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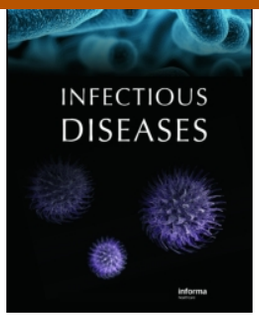

Infectious Diseases

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/infd20

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To cite this article: Nina Handal, Jimmy Whitworth, Anita Blomfeldt, Heidi Johanne Espvik, Elisabeth Lysaker, Jan Erik Berdal & Silje Bakken Jørgensen (2021): Comparison of SARS-CoV-2 infections in healthcare workers with high and low exposures to Covid-19 patients in a Norwegian University Hospital, Infectious Diseases, DOI: 10.1080/23744235.2021.1885734

To link to this article: https://doi.org/10.1080/23744235.2021.1885734

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Published online: 23 Feb 2021.

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INFECTIOUS DISEASES,
2021; VOL. 0,
NO. 0, 1–10

https://doi.org/10.1080/23744235.2021.1885734

ORIGINAL ARTICLE

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Comparison of SARS-CoV-2 infections in healthcare workers with high and low exposures to Covid-19 patients in a Norwegian University Hospital

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ABSTRACT

Introduction: A year into the pandemic, the knowledge of SARS-CoV-2 infection risks among healthcare workers remains limited. In this cross-sectional study, we examined whether healthcare workers with high exposure to Covid-19 patients had a higher risk of SARS-CoV-2 infection than other healthcare workers in a Norwegian University Hospital. We also investigated the prevalence of asymptomatic healthcare workers in a ward with a SARS-CoV-2 outbreak.

Methods: Healthcare workers from five wards at Akershus University Hospital were included between May 11 and June 11, 2020. Blood samples were analyzed for SARS-CoV-2 antibodies and seroprevalences compared between participants with high and low exposure to Covid-19 patients. Demographic data and SARS-CoV-2 infection risk factors were recorded in a questionnaire. Naso-/oropharyngeal swabs from participants from the outbreak ward were analyzed by reverse transcriptase-polymerase chain reaction.

Results: 360/436 (82.6%) healthcare workers participated. 9/262 (3.4%) participants from wards with high exposure to Covid-19 patients were SARS-CoV-2 seropositive versus 3/98 (3.1%) from wards with low exposure (OR 1.13; 95%CI 0.3–4.26, $p = .861$). SARS-CoV-2 antibodies were found in 11/263 (4.2%) participants who had worked one or more shifts caring for Covid-19 patients versus in 1/85 (1.2%) without any known occupational Covid-19 exposure (OR 3.67; 95%CI 0.46–29.06, $p = .187$). SARS-CoV-2 was detected in naso-/oropharyngeal swabs from 2/78 (2.6%) participants.

Conclusion: We found no significantly increased risk of SARS-CoV-2 infection in healthcare workers with high exposure to COVID-19 patients. Five healthcare workers had either serologic or molecular evidence of past or present unrecognized SARS-CoV-2 infection.

KEYWORDS
SARS-CoV-2
COVID-19
SARS-CoV-2 antibodies
healthcare workers
transmission
asymptomatic

ARTICLE HISTORY
Received 27 November 2020
Revised 30 January 2021
Accepted 31 January 2021

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Introduction

Reports of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infections among healthcare workers (HCWs) vary substantially between countries affected by the pandemic [1–7]. Assessing the true work-related risk of infection is difficult as HCWs are exposed to SARS-CoV-2 infection both in the community and at work. Therefore, the risk of infection will depend on many factors, including the SARS-CoV-2 prevalence in the community, national and local strategies to combat the virus, organization of healthcare and infection prevention and control (IPC) routines, including access to, and proper use of, personal protective equipment (PPE).

In this cross-sectional study, performed in a Norwegian University Hospital, we examined the risk of SARS-CoV-2 infection among HCWs in a setting with low community prevalence and high standard of IPC routines. The aim was to determine whether HCWs in Covid-19 wards had a higher risk of SARS-CoV-2 infection than other HCWs by comparing seroprevalences in the two groups. In addition, the prevalence of asymptomatic HCWs in a ward with an ongoing SARS-CoV-2 outbreak was investigated by analyzing naso-/oropharyngeal swabs by reverse transcriptase-polymerase chain reaction (RT-PCR).

Methods

Setting

Akershus University Hospital is the largest acute care hospital in Norway with 1000 beds and 10,000 employees, serving 640,000 people (10% of the Norwegian population). The SARS-CoV-2 seroprevalence in the two counties within the hospital's catchment area was estimated at approximately 1.4% (0.1 − 4.9%)−4.2% (0.9 − 10.4%) in April − May 2020 [8]. The hospital received the first Covid-19 patient on March 5, 2020. One hundred forty-seven Covid-19 patients had received treatment and 54 hospital employees had tested positive for SARS-CoV-2 (symptom-based testing) by the time the study commenced.

Built in 2008, the hospital buildings are modern with mainly single or double rooms with separate toilets, both in the regular wards and in the intensive care unit (ICU). Barrier precautions were applied around each Covid-19 patient, and none of the wards included in the study had any cohort areas with more than two patients. Mandatory use of PPE and enhanced IPC routines were implemented in March 2020 for staff, patients and visitors. Still, in one Covid-19 ward an accumulation of SARS-CoV-2 infections among HCWs over the course of four weeks indicated a possible ongoing outbreak at the start of the study. Transmission between staff members mediated by pre- or asymptomatic persons was considered a possibility.

Data collection

HCWs were invited from five wards: Covid ward A ($N = 92$), Covid ward B ($N = 75$), ICU ($N = 148$), an orthopaedic ward ($N = 70$) and the Department of Microbiology and Infection Control ($N = 51$). HCWs in the first three wards had high exposure to Covid-19 patients whereas HCWs in the last two wards had little or no known work-related exposure. Exposure at work was defined primarily by a HCW's affiliation with a ward. However, since some Covid-19 patients admitted due to orthopaedic disorders were treated in the orthopaedic ward, and some orthopaedic HCWs were re-allocated to high-exposure wards, the number of shifts HCWs spent caring for Covid-19 patients was also recorded.

The HCWs were recruited from May 11 to June 11, 2020. Blood samples for analysis of SARS-CoV-2 antibodies were collected on the day of study inclusion and a paper questionnaire filled in, which recorded demographic data and SARS-CoV-2 infection risk factors, including infection control training and routines (Appendix A). In addition, naso-/oropharyngeal swabs were collected from HCWs from the outbreak ward for analysis by RT-PCR.

Serology

Blood samples were collected using Vacuette® Tube (Greiner Bio-One, Kremsmünster, Austria). The samples were centrifuged at 2000 G within 2 h after sampling and stored in −20 °C. All serum samples were analyzed with the Elecsys® Anti-SARS-CoV-2 immunoassay (Roche Diagnostics, Basel, Switzerland) on an automated platform (Cobas®, Roche Diagnostics, Basel, Switzerland). The immunoassay detects IgG/IgM to the SARS-CoV-2 nucleocapsid antigen [9]. Based on an in-house validation, the hospital laboratory has introduced an equivocal zone and uses the following cut-off index (COI): Non-reactive (<0.5), equivocal zone (≥0.5–<1) and reactive (≥1). To ensure high specificity, samples with equivocal or unexpected reactive test results (participants without prior knowledge of SARS-CoV-2 infection) were retested with

the Roche test, and with a second test, the Liaison® SARS-CoV-2 S1/S2 IgG (DiaSorin, Saluggia, Italy), which detects SARS-CoV-2 spike IgG [10]. For one study participant, two samples were in addition analyzed with two more tests in external laboratories (Appendix B).

Reverse transcriptase-polymerase chain reaction

Naso-/oropharyngeal samples were collected in an inhouse viral transport medium and analyzed with RT-PCR for the detection of SARS-CoV-2 on the day of sampling. RNA was isolated with easyMAG® (BioMérieux, Marcy-l'Étoile, France). The RT-PCR is a validated, in-house, qualitative RT-PCR detecting the SARS-CoV-2 viral envelope gene, based on a method published by Corman et al. [11].

Statistics

Microsoft Excel (version 2010) and the statistical software package STATA (version 16) were used for data analysis. SARS-CoV-2 seroprevalences were compared between HCWs with high and low exposure to Covid-19 patients, both grouped by wards and by self-reported exposure. *p*-values were calculated using either logistic regression for categorical variables with more than two categories or a chi-squared test for 2×2 tables (with *p*-values $\leq$ .05 considered to indicate statistical significance).

Ethics committee approval

Ethical approval was granted from the Norwegian Regional Committee for Medical and Health Research Ethics on May 4, 2020 (REK ref 138484) and from the Akershus University Hospital's local Data Protection Official on May 8, 2020 (PVO ref 2020_67). Written informed consent was obtained from all study participants.

Results

Study participants and demographic data

Of the 436 HCWs invited, 360 (82.6%) participated in the study. The questionnaire was filled in by 358 (99.4%) participants. Demographic and clinical characteristics are presented in Table 1.

SARS-CoV-2 serology

SARS-CoV-2 antibodies were detected in 12/360 (3.3%) participants (Table 2), where nine had previous PCR-confirmed SARS-CoV-2 infection (eight before study inclusion and one at study inclusion from the outbreak ward). Three HCWs (one each from Covid ward B, the ICU and the orthopaedic ward) had positive SARS-CoV-2 serology without a previous diagnosis of Covid-19. In four HCWs, additional blood sampling after 5–6 weeks was necessary to reach a conclusion about serological status due to equivocal or unexpected positive results (Appendix B).

Association between SARS-CoV-2 seropositivity and exposure at work

The results are summarized in Table 2. SARS-CoV-2 antibodies were detected in nine (3.4%) HCWs in the high exposure wards versus in three (3.1%) in the low/no exposure ward, with an OR of 1.13 (95%CI $0.3 - 4.26$, $p = .861$). SARS-CoV-2 antibodies were found in 11 (4.2%) HCWs who had worked at least one or more shifts with Covid-19 patients versus in one (1.2%) who had no occupational exposure to Covid-19 patients. The OR was 3.67 (95%CI $0.46 - 29.06$, $p = .187$).

Two of the SARS-CoV-2 infected HCWs in the ward with an outbreak did not participate in the study. However, calculations show that their participation would not have changed the interpretation of the association between SARS-CoV-2 seropositivity and exposure at work.

Risk factors related to work

Possible risk factors for SARS-CoV-2 infection related to work are summarized in Table 3. The participants had two opportunities for free text comments: one regarding any additional breaches of IPC routines except those listed in the questionnaire, and one regarding any further comments on working during the Covid-19 epidemic. As the free text comments mainly addressed the same issues, results are presented in Figure 1. Concerns regarding poorly fitting PPE and lack or reuse of PPE were the most frequent issues.

SARS-CoV-2 RT-PCR

SARS-CoV-2 was detected by RT-PCR in two (2.6%) of the 78 HCWs tested from the outbreak ward. The first HCW had mild upper respiratory symptoms assumed to

Table 1. Demographic and clinical characteristics of the study participants.

	Total *N* (%)[a]	Wards with high exposure to Covid-19 patients *N* (%)[a]	Wards with low exposure to Covid-19 patients *N* (%)[a]
Department	360	262	98
Covid A	80 (22.2%)	80 (30.5%)	–
Covid B	61 (16.9%)	61 (23.3%)	–
Intensive care unit	121 (33.6%)	121 (46.2%)	–
Orthopaedic ward	49 (13.6%)	–	49 (50%)
Dep. Microbiology/Infection Control	49 (13.6%)	–	49 (50%)
Occupation	360	262	98
Doctors	106 (29.4%)	79 (30.2%)	27 (27.6%)
Nurses	199 (55.3%)	169 (64.5%)	30 (30.6%)
Healthcare assistants	18 (5%)	14 (5.3%)	4 (4.1%)
Biomedical laboratory scientists	32 (8.9%)	0	32 (32.7%)
Researchers/consultants	5 (1.4%)	0	5 (5.1%)
Gender	360	262	98
Female	275 (76.4%)	197 (75.2%)	78 (79.6%)
Male	85 (23.6%)	65 (24.8%)	20 (20.4%)
Age	360	262	98
$\leq$40 years	187 (51.9%)	134 (51.1%)	53 (54.1%)
41–60 years	156 (43.3%)	118 (45%)	38 (38.8%)
$\geq$61 years	17 (4.7%)	10 (3.8%)	7 (7.1%)
Comorbidities[b]	339	245	94
Asthma or COPD	27 (8.0%)	21 (8.6%)	6 (6.4%)
High blood pressure (medicated)	18 (5.3%)	11 (4.5%)	7 (7.4%)
Heart failure or myocardial infarction	2 (0.6%)	0	2 (2.1%)
Diabetes mellitus (types I or II)	6 (1.8%)	4 (1.6%)	2 (2.1%)
Immunological disease[c]	3 (0.9%)	1 (0.4%)	2 (2.1%)
Cancer (currently treated)	1 (0.3%)	1 (0.4%)	0
None of these	289 (85.3%)	211 (86.1%)	78 (83%)
Missing data	19	15	4
Immunosuppressive medicine	355	257	98
Yes	8 (2.3%)	5 (1.9%)	3 (3.1%)
No	347 (97.8%)	252 (98.1%)	95 (96.9%)
Missing data	3	3	0
Pregnant	260	187	73
Yes	12 (4.4%)	7 (3.7%)	5 (6.8%)
No	248 (90.5%)	180 (96.3%)	68 (93.2%)
Missing data	15	10	5
Symptoms after February 1, 2020[b]	354	256	98
Cough	125 (35.3%)	100 (39.1%)	25 (25.5%)
Fever	36 (10.2%)	30 (11.7%)	6 (6.1%)
Breathlessness	43 (12.2%)	32 (12.5%)	11 (11.2%)
Loss of taste or sense of smell	12 (3.4%)	10 (3.9%)	2 (2%)
Headache	165 (46.6%)	117 (45.7%)	48 (49%)
Muscle ache	56 (15.8%)	44 (17.2%)	12 (12.2%)
Stuffy/runny nose	162 (45.8%)	118 (46.1%)	44 (44.9%)
Sore throat	152 (42.9%)	114 (44.5%)	38 (38.8%)
General malaise	86 (24.3%)	62 (24.2%)	24 (24.5%)
Abdominal pain	42 (11.9%)	31 (12.1%)	11 (11.2%)
Nausea	34 (9.6%)	25 (9.8%)	9 (9.2%)
Unusual loose stools	24 (6.8%)	17 (6.6%)	7 (7.1%)
No symptoms	73 (20.6%)	50 (19.5%)	23 (23.5%)
Missing data	4	4	0
SARS-CoV-2 PCR test before study	358	260	98
Yes	119 (33.2%)	95 (36.5%)	24 (24.5%)
No	239 (66.8%)	165 (63.5%)	74 (75.5%)
SARS-CoV-2 PCR result before study	118	94	24
Positive	8 (6.8%)	6 (6.4%)	2 (8.3%)
Negative	110 (93.2%)	88 (93.6%)	22 (91.7%)
Missing data	1	1	0

[a]The percentage is calculated using the total number of answers as the numerator (i.e. excluding missing data).
[b]Multiple choices possible.
[c]Rheumatoid arthritis or systemic lupus erythematosus.

be allergy. Another sample was taken the next day to exclude a false-positive test or laboratory mistake, but the second sample was also positive. The second HCW was asymptomatic at the time of testing, but symptoms appeared around 12 h later, and the HCW was reclassified as a presymptomatic case.

Table 2. Association between SARS-CoV-2 seropositivity and exposure at work.

	Total N1 (%)[a]	SARS-CoV-2 seropositive		
		N2 (%)[b]	Crude OR (95% CI)	*p* Value
Department	360			
Covid A	80 (22.2%)	6 (7.5%)	1.24 (0.30 – 5.22)	.766
Covid B	61 (16.9%)	2 (3.3%)	0.52 (0.08 – 3.24)	.483
Intensive care unit	121 (33.6%)	1 (0.8%)	0.13 (0.01 – 1.26)	.078
Orthopaedic ward	49 (13.6%)	3 (6.1%)	1.00 (reference)	
Dep. Microbiology/Infection Control	49 (13.6%)	0	–	
Department, grouped by exposure	360			
High exposure (Covid A, Covid B, ICU)	262 (72.8%)	9 (3.4%)	1.13 (0.30 – 4.26)	.861
Low exposure (orthopaedic and MIC)	98 (27.2%)	3 (3.1%)	1.00 (reference)	
Work exposure Covid-19	348			
>30 shifts on ward w/ Covid-19 patients	132 (37.9%)	3 (2.3%)	1.65 (0.17 – 16.17)	.667
11–30 shifts on ward w/ Covid-19 patients	75 (21.6%)	5 (6.7%)	5.07 (0.58 – 44.52)	.143
<10 shifts on ward w/ Covid-19 patients	56 (16.1%)	3 (5.4%)	4.02 (0.41 – 39.72)	.234
Handled Covid-19 samples at the lab	13 (3.7%)	0	–	
No known exposure	72 (20.7%)	1 (1.4%)	1.00 (reference)	
Missing data	10			
Work exposure Covid-19, grouped	348			
Any shifts on ward with Covid-19 patients	263 (75.6%)	11 (4.2%)	3.67 (0.46 – 29.06)	.187
Samples at lab/no known ward exposure	85 (24.4%)	1 (1.2%)	1.00 (reference)	

[a]The percentage is calculated using the total number of answers as the numerator (i.e. excluding missing data).
[b]N2 = number of seropositives out of the total number in each row.

Table 3. Possible risk factors for SARS-CoV-2 infection related to work.

	Total *N* (%)[a]	Wards with high exposure to Covid-19 patients *N* (%)[a]	Wards with low exposure to Covid-19 patients *N* (%)[a]
PPE training after 1st March 2020	351	253	98
Received training	247 (70.4%)	212 (83.8%)	35 (35.7%)[b]
Received no training	63 (17.9%)	33 (13%)	30 (30.6%)
Not applicable to the HCW	41 (11.7%)	8 (3.2%)	33 (33.7%)
Missing data	7	7	0
Experience with PPE/IPC routine[c]	294	214	80
Damaged/nonfunctional PPE	76 (25.9%)	71 (33.2%)	5 (6.3%)
Lack of PPE	86 (29.3%)	75 (35%)	11 (13.8%)
Other breaches of IPC routines	57 (19.4%)	52 (24.3%)	5 (6.3%)
Not applicable to the HCW	126 (42.9%)	64 (29.9%)	62 (77.5%)
Missing data	64	46	18
Experienced any IPC routine breaches	294	214	80
Yes	171 (58.2%)	151 (70.6%)	20 (25%)
No or Not applicable to the HCW	123 (41.8%)	63 (29.4%)	60 (75%)
Missing data	64	46	18
Worked in other wards of the hospital	356	259	97
Yes	97 (27.2%)	80 (30.9%)	17 (17.5%)
No	259 (72.8%)	179 (69.1%)	80 (82.5%)
Missing data	2	1	1
Worked in other healthcare services outside the hospital	355	258	97
Yes	19 (5.4%)	15 (5.8%)	4 (4.1%)
No	336 (94.6%)	243 (94.2%)	93 (95.9%)
Missing data	3	2	1

[a]The percentage is calculated using the total number of answers as the numerator (i.e. excluding missing data).
[b]32/49 (65.3%) HCWs from the orthopaedic ward had received PPE training.
[c]Multiple choices possible.

Discussion

We compared the SARS-CoV-2 seroprevalence in HCWs with high and low occupational exposure to Covid-19 patients. There was no evidence of a significantly increased risk of SARS-CoV-2 infection in HCWs with high exposure, grouped by either wards or number of shifts treating Covid-19 patients. These findings are in accordance with other studies which found no increased infection risk among HCWs caring for Covid-19 patients [12–14]. However, intra-hospital transmission cannot be ruled out in any of the HCWs in our study. Further, the results must be interpreted with caution due to the low number of seropositive HCWs in both groups, which makes the study vulnerable to type II error. Other studies have reported a significantly higher prevalence in HCWs than in the community [4,15–19], suggesting an occupational hazard and emphasizing the importance of robust IPC measures to protect HCWs. While proper use of PPE has proven protective in several studies [20,21], long working hours, high work intensity, work in either

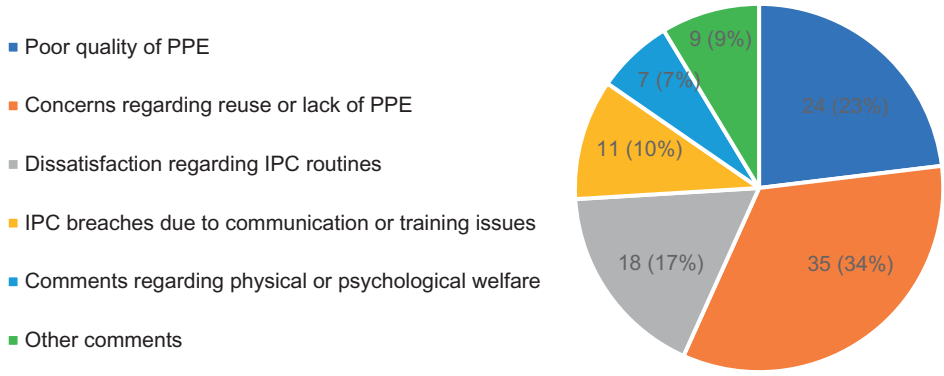

Figure 1. Free text comments regarding PPE and IPC routines during work with Covid-19 patients ($N = 104$ comments).

high or low exposure wards, inadequate PPE, insufficient IPC training, lack of monitoring of IPC routines and poor hand hygiene have been identified as risk factors for contracting SARS-CoV-2 in healthcare settings [1,22–24]. In our study, it was reassuring that the majority of HCWs in patient care had received training in the use of PPE during the pandemic, but worrying that more than half of the responding participants had experienced one or more breaches in IPC routines. Most of those breaches pertained to poorly fitting PPE and reuse of PPE, which resulted from the sudden rise in global demand for, and subsequent lack, of PPE.

A secondary objective in our study was to examine whether asymptomatic carriage of SARS-CoV-2 in HCWs was prevalent in a ward with a possible outbreak. Two HCWs tested SARS-CoV-2 positive in naso-/oropharyngeal swabs. None was truly asymptomatic, as one had very mild upper respiratory symptoms and the other was a presymptomatic case. In addition, three HCWs from other wards had positive SARS-CoV-2 serology without any previous diagnosis of Covid-19, probably due to the absence of notable symptoms. This shows that HCWs may unknowingly be at work during an infectious stage of SARS-CoV-2 infection, being either asymptomatic, presymptomatic or with mild symptoms as mistakenly attributed to other causes. Almost 80% of the study participants had experienced at least one or more respiratory, gastrointestinal or other symptoms in the past three months, but only 12 (3.3%) participants had positive SARS-CoV-2 serology. The upcoming cold season might thus pose challenges in balancing work restrictions for HCWs with symptoms that cannot empirically be excluded as related to SARS-CoV-2 infection while securing enough staff at work. Planning of hospital activities should take this into account.

Despite several reports of outbreaks in healthcare settings [25–27], the extent to which asymptomatic or presymptomatic SARS-CoV-2 infection contributes to transmission among colleagues and patients in healthcare settings is still poorly understood [28]. The most infectious period of SARS-CoV-2 infected individuals is right before and at the time of onset of symptoms, when the viral load in the upper airways is highest [29,30]. Several studies have found no difference in the viral load of nasal swabs between asymptomatic and symptomatic cases [31,32]. This indicates a high potential for asymptomatic and presymptomatic transmission. However, even if the viral load in the airways is comparable in asymptomatic and symptomatic patients, the presence of cough, sneezing or nasal secretion is likely to enhance viral transfer, and several studies have concluded that asymptomatic cases transmit less virus than symptomatic cases [33–36]. This conclusion is supported by our study, as no outbreaks were recorded among employees or patients in the wards of the three HCWs with an unexpected positive serology. Transmission between the two RT-PCR positive HCWs from the outbreak ward was deemed likely based upon epidemiological data and whole-genome sequencing (data to be published), but these HCWs were not asymptomatic.

Limitations

As the seropositivity rate was low in both groups, a type II error cannot be ruled out. Power calculations showed that we could not detect any true difference less than 8.9% between the two groups. Further, it is not clear whether everyone infected develops antibodies, especially those with only mild symptoms [37]. Although all HCWs with a PCR-confirmed SARS-CoV-2 infection had detectable SARS-CoV-2 antibodies, false-negative tests cannot be excluded.

Conclusion

In conclusion, we found no significantly increased risk of SARS-CoV-2 infection in HCWs with a high exposure to

Covid-19 patients in our hospital. Five HCWs had either serologic or molecular evidence of past or present SARS-CoV-2 infection without being aware of having been infected. More studies are needed to assess the infection risks to HCWs caring for Covid-19 patients as well as the role HCWs play in-hospital transmission, including asymptomatic or presymptomatic HCWs. Meanwhile, health authorities should monitor SARS-CoV-2 infection in HCWs to ensure safe working conditions by adjusting and facilitating the adherence to appropriate IPC measures.

Acknowledgement

The authors express our gratitude to Tina Fure Torkehagen, study nurse in the Department of Microbiology and Infection Control, who arranged practical aspects of the study and helped include participants. We are grateful to Elisabeth Jørgensen and her crew at the Covid-19 diagnostic station for their help in collecting blood samples and swabs for RT-PCR from the participants from the outbreak ward. The authors acknowledge the work performed by the biomedical laboratory scientists in the Division for Diagnostics and Technology for performing RT-PCR analyses. The authors further appreciate the help from Aina Haugen Lykkja at the Department of Microbiology, Innlandet Hospital, Lillehammer, and Fridtjof Lund-Johansen, Department of Immunology, Oslo University Hospital, in analysing a serum sample from a study participant.

Disclosure statement

The authors report no conflict of interest.

The article summarises the major findings from a Master thesis submitted in September 2020 to the London School of Hygiene and Tropical Medicine by the first author.

Funding

The study was financed by the Department of Microbiology and Infection Control at Akershus University Hospital, Lørenskog, Norway.

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Appendix A

Questionnaire CoVProtect Study (English translation)

Study ID:_____
Year of birth: _____
Date the form is filled in: _____

1) Gender:
☐ Man ☐ Woman ☐ Other

2) Position:
☐ Senior consultant ☐ Jr consult. ☐ Nurse ☐ Assistant nurse
☐ Bioengineer ☐ Health Secretary/consultant ☐ Other:_____

3) Are you pregnant?
☐ Yes ☐ No ☐ Not relevant

4) Do you have any of the following diseases? *Multiple choices possible*
☐ Asthma or COPD
☐ High blood pressure treated with medications
☐ Rheumatoid arthritis or Systemic lupus erythematosus
☐ Heart failure or myocardial infarction
☐ Cancer currently treated
☐ Diabetes mellitus (type I or II)
☐ None of these

5) Do you/have you since 1st March 2020 use/used immunosuppressive medicine such as: Prednisolone > 20 mg/day, CellCept, cytostatic drugs, TNF-α inhibitor or other?
☐ Yes ☐ No

6) a) Number of adults, 18 years or older, in the household except yourself: _____
b) Number of children under the age of 18 years in the household: _____

7) Have you had any of the following symptoms in the period between 1st of February and now? *Multiple choices possible*
☐ Cough ☐ Fever (>38 °C) ☐ Breathlessness ☐ General malaise/ tiredness
☐ Muscle ache ☐ Headache ☐ Stuffy or runny nose ☐ Unusual loose stool
☐ Sore throat ☐ Loss of taste or sense of smell ☐ Nausea ☐ No symptoms
☐ Abdominal pain

8) Have you previously been tested for Covid-19? *(prior to inclusion in this study)*
a) ☐ Yes ☐ No
b) If yes – date: _____
c) Test result:
☐ Detected ☐ Not detected

9) Have you travelled abroad after 1st of February 2020?
☐ Yes ☐ No

10) a) Have you been in close contact with someone with confirmed Covid-19 except at work?
Close contact is defined as: a) Had physical contact or b) been with someone with Covid-19 at less than 2 metres distance for more than 15 min.
☐ Yes ☐ No
b) If yes, who? *Multiple choices possible*
☐ Spouse/sexual partner
☐ Other household member
☐ Friend
☐ Own children in the household
☐ Family member outside the household
☐ Other contact

11) Has your partner or one or more of your household members had possible Covid-19 symptoms without being tested?
☐ Yes ☐ No

12) If you have had symptoms/Covid-19 *and* have been in close contact with someone with proven Covid-19: When did your symptoms occur?
Close contact is defined as: a) Had physical contact or b) been with someone with Covid-19 at less than 2 metres distance for more than 15 min.
☐ Before the close contact got symptoms
☐ After the close contact got symptoms
☐ Don't know
☐ I didn't have close contact with anyone with Covid-19
☐ I haven't had symptoms

13) Check where you have worked in the period between 1st March 2020 to the present day:
Multiple choices possible
☐ Covid 1 (Infectious medicine ward)
☐ Covid 2 (Pulmonary ward)
☐ Intensive care unit/MO
☐ SOP
☐ PO
☐ DKS
☐ Orthopaedic department
☐ Department of Microbiology and Infection Control
☐ None of these. Which: _____

14) Have you worked in other units at Ahus in the period between 1st March 2020 and now?
a) ☐ Yes ☐ No
b) If yes, what other wards have you worked in? _____

15) Have you worked in other healthcare services except Ahus in the period between 1st March 2020 and now? (e.g. nursing homes, community emergency care, home nursing, etc.)
☐ Yes ☐ No

16) To what extent have you worked with patients with confirmed Covid-19 at Ahus:
☐ In total > 30 shifts on a ward with Covid-19 patients
☐ In total 11-30 shifts on a ward with Covid-19 patients
☐ In total < 10 shifts on a ward with Covid-19 patients
☐ Handled Covid-19 samples at the lab
☐ I have no known exposure to Covid-19 patients or sample material at work

(*continued*)

17) Use of personal protective equipment for employees who have treated patients with Covid-19 or sample material from Covid-19 patients:
Check if the statement matches any experience you have had at work during the Covid-19 epidemic. Multiple choices possible.
☐ I have experienced that protective equipment has broken and lost function during use
☐ I have experienced a lack of personal protective equipment which has led to a violation of the infection prevention and control routines
☐ I have experienced other breaches of infection prevention and control routines,
describe:_____
☐ Not applicable to me

18) Have you under the pandemic used personal protective equipment that you have been uncertain how best to use?
☐ Yes ☐ No ☐ Not applicable to me

19) Have you been trained in the use of personal protective equipment one or more times during the period between 1st January and 1st March 2020?
☐ Yes ☐ No ☐ Not applicable to me

20) Have you received training in the use of personal protective equipment after 1st March 2020?
☐ Yes ☐ No ☐ Not applicable to me

21) In what form have you been trained? *Multiple choices possible*
☐ Group training ☐ Other
☐ One-to-one training ☐ Not applicable to me
☐ E-learning/online teaching/webinar

22) Do you have any other comments related to your work with Covid-19 patients?

Appendix B

SARS-CoV-2 analysis of first and second samples in four participants

	Elecsys® Anti-SARS-CoV-2	Liaison® SARS-CoV-2 S1/S2 IgG	Conclusion
HCW 1:			
Sample 1	Equivocal (COI 0.557)	–	Non-reactive
Sample 2	Non-reactive (COI 0.239)	Non-reactive (3.8 AU/ml)	
HCW 2:			
Sample 1	Equivocal (COI 0.505)	Non-reactive (10 AU/ml)	Reactive (IgM in first sample,
Sample 2	Reactive (COI 1.710)	Reactive (37.5 AU/ml)	IgG in second sample)
HCW 3:			
Sample 1	Reactive (COI 58.7)	Reactive (33.3 AU/ml)	Reactive (excluded lab mistake)
Sample 2	Reactive (COI 90.1)	Reactive (125 AU/ml)	
HCW 4:			
Sample 1	Reactive (COI 119)	Non-reactive (9.74 AU/ml)	Reactive (IgG only towards nuclecapsid,
Sample 2	Reactive (COI 137)	Non-reactive (8.49 AU/ml)	not spike antigen)[a]

[a]The samples were in addition tested with Abbott SARS-CoV-2 IgG assay (Abbott, IL) in an external laboratory, which was reactive. In a further analysis with an in-house test in another external laboratory, the sample tested reactive towards SARS-CoV-2 nucleocapsid antigen and one of two receptor binding domains on the spike protein, but negative towards spike IgG.