


BMJ Open SARS-CoV-2 seroprevalence in healthcare workers of a teaching hospital in a highly endemic region in the Netherlands after the first wave: a cross-sectional study

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ABSTRACT

Objective To study the SARS-CoV-2 infection rate among hospital healthcare workers after the first wave of the COVID-19 pandemic, and provide more knowledge in the understanding of the relationship between infection, symptomatology and source of infection.

Design A cross-sectional study in healthcare workers.

Setting Northern Limburg, the Netherlands.

Participants All employees of VieCuri Medical Center (n=3300) were invited to enrol in current study. In total 2507 healthcare workers participated.

Intervention Between 22 June 2020 and 3 July 2020, participants provided venous blood samples voluntarily, which were tested for SARS-CoV-2 antibodies with the Wantai SARS-CoV-2 Ig total ELISA test. Work characteristics, exposure risks and prior symptoms consistent with COVID-19 were gathered through a survey.

Main outcome measure Proportion of healthcare workers with positive SARS-CoV-2 serology.

Results The overall seroprevalence was 21.1% (n=530/2507). Healthcare workers between 17 and 30 years were more likely to have SARS-CoV-2 antibodies compared with participants >30 years. The probability of having SARS-CoV-2 antibodies was comparable for healthcare workers with and without direct patient (OR 1.42, 95% CI 0.86 to 2.34) and COVID-19 patient contact (OR 1.62, 95% CI 0.80 to 3.33). On the contrary, exposure to COVID-19 positive coworkers (OR 1.83, 95% CI 1.15 to 2.93) and household members (OR 6.09, 95% CI 2.23 to 16.64) was associated with seropositivity. Of those healthcare workers with SARS-CoV-2 antibodies, 16% (n=85/530) had not experienced any prior COVID-19-related symptoms. Only fever and anosmia were associated with seropositivity (OR 1.90, 95% CI 1.42 to 2.55 and OR 10.51, 95% CI 7.86 to 14.07).

Conclusions Healthcare workers caring for hospitalised COVID-19 patients were not at an increased risk of infection, most likely as a result of taking standard infection control measures into consideration. These data show that compliance with infection control measures is essential to control secondary transmission and constrain the spread of the virus.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Large-scaled cross-sectional SARS-CoV-2 antibodies screening of healthcare workers in a highly endemic region in the Netherlands.
- ⇒ Detailed questionnaire of COVID-19 exposures and symptoms consistent with COVID-19.
- ⇒ Screening immediately after the first epidemic wave in the Netherlands and before easing of the national lockdown measures, allowing potential exposure sources to be restricted.
- ⇒ The demographic profile of the spread of the virus among this group of healthcare workers is limited as participants were not asked for their ethnicity, residency or activity in previous festivities.
- ⇒ The probability of having SARS-CoV-2 antibodies on exposure to one specific COVID-19 source might be influenced by other COVID-19 sources, although minimised by including these as confounders in statistical analysis.

INTRODUCTION

The SARS-CoV-2 was first reported in Wuhan, China, mid-December 2019. Due to the rapid and worldwide spread of the virus, the WHO officially declared the COVID-19 outbreak a pandemic on 11 March 2020.¹ On February 27, the first case of COVID-19 was confirmed in the Netherlands.² Within a month, more than 10 000 cases had been confirmed.³ The spread of the virus started initially in the southern regions of the Netherlands. VieCuri Medical Centre, located in the province of Limburg in the south of the Netherlands, was located in a highly endemic area.

'Intelligent lockdown measures' were announced by the Dutch government on 12 March, targeting transmission in the community,⁴ whereas infection by patient contact and among hospital employees was primarily addressed by hospital policy. The VieCuri

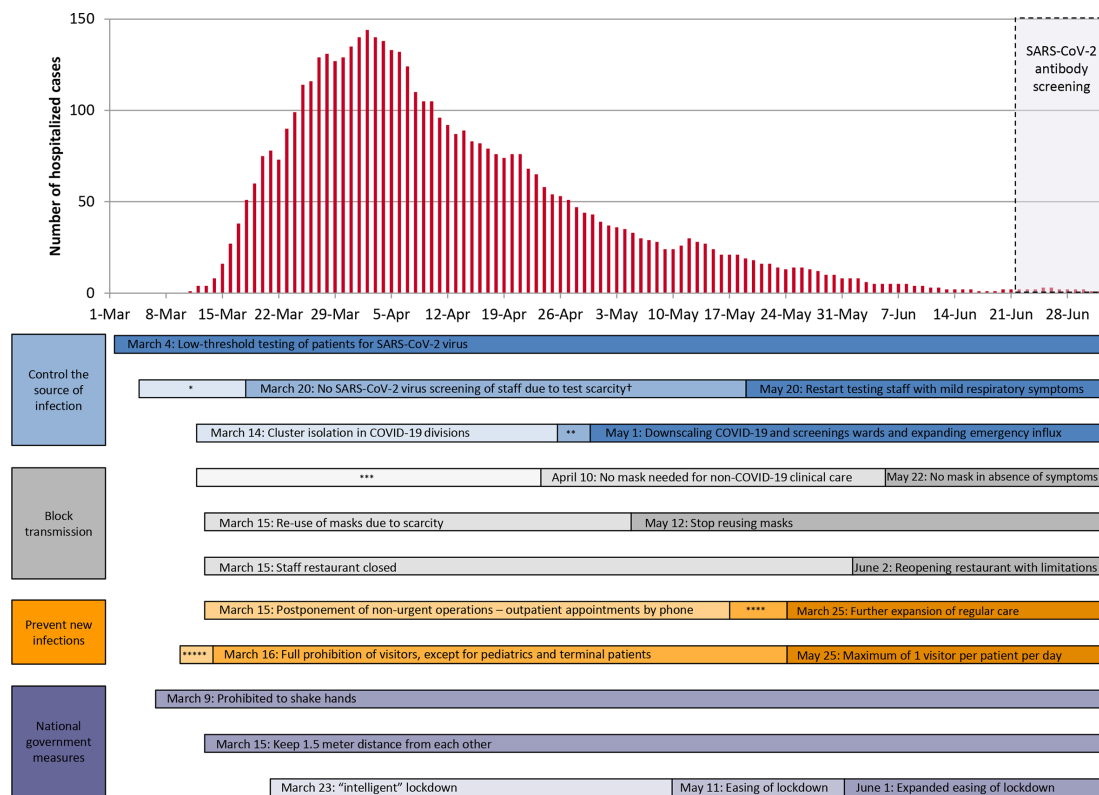


Figure 1 Timeline of hospitalised patients in VieCuri per day and infection prevention measures taken internally over time. The chart shows the number of COVID-19 patients admitted at the hospital each day between March and June 2020. HCWs have been screened on the presence of SARS-CoV-2 antibodies between 22 June 2020 and 3 July 2020. Infection prevention measures taken by the hospital and taken over from the Dutch government policy, are depicted below the chart. *March 7: Testing on SARS-CoV-2 virus of HCW with mild respiratory symptoms; †HCW with mild respiratory symptoms have to work wearing a surgical mask; **27 April: Downscaling IC capacity; ***14 March: FFP1 and surgical type II R face masks for clinical care, FFP2 masks for medical procedures following aerosol release; ****18 May: Start regular care of patients with urgent care; *****12 March: maximum of 1 visitor per patient per day, expect for paediatrics, ICU and terminal patients. FFP, filtering facepiece; HCW, healthcare worker; ICU, intensive care unit.

hospital responded quickly to the emerging outbreak and implemented infection prevention and control measures from 4 March 2020. This included low-threshold testing of patients, limitation in numbers of visitors per patient and scaling down (non-urgent) operations, listed in figure 1. The first confirmed COVID-19 case in the hospital concerned a healthcare worker (HCW), on 8 March, only a few days before the first COVID-19 confirmed patient was hospitalised at VieCuri on 11 March. During the first wave of the COVID-19 pandemic in the Netherlands (February to June 2020) a total of 408 patients with COVID-19 have been hospitalised at VieCuri (figure 1). The Netherlands had to contend with insufficient test capacity, therefore only at the end of the first wave increased test capacity allowed HCW to be screened for SARS-CoV-2 again.⁵ As a result, the overall picture of infections, and therefore risks as well, within hospital settings remained unknown.

Caring for patients with COVID-19 (besides exposure to infected family members and colleagues or community transmission) potentially placed front-line HCW at an increased risk of becoming infected with the new virus. Several studies found that the COVID-19 incidence in HCW was higher than in the general population,

suggesting nosocomial transmission and emphasises the importance of personal protective equipment (PPE) to prevent HCW infections, subsequently reducing secondary transmission.^{6–10} A Scottish study showed a higher hospital admission risk in patient facing HCW, as well as in household members of HCW with patient care, compared with non-patient facing HCW.⁷ Moreover, Shields *et al*¹¹ identified different risks of seropositivity between different groups of HCW, suggesting different exposure risks exist within the hospital environment.

On the other hand, the WHO-China Joint Mission and preliminary Chinese household transmission studies have shown that transmission within healthcare settings and among HCW was not of major contribution to the spread of SARS-CoV-2 and have suggested HCW to have been infected within the household rather than in healthcare setting.¹² Various studies support these data suggesting staff have been most at risk at home and have acquired an infection outside the hospital.^{13 14} They imply that transmission occurred at specific social events in the community rather than within hospital settings and therefore do not support widespread nosocomial transmission as the source of infection in patients or HCW.¹⁵

Due to the fact that front-line HCW in patient-facing roles appeared to be at risk of infection, seroprevalence studies are useful to estimate the risk among HCW and to provide insight into the relationship between infection, symptomatology, and source of infection. Such knowledge is important to reflect on hospital policy regarding infection prevention and control measures, protecting HCW and controlling rates of secondary transmission. Therefore, we conducted a cross-sectional study of hospital staff at VieCuri Medical Centre to determine the seroprevalence of SARS-CoV-2 antibodies and the relationship to prior symptoms, work characteristics and potential exposure, both in the hospital and private situation.

METHODS

Study design and population

A cross-sectional study of HCW at VieCuri Medical Centre was performed between 22 June 2020 and 3 July 2020. All employees (n=3300) were invited to participate in current study via internal communication (mail and intranet). Participation was fully voluntary and all participants provided a digital informed consent prior to enrolment in the study. Only individuals employed by the hospital, interns and volunteers, at the moment of blood collection, were included.

All participants (n=2507) voluntarily provided a venous blood sample (10 mL) for SARS-CoV-2 antibody detection, using the Wantai SARS-CoV-2 Total Ab ELISA. Serologic analysis was performed at the Serology division of the department of Medical Microbiology, VieCuri Medical Centre, Venlo. The cut-off value for positive serostatus was set at a ratio of >1.0. Prior validation of this assay in Dutch laboratories showed a sensitivity of 97.5% in patients with severe (PCR-confirmed) infections (n=646) when samples were collected >14 days after onset of illness. The specificity of the ELISA was 99.6% (n=1334).¹⁶

Participants were asked to complete an online questionnaire covering exposure risks (COVID-19 confirmed and suspected patient, coworker and household contact), (severity of) prior COVID-19-related symptoms between 1 March and the date of the questionnaire, hospital department and occupation.

Outcomes

The primary outcome was the proportion of HCW with positive SARS-CoV-2 serology. Secondary outcomes consisted of the probability of having SARS-CoV-2 antibodies among HCW according to different age categories, exposure risks (patients, coworkers and household) and work characteristics (department and occupation). Therefore, all participating HCW were clustered. Strict department clustering was challenging due to continuous exchange of staff during the first wave. A general subdivision was used to analyse the differences in seropositivity between HCW with and without direct COVID-19 and non-COVID-19 patient contact. When distinguishing individual hospital departments, we focused only on those

wards most and least involved in the care of COVID-19 patients. Since the general internal medicine and pulmonary medicine were both occupied with patients with COVID-19 and personnel continuously exchanged on these wards, we chose to combine these two wards in the analysis. Moreover, symptomatic predictors for the presence of SARS-CoV-2 antibodies were identified.

Under the General Data Protection Regulation, we did not use the hospital HR database for occupational information on all HCW. Occupational roles were broadly categorised according to predesignated occupations stated in the survey. HCW categorised as 'other' had been subdivided according to the presence or absence of direct patient contact. Classification bias was minimised by minimal changes to occupational roles reported by all HCW. Nevertheless, all exposures in combination with occupational roles were checked in order to guarantee continuity. We checked whether reported patient contact met the definition of 15 min within 1.5 metres.

Statistical analysis

Collected data were analysed using IBM SPSS Statistics V.24.0. The seroprevalence was calculated and expressed as a percentage. The χ^2 test was used to analyse differences in seroprevalence between men and women, independent samples t-test to compare age between seropositive and seronegative HCW. Age was subsequently categorised and analysed with bivariate logistic regression using seropositivity as outcome variable. Multivariate logistic regression was performed to estimate the adjusted OR and 95% CIs to assess differences in probability of a positive test by reported symptoms and their severity, independently, in which all symptoms were included as covariates. Additionally, this analysis was used to examine age differences in absence of (severe) symptoms. Moreover, multivariate logistic regression has also been applied to assess the odds of seropositivity for work characteristics and the potential infection sources (patients, coworkers and household).

When examining the probability of positive serology, distinct reference groups were used. For the analysis of exposure risks we chose to compare HCW exposed to a potential infection source (patient, coworker and household) to HCW reported not to have been exposed to any COVID-19 contact, neither confirmed nor suspected and therefore mutually comparable. When analysing the probability of SARS-CoV-2 seropositivity among different hospital departments, HCW without direct patient contact were used as a reference group, since this subgroup had the least exposure within the hospital.

Covariates

Hospital department, occupation, age and contact with COVID-19 confirmed and suspected individuals were identified as confounders and included in multivariate analyses. The adjustment for COVID-19 suspected contacts was of great importance. HCW had been in contact with patients who were highly suspected of COVID-19 but the diagnosis still had to be confirmed by

Table 1 Demographics of study participants

	All HCW	Seropositive	Seronegative	Seroprevalence (%)	P value
n	2507	530	1977	21.1	
Age (years), median (IQR)	45 (32–56)	42 (28–55)	46 (33–56)		<0.001
Sex, n (%)					
Male	454 (18.1)	89 (16.8)	365 (18.5)	19.6	0.376*
Female	2053 (81.9)	441 (83.2)	1612 (81.5)	21.5	
* $\chi^2=0.786$.					

additional tests. Due to test scarcity in the first few months of the pandemic, only patients were tested by PCR. So HCW were unable to get tested for SARS-CoV-2 when COVID-19 was suspected, and therefore, never confirmed. Moreover, in that period (March–June) hardly any other respiratory viruses were found. Adjustment for work characteristics and age filtered out potential cluster infections within the hospital.

Patient and public involvement

No patients or public were involved in defining research questions or outcome measures, nor were they asked to provide input on the design and conduct of the study. No patients were involved in the interpretation and dissemination of the study results. Results were presented within the hospital and conclusions about specific departments were checked with representatives of the concerning department.

RESULTS

A total of 2507 HCW participated in current study (76%) of which 202 physicians, 745 nurses, 459 paramedical staff and 1101 others including technical and administrative staff, housekeepers, students and volunteers. The median age was 45 years (range 17–80). The seroprevalence among HCW at VieCuri Medical Center between 22 June and 3 July was 21.1% (n=530/2507) (table 1). In total, one HCW (female, 63 years) had to be hospitalised due to COVID-19, but was not admitted to the ICU.

There was no difference in seropositivity between men and women (19.6% vs 21.5%, $\chi^2=0.786$, p=0.376). On average seropositive HCW were younger than seronegative HCW (42 vs 46 years; p<0.001). Participants ≤ 30 years were more likely to have SARS-CoV-2 antibodies compared with participants older than 30 years (figure 2).

Participants who have worked from home, and who were therefore not present in the hospital in the period March–June, had similar seroprevalence compared with participants who did work in the hospital (17.9% vs 21.2%, $\chi^2=0.370$, p=0.543). A total of 745 HCW reported not to have been exposed to any COVID-19 confirmed or suspected contact, of which 11.7% were seropositive (n=87/745). This subpopulation had a significantly lower seroprevalence compared with HCW exposed to at least one potential infection source (11.7% vs 25.1%,

$\chi^2=56.936$, p<0.001). This subgroup, with no known risk, is used as reference group when examining exposure risks. Of all HCW, 62.1% (n=1556/2,507) was involved in patient care. Seroprevalence among these HCW with direct patient contact was 24.6% (n=383/1556) and the probability of having SARS-CoV-2 antibodies was comparable to HCW without direct patient contact (OR 1.42, 95% CI 0.86 to 2.34). Subsequently, HCW with and without direct contact with COVID-19 patients had similar seropositivity probability (OR 1.62, 95% CI 0.80 to 3.33) (figure 3A). Exposure to COVID-19 positive co-workers (OR 1.83, 95% CI 1.15 to 2.93) or household members (OR 6.09, 95% CI 2.23 to 16.64), on the contrary, was associated with positive serology.

Additionally, seroprevalence was mapped across different departments within VieCuri. Multivariate logistic regression, in which the HCW without any patient contact was used as reference group, confirmed that working at COVID-19 departments did not increase the probability of a SARS-CoV-2 infection (figure 3B). In addition, there was no association between occupation and the presence of SARS-CoV-2 antibodies, although paramedical staff seemed to have a lower probability compared with other staff without patient contact (OR 0.66, 95% CI 0.45 to 0.98) (online supplemental figure 1). Examining

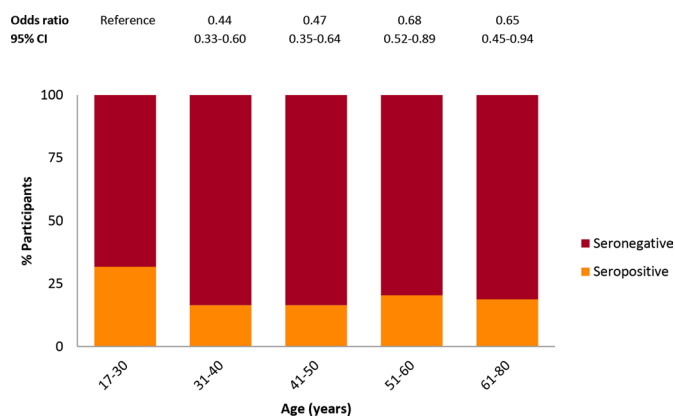
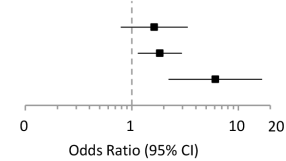


Figure 2 SARS-CoV-2 seropositivity among different age categories. Age categories are defined by years. ORs and 95% CIs are based on multivariate logistic regression analysis, with age group 17–30 years as reference group and adjusted for COVID-19 confirmed and suspected contact, occupation and department as confounders.

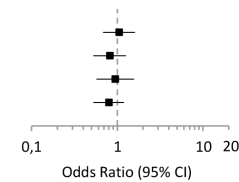
A

	Number of HCW with SARS-CoV-2 antibodies/total		Odds ratio (95% CI)
	Exposure present	Absence of any COVID-19 exposure	
COVID-19 patient contact	299/1088	87/745	1.62 (0.80-3.33)
COVID-19 co-worker contact	215/919	87/745	1.83 (1.15-2.93)
COVID-19 household contact	44/85	87/745	6.09 (2.23-16.64)



B

	Number of HCW with SARS-CoV-2 antibodies/total	Odds ratio (95% CI)
HCW without direct patient contact	147/951	Reference group
COVID-19 confirmed nursing wards	193/660	1.05 (0.69-1.60)
COVID-19 suspected nursing wards	93/400	0.82 (0.53-1.25)
Non-COVID-19 nursing wards	45/187	0.95 (0.58-1.55)
Outpatient department	52/309	0.80 (0.53-1.19)



C

	Number of HCW with SARS-CoV-2 antibodies/total		Odds ratio (95% CI)
	Working at department	HCW without direct patient contact	
COVID-19 nursing wards*	120/337	147/951	1.86 (0.93-3.74)
Intensive Care	28/199	147/951	1.01 (0.43-2.33)
Pediatrics	11/45	147/951	1.93 (0.67-5.55)
Emergency Care	23/88	147/951	1.41 (0.58-3.45)
Housekeeping	9/50	138/901**	1.05 (0.49-2.26)
General Surgery	39/103	147/951	3.39 (1.32-8.71)

*COVID-19 nursing wards included General Internal and Pulmonary Medicine

** the 50 missing participants in this reference group are working at the housekeeping department

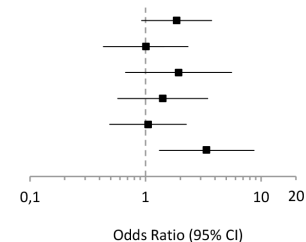


Figure 3 The probability of SARS-CoV-2 seropositivity among HCW according to different exposure risks and hospital departments. (A) HCW exposed to (COVID-19 positive) HCW exposed to COVID-19 positive patient, coworker and household contact are compared with HCW without either confirmed or suspected COVID-19 exposure. OR and 95% CIs are based on multivariate logistic regression analysis, adjusted for age, COVID-19 confirmed and suspected contacts, occupation and department as confounders. (B, C) HCW working at the department are compared with HCW working without direct patient contact. ORs and 95% CIs are based on multiple logistic regression analysis, adjusted for age, COVID-19 confirmed and suspected contact, and occupation as confounders. HCW, healthcare worker.

several individual working departments within VieCuri, focusing on the wards most and least involved in the care of COVID-19 patients, seroprevalence was highest in participants working at COVID-19 nursing wards (35.6%, $n=120/337$) and general surgery (37.9%, $n=39/103$) and lowest in the intensive care (14.1%, $n=28/199$) and housekeeping (18%, $n=9/50$) (figure 3C). Using HCW without direct patient contact as a reference population in multivariate logistic regression, only an increased OR of seropositivity was observed in HCW working at general surgery (OR 3.39, 95% CI 1.32 to 8.71).

We explored the relationship between seroprevalence and prior symptoms consistent with COVID-19 listed in figure 4. An extensive number of participants had experienced at least one prior symptom ($n=1807/2507$ (72.1%)). These HCW had a significantly greater seroprevalence compared with the HCW who remained

completely asymptomatic since the corona outbreak in the Netherlands (24.6% vs 12.1%, $\chi^2=47.164$, $p<0.001$) (online supplemental figure 2A). Additionally, no age differences are identified among asymptomatic seropositive HCW (OR 1.00, 95% CI 0.849 to 1.181). Besides not experiencing fewer symptoms, seropositive HCW ≤ 30 years also did not experience less severe symptoms (online supplemental figure 2B,C).

Of those individuals with SARS-CoV-2 antibodies, 16% ($n=85/530$) had not experienced any prior COVID-19-associated symptoms. Anosmia ($n=422$) was most strongly associated with seropositivity (59.5% vs 13.4%; OR 10.51, 95% CI 7.86 to 14.07). Furthermore, fever ($n=820$) was also a symptomatic predictor for positive serology (33.9% vs 14.9%; OR 1.90, 95% CI 1.42 to 2.55) (figure 4).

Participants were also asked to report the severity of their symptoms on a scale of 1–10. Severity scores of 1–3

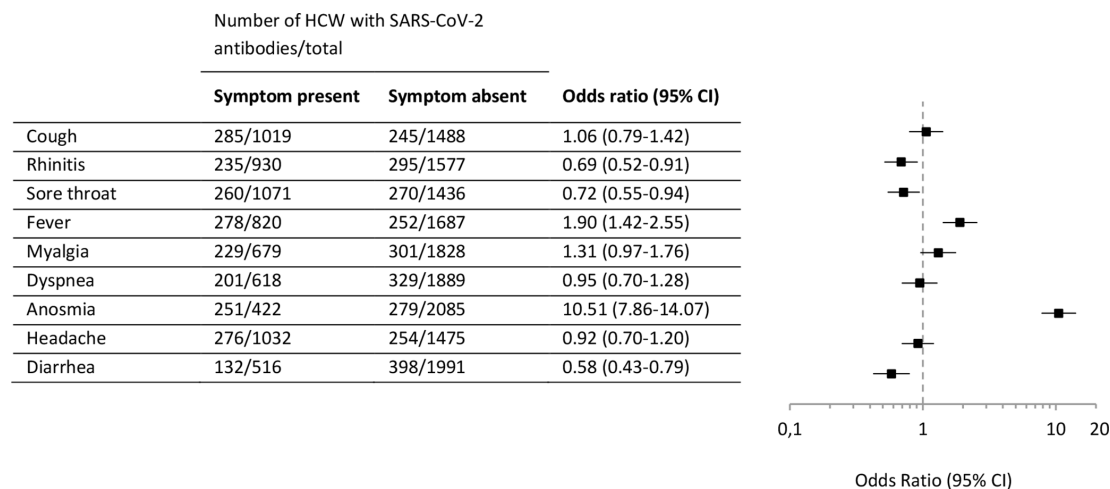


Figure 4 Symptomatic predictors for the presence of SARS-CoV-2 antibodies. ORs and 95% CIs are based on multivariate logistic regression analysis with all symptoms included in the model. HCW, healthcare worker.

is categorised as mild, scores 4–7 as moderate and 8–10 as severe. Multiple logistic regression showed an increasing seroprevalence with increasing severity of fever and anosmia (online supplemental figure 3). Severe anosmia (n=210) was highly associated with the presence of SARS-CoV-2 antibodies (78.6% vs 13.4%; OR 23.74, 95% CI 16.67 to 33.78).

DISCUSSION

Overall, 21.1% of HCW in a teaching hospital in a highly endemic region after the first wave was seropositive. The seroprevalence was significantly higher among HCW aged 17–30 years compared with >30 year old HCW, 16% of seropositive participants stayed asymptomatic after a SARS-CoV-2 infection and fever, and especially anosmia, were associated with positive serology. Furthermore, our results show that, when accounting for confounders in a large sample, HCW having contact with COVID-19 positive coworkers and household members were, respectively, twofold and sixfold more likely to be seropositive.

Important here to highlight the implement of adjustments in the analyses. A large amount of HCW reported to have been exposed to a COVID-19 suspected contact additional to a COVID-19 confirmed individual. Creating single exposure subgroups by dismissing these contaminated exposures, did result in too small sample sizes with insufficient statistical power. As a consequence, we were unable to completely isolate exposure sources from each other. Therefore, we chose to redistribute the group of HCW for every exposure, thereby accepting the chance that the outcome might be influenced by other COVID-19 exposures. To account for this, multivariate logistic regressions were adjusted for the remaining COVID-19 contacts. Besides, due to test scarcity only patients were tested for SARS-CoV-2 at the start of the first epidemic wave. Absenteeism among VieCuri staff did not increase in that period,

which makes us believe many infections have remained unknown. Moreover, many HCW have been in contact with highly suspected COVID-19 patients pending a PCR. For example at the emergency care department, responsible for the largest COVID-19 patient influx. Therefore, reported suspected COVID-19 contact is an important factor when analysing exposure risks. Nevertheless, the results should be addressed with care.

Differences in study populations and screening period of previous serological studies make results difficult to compare. Similarly, the study region. One month into the pandemic the overall seroprevalence in the Netherlands was 2.7%, based on plasma samples of 7361 regular blood plasma donors, collected between 1 April 2020 and 15 April 2020.¹⁷ Regional mapping showed a prevalence of 6.9% in Northern and central Limburg, the region in which VieCuri Medical Centre is located. The difference to our reported seroprevalence could be explained by the time of sample collection. Our study has been performed 2.5 months later into the pandemic, right after the first wave, while the time of testing of Slot *et al* was relatively early after the outbreak. Also the subjects enrolled in the study were healthy at the time of donation, and had not reported health issues 2 weeks before donation. This could therefore result in an under-representation of donors who suffered or recovered from COVID-19.¹⁷ The magnitude of regional differences in serostatus are also reflected by a serological study in HCW of the Amsterdam University Medical Centers between March and June, where the highest seroprevalence observed was 13.2% in HCW who were in direct contact with COVID-19 patients, vs 3.6% in HCW without direct patient contact, while the seroprevalence in our total study population was 21.1%.¹⁸ At the beginning of the pandemic, the Southeast region of the Netherlands was considered a COVID-19 hotspot, while community transmission in Amsterdam was still low. Our data

suggest most infections arise from the household, while Sikkens *et al* reported HCW working at COVID-19 wards to be at increased risk of infection, with transmission between HCW as a major contributor.¹⁸ Nevertheless, both studies indicate the potential impact of infection risks due to HCW-HCW interaction. Similar results were found by Steensels *et al*,¹⁴ using the same study design, where most infections were most likely acquired in the community. In line with these serological studies, research using PCR to screen mildly symptomatic HCW also reported no nosocomial transmission but many of the infections to be acquired rather in the community and social gatherings.^{13 15}

Previous research has shown that people aged 20–30 have the highest rates of COVID-19 infections.^{6 19–22} Furthermore, some of the Dutch (healthy and symptom free) blood donors have been tested for the presence of SARS-CoV-2 antibodies. Results show that between 1 April 2020 and 15 April 2020, the seroprevalence in donors aged 18–30 years was significantly higher compared with other age groups (4.2% vs 2.4%).¹⁷ However, age differences varied substantially among areas throughout the country. When correcting for region of residence no additional association between age and seropositivity was shown. The celebration of Carnival in the South and Southeaster regions of the country in the last week of February 2020 is thought to have caused the regional variation, even before the start of the epidemic in the Netherlands and the introduction of social distancing and social restrictions.^{17 23} Carnival is celebrated especially, and more exuberantly, among the younger generation and since they often show no or only mild symptoms, and are unaware they are infected, they could have unknowingly spread the virus. This study supports this hypothesis by observing almost twice as many infections among the participants ≤ 30 years. Preliminary studies suggest that these young adults will only have few or no symptoms at all, and that the physical effects of the disease are less severe.^{24–27} However, our data suggest that there is no difference between different age groups regarding the presence and severity of COVID-19-related symptoms. After adjustments for exposures within the hospital and household, the association between serology and age remains, suggesting that the young adults got infected elsewhere and thereby supporting the hypothesis of Carnival as point of origin. Nevertheless, it is important to mention that information on participation in any Carnival festivity of the participated HCW was missing in the survey. Therefore, this assumption has to be addressed with care.

Furthermore, we could not identify significant variations in seroprevalence between different hospital departments apart from HCW working at the general surgery. The higher seropositivity could not be explained based on the survey. Additional inquiries were made to identify the potential origin of the high number of infections. It appeared that in March, before

the partial national lockdown and restrictions inside the hospital environment, a social gathering took place among members of this department. Afterwards it appeared that one of the attendees was infected. This could have potentially caused the spread of the virus among general surgery members. Unfortunately, the sample sizes within the department were too small to analyse the risk of exposure to coworkers to confirm this presumption. This cluster at the surgical ward, in combination with no further significant variations among different groups of HCW, emphasises the importance of social distancing in slowing down the spread of COVID-19 and implies proper use of PPE promoted by the hospital when HCW are facing (COVID-19) patients, which included eye protection, long-sleeved disposable apron and gloves in addition to, initially, Filtering Facepiece 2 (FFP2) masks, later on surgical mouth-nose masks and good hand hygiene.

Not only proper use of PPE while caring for COVID-19 patients is essential to prevent infection, research shows that break room exposure to another HCW without wearing a mask is associated with increased risk for HCW infection.^{28 29} The necessity of infection prevention and control measures was emphasised again with multiple clusters of infections among VieCuri employees at the second epidemic wave from October 2020. Inquiries suggest that HCW-HCW interaction might have initiated the spread of the virus.

There are a number of limitations to this study additional to the analysis on exposure risks. Participants could not define the amount of time they were in close contact with a COVID-19 confirmed or suspected patient or colleague. Due to these limitations of the questionnaire, the degree of exposure to COVID-19 contacts could vary between HCW. Serology testing indicates the percentage of participants that developed SARS-CoV-2 antibodies on infection. However, a negative Wantai total Ab ELISA test cannot rule out a possible infection followed by no or no detectable antibody levels. Besides, previous research showed a decline in SARS-CoV-2 antibodies over time following acute infection.^{30–32} Therefore, the seroprevalence might be underestimated. On the other hand, the cut-off value for positive serostatus was set at a value of 1.0 in this study, while in daily practice values between 1.0 and 3.0 are considered questionable. This may result in an overestimation of true seroprevalence. Finally, participants were not able to indicate their ethnicity or residency in the survey. This data could have been of value in creating an epidemiological profile of the spread of the virus considering some of the surrounding villages were COVID-19 hotspots.

The strengths of the study include the large sample size of this hospital-wide screening study for SARS-CoV-2 antibodies in HCW in a teaching hospital right after the first epidemic wave in the Netherlands and before easing of the national lockdown measures. This restricted the potential exposure sources. The study



had high participation rate and in contrast to previous screening studies, participants were not selected based on presence of symptoms or exposures as all HCW at VieCuri were offered serological testing without inclusion criteria. Additionally, COVID-19-related symptoms were queried to detail, allowing for analyses on severity of symptoms.

In conclusion, HCW could face a high risk of SARS-CoV-2 transmission while providing care for suspected or confirmed COVID-19 patients. Yet, they had no increased seroprevalence of previous COVID-19 infection compared with HCW without direct patient contact. Therefore, proper use of PPE and the implementation and compliance to basic infection control precautions are essential to control secondary transmission and constrain the spread of the virus inside the hospital.

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