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Original Article

Transmission of severe acute respiratory coronavirus virus 2 (SARS-CoV-2) between hospital workers and members of their household: Nationwide, registry-based, cohort study from Norway

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Abstract

Background: Understanding and limiting infection in healthcare workers (HCWs) and subsequent transmission to their families is always important and has been underscored during the COVID-19 pandemic. Except in specific and local settings, little is known about the extent of such transmissions at the national level.

Objective: To describe SARS-CoV-2 infection in HCWs and to estimate the risk of HCWs transmitting COVID-19 to their household members, including calculating the secondary attack rate to household members and estimating the risk for hospital workers to contract COVID-19 at home.

Methods: Using individual-level data on all HCWs employed in Norwegian hospitals and their household members, we identified (1) the number of HCWs who tested positive for SARS-CoV-2 between August 2020 and September 2021 and the proportion of those who were index cases in their own household and (2) the number of HCWs who were secondary cases in their own households.

Results: During this period, ~3,005 (2,6%) hospital workers acquired COVID-19. Almost half of all hospital workers with confirmed COVID-19 were likely index cases in their own households. When the index case in a family was an HCW, the secondary attack rate was 24.8%. At least 17.8% of all confirmed COVID-19 cases among hospital workers were acquired in the household.

Conclusions: Our results suggest not only that many HCWs are infected with SARS-CoV-2 in their households but also that infected HCWs constitute a serious infection risk to members of the HCW's household.

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Minimizing the incidence of coronavirus disease 2019 (COVID-19) in healthcare workers (HCWs) is vital to maintaining capacity in the healthcare system. The COVID-19 incidence rate has been high in many groups of HCWs, also compared with the general population.[1–4] Infection rates, however, have been higher among some non-clinical staff (eg, cleaning staff) than nurses and physicians,[2,5] suggesting that clinical interaction with COVID-19 patients may not be the most important determinant of infection in HCWs.

HCWs may be infected through exposure at work, but during periods of high community prevalence they may also be infected in their households or community. Thus, a range of interventions have been implemented to maintain capacity in the healthcare system, including prioritization of HCWs in national vaccination programs. Indeed, infected HCWs may also transmit the virus to their colleagues, patients, and their families. Transmission from HCWs to their household members implies that the societal costs of nosocomial COVID-19 in HCWs exceeds its detrimental impacts on the HCWs, the patients, and the operation of the services.

Here, we describe severe acute respiratory coronavirus virus 2 (SARS-CoV-2) infections in HCWs, and we provide new analyses to estimate the risk of HCWs transmitting SARS-CoV-2 to their household members as well as the risk for hospital workers to contract COVID-19 at home.

Methods

Study setting

We followed hospital workers from August 1, 2020, to September 1, 2021. During this period, national guidelines recommended that HCWs be provided free access to tests. Although Norway had not introduced regular testing of asymptomatic vaccinated HCWs during the study period, there was a low threshold after exposure with mild symptoms. Daily testing was recommended in outbreak settings.

Follow-up ended September 1, 2021, when testing practices changed with the increased use of home tests. First the α (alpha)

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variant and then the δ (delta) variant were dominant during the study period. HCWs were prioritized in the Norwegian vaccination program, and a large proportion were vaccinated during the first months of 2021. By the end of follow-up, 95.5% of all hospital workers in our sample and 87.4% of the rest of the population aged >18 years had been vaccinated with at least a first dose.

Data acquisition

We collected individual-level data from BeredtC19, an emergency preparedness register established by the Norwegian Institute of Public Health (NIPH) in cooperation with the Norwegian Directorate of Health to provide real-time knowledge during the COVID-19 pandemic. BeredtC19 contains individual-level data for all Norwegian residents, and this study utilized data in BeredtC19 originating from the Register of Employers and Employees (AA-reg), the Norwegian Population Registry (Popreg), the Norwegian Immunisation Registry (SYSVAK) registers maintained by Statistics Norway (SSB), and the Norwegian Surveillance System for Communicable Diseases (MSIS).

The sample comprised all workers aged 18–70 in full-time contracts (≥30 hours per week) who worked at a hospital and these workers' household members. Hospital workers were identified through the Register of Employers and Employees, based on the organizational 5-digit NACE-code (86.101, 86.102, or 86.103). We categorized HCWs following Molvik et al,[2] using ISCO-08 4-digit occupation codes in combination with standard industrial classifications from the AA-reg (see Molvik et al[2] for details). Employees who did not fall within one of the prespecified occupational groups were categorized as "administrative or support staff"; this group included management, kitchen staff, secretaries, and janitors.

Some workers were registered with >1 employment; the following algorithm was applied to assign them to 1 employment relationship: (1) all contracts of <30 hours per week were excluded, (2) all contracts terminated before August 1, 2020, were excluded, (3) if the person was registered with a positive COVID-19 test, that person was linked to the job(s) that he or she had at the time of testing, and (4) the employment relationship with the latest start date was chosen in the few cases with >1 remaining relationship for a worker. Data from the SSB were used to identify the hospital workers' household members. The SSB defines a household as comprising every resident of 1 dwelling (excluding institutions), typically 1 family living in the same housing unit at the same address. The household data were from 2020, implying that household members born after 2020 could not be included.

It is mandatory for laboratories in Norway to register all PCR-tests for SARS-CoV-2 in MSIS, and this is done electronically. For the few persons who had been registered with SARS-CoV-2 twice, only the first date was included in this analysis.

Definitions

Where and when transmission occurs is not always possible to determine decisively with either registry or case-finding data. We approximated transmission pathways using the date a positive sample was taken. An index case was defined as the first person (using a fortnight washout period) in a household who tested positive for SARS-CoV-2, and the date of sample collection was assumed to represent the onset of the infection episode. When >1 person tested positive on the same test date, both were considered index cases. Secondary cases were defined as household members who tested positive with a test date 1–14 days after the sampling date of the index case. When >14 days had passed since the last positive test, any new positive case within the household was considered an index case. Consequently, there could be multiple index cases at multiple dates within the same household; however, a household member could only be an index case once.

In this study, we were primarily interested in 2 transmission pathways: (1) transmission from the HCW to a household member of the HCW, labelled HCW→HH (ie, the HCW was the index case in the household) and (2) transmission from a household member to the HCW, labelled HH→HCW (ie, the HCW was a secondary case in the household).

Without careful on-site investigations of transmission pathways and whole-genome sequencing of the viruses, it was not possible to verify that the index case was the primary case. To ensure that our main results were not driven by such misclassifications, we undertook some robustness checks in which index cases and secondary cases were defined more narrowly. Specifically, we excluded events in which there were <3 and >10 days between the index case and secondary case. Results of these checks are presented in the Appendix (online).

The household secondary attack rate was defined as the number of secondary cases within 14 days after the index case among susceptible members of the household. The secondary attack rate was calculated only for multimember households with only 1 healthcare worker. Because we allowed for multiple index cases within a household, household members who tested positive previously were excluded from the denominator. Robustness checks of the secondary attack rate were calculated, in which only secondary cases 3–7 days after the index case were included in the numerator (Appendix online). We performed a similar robustness check for events in which the hospital workers were secondary cases in their own households.

Statistical analysis

The 95% confidence intervals (95% CI) around the secondary attack rate were calculated using the Wilson method. We used R version 4.0.2 statistical software (R Foundation for Statistical Computing, Vienna, Austria) for our analyses.

Results

We identified 66 hospital units (based on the legal organizational number in the AA-reg) and 114,367 employees aged between 18 and 70 years (mean, 41.6; SD, 13.3); among them, 77.3% were women. In total, we collected data on 107,726 households and 294,752 household members. The former included 6,386 households with >1 hospital worker. Furthermore, 2,733 hospital workers were excluded because of missing household data, likely foreign workers.

We identified 3,005 confirmed cases among hospital workers during the study period (August 1, 2020, to September 1, 2021) (Table 1). The national 7-day incidence rate was low during the study period, rarely reaching 150 cases per 100,000 population. The number of new COVID-19 cases among hospital workers has closely followed the national incidence rate, but hospital workers were overrepresented in the first and second waves of the pandemic, and they were underrepresented from the early spring of 2021 when many HCWs were vaccinated (Fig. 1).

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Table 1. Descriptive Statistics for Hospital Workers and their Household Members

Occupation	No.	Confirmed Cases (%)	Women, %	Average Age, Y (SD)	Household Members, Average No. (SD)
Hospital workers					
Physicians	14,701	346 (2.4)	54.1	40.78 (11.26)	2.95 (1.42)
Specialist nurses	17,173	279 (1.6)	90.8	48.2 (11.01)	2.87 (1.33)
Nurses	26,058	749 (2.9)	91.3	37.44 (12.05)	2.72 (1.34)
Nursing associates	9,534	416 (4.4)	73.4	29.61 (11.41)	2.42 (1.42)
Healthcare assistants	5,678	230 (4.1)	89.2	42.43 (15.88)	2.71 (1.39)
Other HCWs	12,820	386 (3.0)	82.6	42.62 (12.95)	2.81 (1.35)
Administrative or support staff	28,399	599 (2.1)	64.9	45.36 (13.02)	2.82 (1.32)
Total	114,363	3 005 (2.6)	77.3	41.63 (13.34)	2.78 (1.36)
Household members of hospital workers					
Physicians	20,150	571 (2.8)	46.7	26.11 (20.08)	3.96 (1.23)
Specialist nurses	27,818	686 (2.5)	31.2	29.07 (20.63)	3.79 (1.15)
Nurses	40,317	1 118 (2.8)	33.4	27.1 (19.36)	3.75 (1.2)
Nursing associates	10,861	526 (4.8)	42.7	32.33 (19.18)	3.74 (1.41)
Healthcare assistants	8,702	352 (4.0)	34.3	32.19 (20.93)	3.77 (1.39)
Other HCWs	20,267	799 (3.9)	35.1	29.54 (20.37)	3.78 (1.23)
Administrative or support staff	43,103	1,227 (2.8)	42.0	30.23 (20.42)	3.72 (1.17)
>1 hospital worker	9,157	330 (3.6)	43.1	20.79 (18.23)	4.43 (1.05)
Total	180,375	5,609 (3.1)	37.9	28.55 (20.18)	3.81 (1.22)

Note. SD, standard deviation; HCW, healthcare worker.

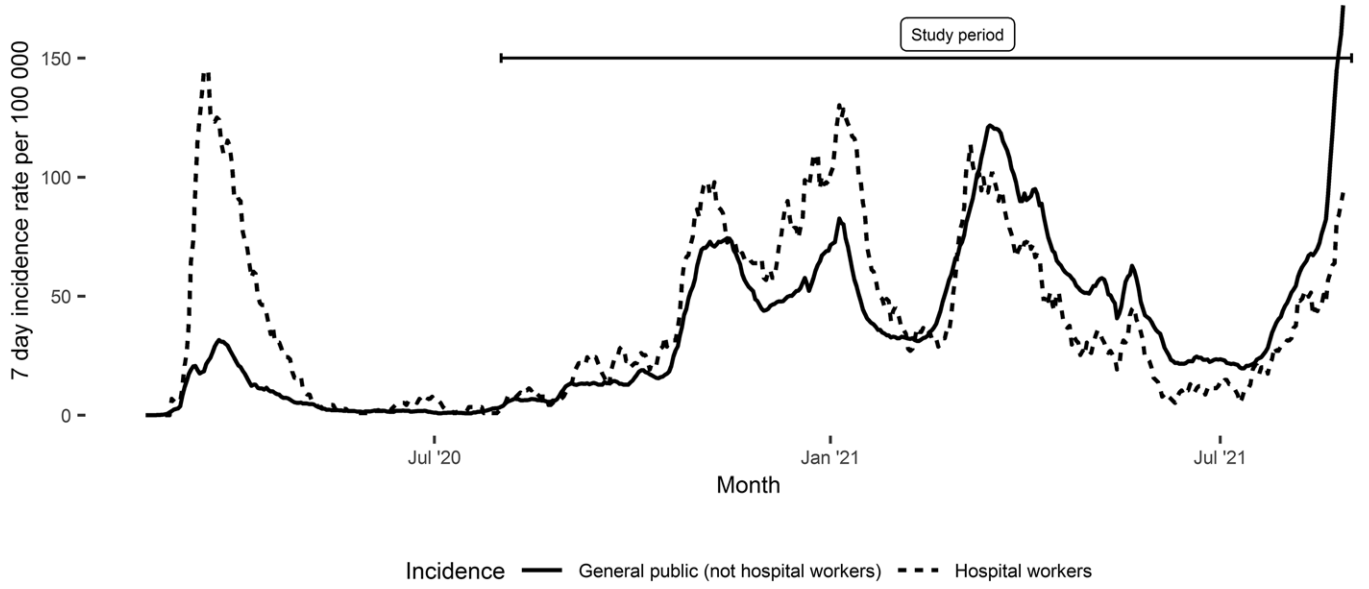

Fig. 1. COVID-19 7-day incidence rate (rolling sum) among hospital workers and the general public after the discovery of COVID-19 and until August 31, 2021.

Hospital workers who were index cases in the household and subsequent transmission to household members

Of the 3,005 cases among hospital workers, 605 were hospital workers who lived alone. Of the remaining 2,400 cases among hospital workers, 1,485 hospital workers were index cases in their own households. Among them, 839 such index cases did not lead to a secondary case in the household. We identified 3,044 susceptible household members and 754 secondary cases, for an overall secondary attack rate of 24.8% (95% CI, 23.2–26.3).

Index cases among administrative or support staff had the highest secondary attack rate in their households (Table 2). Index cases among nursing associates had the lowest secondary attack rate. Nursing associates were generally younger than index cases in other occupations. The secondary attack rate remained relatively

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Table 2. Index Cases Among Hospital Workers in Multimember Households and the Subsequent Secondary Attack Rate

	Index Cases			Secondary Attack Rate, % (95% CI)		
Occupation	No.	Avgerage Age, Y	Female, %	Overall	Aug 2020–Dec 2020	Jan 2021–Aug 2021
Physicians	279	39.4	61	26.9 (23.4–30.7)	24.6 (19.2–31.1)	281 (23.7–33)
Specialist nurses	127	36.6	87	28.2 (2.33–33.7)	27.8 (19.9–37.5)	283 (22.4–35.2)
Nurses	411	34.7	92	21.8 (19.2–24.8)	18.6 (14.9–23)	243 (20.6–28.4)
Nusing associates	205	27.6	73	15.1 (11.9–19)	18 (12.3–25.5)	137 (10.1–18.4)
Healthcare assistants	183	39.8	79	29.7 (25.3–34.5)	262 (20.4–32.9)	332 (26.9–40.1)
Other HCWs	142	39.7	56	24.6 (20.3–29.6)	241 (17.9–31.7)	25 (19.3–31.7)
Administrative or support staff	138	46.4	93	32.9 (27.6–38.6)	345 (27.3–42.4)	31 (23.7–39.4)
Total	1485	36.9	78	24.8 (23.3–26.3)	238 (21.5– 26.2)	254 (23.5–27.5)

Note: CI, confidence interval; HCW, healthcare worker.

stable over the 2 periods and for occupation, 23.8% from August through December 2020 and 25.4% from January through August 2021 (Table 2).

In Appendix A (online), we show the secondary attack rate with an alternative definition (see methods section and the description in Appendix A). Although the overall secondary attack rate was much lower with these definitions, differences between occupations remained largely the same. However, the specialist nurses had a higher secondary attack rate than administrative staff or support staff in these alternative specifications (Table A1).

Hospital workers who were secondary cases in their households

Overall, we identified 534 cases (17.8% of all hospital workers cases; 95% CI, 16.4–19.1) in which the hospital worker was the secondary case in their own household (HH→HCW). Other HCWs had the highest proportion of household-acquired cases, and nursing associates had the lowest proportion of household-acquired cases. Index cases tended to be younger than secondary cases, and fewer were female (Table 3).

In Appendix A we show the number of secondary cases among hospital workers with an alternative definition of secondary cases (see methods section, and description in the Appendix A and Table A2 online). The percentage of all cases that were acquired in the household decreased with these definitions. Differences between occupations remained stable. We also split the sample by period (Table A3 online).

Breakdown of the COVID-19 infection rate among hospital workers

Between August 1, 2020, and September 1, 2021, 3.24% of all hospital workers were confirmed with COVID-19 (Table 1). Of these cases, 17.8% (95% CI, 16.4%–19.1%) were secondary cases in their households, and 49.4% (95% CI, 47.6%–51.2%) were index cases in their own households. There was no sign of a positive association between the percentage of cases that were household acquired, and the percentage of confirmed cases among all hospital workers. For example, nursing associates displayed the highest incidence rate, but few of the cases were likely household acquired (Fig. 2). Similarly, the number of cases among hospital workers living alone or living together with other hospital workers was largely proportional to the number of cases overall.

Discussion

Principal findings

In total, 3,005 hospital workers (2.6%) acquired COVID-19 between August 1, 2020, and September 1, 2021. The rate was highest for nursing associates (416 cases, 4.4%) and the rate was lowest rate for specialist nurses (279 cases, 1.6%).

Almost half of all hospital workers with confirmed COVID-19 were likely index cases in their own households (49.4%), risking onward transmission to their household members. The 14-day presumed household secondary attack rate when the index case was a hospital worker was 24.8%. The secondary attack rate was highest for administrative or support staff (32.9 %) and was lowest for nursing associates (15.1%).

A significant percentage (17.8%) of all confirmed COVID-19 cases among hospital workers were likely acquired in the household, and "other" HCWs had the highest percentage of household-acquired cases and nursing associates had the lowest percentage.

Breaking down the rate of COVID-19 among hospital workers, we see no positive association between higher rates in certain occupational groups and a higher overall rate of household acquired cases. Rather, among those occupation with the highest incidence, the proportion of cases that was likely household acquired was smaller than in occupations with a lower incidence.

Comparison to previous studies

To our knowledge, the current study is the first attempt to attempt to understand the hospital worker COVID-19 rate by determining which hospital workers were index cases or secondary cases in their own households. Several research groups have investigated

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Table 3. Occupation and Characteristics of Hospital Workers Who Were Secondary Cases in Their Household and Characteristics of the Non–Hospital Worker Index Cases.

	Household-Acquired Cases					Characteristics of Non–Hospital Worker Index Cases	
Occupation	Frequency	%	Average Age, Y	Female,%	Average Days Since Index	Average Age, Y	Female, %
Physicians	51	15	42.6	57	4.22	28.8	47
Specialist nurses	69	25	44.5	96	4.88	33	14
Nurses	113	15	38.4	91	4.07	29	28
Nusing associates	39	9	30	69	4.15	31.6	37
Healthcare assistants	30	13	38.4	87	3.97	26.4	42
Other HCWs	101	26	39.2	87	4.25	33.6	29
Administrative or support staff	131	22	43.3	68	3.85	30.6	37
Total	534	18	40.4	80	4.17	30.8	32

Note. HCW, healthcare worker.

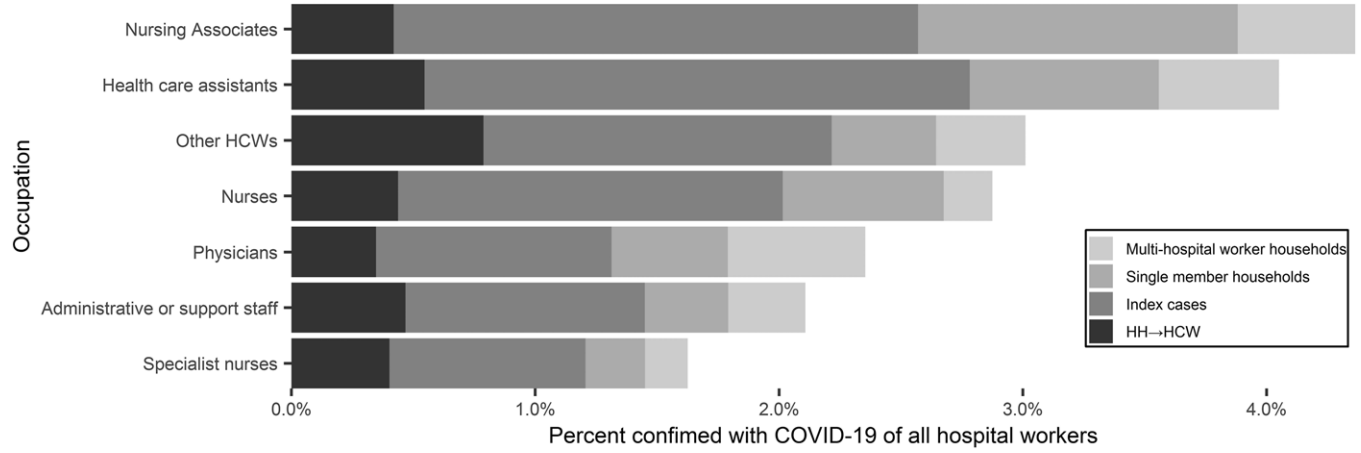

Fig. 2. Percent confirmed with COVID-19 between August 1, 2020, and August 31, 2021, of all hospital workers according to occupational group.

transmission between the hospital and the community in general. Mo et al[6] demonstrated that HCWs exposed to patients or colleagues with infections acquired in the hospital were more likely to become infected themselves than HCWs exposed to patients with community-acquired infections. The findings suggest that patients who have contracted COVID-19 before entering the hospital are less likely to transmit COVID-19 than patients or workers in whom the infection was discovered after admission. Emecen et al[7] reported similar results. Almost 80% of all clusters (ie, 2 or more workers were exposed to the same COVID-19 case) they studied were HCW-to-HCW contact clusters. For contact between HCWs, with higher intensity (ie, no mask use <1 m distance), high-risk exposure was higher in support staff, in non–patient-care settings, and in social contacts.

Several of the studies based on serology analysis have also sought to determine whether hospital workers who are at high risk of exposure to COVID-19 at work are also more likely to be seropositive. Results are mixed. Several studies report that the relationship between occupation or placement (ie, patient facing occupations, working in COVID-19-wards, and seropositivity) is statistically nonsignificant,[8–10] though other studies report a positive relationship.[11–13] In contrast, having a household contact with suspected or confirmed COVID-19[12,14] or larger household size[9] has generally been associated with higher antibody positivity and is often reported as the strongest predictor for seropositivity. Our results support this finding.

The household secondary attack rate from hospital workers to household members was similar to those reported in other studies on secondary attack rate based on registry data from Norway.[15–17]

Interpretations and implications

The impact of work-related infections on HCWs is not only a burden to the HCWs themselves but also to those infected by the HCWs. Our data enabled us to identify hospital workers who were index cases in their own households, and thus to estimate how HCWs transmit COVID-19 to members of their household. Our results show that 24.8% of the remaining household members in multiple-person households are confirmed with COVID-19 within 14 days. This finding confirms that the detrimental societal effects of nosocomial infections to HCWs go beyond the infection to the HCWs themselves. Indeed, in addition to the substantial transmissions in the household, HCWs may also transmit the virus to other patients, colleagues, and other close contacts, and subsequent transmissions may occur from these secondary cases. Breaking or altogether avoiding such chains of transmission from HCWs

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to their households and other contacts can thus have substantial societal benefits, implying that the resources allocated to precautions should be high.

On the other hand, work-associated infections in HCWs or the fear thereof can have a detrimental impact on healthcare services and society at large. The fear of being infected at work may result in HCWs choosing other jobs. Moreover, these infections can be a serious threat to the health of the HCWs and to the operation and capacity of the health services. However, assessing the incidence rate of work-related infections in HCWs at the hospital during the pandemic at regional or national level is inherently difficult. Infection among HCWs often occurs among those who do not work directly with COVID-19 patients.[5,10] Indeed, many HCWs are likely to be infected in their local communuty, at home or elsewhere. Hence, the crude incidence rate of SARS-CoV-2 among HCWs likely overstates infections among HCWs that can be traced to their occupational activities. The data we had enabled us to identify HCWs who were secondary cases in their own households and, thus, to calculate infection rates of HCWs excluding those who were secondary cases in their households. Our results show that ~18% of hospital workers with confirmed COVID-19 were secondary cases in their households, suggesting that they were infected at home rather than at work.

Strengths and limitations

In this study, we were able to combine registry data on households and hospital workers to break down the hospital-worker infection rate into cases that were likely acquired in the household versus cases that were acquired elsewhere. We were able to quantify the likelihood of forward transmission when a hospital worker was an index case in his or her household. This gave us a wider perspective on the societal costs of infections in hospital workers.

This study had several limitations. First, we were not able to quantify the risk of COVID-19 associated with working as an HCW that stems from contacts with patients or colleagues. Secondly, when the time between positive tests for 2 or more household members is short, we may have misclassified index and secondary cases, though our robustness checks suggest that this did not seriously influence the results. Furthermore, testing practices might have introduced downward bias to our estimate of the share of hospital workers who were secondary cases at home. Hospital workers might have been tested more often than many other groups because of their work. Differences in infections between occupational groups can thus reflect differences in testing. Similarly, differences in vaccination rates could have led to differences in the rates of symptomatic cases and infectiousness. Furthermore, undetected cases could have biased the results, but the testing of HCWs has been regular since July 2020. Lastly, our household data were from 2020, and households that were split up or changed composition since then would have been falsely grouped in our data from 2021.

In conclusion, our study suggests not only that many hospital workers are infected with SARS-CoV-2 in their household but also that infected hospital workers constitute a serious infection risk to members of the HCW's household.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2022.108

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