

Coronavirus Pandemic

What influences the infection of COVID-19 in healthcare workers?

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Abstract

Introduction: The outbreak of COVID-19 has spread worldwide. The evidence about risk factors of healthcare workers who infected COVID-19 is limited. This study aims to describe characteristics and influencing factors of the COVID-19 infection in healthcare workers.

Methodology: The study was performed among COVID-19 infected and uninfected healthcare workers in three hospitals in Wuhan. A total of 325 healthcare workers participated; among them 151 COVID-19-infected healthcare workers were included. Characteristics of infected healthcare workers, and influencing factors including exposure histories, the use of protective equipment in different risk conditions and areas, perceptions, emotions, satisfactions and educations were described and analyzed.

Results: Healthcare workers got infected clustered mostly in the physical examination center. When performing general operations on confirmed or suspected patients, the use of protective equipment including the effectiveness of masks ($p < 0.001$), gloves ($p < 0.001$); and the use of gloves ($p < 0.001$), suits ($p < 0.001$), gowns ($p < 0.001$), shoe covers ($p < 0.001$), and hats ($p < 0.001$) were protective factors. The use of protective equipment was a protective factor in most cases. Negative emotions and dissatisfaction to the hospital response were associated with the increased risk of infection.

Conclusions: The use of protective equipment, emotions and satisfactions to hospital responses are key COVID-19-infected factors. The awareness, the supply and the use of protective equipment, the layout of departments and other environmental and management factors should be strictly equipped. In addition, hospitals should also pay attention to emotions and satisfaction of healthcare workers.

Key words: COVID-19; healthcare workers; personal protective equipment; infection prevention and control; satisfaction.

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Introduction

In December 2019, a novel coronavirus pneumonia now known as COVID-19 broke out in Wuhan, Hubei Province, China, and the infection spread across the whole China and even other countries in a short time. On January 21, 2020, with the approval of the General Office of the State Council, the National Health Commission included COVID-19 as a Class B infectious disease, and adopted measures for the prevention and control as Class A infectious diseases in China. All provinces and cities also successively launched Level I public health emergencies response. The World Health Organization announced that COVID-19 is characterized as a pandemic. However, the mode of transmission is not fully understood [1]. Healthcare workers (HCWs) are on the front line of combat and the last line of defense and their safeties are the focus of the whole society. Their protection

challenges the infection prevention and control management in hospitals. To explore the reason why they get infected is important, which may be the key to understand the transmission path of COVID-19.

Protecting frontline HCWs against COVID-19 is a critical challenge and of particular importance. Pei [2] found that educations and infection prevention and control behaviors are protective factors, while the tracheal intubation is a risk factor during SARS outbreak. Zhang [3] concluded that the supply of personal protective equipment (PPE), behaviors of HCWs during infection control and supports for organization and mental health are important aspects to protect HCWs in the COVID-19 outbreak. However, relative studies concerning COVID-19-infected HCWs are limited. This article aims to investigate characteristics and related factors of COVID-19

infections in HCWs to provide the scientific evidence to prevent and control COVID-19 infections.

Methodology

Study design and participants

We surveyed COVID-19-infected HCWs in three hospitals in Wuhan, including Tongji hospital, Hubei provincial hospital of integrated Chinese and Western medicine, and Tianyou hospital affiliated to Wuhan university of science and technology, all of which are major tertiary teaching hospitals and in charge of treatments for COVID-19-infected patients in the epidemic period. All diagnosed COVID-19-infected HCWs reported inside hospital and non-infected HCWs in the same working environment who were willing to participate completed questionnaires. A total of 325 HCWs were surveyed. Among them, 151 HCWs were diagnosed as COVID-19 with the positive nucleic acid test or clinical diagnosis.

Data collection

A structured self-administered questionnaire was used to collect data. The survey was conducted from February 11 to February 15, 2020 in the form of electronic questionnaires.

The questionnaire mainly included: 1) clinical symptoms and demographic characteristics of infected HCWs, 2) exposure histories (life exposures or not, work exposures or not, early or late exposures), 3) the level of PPE (the effectiveness of masks, the effectiveness of gloves, the use of goggles, protective suits, gowns, shoe covers, hats used by HCWs in different risk conditions (general operations and aerosol operations for diagnosed or suspected patients, operations for general patients) and areas (rest areas, living areas and semi-contaminated areas) [2,4], 4) perceptions of COVID-19 (HCWs heard COVID-19 early or late; perceived COVID-19 serious early or late) [5], 5) emotions with respect to COVID-19 (anxiety, fear, worry, positive) [6,7], 6) satisfactions of HCWs regarding hospital responses to COVID-19 (the supply for PPE, the timely treatment if infected, the disinfection of environment, the proper schedule, the mood comfort, the security guarantee, the remedial measure if infected) [8], 7) educations from the hospital infection department (early or late educations and audits).

Measurements

The effectiveness of masks was judged according to the mask selection guideline issued by the National Health Commission in China [9]: the N95/KN95

standard particulate protective mask or the medical protective mask and above should be worn by HCWs when caring for COVID-19 patients; people in other areas of the hospital need to wear masks above medical surgical masks. The glove wearing should be above latex/nitrile gloves.

The use of PPE was measured by whether or not it was used. Based on the developing trend of the epidemic and results of actual investigations, exposures and perceptions of HCWs were defined as early or late by the boundary of January 1, 2020. Educations and audits from the hospital infection department were defined as early or late by the boundary of January 20, 2020.

Based on previous studies that negative emotions (i.e., anxiety, fear, worry) and the positive emotion worsened extensively due to the epidemic, we asked the extent HCWs experienced anxiety, fear, worry and positive emotions, along a five-point Likert scale that ranged from 1 (not at all) to 5 score (very much) [6]. Satisfactions were measured using a five-point Likert scale that ranged from 1 (very dissatisfied) to 5 score (very satisfied) [10].

Statistical analysis

Continuous variables were described using means and standard deviations. Categorical variables were described using percentages and frequency rates. Independent sample t or t' tests were used to compare means for continuous variables. χ^2 tests or Fisher exact tests were performed to compare proportions for categorical variables. All statistical analyses were performed using IBM SPSS Version 20.0 (IBM, New York, NY, USA). Two-sided α of less than 0.05 was considered statistically significant.

Results

Characteristics of infected HCWs

Most of infected HCWs had symptoms of fever (71.52%), fatigue (65.56%), cough (60.93%), sore throat (51.66%), and muscle aches (56.29%). Obvious concentrated outbreaks existed, including 14 (9.27%) infected HCWs at the physical examination center, 11 (7.28%) in the emergency department, 8 (5.30%) in the thoracic surgery department, and 8 (5.30%) in the digestive medicine department. Professions of HCWs mainly concentrated in nurses (45.70%), doctors (33.77%), but also some technicians (9.27%), security and cleaning staffs (3.31%), and financial staffs (7.95%). 45 (29.80%) HCWs were male and 106 (70.20%) were female. The average age was 42.58 \pm 14.73 years.

Table 1. Relationship between HCWs infections and exposures.

	Infected (N = 151)	Uninfected (N = 174)	Total (N = 325)	P-value
Life exposures				
Yes	19 (12.58%)	19 (10.92%)	38 (11.69%)	0.642
No	132 (87.42%)	155 (89.08%)	287 (88.31%)	
Work exposures				
Yes	89 (58.94%)	108 (62.07%)	197 (60.62%)	0.565
No	62 (41.06%)	66 (37.93%)	128 (39.38%)	
Experience of treating or caring confirmed or suspected patients				
Yes	89 (58.94)	108 (62.07%)	197 (60.62%)	0.565
No	62 (41.06)	66 (37.93%)	128 (39.38%)	
Experience of performing aerosol-produced operations for confirmed or suspected patients				
Yes	17 (11.26)	26 (14.94)	43 (13.23)	0.328
No	134 (88.74)	148 (85.06)	282 (86.77)	
	Infected (N = 89)	Uninfected (N = 108)	Total (N = 197)	P-Value
Work exposures early or late				
Early ^a	26 (29.21)	24 (22.22)	50 (25.38)	0.262
Late	63 (70.79)	84 (77.78)	147 (74.62)	

a: the exposure before January 1, 2020 was defined as early; after January 1st, 2020 was defined as late.

Table 2. Relationship between infection and use of PPE in different operations.

		Operations on confirmed or suspected patients			Aerosol-produced operations on confirmed or suspected patients			Operations for general patients		
		Infected (N = 89)	Uninfected (N = 108)	P-value	Infected (N = 17)	Uninfected (N = 26)	P-value	Infected (N = 151)	Uninfected (N = 174)	P-value
Mask types ^a	Effective	44 (49.44)	80 (74.07)	< 0.001	11 (64.71)	23 (88.46)	0.061	119 (78.81)	163 (93.68)	< 0.001
	Ineffective	45 (50.56)	28 (25.93)		6 (35.29)	3 (11.54)		32 (21.19)	11 (6.32)	
Glove types ^b	Effective	60 (67.42)	98 (90.74)	< 0.001	13 (76.47)	22 (84.62)	0.502	-	-	-
	Ineffective	29 (32.58)	10 (9.26)		4 (23.53)	4 (15.38)		-	-	
Goggles	Use	24 (26.97)	78 (72.22)	< 0.001	12 (70.59)	21 (80.77)	0.44	-	-	-
	Not use	65 (73.03)	30 (27.78)		5 (29.41)	5 (19.23)		-	-	
Suits	Use	20 (22.47)	77 (71.30)	< 0.001	9 (52.94)	21 (80.77)	0.052	-	-	-
	Not use	69 (77.53)	31 (28.70)		8 (47.06)	5 (19.23)		-	-	
Gowns	Use	25 (28.09)	74 (68.52)	< 0.001	12 (70.59)	22 (84.62)	0.269	-	-	-
	Not use	64 (71.91)	34 (31.48)		5 (29.41)	4 (15.38)		-	-	
Shoe covers	Use	19 (21.35)	71 (65.74)	< 0.001	8 (47.06)	17 (65.38)	0.234	-	-	-
	Not use	70 (78.65)	37 (34.26)		9 (52.94)	9 (34.62)		-	-	
Hats	Use	68 (76.40)	103 (95.37)	< 0.001	17 (100.00)	24 (92.31)	0.667	99 (65.56)	158 (90.80)	< 0.001
	Not use	21 (23.60)	5 (4.63)		0 (0.00)	2 (7.69)		52 (34.44)	16 (9.20)	

a: N95/KN95 standard particulate protective masks or medical protective masks and above worn by HCWs in operations on confirmed or suspected patients in caring patients with COVID-19 were effective; medical surgical masks and above worn by HCWs in operations for general patients were effective; b: The glove above latex/nitrile glove was effective.

Table 3. Relationship between infections and the use of PPE in different areas.

		Rest areas			Living areas			Semi-contaminated areas		
		Infected (N = 151)	Uninfected (N = 174)	P-value	Infected (N = 151)	Uninfected (N = 174)	P-value	Infected (N = 151)	Uninfected (N = 174)	P-value
Mask types ^a	Effective	101 (66.45)	119 (68.39)	0.773	90 (59.60)	104 (59.77)	0.976	119 (78.81)	164 (94.25)	< 0.001
	Ineffective	50 (32.89)	55 (31.61)		61 (40.40)	70 (40.23)		32 (21.19)	10 (5.75)	
Hats	Use	46 (30.46)	81 (46.55)	0.003	30 (19.87)	49 (28.16)	0.082	85 (60.71)	156 (89.66)	< 0.001
	Not use	105 (69.54)	93 (53.45)		121 (80.13)	125 (71.84)		55 (39.29)	18 (10.34)	

a: Medical surgical masks and above worn by HCWs in rest areas, living areas and semi-contaminated areas were effective.

Relationship between HCWs infections and exposures

Of the 325 HCWs, 11.69% had histories of life exposures; 60.62% had histories of work exposures, namely histories of treating or caring for a confirmed or suspected patient; and 13.23% HCWs had performed aerosol-produced operations for confirmed or suspected patients. 74.62% of HCWs had the experience of work exposures after January 1, 2020. Statistical results found that no significant difference in the risk of infections between yes and no exposures, as well as early and late exposures (Table 1).

Relationship between infections and the use of PPE

In different areas and conditions of the hospital, HCWs adopted different levels of prevention and control measures. The use of PPE such as effective masks ($p < 0.001$), effective gloves ($p < 0.001$), the use of goggles ($p < 0.001$), protective suits ($p < 0.001$), gowns ($p < 0.001$), shoe covers ($p < 0.001$), and hats ($p < 0.001$) were protective factors of HCWs infections when performing general operations for confirmed or suspected patients. When performing aerosol-produced operations for confirmed or suspected patients, no difference existed in the effectiveness of masks and gloves and the use of PPE in infected and uninfected HCWs. In rest areas ($p = 0.003$), semi-contaminated areas ($p < 0.001$) and operations for general patients ($p < 0.001$), the use of hats was better in uninfected HCWs than those infected. Meanwhile, in semi-contaminated areas ($p < 0.001$) and operations for general patients ($p < 0.001$), the type of masks used by uninfected HCWs was more effective than those used by the infected (Tables 2 and 3).

Relationship between infections and perceptions, educations, emotions and satisfactions with hospital responses to COVID-19

Most HCWs heard COVID-19 before January 1, 2020, and most HCWs perceived the severity of COVID-19 after January 1, 2020. And HCWs who heard COVID-19 earlier had a lower risk of infection ($p = 0.015$), but perceived COVID-19 serious early or late had no difference. Nearly 60% HCWs received educations from the hospital infection department before January 20, 2020, and early or late educations and audits had no effects on the infection of HCWs (Table 4).

Confronted with COVID-19, the fear of HCWs was the most prominent, and HCWs were most satisfied with the mood comfort from the hospital. Infected HCWs were more anxious ($p < 0.001$), feared ($p = 0.009$), worried ($p < 0.001$), and more negative ($p < 0.001$) than uninfected HCWs. Uninfected HCWs were more satisfied than infected HCWs in the supply for PPE ($p = 0.031$), the timely treatment if infected ($p = 0.031$), the disinfection of environment ($p = 0.005$), the security guarantees ($p = 0.045$) and the remedial measure if infected ($p < 0.001$) from the hospital (Table 5).

Discussion

In this study, we found that COVID-19-infected HCWs outbreak concentrated in the emergency department and the non-high-risk department, and the effectiveness, the use of PPE, emotions and satisfactions to hospital response are key factors associated COVID-19 infections.

Table 4. Relationship between infections and perceptions and educations.

	Infected (N = 151)	Uninfected (N = 174)	Total (N = 325)	P-value
Perceptions				
Heard				
Early	90 (59.60)	126 (72.41)	216 (66.46)	0.015
Late	61 (40.40)	48 (27.59)	109 (33.54)	
Perceived serious				
Early	33 (21.85)	44 (25.29)	77 (23.69)	0.468
Late	118 (78.15)	130 (74.71)	248 (76.31)	
Educations				
Early or late educations				
Early	91 (60.26)	111 (63.79)	202 (62.15)	0.513
Late	60 (39.74)	63 (36.21)	123 (37.85)	
Early or late audits				
Early	87 (57.62)	108 (62.07)	195 (60.00)	0.414
Late	64 (42.38)	66 (37.93)	130 (40.00)	

a: heard and perceived serious before January 1, 2020 was defined as early; after January 1, 2020 was defined as late; b: educations and audits before January 20, 2020 were defined as early; after January 20, 2020 were defined as late.

Table 5. Relationship between emotions and satisfactions with hospital responses.

	Infected (N = 151)	Uninfected (N = 174)	Total (N = 325)	P-value
Emotions				
Anxiety	4.08 ± 0.91	3.61 ± 0.80	3.83 ± 0.88	< 0.001
Fear	4.40 ± 0.73	4.19 ± 0.69	4.29 ± 0.72	0.009
Worry	4.38 ± 0.76	4.04 ± 0.79	4.20 ± 0.80	< 0.001
Positive	3.46 ± 1.11	3.84 ± 0.80	3.66 ± 0.98	< 0.001
Satisfactions				
Supply for PPE	4.19 ± 1.03	4.40 ± 0.72	4.30 ± 0.88	0.031
Timely treatment if infected	4.18 ± 1.06	4.49 ± 0.81	4.34 ± 0.95	0.031
Disinfection of environment	4.14 ± 1.09	4.44 ± 0.72	4.30 ± 0.92	0.005
Proper schedule	4.24 ± 1.08	4.43 ± 0.76	4.34 ± 0.93	0.068
Mood comfort	4.25 ± 1.03	4.43 ± 0.73	4.35 ± 0.88	0.068
Security guarantee	4.21 ± 1.13	4.43 ± 0.72	4.33 ± 0.94	0.045
Remedial measure if infected	3.73 ± 1.45	4.27 ± 1.01	4.02 ± 1.26	< 0.001

In this study, the departments of this outbreak were mainly concentrated in the physical examination center, the emergency department, the thoracic surgery department, and the digestive medicine department. The emergency department is a relative high-risk department of COVID-19, and the emergency department environment in the investigated hospitals is relatively airtight. Although HCWs have adequate protections, the relatively airtight environment and high density of patients may cause aerosol transmissions in confined spaces, increasing risks of infections in the emergency department [11,12]. Further attentions need to be paid to the protection level and the environmental cleanliness of high-risk departments. In addition, more than one half of the infected HCWs have symptoms of fever, fatigue, cough, sore throat, and muscle soreness.

Other outbreak departments are low-risk departments. However, the thoracic surgery and the gastroenterology department have a high risk of exposure in operations (bronchoscopy, stool) [13,14] with asymptomatic patients [15], in addition with the lower level of protections for HCWs, which may be related to the high infection rate. In addition, HCWs in the physical examination center usually face healthy people, resulting in the poor protection awareness, the low protection level, and poor protection behaviors, which may increase the risk of infection.

Conclusively, the infection of HCWs mainly occurs in general departments and relative high-risk emergency departments, but not in high-risk or fever clinics that specialize in infectious diseases and isolation wards [16]. This is largely due to the high risk of treating asymptomatic patients, the relatively weaker awareness and equipment to prevent and control COVID-19 infection [17], as well as the ignorance of environmental cleanliness. Therefore, the level of

protection of HCWs in non-high-risk departments should also be given more attention.

Our study suggested that PPE is used more in uninfected HCWs than those infected in general procedures on diagnosed or suspected patients. It was also indicated that in clean areas and semi-contaminated areas, prevention and control behaviors of uninfected HCWs are significantly better than those of infected HCWs. Surprisingly, no difference exists in the effectiveness and the use of PPE between infected and uninfected HCWs in procedures that may produce aerosols on confirmed or suspected patients. Similarly, no correlation exists between the exposure of life and work and infection. It can be seen that the degree of risks of exposures and operations are not the key of COVID-19 infection in HCWs. Different from studies that aerosol-produced operations are major causes of SARS infection in HCWs [18], this operation does not increase the risk of infection of HCWs in this study, which may be related to the adequate type and the use of PPE by HCWs. This illustrates the key role of use of PPE in the prevention and control of COVID-19. Researches showed that the use of PPE also plays a vital role in preventing other infectious diseases [19,20]. This result also suggested that HCWs have a strong awareness of PPE in high-risk operations or in high-risk contaminated areas. However, in general operations with lower risk and in clean areas or potentially contaminated areas, the use of PPE in HCWs is weak. Once encountering an asymptomatic infected patient or a colleague infected, it is easy to cause an outbreak in the department [21]. It is worth noting that some fever clinics / isolation wards are temporarily and urgently renovated, and contaminated areas and clean areas are not strictly separated, which is easy to cause cross-infection. Similarly, Kilmarx commented that incorrect

triages and infrastructure restrictions for temporary renovation facilities are important reasons for Ebola-infected HCWs, such as the lack of barriers to isolate Ebola wards, rather than the use of PPE [22]. In addition, other environmental or management factors such as the bed spacing, the availability of sanitation facilities, etc. are also important causes of infection [23].

This study indicated that the supply for PPE, the timely treatment, the disinfection of environment, the security guarantee and the remedial measure are closely related to the infection of HCWs. Negative emotions are also associated. Chen's study also indicated that the vitality and the mental health status of HCWs after isolation were lower than those in control group [24]. Researchers also pointed out that when medical professionals face critical infectious diseases (e.g., SARS), burnout, psychological distress, and posttraumatic stress all increase significantly [25]. Therefore, hospitals should pay attention to satisfy the need of HCWs at work during the period of SARS-COV-2 and other fulminating infectious diseases, so that they can have a high emotion [26,27]. The virus has spread throughout the country and even all over the world, and the anti-epidemic combat may last for a long time. Therefore, hospital logistics and management staffs need to be prepared for the long-term combat and take work needs of HCWs into account. It is also necessary to arrange shifts reasonably to prevent HCWs from the increasing risk of infections due to the decreased resistance and immunity.

The main symptoms are the same as those of general patients in recent COVID-19 studies [28,29]. Similar to SARS-infected HCWs, nurses are mainly infected HCWs. Until now, the main transmission routes of COVID-19 were droplets and contact transmission, and nurses are the HCWs most in close contact with patients [2].

According to researches and clinical infection prevention practices, the following measures are needed: 1) strictly partitioned layout, strictly separation of the contaminated area from the clean area to avoid cross contamination; 2) establishment of the monitoring system for monitoring the health of patients and staffs timely to detect and isolate infected persons early; 3) training in all HCWs about the prevention and control; 4) establishment of special auditing system to inspect and supervise the wearing and removal of PPE for HCWs; 5) establishment of an inspection and supervision system to find and solve infection-associated problems in the hospital; 6) adequate supplies of PPE; 7) shift arrangements reasonably to

avoid overwork; 8) strengthening the environmental ventilation, cleaning and disinfection. The limitation is that we only analyzed the data from Wuhan city, which may limit the generalization of this research.

Conclusions

HCWs have an outbreak in concentrated departments in the hospital. The COVID-19 infection is associated with the effectiveness and the use of PPE, emotions and satisfactions to hospital responses. To protect HCWs, the supply, the awareness and the use of PPE in HCWs in non-high-risk departments should be promoted. The layout of wards and other environmental and management equipment should be strictly implemented. In addition, hospitals should also pay attention to emotions of HCWs and provide satisfied relevant supports.

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Authors' Contributions

QZ and XPZ developed the design and drafted the manuscript. XQL, LT collected data, along with the study team. QZ analyzed the data and XPZ revised the manuscript. All authors contributed to the design of the study and approved the final version of the article.

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