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Covid-19 infection and diffusion among the healthcare workforce in a large university-hospital in northwest Italy

Giacomo Garzaro[1,2], Marco Clari[1], Catalina Ciocan[1,2], Eugenio Grillo[I], Ihab Mansour[1], Alessandro Godono[1], Lorenza Giuditta Borgna[1], Veronica Sciannameo[3], Giuseppe Costa[4], Ida Marina Raciti[5], Fabrizio Bert[1,5], Paola Berchialla[4], Maurizio Coggiola[2], Enrico Pira[1,2]

for the Unito and CSSto COVID-19 Occupational Health working group[I]

1. University of Torino, Department of Public Health and Pediatrics
2. Città della Salute e della Scienza di Torino University Hospital, Occupational Health Service
3. University of Padova, Unit of Biostatistics, Epidemiology and Public Health, Department of Cardiac, Thoracic, Vascular Sciences and Public Health
4. University of Torino, Department of Clinical and Biological Sciences
Cardiac, Thoracic, Vascular Sciences and Public Health
5. Città della Salute e della Scienza di Torino University Hospital, Molinette Hospital

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Abstract

Backgroud: *Since the beginning of the coronavirus disease 2019 (COVID-19) outbreak, healthcare workers (HCWs) have been the workers most likely to contract the disease. Intensive focus is therefore needed on hospital strategies that minimize exposure and diffusion, confer protection and facilitate early detection and isolation of infected personnel.* **Methods:** *To evaluate the early impact of a structured risk-management for exposed COVID-19 HCWs and describe how their characteristics contributed to infection and diffusion. Socio-demographic and clinical data, aspects of the event-exposure (date, place, length and distance of exposure, use of PPE) and details of the contact person were collected.* **Results**: *The 2411 HCWs reported 2924 COVID-19 contacts. Among 830 HCWs who were at 'high or medium risk', 80 tested positive (9.6%). Physicians (OR=2.03), and non-medical services resulted in an increased*

[I] **UniTo and CSSTo COVID-19 Occupational Health working group**: Enrico Bergamaschi, MD; Davide Bosio, MD; Nadia Cotto, MD; Donatella Fabbro, MD; Riccardo Falcetta, MD; Luciano Forno, MD; Ivana Griseri, MD; Attilia Gullino, MD; Luigi Luccoli, MD; Giovanni Maina, MD; Ferruccio Perrelli, MD; Maria Grazia Putzu, MD; Antonella Spigo, MD; Marco Turbiglio, MD, of the occupational health service of the Città della Salute e della Scienza di Torino University Hospital, Turin, Italy. Vittorio Accardo, MD; Alessandro Beneduce, MD; Valentina Boetto, MD; Michele Caniglia, MD; Roberta Caputo, MD; Annapaola Carosio, MD; Carlotta Castagneris, MD; Erminia Citino, MD; Giuseppe Clemente, MD; Riccardo Corgiat Loia, MD; Maria Luigia De Piano, MD; Michael Declementi, MD; Roberto Frammartino, MD; Massimiliano V. Leone, MD; Denis Longo, MD; Nicolò Milanesio, MD; Gianvito Pellecchia, MD; Andrea Rolfo, MD, all occupational health residents of the University of Torino, Turin, Italy. Carlo Mamo, MD, ASL TO3; Andrea Ricotti, MD, University of Torino.

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Corresponding author: Marco Clari, University of Torino, Department of Public Health and Pediatrics Via Santena 5 bis 10126, Turin, Italy - Phone: +390116705831 - Email: marco.clari@unito.it

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risk (OR=4.23). Patient care did not increase the risk but sharing the work environment did (OR=2.63). There was a significant time reduction between exposure and warning, exposure and test, and warning and test since protocol implementation. HCWs with management postitions were the main source of infection due to the high number of interactions. **Discussion***: A proactive system that includes prompt detection of contagious staff and identification of sources of exposure helps to lower the intra-hospital spread of infection. A speedier return to work of staff who would otherwise have had to self-isolate as a precautionary measure improves staff morale and patient care by reducing the stress imposed by excessive workloads arising from staff shortages.*

Riassunto

«Come l'infezione da COVID-19 si è diffusa tra i lavoratori di un grande ospedale universitario nel nord-ovest Italia» **Introduzione***: Fin dall'inizio dell'epidemia di Coronavirus-2019 (COVID-19), gli operatori sanitari (HCW) sono stati i lavoratori che hanno avuto maggiori probabilità di contrarre la malattia. È pertanto necessario un focus sulle strategie ospedaliere per ridurre al minimo l'esposizione e la diffusione dell'infezione, e che possano facilitare l'individuazione precoce e l'isolamento del personale infetto.* **Metodi***: Valutare l'impatto iniziale di una gestione strutturata del rischio per gli HCW esposti a COVID-19 e descrivere come le loro caratteristiche hanno contribuito all'infezione e alla sua diffusione. Sono stati raccolti dati socio-demografici e clinici, aspetti dell'esposizione (data, luogo, lunghezza e distanza dell'esposizione, uso dei DPI) e dettagli della persona fonte.* **Risultati***: 2411 operatori sanitari hanno riportato 2924 contatti COVID-19. Tra gli 830 operatori sanitari a rischio alto o medio, 80 sono risultati positivi (9,6%). I medici (OR = 2,03) e i servizi non medici hanno comportato un aumento del rischio (OR=4,23). L'assistenza ai pazienti non ha aumentato il rischio, ma una condivisione dell'ambiente di lavoro (OR=2,63). Vi è stata una significativa riduzione del tempo tra esposizione e segnalazione, esposizione e test e segnalazione e test dall'implementazione del protocollo. Gli operatori sanitari con ruolo di coordinamento è stata la principale fonte di infezione a causa dell'elevato numero di interazioni all'inizio dell'epidemia.* **Discussione***: Un sistema proattivo che includa la rilevazione tempestiva del personale contagioso e l'identificazione delle fonti di esposizione aiuta a ridurre la diffusione dell'infezione all'interno dell'ospedale. Un rapido ritorno al lavoro dei lavoratori, che altrimenti avrebbero dovuto autoisolarsi come misura precauzionale, migliora la cura dei pazienti riducendo lo stress imposto da carichi di lavoro eccessivi derivanti dalla carenza di personale.*

Introduction

While the COVID-19 lockdowns and social isolation measures are reducing the spread of the infection (25), many healthcare workers (HCWs), including managers and support staff (22), have to face this world emergency by working in high-risk environments (24). In Italy, despite the introduction of several measures to reduce the risk of exposure, over 15,000 HCWs have been infected with COVID-19 and nearly 200 have died since the beginning of the outbreak (14). Traffic control bundling, a system of triaging patients in screening stations outside the hospital, has been used to enable the prompt isolation and treatment of those with suspected COVID-19 (27). Dedicated guidelines have been introduced to ensure the correct use of personal protective equipment (PPE) by HCWs (11). However, these measures on their own are not enough to stop the spread of infection. A comprehensive plan is required that needs to include monitoring of HCWs exposure and development of symptoms (6), as well as early testing for COVID-19 infection (9). Reinforcement of hygiene regulations as well as appropriate and timely work restrictions and quarantine can then be implemented (6). This would serve the dual purpose of protecting patients and staff and facilitating the prompt return to work of exposed, but not infected, HCWs.

Following the local outbreak of COVID-19 in Turin, the Occupational Health Service of a tertiary care facility (comprised of four hospitals) implemented a comprehensive plan in the form of a structured risk-management protocol for exposed HCWs. This case series describes the impact of the protocol and how the HCWs characteristics contributed to COVID-19 infection and diffusion.

Methods

Study setting

Città della Salute e della Scienza di Torino University-Hospital is a large tertiary care network in Northwest Italy. It comprises four hospitals with a total of 2339 beds: a general hospital (1176 beds), a trauma center (405 beds), a maternity and a children's hospital (489 and 278 beds respectively). A total HCW population of 11388 includes physicians (n=1766), residents (n=1558), nurses (n=3895), nurse aides (n=1528), rehabilitation therapists (n=148), medical/X-Rays technologists (n=779), administrative (n=1150) and non-medical staff (n=564). The management of patients often requires a multidisciplinary approach involving specialists from different departments. There is therefore a high level of interaction between HCWs.

Index case

On March 02, 2020 an 80-year-old male attended the ER with fever and shortness of breath. Fever onset was four days prior to admission. The patient had no known contact with cases of COVID-19. The medical history comprised hypertension and dementia. Radiographic appearance of pneumonia was observed. Antibiotic and support oxygen therapy were prescribed. On March 05, 2020 the patient became hypoxemic and required high flow oxygen therapy. Viral respiratory panel and blood bacterial analysis were unrevealing. Following the Centers for Disease Control and Prevention (CDC) testing criteria for patients with atypical pneumonia, the patient was tested for COVID-19 resulting in the first positive case in the hospital (7). After a few hours the patient was intubated due to respiratory failure and admitted to the Intensive Care Unit (ICU).

Study population and data collection

Before the index case the Occupation Health Service (OHS) followed the National Health Institute guidelines for the identification of suspected cases of COVID-19 (15). Immediately after, and in response to the local outbreak of COVID-19, the OHS implemented a structured risk-management protocol for exposed HCWs, enforcing it on March 6, 2020. The protocol was created following the European CDC the National Health Institute recommendations regarding COVID-19 management in a healthcare setting (11, 15).

All HCWs in contact with a suspected or confirmed COVID-19 case had to complete a warning form including socio-demographic data, aspects of the event-exposure (date, place, length and distance of exposure, use of PPE) and details of the contact person (if known). Sociodemographic data of contact persons were also collected from hospital records. HCWs were asked to report any symptoms experienced at the time of completion of the warning form.

The warning form was sent to an official e-mail address to get a post-exposure risk evaluation by the OHS. The risk was stratified on three levels based on the presence of symptoms, exposure and use of PPE. HCWs presenting at least one key symptom (fever, cough, and dyspnea) (13) were at high risk. Moderate risk was assigned in case of exposure for more than 15-minutes or at less than 2-meters of distance without the use of proper and undamaged PPE, while low risk was assigned to HCWs exposed for less than 15-minutes and at more than 2-meters or using proper and undamaged PPE. Proper PPE included: double surgical mask (patient and HCW) or FFP2/3 mask for HCW, at least one pair of gloves or hand hygiene after the exposure, goggles or visor, water-resistant long-sleeved gown. For aerosol-generating procedures (e.g., tracheal intubation, bronchial suctioning, bronchoscopy, non-invasive ventilation) (21) HCWs had to wear a FFP2/3 mask along with all the other required PPE.

Low risk HCWs resulted in no concrete actions other than self-monitoring of symptoms and following recommended hygiene rules. In cases of moderate risk, a COVID-19 test was recommended 72 hours post-exposure with the compulsory use of a surgical mask during work until the test result was known. High risk HCWs were required to immediately desist from their working activities, undergo COVID-19 testing, and remain home-quarantined until the results of the test indicated the action that needed to be taken. For all the positive HCWs two-weeks home isolation was required, and a second test was scheduled at the end of the quarantine. If the post-quarantine test was still positive a second test was scheduled a week later. All HCWs had to be microbiologically healed (two negative tests in 48-72 hours) to return to work.

Diagnostic testing for COVID-19 and specimen collection were conducted following CDC guidelines (5). Nasopharyngeal and oropharyngeal fiber swabs were collected and stored in a sterile tube with viral transport media and analyzed in the hospital virology laboratory. The WHO's SARS-CoV-2 rRT-PCR panel for detection of SARS-CoV-2 were followed to perform the tests (23).

All data were anonymized, and the hospital directorate approved data collection and analysis. The research followed ethical principles for medical research involving human subjects expressed by the Declaration of Helsinki.

Statistical analysis

An a priori sample size calculation was not performed, and sample size was equal to the number of HCWs who referred to the OHS. Descriptive analysis was carried out. Categorical variables were presented as numbers (percentage) with 95% CI. Continuous data were expressed as medians with interquartile ranges (IQR) as a measure of variability. A Mann-Whitney U test was used for comparison of quantitative variables and Chi-square or Fisher's exact test for categorical variables as appropriate. Risk of infection was analyzed considering the diagnostic test result as outcome variable and univariate logistic models with Firth correction were applied. Finally, a social network analysis was carried out to reveal the pattern of diffusion of the COVID-19 infection among HCWs. A modularity algorithm was implemented to identify the most connected and the most influential nodes as a proxy of the most important pattern of transmission (3). Modularity algorithm evaluates if the group of nodes are connected among themselves not by random. So, modularity algorithm checks how better the connections are than if those connections were made randomly. Analysis was conducted two-sided and statistical significance was set at $p<0{\cdot}05$. Analysis was performed using R version 3.6.1 (19) and Gephi (2).

Results

Demographic and clinical characteristics of the healthcare workers

During the period from March 06 through March 21, 2411 HCWs reported 2924 COVID-19 contacts. The sample was mostly composed of female HCWs (68·1%, 1636 of 2403 available data; 95% CI 66·2%-69·9%) with a median age of 47·7 years (IQR 37·7-54·8; 95% CI 45·9–48·6) working in inpatient services (51·4%, 1132 of 2204 available data; 95% CI 49·3%–53·5%). Nurses were the HCWs that reported the highest number of warnings (41·4%, 984 of 2375 available data; 95% CI 39·4%–43·4%). 68·4% (1638 of 2395 available data; 95% CI 66·5%-70·3%) of warnings were reported in the general hospital. The main reasons for exposure were direct patient care (31·8%, 656 of 2063 available data; 95% CI 29·8%-33·9%), patient consultation (22·9%, 472 of 2063 available data; 95% CI 21·1%-24·8%), and a shared work environment (20·6%, 426 of 2063 available data; 95% CI 18·9%-22·5%).

After the warnings, 830 'high or medium risk' HCWs were tested for COVID-19 infection. 750 HCWs tested negative (90·4%; 95% CI 88·2%-92·3%); 80 tested positive (9·6%; 95% CI 7·7%-11·9%). The characteristics of the HCWs and the exposure are shown in Table 1.

There was a significant difference in the presence of symptoms experienced by HCWs who tested positive to COVID-19 compared to those who tested negative. Cough was the most frequent symptom reported with a statistically higher presence in HCWs positive to COVID-19 (36·8% vs 25·0%; 95% CI 0·9%-23·3%; $p=0{\cdot}03$). Fever (18·4% vs 3·4%; 95% CI 6·9%-24·6%; $p<0{\cdot}001$) and dyspnea (6·6% vs. 1·1%; 95% CI 0·5%-12·4%); $p<0{\cdot}001$) were also significantly higher in positive HCWs. Among 17 other reported symptoms, anosmia was the only one statistically associated with positive COVID-19 cases (5·0% vs. 0·0%; 95% CI 0·8%-11·1%; $p<0{\cdot}001$).

Table 1 - Demographic and exposure characteristics of healthcare workers tested for COVID-1 9

Characteristics	All	Negative	Positive	*P* Value
No. (%)	830 (100)	750 (90.4)	80 (9.6)	
Sex[a] – No. (%)				
Female	552 (66.7)	497 (66.4)	55 (68.8)	0.677
Male	276 (33.3)	251 (33.6)	25 (31.2)	
Age[a], median (IQR), y	46.0 (35.9-53.2)	45.9 (35.7-53.0)	47.6 (39.6-55.1)	0.159
Service[a] – No. (%)				
Inpatient	414 (54.5)	383 (55.6)	31 (44.3)	
ICU	152 (20.0)	138 (20.0)	14 (20.0)	
ER	80 (10.5)	74 (10.7)	6 (8.6)	0.004
Outpatient	54 (7.1)	50 (7.3)	4 (5.7)	
Non-medical	51 (6.7)	38 (5.5)	13 (18.6)	
Out-of-hospital care	8 (1.1)	6 (0.9)	2 (2.9)	
Role[a] – No. (%)				
Physician	214 (26.1)	182 (24.6)	32 (40.5)	
Resident	79 (9.6)	77 (10.4)	2 (2.5)	
Nurse[b]	351 (42.9)	323 (43.6)	28 (35.4)	
Nurse aide	114 (13.9)	104 (14.1)	10 (12.7)	
Rehabilitation therapist[c]	4 (0.5)	4 (0.5)	0 (0.0)	
Medical/X-Rays technologist	35 (4.3)	33 (4.5)	2 (2.5)	
Administrative staff	12 (1.5)	8 (1.1)	4 (5.1)	
Other non-medical staff	10 (1.2)	9 (1.2)	1 (1.3)	
Type of hospital[a] – No. (%)				
General hospital	562 (68.0)	522 (70.0)	40 (50.0)	
Children's hospital	40 (4.8)	35 (4.7)	5 (6.2)	0.001
Maternity hospital	147 (17.8)	120 (16.1)	27 (33.8)	
Trauma center	77 (9.3)	69 (9.2)	8 (10.0)	
Type of exposure[a] – No. (%)				
Direct care	214 (28.6)	199 (29.4)	15 (21.1)	
Patient consultation	184 (24.6)	170 (25.1)	14 (19.7)	
Shared working environment	145 (19.4)	121 (17.9)	24 (33.8)	
Aerosol-generating procedure[d]	25 (3.3)	24 (3.6)	1 (1.4)	0.021
Non-aerosol-generating procedure	24 (3.2)	20 (3.0)	4 (5.6)	
Other	155 (20.7)	142 (21.0)	13 (18.3)	

Table 1 - Demographic and exposure characteristics of healthcare workers tested for COVID-1 9

Characteristics	All	Negative	Positive	*P* Value
Exposure length[a] – No. (%)				
<15 min	221 (27.9)	198 (27.6)	23 (30.7)	0.575
>15 min	571 (72.1)	519 (72.4)	52 (69.3)	
Exposure distance[a] – No. (%)				
>2 m	60 (7.6)	52 (7.2)	8 (10.7)	0.284
<2 m	734 (92.4)	667 (92.8)	67 (89.3)	

Abbreviations: IQR, interquartile range; ICU, intensive care unit; ER, emergency room.
[a] Presence of missing data. Percentages may not total 100 because of rounding.
[b] Includes nurses, midwives and pediatric nurses.
[c] Includes physiotherapists and speech therapists.
[d] Includes tracheal intubation, bronchial suctioning, bronchoscopy, non-invasive ventilation.

HCWs presented a different risk of infection as shown in Figure 1A. The risk of being infected statistically significantly doubled for physicians (OR=2·03; 95% CI 1·18-3·49). Also, administrative staff had a statistically increased risk (OR=5·77; 95% CI 1·47-19·55). Non-medical services resulted in an increased risk of infection (OR=4·23; 95% CI 1·99-8·63) (Figure 1B). In particular, HCWs working in the maternity hospital had three times more the risk of infection (OR=2·94; 95% CI 1·72-4·95) (Figure 1C). Care for patients did not increase the risk of infection but sharing the work environment (OR=2·63; 95% CI 1·34-5·32) (Figure 1D).

Early impact of the risk-management protocol

Median time from exposure to warning was 5 days (IQR 2-8; 95% CI 5-5), and 6 days to Covid-19 testing (IQR 4-9; 95% CI 6-6). A median of 2 days passed between the warning and the test (IQR 0-4; 95% CI 2-2). HCWs who were at high risk had a increased risk of COVID-19 infection (OR=1·72; 95% CI 1·05-2·77; p=0·027). To evaluate the impact of the risk-management protocol we identified three indexes. There was a significant time reduction between exposure and warning since the protocol implementation (Figure 2A). Also, the time between exposure and test was significantly shorter after our intervention (Figure 2B). Lastly, we observed a significantly decrease period between warning and testing for COVID-19 (Figure 2C).

Diffusion of the COVID-19 infection among healthcare professionals

In 1684 of 2924 (57·6%; 95% CI 55·8%-59·3%) warnings HCWs reported a known exposure to a COVID-19 positive source. 155 sources were identified. Sources had a median age of 55·0 years (IQR 45·3-66·4; 95% CI 53·8–56·9) and were predominantly females (52·9%; 95% CI 44·1%-60·3%). The most frequently reported sources were physicians (49·0%; 95% CI 46·4%-51·7%) followed by patients (28·8%; 95% CI 26·5%-31·3%), nurses (12·1%; 95% CI 10·5%-13·9%), nurse aides (6·0%; 95% CI 4·8%-7·4%), and other HCWs (4·0%; 95% CI 3·1%-5·2%).

The social network analysis revealed the role of the different possible sources of infection who tested positive to COVID-19 for positive HCWs (Figure 3). When patients are the source of the COVID-19 transmission, the cluster is limited to the service in which they were admitted. Generally, patients were a limited source of infection. Physicians were the most important source of transmission. In particular, physicians who work in hospital management positions were connected to more infected HCWs. Equally nurse managers and other healthcare staff in the hospital management were a higher source of infection for other HCWs. In particular HCWs working in the maternity hospital clustered and transmitted infection within the hospital.

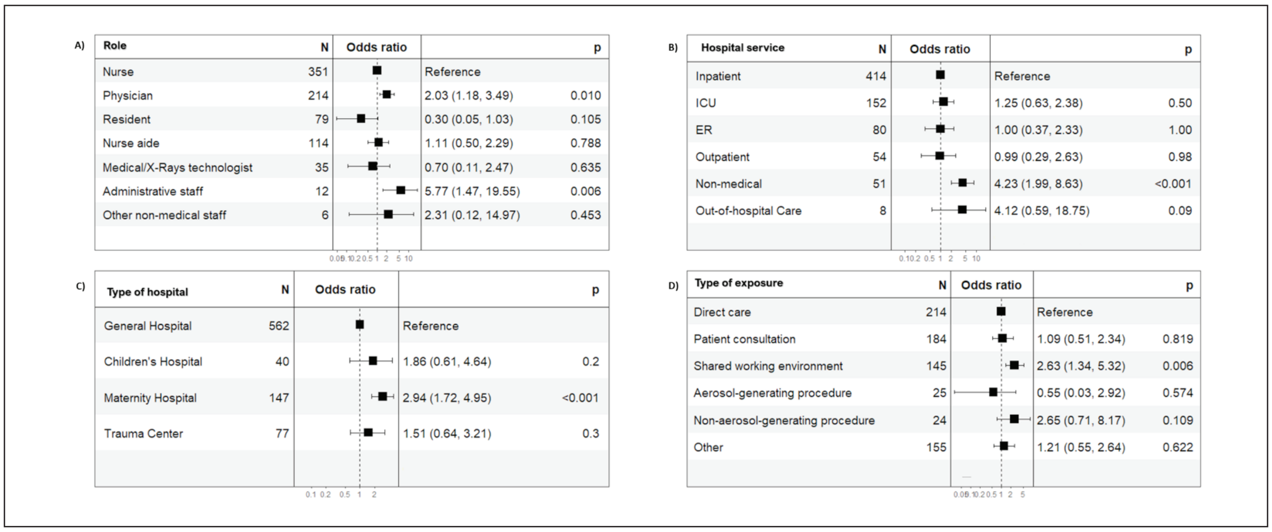

Figure 1 - Risk of infection among healthcare workers role, hospital services, type of hospital and exposure.
Figure 1 shows the risks of COVID-19 infection according to hospital service (A), healthcare workers role (B), type of hospital (C), and type of exposure (D). Squares represent the observed proportions, and the lines extending from the squares are the 95% confidence intervals for these proportions. The confidence intervals that are reported as numbers to the right of the plot are 95% confidence intervals for the difference of proportions from the reference category. Reference categories are identified by the absence of 95% confidence intervals.

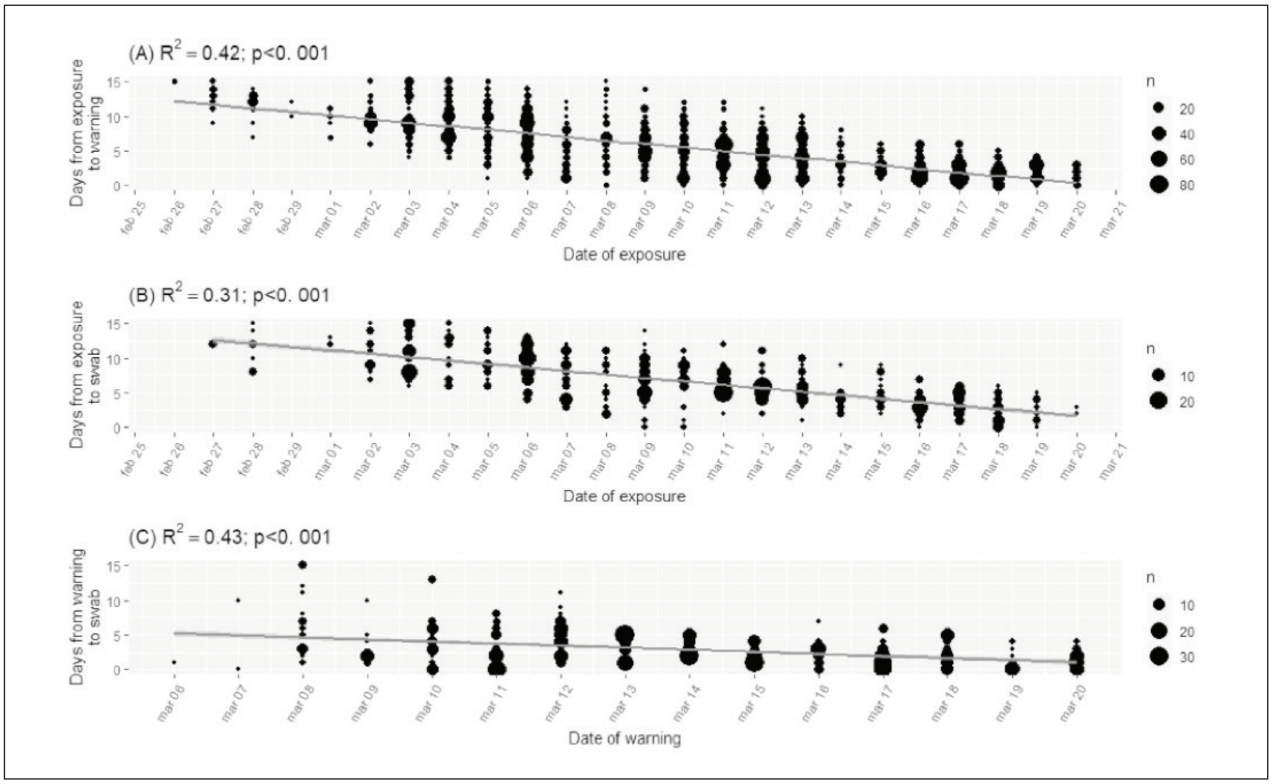

Figure 2 - Trend of exposure, warning, and COVID-19 testing since the protocol implementation on 06 March 2020: time elapsed (days) between exposure to COVID-19 and warning to the occupational health service (2A); days between exposure and testing for COVID-19 (2B); days between warning to the occupational health service and testing for COVID-19 (2C). R^2 indicates the variance explained by the regression model. P-value is for linear trend across days.

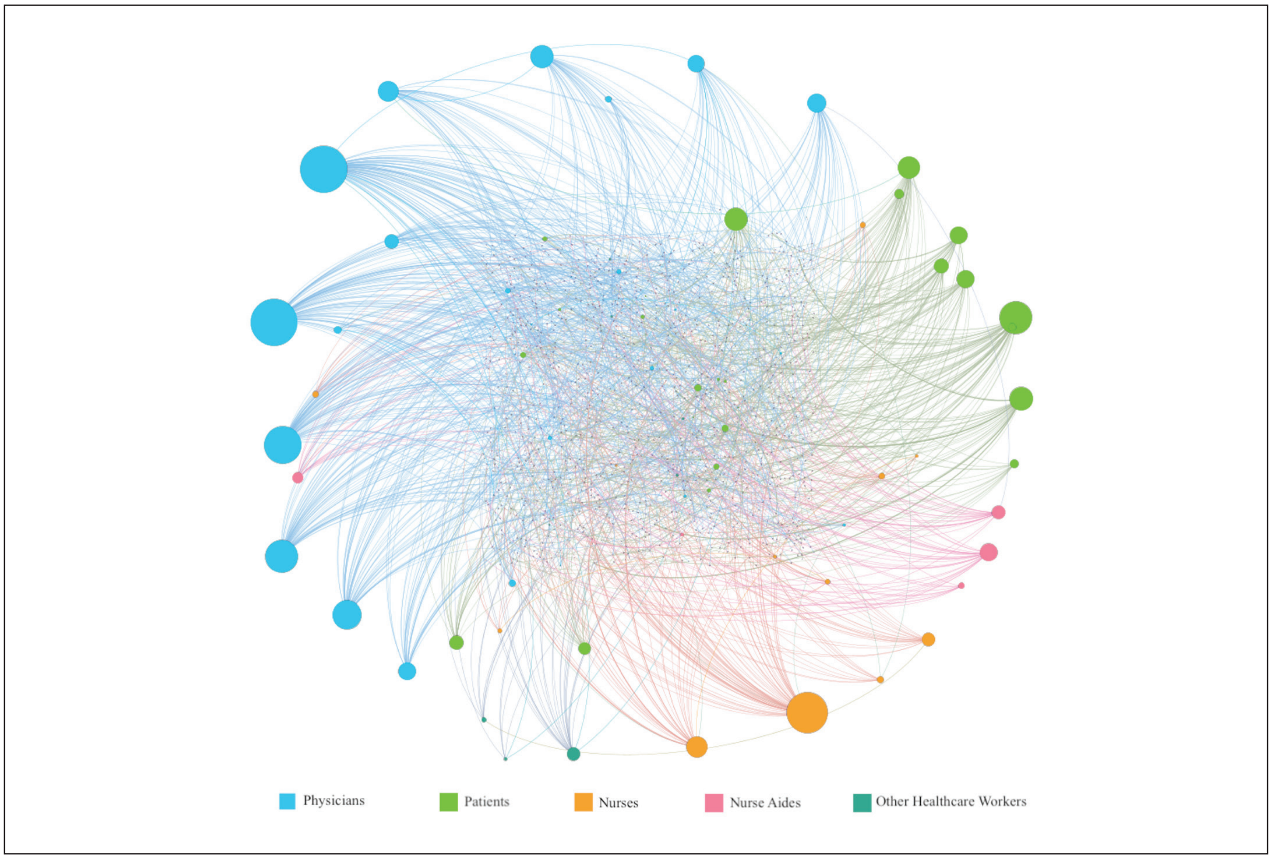

Figure 3 - Social network analysis of COVID-19 positive healthcare workers and sources of infection.
Main sources of infection linked to healthcare workers. Healthcare workers had frequent interaction with each other with few interactions with patients. Each circle represents a source of infection with a color assigned to its role within the hospital. Every line represents an interaction. The bigger the circle the higher the frequency of interaction representing its degree of centrality.

Discussion

This study describes the characteristics of HCWs who were exposed to COVID-19 during their work in a large University-Hospital in Northwest Italy and how these characteristics differed between those who tested positive and negative to COVID-19. Also, we evaluated how the infection has spread within the hospital in the early stage of the crisis and the impact of a risk-management protocol for exposed healthcare workers.

The highest risk to administrative staff could be explained by the lack of consolidated respiratory hygiene habits especially for those working in services that do not have direct contacts with outpatients and visitors (8). The awareness of infectious risk could be lower in these workers as they do not connect with patients (16). In particular, the results of this study represent the early diffusion of the infection when non-healthcare professional were less aware of the COVID-19 infectious risk. This result should be interpreted with caution due to the vast 95% CI. However, results from our study demonstrated that physicians are the main source of infection as well as one of the more vulnerable group. This data was also supported by the social network analysis results that provided evidence that physicians working in hospital management positions spread the infection more than those providing only direct care. This could be due to the frequent meetings they held to manage the critical situation at the beginning of the outbreak. Additionally, many physicians have a consultant role moving around the hospital services. This could be a further way of infection diffusion (4). This is particularly true for the maternity hospital, that, more than other hospitals in our facility, needs consultations from other specialists. The maternity hospital differs substantially from others as its emergency department cannot be shut off, nor the number of births is likely to lower during the lockdown and nosocomial outbreaks frequently start in emergency departments (1). Furthermore, because of the clinical pathway that pregnant women have to follow (emergency department, delivery room, possibly operating room), and because of the eventual byway of the woman and the infant (either of them can be moved into hospital wards or intensive care units) infection spread could potentially be higher. This peculiar aspect undermines the institution of an appropriate traffic control bundling for patients (20). Also, the concentration of highly specialized wards and the consequent various interconnections between structures, with the inevitable high flows of patients and HCWs between them, could increase contagion possibilities. It is therefore important to encourage the use of appropriate hygiene practices in non-clinical environment and particularly by senior physicians and nurses in management positions as well as maternity and admin staff.

In addition to the three key symptoms (cough, fever and dyspnea), anosmia also needs to be evaluated as a COVID-19 related symptom. These data are in line with most recent literature (12, 18), suggesting the possibility to add the symptom in the warning form as a possible positive predictor.

The first choice was to centralize the whole organization, creating an occupational health dedicated working group that received the warnings from all hospital services, assigned cases in risk categories, informed and gave specific indications to the employees and their supervisors, filled in a dedicated database daily transmitted to the Health Directorate. The database was designed as a tool to answer different needs: redistribution of the workforce, swabs scheduling based on risk categories, return to work of HCWs, constant monitoring of the outbreak of the disease and future epidemiological research. Our purpose is to fully implement the whole procedure on a dedicated platform, in order to increase system efficiency, avoid missing or incomplete data and reduce human error.

The development of a risk management protocol and its application could have accelerated the return to work of HCWs, allowing a fair number of qualified personnel according to the needs of each ward. A fast return of employees is crucial to avoid the need to employ new HCWs in a phase characterized by limited resources and hence limit the burden on the healthcare system. Another advantage is represented by the availability of trained staff in the management of critically ill patients with no need of training external HCWs with better outcomes for patients, as well as economic and time-saving benefits (10). HCWs at high risk were identified and resulted in a higher risk of infection. Thus, the risk management protocol could have guaranteed a higher level of security for patients and HCWs reducing the risk of infection.

The role of super-spreaders is yet to be fully analyzed, even if the social network analysis graph suggests an outbreak dynamic characterized by few initial high-infectious HCWs, with a subsequent spike of infected HCWs, and a progressive reduction of virus infectiousness (17, 26) in front of the widespread enforcement of our protocol and an increase in its efficiency, more severe hospital lockdown policies, higher consciousness over respiratory hygiene practices from HCWs and visitors, and higher usage of PPE. The social network analysis shows that the patterns of diffusion were not at random, but that, as previously discussed, workers in the hospital management were more linked to another workers' infection.

Limitations

Our study has some limitations. Firstly, it is plausible that some HCWs did not refer to the OHS after exposure, especially non-occupational exposures. Perhaps they contacted the Public Health System directly, which could have led to a lower reported number of HCWs infected in our sample. Secondly, we had missing data in some warnings. However, due to the high workload during the hospital emergency and to provide objective data without recall bias we decided not to approach the HCWs again.

Lastly, the number of warnings is still increasing. Future research will include analysis of constantly accumulating longitudinal data. Exposure contacts may have been overreported. However, we aimed to treat all the HCWs internally in order to reduce the amount of people referring to their general practitioners. The tendency to over-report could also be a proxy of the increased awareness of HCWs of the importance of an early identification of infection.

Conclusions

Our experience highlighted the significant impact that the outbreak of COVID-19 had on HCWs and on the hospital settings. Our results suggest that a fast response of the OHS is crucial to increase the awareness of HCWs. A proactive warning and recognition of contact with potential sources is able to reduce the time between exposure and testing. This is fundamental to lower the spread of the infection among HCWs and patients. At the same time, early testing after exposure could guarantee a faster return to work and a lower burden on a healthcare system affected by staff shortage and increased workload. Lessons learned from this experience could be adapted in other hospital settings worldwide and help occupational health services to face and react to the COVID-19 emergency.

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