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Research Article

COVID-19 Transmission Among Healthcare Workers

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Abstract

Objectives: It is essential to understand how healthcare workers (HCWs) get infected in order to reduce the infection rate among HCWs and minimize nosocomial transmission of COVID-19. This study aimed to investigate work and community exposure to COVID-19 and infection prevention and control (IPC) measures among infected employees. **Methods:** We conducted a retrospective cross-sectional survey among infected hospital employees from April 2020 to December 2020 at Regional Hospital West Jutland (RHWJ) Denmark. The study included 163 respondents. Analyses were mainly descriptive. The analyses were stratified by two groups; respondents working in COVID-19 wards and respondents working in general wards. **Results:** Analyses showed that 70% of infected hospital employees were exposed to COVID-19 patients. Respondents working in COVID-19 wards were more frequently in contact with COVID-19 patients than employees working in general wards. Approximately 15% of the respondents had been in contact with a person with COVID-19 during leisure time. Respondents working in the COVID-19 wards were more adherent to IPC measures during aerosol generating procedures (AGP) than respondents in general wards. **Conclusion:** Hospital employees most likely acquired their infection during contact with COVID-19 patients. Working in COVID-19 wards, differential IPC training may pose as risk factors associated with COVID-19 transmission.

Keywords: Nosocomial infection; Healthcare workers; Coronavirus disease 2019; Infection prevention and control

Introduction

In the early phase of the coronavirus disease 2019 (COVID-19) pandemic, information on the transmissibility was sparse. Being at the frontline, healthcare workers (HCWs) were considered a high-risk group for infection [1-3]. A review by Chou et al., including 15 studies, reported the prevalence of severe acute respiratory syndrome coronavirus 2 (SARS-Co-V-2) among HCWs to vary from approximately 3% to 39% [4]. In 2020, HCWs accounted for about 5% of notified cases in Denmark [5]. Most Danish and international studies on COVID-19 infection among HCWs have focused on determining the prevalence of SARS-Co-V-2 and clinical characteristics of COVID-19 [4, 6-11]. Other studies have included work and community exposures to COVID-19 among infected HCWs with various findings [12-17].

In Denmark, hospitals were appointed by the Danish Government to establish special COVID-19 wards for confirmed or suspected COVID-19 patients. The hospitals implemented additional droplet infection prevention and control (IPC) measures when in contact with suspected and confirmed COVID-19 patients. The IPC measures comprised personal protective equipment (PPE), such as goggles or face shields, medical gowns and gloves,

surgical masks, and usage of N95/FFP2 masks when conducting or assisting in aerosol-generating procedures (AGP) [18,19]. In addition, HCWs were recommended to apply the national recommendation on social distancing, which comprised avoiding face-to-face contact > 15 minutes and keeping social distance > 1 meter.

At the beginning of the pandemic, the transmission of SARS-Co-V2 was high in the Western part of Jutland compared to the rest of Denmark [20]. Thus, the high number of COVID-19 cases rapidly increased the number of COVID-19 patients admitted to the Regional Hospital West Jutland (RHWJ) Denmark [21]. The RHWJ serves as the main hospital for the approximately 300,000 citizens of West Jutland and has approximately 4,000 hospital employees. In 2020, approximately 300 hospital employees were assigned to work full time or part-time in designated COVID-19 wards. The abrupt rise in the number of COVID-19 patients caused an immense strain on the RHWJs medical service and hospital employees. A seroprevalence study by Jespersen et al. revealed that RHWJ had the highest seroprevalence among hospital employees compared to other hospitals in Central Denmark Region [7]. Furthermore, separated analyses in the study showed a higher COVID-19 infection rate among HCWs working in emergency departments compared to other wards at RHWJ.

Hence, the primary aim of this study was to describe work and community exposure to COVID-19 among infected hospital employees in 2020. Furthermore, the study aimed to describe adherence to additional droplet IPC measures when treating COVID-19 patients. The study compared data from infected employees working in COVID-19 wards with infected employees in general wards.

Methods

Study design and participants

We conducted a retrospective cross-sectional survey among hospital employees at RHWJ from April 2020 to December 2020. All employees were invited to participate in a web-based questionnaire distributed five times by work mail during 2020. Initially, all hospital employees were asked if they had tested positive for COVID-19 by a Polymerase Chain Reaction (PCR) test. Hospital employees who reported to have tested positive for COVID-19 were included and were forwarded to the questions on work and community exposure to COVID-19, demographics, profession, place of employment, lifestyle information, medical illness, clinical COVID-19 symptoms and sickness absence. In addition, those who reported to have treated COVID-19 patients were forwarded questions on their adherence to additional IPC measures. In 2020, the RHWJ had 4,915 hospital employees. A total of 163 of the respondents were included in the total study population, of whom a subsample of 124 respondents was identified as respondents who had been treating COVID-19 patients. For details on how the study population was formed, See Figure 1.

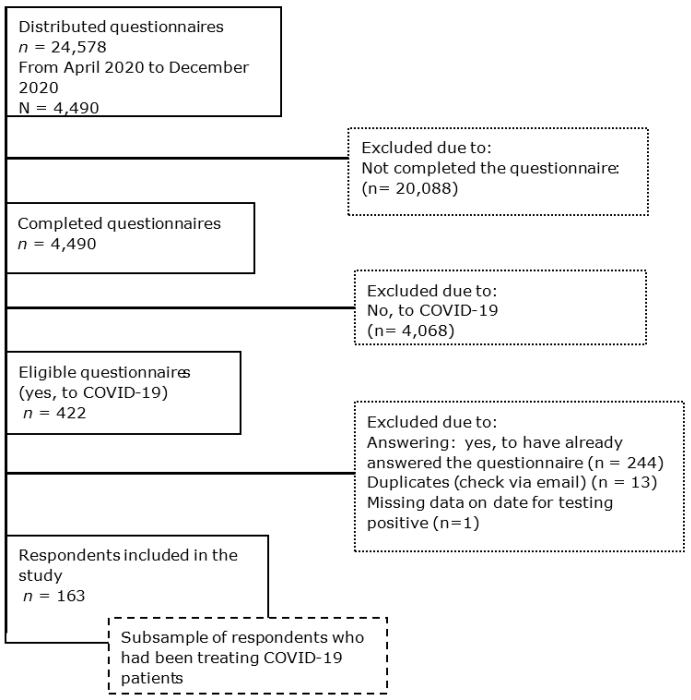

Figure 1: Flowchart of all participants that formed the study population of infected hospital employees.

The study was approved by the hospital management at RHWJ and registered with the Central Denmark Region Research Register (no. 1-16-02-385-20). The survey was voluntary and anonymous, and consent from all respondents was obtained. Ethical approval from the Medical Ethics Committee is not required for this type of study in Denmark.

Content of the questionnaire

The questionnaire consisted of questions on demographics, health status, details regarding the COVID-19 infection, work and community exposure to COVID-19, and information about adherence to additional droplet IPC measures and social distancing was obtained by means of a web-based questionnaire. The questions regarding work exposure to COVID-19 and adherence to additional IPC measures when treating COVID-19 patients were based on WHOs Interim guidance "Risk assessment and management of exposure of health care workers in the context of COVID-19" [2]. The questions regarding community exposure and physical and social distancing were based on the Danish Healthcare Authorities COVID-19 guidelines on COVID-19 contract tracing [22].

Outcome Measurements

Work and community exposure to COVID-19

In this study, work exposure to COVID-19 was defined as contact with COVID-19 patients 14 days before own infection. COVID-19 patients comprised confirmed and suspected COVID-19 patients. The respondents were asked to state whether they had been in contact with a COVID-19 patient (yes/no/don't know). Community exposure was defined as contact with a COVID-19 infected person during leisure time, participation in public or private events 14 days before infection and travel abroad within the last month. We used binary measures (yes/no) for close contact with an infected person, participation in a public or private event 14 days before their infection and travel within the last month.

Adherence to additional IPC measures when treating COVID-19 patients

All respondents having contact with COVID-19 patients were asked about their adherence to additional droplet IPC measures. Information on adherence to additional droplet IPC measures was based on four questions, i.e., (1) face-to-face contact with patient > 15 minutes measured using a 5-point Likert scale ranging from always/most the of the time/occasionally/rarely/ don't know, (2) assisting in AGP, measured categorically (yes/ no/don't know) and with the response option to elaborate use of PPE, (3) physical and social distancing to colleagues by avoiding handshakes and distance > 1 meter, measured on a 4-point Likert scale, ranging from always/most of the time/occasionally/rarely, and (4) social distancing to colleagues during breaks, measured on the 4-point Likert scale.

Other study variables

Demographics and details regarding COVID-19 infection

We used binary measures for sex (male/female), smoking (smokers/non-smokers), and comorbidity (yes/no), whereas height and weight were measured as continuous variables. Comorbidity was defined as the presence of at least one underlying medical condition. A total of 6 comorbidities were included: diabetes, cardiovascular diseases, asthma or other respiratory diseases, intestinal diseases, liver diseases, kidney diseases and the option other diseases. Age was measured in six categories: 20-29, 30-39, 40-49, 50-59, 60-69 and >70 years. Professions were recorded as four job categories: nurses, physicians, other healthcare staff, and others. The category other healthcare staff denoted medical laboratory technicians, hospital porters, occupational- or physiotherapists and service- and healthcare assistants, whereas others contained secretaries and administrative employees.

Details on COVID-19 infection

The length of COVID-19 infection was defined as the number of days between the first symptom and recovery from the infection and split into five categories: 1-7 days, 1-2 weeks, 2-3 weeks, 3-4 weeks, and > 4 weeks. Furthermore, the respondents were asked if they had experienced fever =>38 ^{o}C, sore throat, cough, runny nose, shortness of breath or other symptoms. The symptoms were measured binary (yes/no) and with a response option to elaborate on other symptoms.

Statistical Analysis

The primary outcomes were work and community exposure to COVID-19 among all respondents. The secondary outcome was adherence to additional droplet IPC measures when treating COVID-19 patients. Data were compared between respondents in COVID-19 wards and general wards. Continuous variables are presented as medians with interquartile ranges (IQR) and categorical variables are presented as counts (N) and percentages. Student's t-tests are used to compare continuous variables, and Chi-squared or Fisher´s exact tests are used to compare categorical variables. Missing data was not imputed. The analyses were performed using Stata 17.

Results

This study included 163 respondents infected with COVID-19 in 2020. Most of the respondents were infected from March to May 2020 (data not shown). Table 1 shows the demographics and details regarding the COVID-19 infection in all respondents. Most respondents were HCWs (90%), of which 68% were nurses. More than 90% of the respondents were females, and approximately 21% had comorbidities. About one-third of the respondents were between 40 and 49 years old. The median length of COVID-19 infection was 13.5 days (IQR: 9.00; 19.00). More than 50% of the respondents experienced fever and cough, and more than 40% experienced sore throat, shortness of breath/dyspnea, and runny nose. Approximately 7% suffered from other symptoms as well.

Variables	All respondents (N=163)
Age N (%)	
20-29	22 (13.50)
30-39	35 (21.47)
40-49	53 (32.52)
50-59	38 (23.31)
60-69	14 (8.59)
≥ 70	1 (0.61)
Sex N (%)	
Female	150 (92.02)
Health status N (%) (2) *	
Comorbidity	33 (20.50)
Diabetes	0 (0)
Cardiovascular diseases	0 (0)
Asthma and other respiratory diseases	8 (24.24)
Intestinal diseases	3 (9.09)
Lever diseases	0 (0)
Kidney diseases	1 (3.03)
Other diseases	21 (63.64)
Weight (kg), median (IQR) (3) *	73.00 (65.00; 86.50)
Height (cm), median (IQR) (2) *	169.00 (165.00;174.00)
Smoking N (%)	
Smoker	6 (3.68)
Profession N (%)	
Nurse	111 (68.10)
Physician	19 (11.66)
Other health care staff	23 (14.11)
Other	10 (6.13)
Symptoms N (%)	
Fever >= 38 degrees	110 (67.48)
Sore throat	79 (48.47)
Cough	96 (58.90)
Runny nose	71 (43.56)
Shortness of breath/dyspnea	75 (46.01)

Other symptoms	27 (16.56)
Length of COVID-19 infection, median (IQR) (35) *	13.50 (9.00; 19.00)
Length of COVID-19 infection, N (%) (35) *	
1-7 days	24 (14.72)
1-2 weeks	54 (33.13)
2-3 weeks	28 (17.18)
3-4 weeks	12 (7.36)
> 4 weeks	10 (6.14)
*Indicates the number of missing individuals. Abbreviation: N, number, IQR, interquartile range.	

Table 1: Demographics and details on COVID-19 infection in all respondents. The number of missing values is listed in parenthesis in the first column. Values are listed as numbers and percentages in parenthesis in the second column unless specified otherwise.

Table 2 presents work and community exposures of all respondents and compares respondents working in the COVID-19 wards to respondents working in the general wards.

More than 70% of all respondents had been in contact with COVID-19 patients before their own infection. The number of respondents working in COVID-19 wards with contact with COVID-19 patients was significantly higher than the corresponding number working in general wards; 89% vs 65% ($p < 0.001$). Regarding community exposure, 15% of all respondents reported contact with a person with COVID-19 before their infection, while 11% had participated in a private or public event, and approximately 2% had travelled abroad. Furthermore, the analyses showed that respondents working in general wards were more likely to report contact with a person infected with COVID-19 during leisure time than respondents working in COVID-19 wards.

Exposure history 14 days before COVID-19 infection N (%)		**Respondent groups**		
	All respondents (N=163)	**Respondents in COVID-19 wards (N=74)**	**Respondents in general wards (N=89)**	**P-value**
Work exposure				
Contact with COVID-19 patients				
Yes	124 (76.07)	66 (89.19)	58 (65.17)	<0.001
No	22 (13.50)	7 (9.46)	15 (16.85)	
Not known	17 (10.43)	1 (1.35)	16 (17.98)	
Community exposure				
Contact with a person with COVID-19				
Yes	25 (15.34)	11 (14.86)	14 (15.73)	0.01
No	105 (64.42)	56 (75.69)	49 (55.06)	
Not known	33 (20.25)	7 (9.46)	26 (29.21)	
Participation in private or public events	18 (11.04)	7 (9.46)	11 (12.36)	0.62
Abroad one month before the COVID-19 infection	3 (1.84)	2 (2.70)	1 (1.12)	0.60

Table 2: Work and community exposure to COVID-19 14 days before COVID-19 infection. Data are presented for all respondents and as a comparison between respondents working in the COVID-19 wards and respondents working in the general wards. Values are listed as numbers and percentages in parenthesis.

Table 3 presents the adherence to additional droplet IPC measures among the respondents having contact with COVID-19 patients and the comparison of respondents working in the COVID-19 wards and respondents working in the general wards. More than 60% of all respondents reported face-to-face contact of more than 15 minutes with COVID-19 patients. Likewise, more than 40% of all respondents had been assisting in AGP. Notably, respondents working in COVID-19 wards were significantly more adherent to PPE use during AGP than respondents working in the general wards. The reverse applied regarding physical and social distancing to colleagues by avoiding handshakes and physical distance > 1 meter, where respondents in general wards were better at keeping distance than respondents working in COVID-19 wards.

Adherence to prevent measures when treating COVID-19 patients, N (%)	**All Respondents (N=124)**	**Respondents COVID-19 wards (N=66)**	**Respondents General wards (N=58)**	**P-value**
*Face-to-face patient contact > 15 minutes, N (%), (5)**				
Always	5 (4.20)	1 (1.61)	4 (7.02)	0.68
Most of the time	13 (10.92)	6 (9.68)	7 (12.28)	
Occasionally	64 (53.78)	35 (56.45)	29 (50.88)	
Rarely	32 (26.89)	17 (27.42)	15 (26.32)	
Don't know	5 (4.20)	3 (4.84)	2 (3.51)	
Assisting in aerosol-generating procedures, N (%)				
Yes	51 (41.13)	29 (43.94)	22 (37.93)	0.50
No	53 (42.74)	25 (37.88)	28 (48.28)	
Don't know	20 (16.13)	12 (18.18)	8 (13.79)	
Used personnel protective equipment during aerosol-generating procedures, N (%)				
Yes	35 (68.63)	27 (93.10)	8 (36.36)	< 0.001
No	15 (29.41)	1 (3.45)	14 (63.64)	
Don't know	1 (1.96)	1 (3.45)	0	
Physical and social distance to colleagues, e.g. handshakes and distance > 1 meter, N(%)				
Always	70 (56.45)	33 (50.00)	37 (63.79)	0.05
Most of the time	36 (29.03)	18 (27.27)	18 (31.03)	
Occasionally	9 (7.26)	7 (10.61)	2 (3.45)	
Rarely	9 (7.26)	8 (12.12)	1 (1.72)	
Social distance to colleagues during breaks, N (%)				
Always	45 (36.29)	23 (34.85)	22 (37.93)	0.99
Most of the time	62 (50.00)	34 (51.52)	28 (48.28)	
Occasionally	9 (7.26)	5 (7.58)	4 (6.90)	
Rarely	8 (6.45)	4 (6.06)	4 (6.90)	

***** Indicates the number of missing individuals.

Table 3: Adherence to the additional droplet IPC measures among all respondents treating COVID-19 patients and comparisons of respondents working in the COVID-19 wards and respondents working in the general wards. Values are listed as numbers and percentages in parenthesis unless otherwise specified. The missing values are listed in parenthesis in the first column for all respondents.

Discussion

In this study, we identified contact with COVID-19 patients to be a common exposure among employees infected with COVID-19. In the comparison of employees working in COVID-19 wards and general wards, we found that employees in COVID-19 wards were more frequently in contact with COVID-19 patients than employees in general wards. Surprisingly, we found that employees working in the COVID-19 wards showed higher adherence to PPE use when assisting in AGP than employees working in the general wards.

To our knowledge, this study is one of the first to report that employees working in the COVID-19 wards showed higher adherence to PPE use when assisting AGP than in general wards. We consider two possible explanations for this finding. First, at the beginning of the pandemic, COVID-19 wards received weekly information on coronavirus transmissibility and IPC training in droplet transmission from the hospital IPC unit. This may have resulted in an increased adherence to PPE use in AGP among employees working in COVID-19 wards compared to employees working in general wards. Secondly, working in a COVID-19 ward may have increased the dimension of perceived risk of getting infected with COVID-19 among the employees. Hence, employees working in COVID-19 wards may have increased their use of PPE in AGP due to fear of contracting COVID-19 to themselves and potentially spreading it to their families. In our study, inadequate PPE use in AGP was not considered the most likely risk factor among employees working in COVID-19 wards. Hence, 93% of employees working in COVID-19 wards reported to have used PPE. However, the reverse may have been the case in general wards, where we reported a 36% adherence to PPE use in APG among infected employees. The finding underlined the importance of sufficient IPC training for all HCWs and that a gap in IPC information and training might be a risk factor associated with COVID-19 transmission. However, more comprehensive investigations are needed to evaluate adherence to PPE use among HCWs and to understand the challenges limiting adherence to IPC measures in AGP.

In agreement with our study, other studies have found contact with COVID-19 patients a risk factor among infected hospital employees [10,14,23]. Furthermore, other studies have identified similar characteristics and symptoms among infected hospital employees: female gender, HCWs, primarily nurses and physicians and symptoms such as fever and cough [10, 23-25].

Work and community exposure to COVID-19 among infected hospital employees have only been investigated to a limited degree [14,15]. In line with our findings, the study by Zabarsky et al. found that work exposure was the most common exposure to COVID-19 among infected employees. The study found that 25% of the infected HCWs had high-risk work exposure, and 14% had high-risk community exposure [15]. However, the study used different definitions of work and community exposure. In comparison to our study, the study measured work exposure more comprehensively by including both contact with COVID-19 patients and contact with infected co-workers. Furthermore, the study divided work and community exposure into higher-risk and lower-risk exposures.

A study by Wratil et al. found community exposure and work exposure to COVID-19 to be significantly associated with infection [14].

As expected, we found that employees in COVID-19 wards were more frequently in contact with COVID-19 patients than employees in general wards, indicating that COVID-19 wards may be considered a risk factor for COVID-19 infection among employees. Recent studies have reported similar results [13,16,23]. Another Danish study by Iversen et al. reported that HCWs working in dedicated COVID-19 wards had a significantly higher seroprevalence than other HCWs (RR 1.65, confidence interval = 1.34-2.03, $P< 0.01$) [16]. Furthermore Ran et al., reported that HCWs working in COVID-19 wards had a 2.13 times higher risk of developing COVID-19 compared to HCWs from general wards [23]. In contrast, two studies reported that HCWs working in COVID-19 departments were less affected than HCWs working in other medical departments [12,17]. The study by Maltezou et al. reported that the infection rate among HCWs in non-COVID-19 hospitals was approximately six times higher than the infection rate among HCWs working in designated COVID-19 hospitals.

In our study, 65% of infected employees in general wards had contact with COVID-19 patients prior to their own infection. We hypothesize that this was due to one main reason. Systematic screening for COVID-19 of all patients upon hospital admission was not implemented at the beginning of the pandemic. Therefore, employees would likely have been exposed to unsuspected COVID-19 patients who debuted with symptoms during their admission. Thus, the finding is important for future hospital IPC management during infectious outbreaks like COVID-19.

In general, adherence to physical and social distancing was relatively high among all infected employees. Likely explanations could be that the recommendation of the Danish Health Authority on physical and social distancing and the national lock-down may have led to a nudging behavior among the hospital employees.

The study has some strengths. By conducting this investigation in the early stages of the COVID-19 pandemic, this study contributes with knowledge about the currently sparse research on how hospital employees got infected. Furthermore, we included multiple professions to gain a broader understanding. In addition, we were able to describe various sources of exposure to COVID-19 and adherence to IPC measures. Furthermore, the

study uncovered information on possible differences in exposures between employees working in COVID-19 wards and employees working in other wards.

The study has some limitations due to the study design and the number of infected hospital employees. Firstly, we conducted a single-centre retrospective study, which might affect the external validity and risk of recall bias. Secondly, the study only recruited 52% of the infected hospital employees at RHWJ in 2020, affecting internal validity. Thirdly, we only included infected employees. This could be viewed as a highly selected group contributing to sampling and self-selection bias, leading to over-or underestimating of the work and community exposures to COVID-19, including adherence to additional IPC measures.

We reiterate that this is an observational study, which only provides possible reasons for COVID-19 infection among healthcare workers. Future prospective study is needed to verified and to investigate other potential exposure factors such as ventilation in patient rooms, overcrowding in healthcare stations and adherence of doffing PPE.

Conclusion

Our study confirms that hospital employees infected with COVID-19 most likely acquired their infection during contact with COVID-19 patients and that working in COVID-19 wards may be considered a risk factor associated with COVID-19 infection among hospital employees. Additionally, this study shows that employees working in COVID-19 wards are more adherent to PPE use when assisting in AGP than employees working in general wards, indicating that a gap in IPC information might pose a source of exposure to COVID-19 transmission.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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