UDC 613.6: 616.9: 578.834.1
DOI: 10.21668/health.risk/2022.2.13.eng

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Research article

RISKS OF BECOMING INFECTED WITH SARS-COV-2 FOR MEDICAL PERSONNEL IN A LARGE INDUSTRIAL CITY DURING THE PANDEMIC: COMPARATIVE ASSESSMENT

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The COVID-19 pandemic has produced its effects on functioning of all the state institutions, the public healthcare system being a peculiar one among them. Medical personnel have become an unprotected population group that was actively involved into the epidemic process. Results produced by several studies indicate that relative risks to become infected with COVID-19 are by up to 11.6 times higher for medical personnel than in population at large. A share of medical personnel among patients with COVID-19 varies in different countries, from 4.2 % in China to 17.8 % in the USA. According to official statistics, in 2020 a share of medical personnel who became infected with COVID-19 in in-hospital foci amounted to 68.6 % in the RF regions located in the Urals and Siberian Federal Districts.

High epidemic potential of the virus and intensive mass contacts between medical personnel and their patients make for rapid SARS-CoV-2 spread and infection among them. It is vital to examine all the range of risk factors that cause SARS-CoV-2 infection among medical personnel.

The present study involved using "The map of epidemiological investigation focused on the incidence of the new coronavirus infection (COVID-19) in medical personnel". The map was located on Google Cloud Platform. Overall, 613 medical workers from different medical organizations took part in the research. We applied sociological, epidemiological and statistical research techniques.

We established that work in an infectious diseases hospital increased a relative risk of SARS-CoV-2 infection by 1.8 times (RR = 1.78; 95 % CI [1.65–1.93]). The total risk of SARS-CoV-2 infection was insignificant for workers employed at a medical organization that provided scheduled medical assistance to population (RR = 1.02; 95 % CI [1.00–1.04]). However, certain factors created elevated risks of infection. Any contacts with COVID-19 patients who were close relatives, friends or neighbors were established to be significant (RR = 1.13; 95 % CI [1.04–1.228]).

The research results should be used when organizing work procedures and anti-epidemic activities in infectious diseases hospitals and medical organizations providing scheduled assistance to population. The focus should be on providing medical personnel with personal protective equipment as well as on calculating relevant duration of a work shift relying on the risk-based approach.

Keywords: *pandemic, COVID-19, SARS-COV-2, medical personnel, risk factors of infection, risk-based approach.*

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Pandemic spread of the SARS-CoV-2 virus has influenced functioning of all the state institutions. Public healthcare systems have faced extreme loads in all countries, the Russian Federation included. As of March 01, 2022, more than 438.5 million cases of the infection were registered all over the world; 432.5 million people recovered and 5.9 million died. In the Russian Federation, approximately 16.5 million people became infected and 352.4 thousand of them died. In Sverdlovsk region, 355.3 thousand infection cases and 10.3 thousand fatal outcomes were registered[1].

Medical personnel are exposed to impacts exerted by variable biological factors due to their occupational activities. The SARS-CoV-2 virus is no exception, since it can be considered, among other things, a healthcare-associated infection (HAI). Medical personnel have been at the forefront of fighting against COVID-19 from the very beginning and have become the most unprotected population group that is involved into the epidemic process the most actively [1–3].

There is no sufficient information on COVID-19 incidence among medical personnel; however, some official data highlight that the SARS-CoV-2 infection spreads among the examined occupational group much more actively. Thus, according to official data on registered HAIs cases in the regions included into the Ural and Siberian Federal Districts in 2020, medical personnel accounted for 68.8 % among those who became infected with SARS-CoV-2 in hospital; COVID-19 incidence among them reached 90.4–151.48 per 1000 workers in some regions[2].

Results produced by some research works indicate that medical personnel who have contacts with patients releasing SARS-CoV-2 face by 11.6 times higher risks of infection than population at large [4]. Most researchers work with data on a share of infected medical personnel in the overall structure of COVID-19 patients. Thus, for example, in China a share of infected medical workers amounted to 4.2 % (in particular, 11.9 % in Wuhan); in Italy, 9.0 %, and in the USA, 17.8 %. A study that concentrated on COVID-19 incidence among medical personnel in Italy mentioned 20 % of infected workers among personnel [5–7].

High epidemic potential of the virus as well as close contacts with both co-workers and patients contribute to SARS-CoV-2 infection among medical personnel [3, 8]. In its turn, there are no sufficient data on risks of the infection spread among medical personnel working in different healthcare organizations, for example, infectious diseases hospitals for treating COVID-19 patients or medical organizations that provide scheduled medical aid to population. It is vital to examine the whole range of risk factors causing SARS-CoV-2 infection in detail depending on conditions at workplaces.

Our research goal was to comparatively assess risks of SARS-CoV-2 infection for medical personnel working in different healthcare organizations in a large city during the COVID-19 pandemic.

Materials and methods. The study was accomplished by experts from the Ural-Siberian Scientific Methodical Center for healthcare-Associated Infections Prevention of Rospotrebnadzor's State Research Center of Virology and Biotechnology VECTOR together with experts from the Center for Public Health and Medical Prevention (Ekaterinburg).

The present study involved using "The map of epidemiological investigation focused on the incidence of the new coronavirus infection (COVID-19) in medical personnel" to examine risk factors of infection (hereinafter the Map). It was developed by experts from the Rospotrebnadzor's State Research Center of

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Virology and Biotechnology VECTOR[3]. The Map consisted of seven sections and contained both open and close-ended questions. It was located on Google Cloud Platform and the link to it (URL) was distributed among medical personnel by corporate email and messengers.

We applied sociological, epidemiological (descriptive-estimative and analytical) and statistical procedures in our study.

We estimated whether respondents were equipped with full sets of relevant personal protective equipment (PPE) and used them properly; the estimates relied on the following criteria:

– a full PPE set included protective overall, hat, shoe covers, two pairs of gloves, FFP2 or FFP3 respirator, safety goggles that formed a complete seal around the eyes or a mask that covered the face completely;

– a PPE set without complete protection of the eyes lacked safety goggles with a complete seal or a mask covering the face completely;

– a PPE set without complete protection of the respiratory organs lacked FFP2 or FFP3 respirators (only facemasks or shields were applied etc.).

We estimated whether PPE was replaced with proper regularity using the following criteria: a PPE set should not be used for longer than 4 hours and a mask, longer than 2–3 hours[4]. Contacts a medical worker had with people infected with COVID-19 (relatives, friends, neighbors, co-workers or patients) were established by analyzing a respondent's epidemiological case history taken from the Map.

The obtained data were given as absolute and relative values (%) and were analyzed using conventional statistical procedures. To compare likelihood of an outcome, depending on various risk factors, we created a fourfold contingency table, calculated a relative risk (*RR*) and its 95 % confidence interval (CI).

The differences were considered authentic at $p \leq 0.05$. All the data were statistically analyzed with Microsoft Office 2010, WinPEPI 11.65 software package and "Medical statistics" [5].

Results. Overall, 613 medical workers employed by 18 medical organizations in Yekaterinburg took part in the questioning. They all had previously had COVID-19 (confirmed by laboratory tests); 28 of them (4.6 %) were supervisors at medical organizations (MO), 161 (26.3 %) doctors, 345 (56.3 %) nurses and 26 (4.2 %) medical assistants, 8 (1.3 %) administrative staff, and 45 (7.3 %) other staff of various sex, age and with different work records. Personnel employed at infectious diseases hospitals accounted for 19.1 % (117 people) of the respondents; the remaining 80.9 % (496 people) were employed at MO that provided scheduled medical aid to population. People of employable age (20–55 years) prevailed among infected medical workers and accounted for 79.8 % (489 people). Respondents of both sexes took part in the questioning; however, women prevailed among them (84.2 %) and this was quite typical for public healthcare.

Our study established certain differences in risk factors causing infection spread among

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[5] Meditsinskaya statistika: internet-portal [Medical statistics: Internet-portal]. Available at: https://medstatistic.ru/ (February 04, 2022) (in Russian).

medical personnel depending on working conditions.

Women accounted for 83.9 % (98 people) among medical personnel employed at infectious diseases hospitals; men, 16.2 % (19 people). We did not detect and significant sex-dependent risks of SARS-CoV-2 infection among medical personnel (Table 1).

The age structure of medical personnel employed at infectious diseases hospitals was as follows: 25 workers were aged 20–29 years (21.4 %); 17 workers, 30–39 years (14.5 %); 38 workers, 40–49 years (32.5 %); 19 workers, 50–54 years (16.2 %); 12 workers, 55–59 years (10.3 %); 5 workers, 60–64 years (4.2 %), one workers was aged 65 and older (0.9 %).

We analyzed the occupational structure of medical workers from infectious diseases hospitals and established that MO supervisors accounted for 3.4 % (4 workers); doctors, 18.8 % (22 workers); nurses, 59.8 % (70 workers); medical assistance and janitors, 11.1 % (13 workers); administrative staff, 0.9 % (1 worker); other staff, 6.0 % (7 workers). We detected a significant risk of SARS-CoV-2 infection for those workers employed at infectious diseases hospitals who dealt with cleaning (*RR* = 2.822, 95 % CI [1.85–4.304]).

Medical personnel employed at infectious diseases hospitals had certain hazardous occupational contacts typical for medical care. These contacts involved risky aerosol-generating procedures such as trachea intubation, artificial ventilation (AV), oxygenation with high precision, inhalations, tracheabronchial tree sanitation, taking sputum/smears from the nasopharynx, tracheostomy, bronchoscopy, and cardiopulmonary resuscitation (CPR). Forty-four workers (37.6 %) participated in them. Overall, 92 workers (78.6 %) provided medical aid to COVID-19 patients. Eighty-eight workers (75.2 %) had direct contacts with the environment influenced by an infected patient (personal things, bed linen, a bed, a bedside table etc.). We established a significant risk of infection for all the aforementioned types of contacts. Thus, when a medical worker was present during an aerosol-generating procedure provided to a COVID-19 patient, it increased a risk of infection by 3.1 times (*RR* = 3.129, 95 % CI [2.304–4.25]). When a medical worker directly provided medical aid to a COVID-19 patient, a risk of infection grew by 4.1 times (*RR* = 4.072, 95 % CI [2.695–6.152]). Contacts with the environment influenced by COVID-19 patients (for example, objects they touched or used) resulted in 3.9 times higher risks of infection (*RR* = 3.881, 95 % CI [2.632–5.721]).

One worker (0.9 %) employed at an infectious diseases hospital did not use PPE when contacting COVID-19 patients. Seventy-five workers (64.1 %) used full PPE sets that protected the respiratory organs and eyes and included protective overalls, FFP2/FFP3 respirators, and safety goggles with a complete seal around the eyes. Fifteen workers (12.8 %) employed at infectious diseases hospitals used PPE sets without proper protection for the eyes or respiratory organs. Twenty-three workers (19.7 %) employed at infectious diseases hospitals mentioned not having safety goggles with a complete seal or a mask that covered the whole face in their PPE sets. Protection of the respiratory organs (FFP2 or FFP3 respirators) was absent in PPE sets used by four workers (3.4 %). Only 70.9 % of the workers replaced their PPE sets as regularly as it was stipulated by the existing standards. Use of PPE sets without full protection provided for the eyes and with full protection provided for the respiratory organs increased risks of SARS-CoV-2 infection for medical personnel at infectious diseases hospitals by 1.7 times (*RR* = 1.678, 95 % CI [1.137–2.477]). Failure to replace PPE sets according to the standardized regularity also influenced risks of infection (*RR* = 2.761, 95 % CI [1.923–3.964]).

Thirty-eight workers (33.0 %) had to work in a “red zone” for 6 hours; 5 workers (4.3 %), from 6 to 8 hours; 27 workers (23.5 %), from 8 to 12 hours; and 44 workers (38.3 %), from 12 to 24 hours. One worker (0.9 %) employed at an infectious diseases hospital had a work shift that exceeded 24 hours. We established a risk of SARS-CoV-2 infection to grow as a work shift became

Table 1

Risks of SARS-CoV-2 infection for workers employed at infectious diseases hospitals treating COVID-19 patients

No.	Indicator	Number of healthcare workers with laboratory-confirmed COVID-19	*RR* (relative risk)	95 % CI
sex				
1	men	19	1.031	0.664–1.603
2	women	98	0.97	0.624–1.507
age				
3	20–29 years	25	1.03	0.692–1.531
4	30–39 years	17	0.842	0.527–1.345
5	40–49 years	38	1.214	0.86–1.713
6	50–54 years	19	1.221	0.791–1.885
7	55–59 years	12	1.034	0.605–1.767
8	60–64 years	5	0.607	0.262–1.405
9	65 years and older	1	0.243	0.036–1.657
position				
10	supervisors	4	0.74	0.294–1.86
11	doctors	22	0.65	0.424–0.997
12	nurses	70	1.157	0.829–1.615
13	medical assistants, janitors	13	2.822	1.85–4.304
14	administrative staff	1	0.652	0.103–4.108
15	other staff	7	0.803	0.398–1.619
types of contacts in medical care provision (from the number of answers)				
16	treatment of COVID-19 patient	92	4.072	2.695–6.152
17	presence during aerosol-generating procedures provided to a COVID-19 patient	44	3.129	2.304–4.25
18	having a direct contact with objects influenced by a COVID-19 patient	88	3.881	2.632–5.721
use of PPE, completeness of their sets and replacement (from the number of answers)				
19	not using PPE during contacts with a COVID-19 patient	1	0.302	0.045–2.038
20	using PPE without complete protection of the eyes and respiratory organs	15	0.132	0.079–0.222
21	using PPE without complete protection of the eyes but with complete protection of the respiratory organs	23	1.678	1.137–2.477
22	using PPE with complete protection of the eyes but without complete protection of the respiratory organs	4	0.869	0.35–2.158
23	PPE (incomplete set and non-use when providing medical care to a COVID-19 patient)	43	0.244	0.175–0.341
24	Failure to replace PPE regularly	21	2.761	1.923–3.964
duration of a work shift (from the number of answers)				
25	shift duration up to 6 hours	38	1.618	1.154–2.269
26	shift duration from 6 to 8 hours	5	0.047	0.019–0.113
27	shift duration from 8 to 12 hours	27	2.173	1.526–3.095
28	shift duration from 12 to 24 hours	44	3.946	2.947–5.283
29	shift duration over 24 hours	1	0.629	0.1–3.966
adherence to hand sanitation (from the number of answers)				
30	non-compliance with hands sanitizing standards during medical procedures	1	0.746	0.121–4.615
contacts with COVID-19 patients (from the number of answers)				
31	COVID-19 among relatives, friends, or neighbors	9	0.497	0.262–0.944
32	COVID-19 among co-workers	58	8.896	6.943–11.397
33	**total *RR***		**1.78**	**1.65–1.93**

longer. Thus, a 6-hour work shift increased a risk of SARS-CoV-2 infection by 1.6 times (*RR* = 1.618, 95 % CI [1.154–2.269]); a shift lasting from 8 to 12 hours, by 2.2 times (*RR* = 2.173, 95 % CI [1.526–3.095]); from 12 to 24 hours, by 4.0 times (*RR* = 3.946, 95 % CI [2.947–5.283]).

Adherence to hand sanitation standards is a vital component in infection prevention, medical personnel included. In our study, only one worker (0.9 %) did not adhere to these standards when performing variable medical procedures. Although it was objectively rather difficult to accomplish this procedure in a "red" zone in an infectious diseases hospital, 40 workers (34.2 %) sanitized their hands prior to and after each aseptic procedure and 58 workers (49.6 %) did it after a direct contact with a COVID-19 patient or any objects inside a hospital. We did not detect any significant influence exerted by this factor on probable SARS-CoV-2 infection in this occupational group; however, this fact needs further investigation.

We analyzed epidemiological case histories of workers employed at infectious diseases hospitals. The analysis revealed that nine workers had contacts with COVID-19 patients beyond their MO (close relatives, friends or neighbors) and a share of such contacts equaled 7.7 %. Much more workers employed at infectious diseases hospitals mentioned their contacts with infected colleagues, namely, 59 workers (49.6 %) and this increased risks of SARS-CoV-2 infection by 8.9 times (*RR* = 8.896, 95 % CI [6.943–11.397]).

Risk factors of SARS-CoV-2 infection had certain peculiarities for medical personnel employed at MO that did not treat infectious diseases (Table 2).

Table 2

Risks of SARS-CoV-2 infection for workers employed at medical organizations providing scheduled medical aid to population

No.	Indicator	Number of healthcare workers with laboratory-confirmed COVID-19	*RR* (relative risk)	95 % CI
sex				
1	men	78	0.993	0.892–1.104
2	women	418	1.007	0.905–1.121
age				
3	20–29 years	103	0.993	0.903–1.093
4	30–39 years	86	1.039	0.944–1.143
5	40–49 years	136	0.953	0.871–1.043
6	50–54 years	65	0.95	0.84–1.074
7	55–59 years	49	0.992	0.871–1.13
8	60–64 years	37	1.096	0.974–1.234
9	65 years and older	20	1.184	1.068–1.314
position				
10	supervisors	24	1.062	0.909–1.242
11	doctors	139	1.093	1.011–1.181
12	nurses	275	0.967	0.895–1.044
13	medical assistants, janitors	13	0.608	0.413–0.894
14	administrative staff	7	1.083	0.831–1.411
15	other staff	38	1.047	0.918–1.195
types of contacts in medical care provision (from the number of answers)				
16	treatment of COVID-19 patient	199	0.741	0.681–0.807
17	presence during aerosol-generating procedures provided for a COVID-19 patient	55	0.648	0.541–0.775
18	having a direct contact with objects influenced by a COVID-19 patient	181	0.735	0.672–0.803

Continuation of the Table 2

No.	Indicator	Number of healthcare workers with laboratory-confirmed COVID-19	*RR* (relative risk)	95 % CI
use of PPE, completeness of their sets and replacement (from the number of answers)				
19	not using PPE during contacts with a COVID-19 patient	16	1.169	1.031–1.325
20	using PPE without complete protection of the eyes and respiratory organs	308	1.471	1.347–1.606
21	using PPE without complete protection of the eyes but complete protection of the respiratory organs	55	0.855	0.737–0.993
22	using PPE with complete protection of the eyes but without complete protection of the respiratory organs	20	1.031	0.859–1.238
23	PPE (incomplete set and non-use when providing medical care to a COVID-19 patient)	399	1.502	1.331–1.694
24	Failure to replace PPE regularly	24	0.642	0.487–0.846
duration of the work shift (from the number of answers)				
25	shift duration up to 6 hours	136	0.871	0.778–0.975
26	shift duration from 6 to 8 hours	287	1.567	1.433–1.713
27	shift duration from 8 to 12 hours	72	0.755	0.629–0.907
28	shift duration from 12 to 24 hours	79	0.516	0.402–0.662
29	shift duration over 24 hours	7	1.092	0.838–1.423
adherence to hand sanitation (from the number of answers)				
30	non-compliance with hands sanitizing standards during medical procedures	7	1.06	0.781–1.438
contacts with COVID-19 patients (from the number of answers)				
31	COVID-19 among relatives, friends, or neighbors	88	1.13	1.04–1.228
32	COVID-19 among co-workers	61	0.055	0.018–0.166
33	**total *RR***		**1.02**	**1–1.04**

Women accounted for 84.3 % in these MO (496 people); men, 15.7 % (78 people). Our study did not reveal any sex-dependent risk factors of SARS-CoV-2 infection for medical personnel who provided scheduled medical aid to population.

The age structure in this group was as follows: 103 workers were aged 20–29 years (20.7 %); 86 workers, 30–39 years (17.3 %); 1365 workers, 40–49 years (27.4 %); 65 workers, 50–54 years (13.1 %); 49 workers, 55–59 years (9.9 %); 37 workers, 60–64 years (7.5 %); 20 workers were aged 65 years and older (4.1 %). We established that older workers aged 65 years and more had higher risks of SARS-CoV-2 infection against their younger co-workers (*RR* = 1.184, 95 % CI [1.068–1.314]).

We examined the occupational structure in the group of workers employed at MO providing scheduled medical aid to population. The group included 24 MO supervisors (4.8 %), 139 doctors (28.0 %), 275 nurses (55.5 %), 13 medical assistants and janitors (2.6 %), 7 administrative workers (1.4 %), and 38 other staff (7.7 %). Risks of infection were by 1.1 times higher for doctors due to their specific occupational tasks (*RR* = 1.093, 95 % CI [1.011–1.181]).

Medical personnel dealing with providing scheduled medical aid to population turned out to be not ready to contacts with COVID-19. This resulted in security measures not being observed properly by them when they treated patients with infectious diseases. Yet, COVID-19 was lately diagnosed in many patients treated at those MO and 40.1 % of the respondents (199 people) participated in their treatment, including aerosol-generating procedures with 27.6 % (55 people) of the respondents accomplishing them. Direct contacts with the envi-

ronment influenced by an infected patient (personal things, bed linen, a bed, a bedside table etc.) were mentioned by 181 workers (36.5 %).

Sixteen workers (3.2 %) employed at MO providing scheduled medical aid to population did not use PPE when contacting COVID-19 patients. Only 113 workers (22.8 %) used full sets with complete protection of the respiratory organs and eyes that included overalls, FFP2/FFP3 respirators, and safety goggles with a complete seal around the eyes. PPE sets with either incomplete protection of the eyes or respiratory organs were used by 308 workers (62.1 %). Other fifty-five workers (11.1 %) mentioned absence of safety goggles with a complete seal or a mask covering the whole face. Twenty workers (4.0 %) did not have protection of the respiratory organs (FFP2 or FFP3 respirators in a PPE set). Eighty-four point seven percent of the respondents replaced their PPE with standardized regularity. Failure to use PPE when contacting COVID-19 patients and use of PPE with incomplete protection of the eyes and respiratory organs increased risks of infection by 1.2 (*RR* = 1.169, 95 % CI [1.031–1.325]) and 1.5 times (*RR* = 1.471, 95 % CI [1.347–1.606]) accordingly.

Ninety-eight workers (21 %) in MO providing scheduled medical aid to population had work shifts that lasted up to 6 hours; 282 workers (60.4 %) had to work from 6 to 8 hours; 45 workers (9.6 %), from 8 to 12 hours; 35 workers (7.5 %), from 12 to 24 hours; and 7 workers (1.5 %) had a shift longer than 24 hours. A working shift from 6 to 8 hours long increased risks of infection by 1.6 times (*RR* = 1.567, 95 % CI [1.433–1.713]).

Six respondents (1.2 %) working in MO that provided scheduled medical aid to population failed to sanitize their hands in conformity with the established regulations. One hundred and sixty-three workers (32.9 %) sanitized their hands prior to each aseptic procedure and after it; 169 workers (34.1 %) did it after touching a COVID-19 patient or after contacts with objects influenced by such a patient. We did not establish any elevated risks of infection associated with failure to follow hand sanitation regulations when accomplishing medical procedures. However, this fact requires further investigation.

Workers employed at MO providing scheduled medical aid to population, just as their counterparts working in infectious diseases hospitals, had contacts with COVID-19 patients beyond their workplaces. Thus, 79 respondents (15.9 %) had contacts with relatives, friends or neighbors who were infected with COVID-19; three respondents (0.6 %) contacted infected coworkers. This increased risks of SARS-CoV-2 infection (*RR* = 1.13, 95 % CI [1.04–1.228]). Table 2 provides the complete results produced by analyzing this occupational group.

Discussion. Medical personnel become infected with pathogenic biological agents to a greater or lesser extent regardless of a MO type and what medical aid it provides. However, risks of infection grow significantly during epidemic or pandemic spreads of viruses with high epidemic potential, SARS-CoV-2[6] virus being among them.

Over the last 20 years, the world has faced several epidemics of viral communicable diseases: severe acute respiratory syndrome (SARS) in 2002, A (H1N1) virus flu from 2009 to 2010, Ebola Virus Disease (a major outbreak occurred in West Africa in 2014–2016), and Middle East respiratory syndrome (MERS) in 2015. Every time, health workers have been at the forefront in fighting against these diseases and they have always had high occupational risks of infection, severe disease and fatal outcomes[7] [9]. Undoubtedly, COVID-19 pandemic has already become the most significant event in the 21st century. Starting from the first day of

[6] Prevention, identification and management of health worker infection in the context of COVID-19: Interim guidance. *WHO*, 2020. Available at: https://apps.who.int/iris/bitstream/handle/10665/336265/WHO-2019-nCoV-HW_infection-2020.1-eng.pdf?sequence=1&isAllowed=y (March 01, 2022).

[7] Novaya koronavirusnaya infektsiya COVID-19: professional'nye aspekty sokhraneniya zdorov'ya i bezopasnosti meditsinskikh rabotnikov: metodicheskie rekomendatsii [New coronavirus infection COVID-19: occupational aspects related to preserving health and providing safety for medical personnel: methodical guidelines]. In: I.V. Bukhtiyarov, Yu.Yu. Gorblyanskii eds. Moscow, AMT, Scientific Research Institute for Occupational Medicine, 2021, 132 p. (in Russian).

SARS-CoV-2 spread, medical personnel have been a population group that is the most actively involved into the epidemic process. Public healthcare systems in every country, the Russian Federation included, have been facing extreme loads since the pandemic started. Thus, in China (in Wuhan in particular) during the early stage in SARS-CoV-2 spread from December 2019 to February 2020 a number of COVID-19 cases was by 3.5 times higher among health workers than among population at large[7]. When it comes down to fatal outcomes, we should mention that, according to the WHO report, approximately 115.5 thousand health workers died during the period from January 2020 to May 2021.

High incidence among medical personnel and hospital maintenance staff produces negative effects on quality of emergency and scheduled medical aid provided to population as well as on implementation of prescribed anti-epidemic activities[8]. Given the ongoing pandemic, it is still necessary to examine risk factors of SARS-CoV-2 infection for medical personnel and to use the result of these studies as grounds for developing occupational safety programs both in a specific MO and at the national level as well[9] [10–12].

By now, the basic risk factors of infection have been established. They include providing medical aid to patients with COVID-19 given a significant growth in a number of patients needing hospitalization, incomplete PPE sets or failure to provide all medical workers with them, as well as low adherence to antiseptic hand sanitation among health workers[8] [7, 13].

According to the results of analytical studies accomplished by experts from Denmark and Sweden, infection was the most frequent among male health workers aged younger than 30 [14, 15]. In this study, we did not establish sex to be a significant risk factor of SARS-CoV-2 infection. As for an age of infected medical personnel, we detected a high share of infected workers aged 65 years and older among those employed at MO providing scheduled medical aid to population (*RR* = 1.184, 95 % CI [1.068–1.314]). Those elderly workers were engaged in providing scheduled medical aid due to redistribution of health workers when younger ones had to be transferred to infectious diseases hospitals [16].

Some studies established that in many countries health workers who were involved in providing medical aid at different stages and levels had different risks of SARS-CoV-2 infection. For example, in Italy paramedics and nurses had higher (by 1.5 times) risks of becoming infected with SARS-CoV-2 virus than other medical personnel. In its turn, in Great Britain COVID-19 prevalence turned out to be the highest among workers with non-medical specialties (janitors and cleaners) [17]. The World Health Organization (WHO) also detected high risks for workers who cleaned wards where patients infected with SARS-CoV-2 were treated[8]. Our study also confirms that workers responsible for cleaning hospital wards account for a significant share of infected personnel of infectious diseases hospitals (*RR* = 2.822, 95 % CI [1.85–4.304]). At the same time, doctors working in MO that provided scheduled medical aid to population also had elevated risks of infection since they had to perform primary examinations of patients with unknown infectious status. Still, these risks were a bit less significant (*RR* = 1.093, 95 % CI [1.011–1.181]).

Provision with PPE in sufficient quantities and its proper use as well as relevant quality of this equipment are necessary conditions for reducing risks of infection, especially when it comes down to a global spread of a droplet infection [18, 19]. Thus, Gómez-Ochoa with colleagues (2021) detected a high risk of infection for health workers who used PPE with incomplete protection of the eyes or did not use any PPE at all. The risk grew from 2.82 to 3.72 times [1]. In Great Britain and the USA

[8] COVID-19: Occupational health and safety for health workers: Interim guidance. ILO, WHO, 2021. Available at: https://hlh.who.int/docs/librariesprovider4/hlh-documents/covid-19---occupational-health-and-safety-for-health-workers.pdf?sfvrsn=581e60c6_5 (March 01, 2022).

[9] Caring for those who care: guide for the development and implementation of occupational health and safety programmes for health workers. Geneva, WHO, ILO, 2022, 124 p.

experts also revealed that if health workers who treated patients with COVID-19 did not use a full PPE set or failed to replace it regularly, they had elevated risks of infection that were from 1.31 to 1.46 times higher [4].

We also established in our study that incorrect use of PPE or using incomplete sets made a significant contribution to growing risks of infection, by 1.6 times a (*RR* = 1.678, 95 % CI [1.137–2.477]) when using an incomplete PPE set that did not protect the eyes and up to 2.8 times (*RR* = 2.761, 95 % CI [1.923–3.964]) when workers failed to replace their PPE sets regularly. Medical personnel at MO that provided scheduled medical aid to population did not have enough PPE sets at the first stages in fighting against the infection. This meant they were not ready to interact with COVID-19 patients and, as a result, risks of infection grew for them.

Loads on medical organizations grew drastically due to a significant increase in a number of patients infected with SARS-CoV-2. This resulted in longer work shifts and, consequently, longer contacts between medical personnel and infected patients. The situation was aggravated further by improper PPE use[7]. Chou and others (2020) established that a growth in work shift duration became a significant risk factor of SARS-CoV-2 infection for health workers. This risk grew by 2.2 times (*RR* = 2.173, 95 % CI [1.526–3.095]) for workers employed at infectious diseases hospitals when their work shift lasted 8–12 hours and by up to 4.0 times (*RR* = 3.946, 95 % CI [2.947–5.283]) when it lasted 12–24 hours. However, workers employed at MO that provided scheduled medical aid to population had a risk of infection even if they worked in their usual shifts lasting from 6 to 8 hours (*RR* = 1.567, 95 % CI [1.433–1.713]). This might be due to using an incomplete PPE set [20].

Adherence to hand sanitation regulations when accomplishing medical procedures is a key issue influencing risks of infection[10]. When workers employed at infectious diseases hospitals in China failed to sanitize their hands properly, this created by 3.1 times higher risks of SARS-CoV-2 infection [20]. Some data also indicate that failure to sanitize the hands with skin antiseptic together with irregular hygienic washing was by 2.2–3.0 times more frequent among health workers who had already had laboratory-confirmed COVID-19 [13]. In this study, we did not establish any effects produced by failure to adhere to hand sanitation regulations when accomplishing medical procedures on likelihood of SARS-CoV-2 infection; however, this fact requires further investigation.

Conclusion. We established that working in an infectious diseases hospital created by 1.8 times higher risks of SARS-CoV-2 infection for medical personnel (*RR* = 1.78, 95 % CI [1.65–1.93]). Major risks of infection among medical personnel at infectious diseases hospitals occurred due to the following: treating a patient with COVID-19 (*RR* = 4.072, 95 % CI [2.695–6.152]), accomplishing aerosol-generating procedures (*RR* = 3.129, 95 % CI [2.304–4.25]), direct contacts with the environment influenced by a COVID-19 patient (*RR* = 3.881, 95 % CI [2.632–5.721]), cleaning hospital wards (*RR* = 2.822, 95 % CI [1.85–4.304]), failure to regularly replace PPE (*RR* = 2.761, 95 % CI [1.923–3.964]), use of PPE with incomplete protection provided for the eyes (*RR* = 1.678, 95 % CI [1.137–2.477]). We detected that as a work shift in a “red” zone became longer, risks of SARS-CoV-2 infection for medical personnel grew from 1.6 to 3.9 times (*RR* = 1.618, 95 % CI [1.154–2.269]; *RR* = 3.946, 95 % CI [2.947–5.283]).

The total risks of SARS-CoV-2 infection were insignificant (*RR* = 1.02, 95 % CI

[10] SanPiN 3.3686-21. Sanitarno-epidemiologicheskie trebovaniya po profilaktike infektsionnykh boleznei (utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha RF ot 28 yanvarya 2021 goda № 4) [SanPiN 3.3686-21. Sanitary-epidemiological requirements to communicable diseases prevention (approved by the RF Chief Sanitary Inspector on January 28, 2021 No. 4)]. Razdel XLIV. Profilaktika infektsii, svyazannykh s okazaniem meditsinskoi pomoshchi [Section XLIV. Prevention of healthcare-associated infections]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573660140 (February 03, 2022) (in Russian).

[1.00–1.04]) in medical organizations that provided scheduled medical aid to population. At the same time, some specific risk factors were rather significant, including, for example, a work shift lasting from 6 to 8 hours (*RR* = 1.567, 95 % CI [1.433–1.713]), use of PPE with incomplete protection provided for the eyes and respiratory organs (*RR* = 1.471, 95 % CI [1.347–1.606]), workers' age being 65 years and older (*RR* = 1.184, 95 % CI [1.068–1.314]), failure to use PPE when treating a patient infected with COVID-19 (*RR* = 1.169, 95 % CI [1.031–1.325]). Some non-occupational factors also exerted their influence on risks of SARS-CoV-2 infection for this occupational group, in particular, contacts with close friends or relatives as well as neighbors who were infected with COVID-19 (*RR* = 1.13, 95 % CI [1.04–1.228]).

Global SARS-CoV-2 spread has again highlighted that it is vital to protect health workers when they have to deal with both new and returning infectious agents able to induce an epidemic or even a pandemic.

Our research results should be considered when organizing work and anti-epidemic activities in infectious diseases hospitals and medical organizations providing scheduled medical aid to population. It specifically concerns providing health workers with PPE in these medical institutions and duration of their work shifts. Prevention of infection spread among medical personnel should rely on the risk-based approach and consider risks of exposure to not only known pathogens given the ongoing COVID-19 pandemic but also probable new epidemic threats in future.

Funding. The study was accomplished within the implementation of the research and development project "Examination of the epidemic process and prevention of healthcare-associated viral infections", Reg. No. NIOKTR 121040500099-5.

Competing interests. The authors declare no obvious or potential competing interests that may arise from publishing the present article.

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Received: 24.03.2022
Approved: 15.06.2022
Accepted for publication: 25.06.2022