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Identification of Asymptomatic Severe Acute Respiratory Syndrome Coronavirus 2 Infections among Healthcare Workers at Sultan Qaboos University Hospital, Oman

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Abstract

Objectives: This study aimed to describe the incidence and features of asymptomatic COVID-19 infections among HCWs at a tertiary hospital in Oman. ***Methods:*** This cross-sectional study was conducted between August 2020 and February 2021 among HCWs with no history of COVID-19 infection using an online questionnaire to collect sociodemographic and clinical data. COVID-19 infection was diagnosed using nasopharyngeal/throat swabs, which were tested for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Analyses were performed using Chi-squared test, Fisher's exact test, or univariate ordinary least squares regression, as appropriate. ***Results:*** A total of 583 HCWs participated in the study. Most were female (56.6%) and the mean age was 35 ± 8 years . Only 9.6% (95% confidence interval [CI]: 7.3–12.3%) of the HCWs were at high exposure risk as they were directly involved in the care of COVID-19-infected patients. Overall, 4.1% (95% CI: 2.7–6.1%) of the HCWs screened positive for SARS-CoV-2; of these, five (20.8%) developed symptoms within two weeks. The frequency of SARS-CoV-2 positivity among HCWs working in high, intermediate, low, and miscellaneous risk areas was 1.8% (95% CI: <0.1–9.6%), 2.6% (95% CI: <0.1–6.5%), 5.3% (95% CI: 0.3–9.3%), and 4.8% (95% CI: <0.1–69.3%), respectively. Working in high-risk areas was associated with increased compliance with various infection control strategies (P <0.001). ***Conclusion:*** There was a greater frequency of SARS-CoV-2 positivity among HCWs working in lower-risk areas, whereas HCWs who worked in high-risk areas were significantly more likely to report increased compliance with infection control strategies.

Keywords: SARS-CoV-2; COVID-19 Nucleic Acid Testing; Asymptomatic Infections; Health Personnel; Occupational Exposure; Infection Control; Real-Time Polymerase Chain Reaction; Oman.

Advances in Knowledge

- To the best of the authors' knowledge, the incidence of asymptomatic coronavirus disease 2019 (COVID-19) infections among healthcare workers (HCWs) in Oman has not previously been reported.
- This study found that the prevalence of asymptomatic COVID-19 infections among HCWs working at a tertiary hospital in Muscat, Oman, was 4.1% (95% confidence interval [CI]: 2.7–6.1%), including 1.8% (95% CI: <0.1–9.6%), 2.6% (95% CI: <0.1–6.5%), 5.3% (95% CI: 0.3–9.3%), and 4.8% (95% CI: <0.1–69.3%) of HCWs working in high, intermediate, low, and miscellaneous risk areas, respectively.
- Overall, HCWs in high-risk areas were significantly more likely to adhere to COVID-19 infection control practices, including hand hygiene and wearing appropriate personal protective equipment during interactions with infected patients.

Application to Patient Care

- The findings of this study indicate that asymptomatic COVID-19-infected HCWs may constitute a significant transmission risk in hospital settings.
- Hospital authorities should consider implementing routine interval screening to detect asymptomatic infections among HCWs. In addition, there is a need to increase adherence to infection prevention and control strategies among asymptomatic HCWs in lower-risk areas to reduce the possibility of unknowingly transmitting the disease to others.

Introduction

Coronavirus disease 2019 (COVID-19) is a respiratory illness caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Clinical manifestations of COVID-19 infection range from a mild cough and sore throat to fulminant pneumonia and multi-organ failure; however, a notable proportion of infected patients may be asymptomatic, especially in the early stages of infection.[1–3] In the absence of symptoms, COVID-19 infections can be identified using a positive SARS-CoV-2 RNA test or based on chest X-ray or computed tomography findings.[2] Since the initial outbreak of the disease in December 2019, COVID-19 has proven to be highly transmissible, with more than 5.9 million confirmed cases worldwide as of August 2022.[4]

According to back casting statistical estimates, the rate of COVID-19 infection in the general population is 6.08% (95% confidence interval [CI]: 4.24–10.68%).[5] However, people who reside or work in densely populated or confined environments such as cruise ships, homeless shelters, and prisons can have even higher rates of infection.[6–8] In addition, healthcare workers (HCWs) are at a generally increased risk of COVID-19 infection due to their exposure to, and their role in the care and management of, infected patients. In Hubei, China—the epicentre of the COVID-19 outbreak—the number of infected HCWs increased from 1,502 to 3,062 in the span of 13 days.[9] In the UK, a recent study reported that up to 24.4% of asymptomatic HCWs may demonstrate SARS-CoV-2 seropositivity.[10]

Asymptomatic COVID-19 infections are defined by evidence of SARS-CoV-2 positivity in the absence of self-reported or clinically discernible symptoms.[3] The identification of asymptomatic cases is an important factor in better understanding the epidemiology of infectious diseases and may help inform appropriate measures to prevent transmission. Researchers have warned of the dangers posed by “invisible epidemics” or “silent spread”, both because asymptomatic carriers are unlikely to seek timely treatment—which is concerning as the absence of symptoms does not mean a lack of subclinical damage to the lungs or other organs—as well as because of the risk they pose in unknowingly transmitting the infection to others.[11,12] A recent systematic review and meta-analysis by Ma *et al*. found the pooled percentage of asymptomatic SARS-CoV-2 infections to be 0.25% (95% CI: 0.23–0.27%) among 29,776,306 individuals reported in 95 studies, representing 40.5% of all infections detected in the tested population.[13] Similarly, a narrative review by Oran *et al*. indicated that up to 40–45% of reported SARS-CoV-2 infections are asymptomatic in nature.[12]

In the Gulf Cooperation Council region, few studies have sought to assess the frequency of asymptomatic infections among HCWs. In the United Arab Emirates, researchers reported that up to 43% of identified COVID-19 cases were asymptomatic; however, only 3% of the COVID-19-infected patients being studied (i.e., both symptomatic and asymptomatic cases) were employed in occupations with high exposure risk, including HCWs.[14] Al-Hakami *et al*. identified the prevalence of asymptomatic infections to be 18.3% among 186 HCWs working in tertiary care centres in Southwestern Saudi Arabia.[15] Another study found that the seroprevalence of SARS-CoV-2 was 3.2% among asymptomatic HCWs in a larger tertiary hospital in Riyadh, Saudi Arabia.[16] However, to the best of the authors' knowledge, the incidence of asymptomatic COVID-19-infected HCWs in Oman has not previously been reported. Furthermore, it is unclear whether specific clinical or sociodemographic factors influence the risk of asymptomatic infection in this population. As such, this study aimed to identify the prevalence of and sociodemographic and clinical characteristics associated with COVID-19 infections among asymptomatic HCWs working at a tertiary university hospital in Muscat, Oman.

Methods

This cross-sectional study was conducted between August 2020 and February 2021 at the Sultan Qaboos University Hospital (SQUH), a large tertiary university hospital in Muscat, Oman. The target population included all asymptomatic HCWs from different SQUH departments and of all job titles and responsibilities, including physicians, nurses, medical orderlies and administrative and security personnel. Only HCWs without a previous diagnosis of COVID-19 disease were eligible for inclusion in the study. As such, the inclusion criteria comprised hospital staff working in all clinical or administrative areas of the hospital. The exclusion criteria consisted of staff who were symptomatic on the day of recruitment or those who reported a history of positive SARS-CoV-2 swab results at any point beforehand. However, staff who reported symptoms within 7 days of swab collection were included in the study so long as they were asymptomatic upon the day of recruitment/collection.

An invitation to participate in the study was published on the hospital's home page to recruit participants. Respondents were initially screened for inclusion in the study to identify those who were asymptomatic and had no history of COVID-19 infection. Based on the initial sample size calculation, a total of 992 subjects were needed (496 in each arm) to ensure 90%

power to detect a statistical difference of 10% (i.e., 30% versus 40% when detecting COVID-19 in high-risk versus low-risk areas) at the 5% alpha level. However, only 583 HCWs were recruited and included in the final sample. Participants were subsequently categorised into four groups based on their level of risk of exposure to COVID-19 infected patients, including: (1) high-risk (i.e., HCWs working in COVID-19 wards or the COVID intensive care unit [ICU]); (2) intermediate-risk (i.e., HCWs working in the emergency medicine or family medicine and public health departments and laboratories); (3) low-risk (i.e., HCWs working in all other wards, non-COVID-19 ICU, paediatric ICU, and ambulatory clinics); and (4) miscellaneous risk (i.e., all remaining HCWs).

An online questionnaire was used to collect sociodemographic data from the participants, including their gender, age, working area, place of residence, occupation and education level. In addition, clinical information was elicited, including self-assessed symptomatology, history of contact with COVID-19-infected persons, personal protective equipment (PPE) use and training, and other relevant epidemiological risk factors, including a recent history of inter-city travel or attendance at large social gatherings. The questionnaire was adapted from the World Health Organization's data template; however, modifications were made to include additional information, such as epidemiological risk factors, and the modified version of the questionnaire was not validated.[17] Subsequently, combined nasopharyngeal/throat swabs were collected from all participants by trained research assistants. RNA was extracted from the respiratory samples using fully automated nucleic acid extraction systems, including either the MagNA Pure LC 2.0 Total Nucleic Acid Isolation Kit (Roche Diagnostics GmbH, Mannheim, Germany) or Liferiver EX3600 Automated Nucleic Acid Extraction System (Shanghai Bio-Tech Co. Ltd., Shanghai, China).

The extracted RNA was tested for SARS-CoV-2 using real-time polymerase chain reaction (PCR) performed using either the LightMix® Modular SARS-CoV-2 Assay (Roche Diagnostics GmbH), Liferiver Novel Coronavirus Real Time Multiplex RT-PCR (Shanghai Bio-Tech Co. Ltd.), or TaqPath™ RT-PCR COVID-19 Kit (Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA). Samples were considered positive when at least two targeted genes were detected, negative when all targeted genes were negative, and inconclusive when only one gene was detected. Repeat sampling and testing was performed for all inconclusive cases. Participants with positive COVID-19 results were informed of their diagnosis within

24–48 hours and quarantined as per local guidelines; in addition, they were assessed for symptomatology for up to 2 weeks from the time of test positivity.

Statistical analyses were conducted using the STATA statistical software package, Version 16.1 (STATA Corp., College Station, Texas, USA). Descriptive results were presented as frequencies and percentages (categorical variables) or means and standard deviations (continuous variables), as appropriate. Differences between exposure risk groups (i.e., HCWs working in high, intermediate, low, and miscellaneous risk areas) were analysed using either Pearson's Chi-squared test or Fisher's exact test (for cell frequencies of <5). Differences between continuous variables were assessed using univariate ordinary least squares regression. The *a priori* two-tailed level of significance was set at the 0.05 level.

Ethical approval for this study was obtained from the Medical Research and Ethics Committee of Sultan Qaboos University, Muscat, Oman. All HCWs provided written informed consent prior to participation in the study. All study procedures were performed in accordance with local and international ethical standards. Data confidentiality was ensured at all times in order to ensure privacy.

Results

Of the 583 HCWs who participated in the study, over half were female (n = 330; 56.6%) and approximately one-third (n = 212; 36.4%) were of Omani nationality. The mean age was 35 ± 8 years (range: 22–59 years). Overall, 24 HCWs (4.1%; 95% CI: 2.7–6.1%) tested positive for SARS-CoV-2 based on the RNA test; of these, five (20.8%; 95% CI: 7.1–42.2%) developed COVID-19 symptoms within two weeks of swab collection, including cough, fever, sore throat, body aches, and pain. In addition, some of the participants reported a history of symptoms within the week prior to the swab collection, although they were asymptomatic upon enrolment into the study. The three most common of the pre-swab symptoms were sore throat (n = 48; 8.2%;), muscle aches (n = 47; 8.1%), and fatigue (n = 42; 7.2%).

The distribution of SARS-CoV-2 positivity among asymptomatic HCWs working in high, intermediate, low, and miscellaneous risk areas was 1.8% (95% CI: <0.1–9.6%), 2.6% (95% CI: <0.1–6.5%), 5.3% (95% CI: 0.3–9.3%), and 4.8% (95% CI: <0.1–69.3%), respectively

[Table 1]. High-risk areas were more likely to be staffed by women than men in comparison to intermediate, low, or miscellaneous risk areas (71.4% versus 64.3%, 65.2%, and 33.7%, respectively; *P* <0.001). In addition, participants who reported having a sore throat in the week prior to swab collection were less likely to work in high-risk areas compared to intermediate, low, or miscellaneous risk areas (1.8% versus 10.4%, 11.1%, and 4.8%, respectively; *P* = 0.026). No significant differences in age or other symptomatology were noted according to differences in risk areas, including fever, fatigue, cough, sore throat, loss of taste or smell, shortness of breath, chest pains, muscle aches, and nausea/vomiting/diarrhoea.

Participants working in high-risk areas were significantly more likely to adhere to anti-COVID-19 protective measures compared to HCWs working in intermediate, low, or miscellaneous risk areas. Specifically, they were significantly more likely to wear PPE as recommended during interactions with COVID-19-infected patients (94.6% versus 86.4%, 57.5%, and 54.8%, respectively; *P* <0.001) and perform hand hygiene before and after interactions with COVID-19-infected patients (94.6% versus 89.6%, 66.2%, and 63.3%, respectively; *P* <0.001). In addition, when performing aerosol-generating procedures on COVID-19-infected patients, HCWs working in high-risk areas were significantly more likely to wear gloves (92.9% versus 85.7%, 61.8%, and 56.6%, respectively; *P* <0.001), wear fit-tested N95 or equivalent respirators (69.6% versus 46.1%, 39.6%, and 44%, respectively; *P* <0.001), wear face shields (92.9% versus 81.8%, 53.1%, and 47.6%, respectively; *P* <0.001), and remove and replace their PPE according to hospital policy (92.9% versus 85.7%, 69.9%, and 53%, respectively; *P* <0.001) compared to those working in intermediate, low, or miscellaneous risk areas. No significant differences were observed in terms of recent epidemiological risk factors (e.g., recent history of travel, attendance at social gatherings, or contact with an infected person) according to differences in exposure risk [Table 2].

Discussion

In the current study, the overall prevalence of asymptomatic COVID-19 infections among HCWs working at a large tertiary hospital in Muscat was 4.1%; of these, 20.8% developed mild symptoms within two weeks of swab collection. Previous studies have shown comparable prevalence rates of positive SARS-CoV-2 findings among asymptomatic HCWs elsewhere around the world (3.4–7.1%).[18–20] Overall, 9.6% of the asymptomatic HCWs enrolled in the present study were involved directly in the care of COVID-19-infected patients and therefore faced a high risk of exposure to infection, while 64% had either a low or miscellaneous/unknown risk of exposure to COVID-19-infected patients.

Interestingly, adherence to various COVID-19 infection control and protective measures was significantly higher among HCWs working in high-risk areas in the current study compared to those working in lower-risk areas. This could be attributed to an increased awareness of patient COVID-19 status and clinical condition on the part of HCWs working in high-risk areas. Nevertheless, it is important to acknowledge that pre-admission PCR testing for COVID-19 was not mandatory for asymptomatic patients; as a result, HCWs working in low-risk areas may have been more frequently exposed to undiagnosed patients without being aware. On the other hand, no significant differences were noted with regards to the frequency of various epidemiological risk factors regardless of risk exposure level, including recent inter-city travel, attendance at social gatherings, and visiting relatives. However, due to the self-reported nature of these findings, the role of community transmission cannot be dismissed entirely.

There is evidence to indicate that viral shedding and disease transmission can occur in the absence of symptoms (asymptomatic cases), as well as before symptom onset (presymptomatic cases).[21–23] He *et al*. estimated that viral shedding in patients with laboratory-confirmed COVID-19 infections peaked at or before symptom onset, thus posing a substantial risk of transmission before symptoms in the index case are clinically discernible.[21] Moreover, according to an analysis of seven epidemiological clusters, Wei *et al*. found that presymptomatic transmission of COVID-19 occurred on an average of 1–3 days before symptom onset.[22] Zou *et al*. reported that viral loads detected in asymptomatic patients were similar to those found in symptomatic patients; in addition, the researchers confirmed that the median duration of viral shedding among asymptomatic individuals was 16.4 days (interquartile range: 7–28 days), comparable to symptomatic patients with mild-to-moderate disease severity.[23] Such findings highlight the importance of preventing the spread of infections by asymptomatic individuals.

Chow *et al*. assessed the spectrum of initial symptoms among HCWs working in a long-term care facility in the USA; the researchers found that the median interval between disease onset and the appearance of established COVID-19 screening symptoms was 2 days (range: 1–7 days).[24] Treibel *et al*. also noted that 27% of HCWs working in a UK-based hospital who tested positive for SARS-CoV-2 reported no symptoms in the week before or after testing positive.[18] More inclusive contact tracing criteria are therefore needed to capture potential transmission events before symptom onset.[21,22] Thus, a universal testing strategy, rather than a symptom-triggered approach, is recommended to identify and mitigate the spread of COVID-19 by asymptomatic individuals.[24] Moreover, the use of combined nasal/throat swabs is recommended due to conflicting findings as to differences in viral loads detected in swab samples obtained from the nose compared to the throat.[22,23] Chow *et al*. also noted that the inclusion of additional symptoms during COVID-19 screening, such as myalgias and chills, increased case detection by 6.3%.[24]

The findings of this study underscore the need for additional measures to prevent asymptomatic infection spread by HCWs. It is recommended that all HCWs routinely wear face masks and other appropriate PPE and conform to institutional hand hygiene and infection control measures in order to prevent presymptomatic or asymptomatic transmission. Such measures are particularly crucial for HCWs working in critical, chronic or long-term patient care and in areas with a high frequency of community transmission.[24] Other researchers have also recommended the implementation of a traffic control bundling approach to protect HCWs and to mitigate infection spread during epidemics in which patients are triaged prior to entering the hospital and there is a clear segregation of different risk zones, with strict disinfection protocol stations set up at inter-zone boundaries.[25,26]

Nevertheless, it is important to note that such recommendations may not be helpful to prevent the spread of COVID-19 infections via community transmission. The difference between nosocomial and community infections is contingent upon setting; nosocomial infections refer to those that originate in hospital settings, so long as the infection was not present or incubating upon admission, while community-acquired infections represent those which develop elsewhere.[27] Developing effective infection prevention and control measures is only possible by understanding differences between specific transmission settings and how these contribute to the spread of a specific disease.[28] However, distinguishing between hospital-acquired and community infections is often challenging due to uncertainty as to the onset of the infection (i.e., prior to or within 48 hours of admission to hospital). Moreover, in the context of the present study, this determination would be made even more difficult in the absence of clinically discernible symptomatology. As such, stringent surveillance measures for all patients upon admission, and the routine screening of HCWs, are recommended to determine whether COVID-19 infections can be classified as community or hospital-acquired.

This study was subject to several limitations, including the observational design, small sample size, and absence of compulsory COVID-19 screening for HCWs. The present study was also limited by the smaller sample size (N = 583) in relation to original requirements based on sample size calculations with 90% power (N = 992). Further studies are therefore warranted to corroborate the findings. Due to the voluntary nature of enrolment, there is a high possibility of selection bias in the sample. Furthermore, as a single-centre study covering a known geographical area, the findings may not reflect the true incidence of asymptomatic HCWs in other institutions in Muscat or elsewhere in Oman. Moreover, the study period did not include the peak of the pandemic which could have resulted in a lower prevalence. It is also important to note that the analysis did not distinguish between asymptomatic and presymptomatic infections and did not consider vaccination status as the vaccine roll-out in Oman occurred after the recruitment and data collection process had already begun.

In addition, the current study did not assess individual levels of occupational risk exposure other than by designating risk levels to specific working areas. Thus, future research should be conducted to determine individual levels of occupational risk exposure, for instance using the WHO risk assessment tool for HCWs.[29] In addition, other variables which could influence risk of infection, such as demographic characteristics and ethnicity, were not considered in the analysis. These factors should be considered in future studies. Finally, findings related to the participants' recent epidemiological history were self-reported in nature and may therefore have been subject to recall and social desirability bias; as such, community transmission might have played a more significant role in the transmission of COVID-19 among HCWs than indicated.

Conclusion

Asymptomatic COVID-19-infected HCWs constitute a significant transmission risk in hospital settings. Overall, 4.1% of the studied asymptomatic HCWs screened were positive for SARS-CoV-2. Moreover, there was greater frequency of SARS-CoV-2 positivity among HCWs working in lower-risk areas, whereas HCWs who worked in high-risk areas were significantly more likely to report increased compliance with infection control strategies.

Hospital authorities should therefore implement interval screening for the detection of asymptomatic infections among HCWs, in addition to enforcing adherence to infection control strategies.

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Conflicts of Interest

The authors declare no conflict of interests.

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Authors' Contribution

AAS, MAJ, AAA and AB conceptualized and designed the study. AAS, AAA and IAZ drafted the proposal and MAJ revised it. AAS, MAJ, AAA and AB prepared the questionnaire. AAS and AAA supervised the work and the data collection process. FAA provided equipment needed for sample analysis. KAM, FBA, AAQ and HAG contributed to the processing of laboratory samples. AAS and AAA analysed the data. IAZ provided statistical advice on study design and conducted the statistical analysis of the data. AAS, AAA, AB, IAZ and KAM contributed to drafting the manuscript. AAS, MAJ, AAA, AB, IAZ and KAM revised the manuscript. All authors approved the final version of the manuscript.

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Table 1: Distribution of positive coronavirus disease 2019 cases among asymptomatic healthcare workers at Sultan Qaboos University Hospital, Muscat, Oman, according to in-hospital exposure risk status (N = 583)

Risk* status	**n (%)**	
	Total	**Positive† COVID-19 cases**
High	56 (9.6)	1 (1.8)
Intermediate	154 (26.4)	4 (2.6)
Low	207 (35.5)	11 (5.3)
Miscellaneous	166 (28.5)	8 (4.8)
Total	583 (100)	24 (4.1)

*COVID-19 = coronavirus disease 2019. *Participants were stratified according to level of risk of exposure to COVID-19 infected patients as either high-risk (those working in COVID-19 wards or the COVID intensive care unit [ICU]), intermediate-risk (those working in the emergency medicine or family medicine and public health departments and laboratories), low-risk (those working in all other wards, the non-COVID-19 ICU, paediatric ICU, and ambulatory clinics), or miscellaneous risk (those working in all other hospital areas). †Positivity was based on real-time polymerase chain reaction of RNA extracted from combined nasopharyngeal/throat swab samples.*

Table 2: Epidemiological history and adherence to anti-coronavirus disease 2019 protective measures among asymptomatic healthcare workers at Sultan Qaboos University Hospital, Muscat, Oman, stratified by in-hospital exposure risk (N = 583)

Item		**Risk* status, n (%)**				***P* value**
		High (n = 56)	**Intermediate (n = 154)**	**Low (n = 207)**	**Miscellaneous (n = 166)**	
Epidemiological history	Have you recently traveled between cities?	7 (12.5)	23 (14.9)	32 (15.5)	22 (13.3)	0.904
	Have you attended a gathering with a person who has had SARS-CoV-2 detected?	3 (5.4)	22 (14.3)	16 (7.7)	20 (12)	0.115
	Have you visited relatives within the last 14 days?	7 (12.5)	29 (18.8)	39 (18.8)	38 (22.9)	0.397
	Have many times have you gone shopping in the last 14 days?					0.437
	1–2	44 (78.6)	111 (72.1)	157 (75.8)	134 (80.7)	
	3–5	10 (17.9)	35 (22.7)	44 (21.3)	24 (14.5)	
	>5	2 (3.6)	8 (5.2)	6 (2.9)	8 (4.8)	
	How often do you adhere to physical distancing requirements (i.e., keeping 1–2 m from others) during your daily activities?					0.448
	Always	12 (21.4)	29 (18.8)	32 (15.5)	17 (10.2)	
	Mostly	34 (60.7)	87 (56.5)	125 (60.4)	103 (62)	
	Sometimes	10 (17.9)	37 (24)	49 (23.7)	46 (27.7)	
	Never	0 (0)	1 (0.6)	1 (0.5)	0 (0)	
	Have you provided direct care to a confirmed COVID-19 patient?	52 (92.9)	95 (61.7)	53 (25.6)	20 (12)	<0.001
	Have you had unprotected contact with a confirmed COVID-19 patient?	10 (17.9)	41 (26.6)	19 (9.2)	9 (5.4)	<0.001
	Were you present during any aerosol-generating procedure performed on a patient?	39 (69.6)	65 (42.2)	27 (13)	10 (6)	<0.001

	Were you recently in an environment in which a confirmed COVID-19 patient was present?	47 (83.9)	102 (66.2)	66 (31.9)	30 (18.1)	<0.001
Compliance with infection control measures	Have you been wearing PPE as recommended during interactions with COVID-19-infected patients?	53 (94.6)	133 (86.4)	119 (57.5)	91 (54.8)	<0.001
	Do you remove PPE as recommended after interactions with COVID-19-infected patients?	53 (94.6)	132 (85.7)	118 (57)	93 (56)	<0.001
	Do you perform hand hygiene before and after interactions with COVID-19-infected patients?	53 (94.6)	138 (89.6)	137 (66.2)	105 (63.3)	<0.001
	Do you wear PPE during any aerosol-generating procedures performed on COVID-19-infected patients?	51 (91.1)	132 (85.7)	119 (57.5)	88 (53)	<0.001
	Do you wear gloves during aerosol-generating procedures performed on a COVID-19 patient?	52 (92.9)	132 (85.7)	128 (61.8)	94 (56.6)	<0.001
	Do you wear fit-tested N95 or equivalent respirators during aerosol-generating procedures performed on COVID-19-infected patients?	39 (69.6)	71 (46.1)	82 (39.6)	73 (44)	0.001
	Do you wear face-shields during aerosol-generating procedures performed on COVID-19-infected patients?	52 (92.9)	126 (81.8)	110 (53.1)	79 (47.6)	<0.001
	Do you wear disposable gowns during aerosol-generating procedures performed on COVID-19-infected patients?	52 (92.9)	131 (85.1)	120 (58)	84 (50.6)	<0.001
	Do you remove and replace PPE according to hospital regulations during aerosol-generating procedures performed on COVID-19-infected patients?	52 (92.9)	132 (85.7)	124 (59.9)	88 (53)	<0.001

*SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2; COVID-19 = coronavirus disease 2019. *Participants were stratified according to level of risk of exposure to COVID-19 infected patients as either high-risk (those working in COVID-19 wards or the COVID intensive care unit [ICU]), intermediate-risk (those working in the emergency medicine or family medicine and public health departments and laboratories), low-risk (those working in all other wards, the non-COVID-19 ICU, paediatric ICU, and ambulatory clinics), or miscellaneous risk (those working in all other hospital areas).*