafeteria and pharmacy stuff and administrative workers turned out to be unexpectedly high. This could have happened because since the beginning of the pandemic, the spread of new coronavirus infection has occurred not only through patients with obvious symptoms, but also due to the presence of asymptomatic carriers of SARS-CoV-2.

CONCLUSIONS

A retrospective analysis of screening for antibodies to SARS-CoV-2 at the height of the pandemic (summer 2021), supported by questionnaires, revealed differences in seroprevalence, vaccination and incidence of new coronavirus infection depending on profession. Not only doctors and nurses, but also non-medical staff of the ophthalmology center had a high seroprevalence to SARS-CoV-2. Anti-epidemic measures for these groups will reduce the spread of infectious diseases and help retain staff during the seasonal increase in incidence. The percentage of people with antibodies to SARS-CoV-2 6 months after vaccination or COVID-19 differs in beginning and the height of the pandemic.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Committee on Biomedical Ethics at the Federal Research Center of Fundamental and Translational Medicine (protocol No. 22-20, November 6, 2020).

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Data availability statement

The data presented in this study are available on request from the corresponding author due to ethical and privacy.

Conflicts of interest

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

REFERENCES

1. Liviero F, Volpin A, Furlan P, Battistella M, Broggio A, Fabris L, et al. The impact of SARS-CoV-2 on healthcare workers of a large University Hospital in the Veneto Region: Risk of infection and clinical presentation in relation to different pandemic phases and some relevant determinants. *Front Public Health*. 2023; 11: 1250911. doi: 10.3389/fpubh.2023.1250911

2. Palyanova N, Sobolev I, Alekseev A, Glushenko A, Kazachkova E, Markhaev A, et al. Genomic and epidemiological features of COVID-19 in the Novosibirsk Region during the beginning of the pandemic. *Viruses*. 2022; 14(9): 2036. doi: 10.3390/v14092036

3. Metzger C, Leroy T, Bochnakian A, Jeulin H, Gegout-Petit A, Legrand K, et al. Seroprevalence and SARS-CoV-2 invasion in general populations: A scoping review over the first year of the pandemic. *PLoS One*. 2023; 18(4): e0269104. doi: 10.1371/journal.pone.0269104

4. Moreno-Medina K, Sáenz Pérez LD, Villar JC, Váquiro Herrera E, Pérez Franco JE, Varón-Vega FA, et al. SARS-CoV-2 seroprevalence in workers from a Colombian University Hospital. *Occup Med (Lond)*. 2023; 73(3): 128-132. doi: 10.1093/occmed/kqad003

5. Tariverdi M, Mohammadi H, Hassanzadeh F, Tamaddondar M. Seroprevalence of anti-SARS-CoV-2 IgG antibodies pre- and post-COVID-19 vaccination in staff members of Bandar Abbas Children's Hospital. *BMC Infect Dis*. 2024; 24(1): 253. doi: 10.1186/s12879-023-08863-z

6. Williamson JC, Wierzba TF, Santacatterina M, Munawar I, Seals AL, Pittman Ballard CA, et al.; North Carolina sites of the COVID-19 Community Research Partnership. Analysis of accumulated SARS-CoV-2 seroconversion in North Carolina: The COVID-19 Community Research Partnership. *PLoS One*. 2022; 17(3): e0260574. doi: 10.1371/journal.pone.0260574

7. Krieger EA, Samodova OV, Schepina IV, Shagrov LL, Zvezdina YuM. Humoral immunity to new coronavirus infection and vitamin D level in healthcare workers. *Journal Infectology*. 2023; 15(2): 93-104. (In Russ.) doi: 10.22625/2072-6732-2023-15-2-93-104

8. Blokh AI, Panyushkina II, Pakhtusova PO, Sergeeva IV, Levahina LI, Burashnikova IP, et al. Assessment of seroconversion to SARS-CoV-2 in health care unit personnel. *Epidemiology and Vaccinal Prevention*. 2021; 20(5): 32-38. (In Russ.) doi: 10.31631/2073-3046-2021-20-5-32-38

9. Xia J, Tong J, Liu M, Shen Y, Guo D. Evaluation of coronavirus in tears and conjunctival secretions of patients with SARS-CoV-2 infection. *J Med Virol*. 2020; 92(6): 589-594. doi: 10.1002/jmv.25725

10. Lacorzana J, Ortiz-Perez S, Rubio Prats M. Incidence of COVID-19 among ophthalmology professionals. *Med Clin (Barc)*. 2020; 155(5): 225. doi: 10.1016/j.medcli.2020.05.018

11. Sacchi M, Lizzio RAU, Villani E, Tagliabue E, Monsellato G, Pajardi G, et al. Prevalence of SARS-CoV-2 amongst ophthalmologists throughout the first and second waves of the pandemic. *Medicine (Baltimore)*. 2021; 100(50): e28192. doi: 10.1097/MD.0000000000028192

12. Palyanova NV, Sobolev IA, Palyanov AY, Kurskaya OG, Komissarov AB, Danilenko DM, et al. The development of the SARS-CoV-2 epidemic in different regions of Siberia in the 2020–2022 period. *Viruses*. 2023; 15(10): 2014. doi: 10.3390/v15102014

13. *Yandex DataLens*. URL: https://datalens.yandex/7o7is1q6ikh23?tab=X1&state=42db05f5180 [date of access: 7.05.2024].

14. Analysis of four-field contingency tables (comparison of percentages in two groups) (online calculator). *Medstatistic*. (In Russ.). URL: https://medstatistic.ru/calculators/calchi.html [date of access: 7.05.2024].

15. *Calculate confidence limits for a sample proportion*. URL: https://epitools.ausvet.com.au/ciproportion [date of access: 1.12.2024].

16. Post N, Eddy D, Huntley C, van Schalkwyk MCI, Shrotri M, Leeman D, et al. Antibody response to SARS-CoV-2 infection in humans: A systematic review. *PLoS One*. 2020; 15(12): e0244126. doi: 10.1371/journal.pone.0244126

17. Wang K, Long QX, Deng HJ, Hu J, Gao QZ, Zhang GJ, et al. Longitudinal dynamics of the neutralizing antibody response to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. *Clin Infect Dis*. 2021; 73(3): e531-e539. doi: 10.1093/cid/ciaa1143

18. Fatkhutdinova LM, Badamshina GG, Sizova EP, Patyashina MA, Stavropolskaya LV, Gabidinova GF, et al. Immune response to SARS-CoV-2 and the risk of COVID-19 among different groups of healthcare workers. *Russian Journal of Occupational Health and Industrial Ecology*. 2021; 61(5): 286-304. (In Russ.). doi: 10.31089/1026-9428-2021-61-5-286-304

19. Wiggen TD, Bohn B, Ulrich AK, Stovitz SD, Strickland AJ, Naumchik BM, et al. SARS-CoV-2 seroprevalence among healthcare workers. *PLoS One*. 2022; 17(4): e0266410. doi: 10.1371/journal.pone.0266410

20. Agafonova EV, Kulikov SN, Reshetnikova ID, Tyurin YuA, Gilyazutdinova GF, Lopushov DV, et al. Seroprevalence study results to SARS-CoV-2 in healthcare workers: age and professional aspects. *Epidemiology and Vaccinal Prevention*. 2021; 20(2): 49-57. (In Russ.). doi: 10.31631/2073-3046-2021-20-2-49-57

21. de Visscher N, Holemans X, Gillain A, Kornreich A, Lagasse R, Piette P, et al. SARS-CoV-2 seroprevalence among healthcare workers after the first and second pandemic waves. *Viruses*. 2022; 14(7): 1535. doi: 10.3390/v14071535

22. Ige FA, Ohihoin GA, Osuolale K, Dada A, Onyia N, Johnson A, et al. Seroprevalence of SARS-CoV-2 IgG among healthcare workers in Lagos, Nigeria. *PLoS One*. 2023; 18(10): e0292440. doi: 10.1371/journal.pone.0292440

23. WHO. *Protocol for assessment of potential risk factors for coronavirus disease 2019 (COVID-19) among health workers in a health care setting. Version: 2.2.* 2020. WHO/2019-nCoV/HCW_risk_factors_protocol/2020.3

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