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Masks Prevent Hospital-acquired COVID-19: A Single Hospital Experience in Taiwan

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Abstract

To estimate the hospital attack rate of coronavirus disease 2019 (COVID-19) and the stratified basic reproduction number (R_0) of its causative agent severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in a hospital setting in Taiwan. A total of 138 healthcare workers (HCWs) in a hospital who were exposed to COVID-19 within a patient household (January 14 to March 7, 2020) were divided into two groups, based on their exposure level. All HCWs received throat swab SARS-CoV-2 RT-PCR detection twice. Routine infection control policies included environmental disinfection, use of personal protective equipment (PPE), and hand hygiene per Taiwan Centers for Disease Control guideline. The estimated attack rate and the R_0 were calculated. Compared with the "low-risk" exposure group, the "high-risk" exposure group was less likely to have used partial PPE, and more likely to have had contact time >1 hour, performed "aerosol-production" tasks, and developed symptoms during quarantine. None of the HCWs in either group acquired COVID-19. All HCWs wore surgical masks and performed routine environmental disinfection. Estimated R_0 was 1.46 and 0 for household and HCW models, respectively, implying that the index patient did not transmit COVID-19. Using masks may help prevent hospital-acquired COVID-19. (J Intern Med Taiwan 2021; 32: 32-39)

Key Words: Basic reproduction number, COVID-19, Masks, Personal protective equipment, SARS-CoV-2

Introduction

During the 2003 severe acute respiratory syndrome (SARS) epidemic in Taiwan, 137 medical staff were infected and 26 deaths were recorded at Hoping Hospital in Taipei city[1]. In the aftermath of this outbreak, the Taiwan Centers for Disease Control (TCDC) created guidelines on airborne infection control within hospitals, which included the use of masks[2] and procedures on hand washing and environmental cleaning[3]. The three significant changes that were suggested by the TCDC are as follows: 1. use of different types of face masks such as surgical masks at the outpatient department (OPD) and N95 face masks during medical treatments with high-risk aerosol production; 2. fre-

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quent hand washing including five indications for handwashing, rules for handwashing equipment in the intensive care units, general wards, and open departments of the hospital; and 3. 1:10 dilution of household bleach solution containing 5% sodium hypochlorite was suggested as environmental cleaning disinfectants.

Toward the end of 2019, another coronavirus epidemic occurred; this one was caused by a novel coronavirus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or "2019 novel coronavirus (2019-nCoV), causing the pandemic "coronavirus disease 2019" or "COVID-19" named by the World Health Organization. The risk of hospital-acquired infection became a major concern worldwide[4], bringing mortality rates among hospital staff to public attention. The risk of hospital-acquired COVID-19 infection is relatively high owing to the added transmission risk within households[5]. We present a household cluster with COVID-19 confirmed by testing of a throat swab sample using real-time reverse transcription polymerase chain reaction (RT-PCR) in February 2020. All household contacts of the index patient and the 138 healthcare workers (HCWs) who met with them were identified and quarantined. This study aimed to estimate the stratified basic reproduction number (R_0) of SARS-CoV-2 in a hospital setting, which represents the risk of hospital-acquired transmission. Further, the study of the rate of infection and R_0 in a hospital that followed the guidelines set by the TCDC would aid in identifying methods to prevent hospital-acquired transmission of SARS-CoV-2.

Patients and methods

A six-household cluster with COVID-19 and in-hospital contacts have been reported in Taiwan to date[5]. All contact history within a single hospital was investigated. The index case was an older adult male with pneumonia, admitted to the general ward on February 9, 2020. He had no history of overseas travel. He was intubated and transferred to the intensive care unit (ICU) 7 days later. Because of progressive pneumonia of unknown cause, he was tested for SARS-CoV-2 using RT-PCR, which was confirmed positive on February 22. His family and caregiver were examined immediately. All COVID-19 patients were quarantined according to infection control guidelines. Overall, this household cluster included an index case, five infected members, and four uninfected members, yielding a household attack rate of 55.6% (5/9).

We tested the HCWs who encountered these patients for possible SARS-CoV-2 transmission between January 14 and March 7, 2020. During this period, these five infected family members visited our hospital to take care of the patient. In total, 138 HCWs who had contact with these six infected patients' households were included in this study. The HCWs who had contact with the other four uninfected members were not tested due to the low risk of SARS-CoV-2 transmission. Clinical tasks included those associated with high-risk of aerosol production such as bronchoscopy, nebulizer inhalation, endotracheal tube intubation procedures, sputum suctioning, and pan endoscopy. Other routine clinical tasks included lumbar puncture, electroencephalography, computed tomography, portable chest radiography, administration of intravenous injections and medications, outpatient examinations, patient body care, daily environmental cleaning, and hair styling. The dates on which the HCWs encountered the patients are recorded in Figure 1.

In our hospital, routine infection control policies included environmental disinfection, use of personal protective equipment (PPE), and hand hygiene per TCDC and the United States Centers for Disease Control and Prevention (CDC) guidelines[6,7]. Routine hospital infection control policies in our hospital are as follows. Environmental cleaning and disinfection procedures were per-

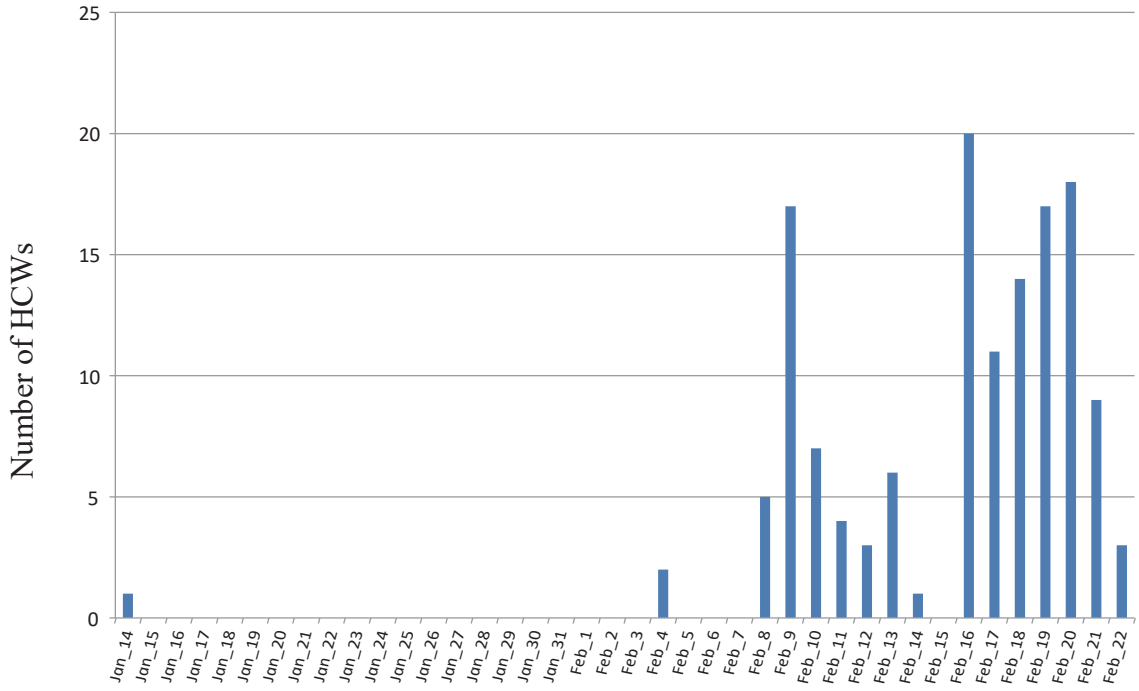

Figure 1. Daily number of contacts in a hospital located in a city of Taiwan (January to February 2020)
The X axis shows the dates from January 14 when a member of one household cluster came in contact with healthcare workers (HCWs) at the outpatient department to February 22 when the index patient tested positive for severe acute respiratory coronavirus 2 (SARS-CoV-2) using reverse transcription polymerase chain reaction (RT-PCR).
The Y axis shows the number of HCWs who encountered this family cluster. The index patient was intubated on February 16, a day that recorded the highest number of contacted HCWs in the general ward. The number of contacted HCWs came down after February 19 when the index patient was quarantined in a negative pressure intensive care unit.

formed consistently with 1:10 dilution of household bleach solution, containing 5% sodium hypochlorite. Disinfection by wiping high-touch surfaces or immersion of any object contaminated by a large amount of body fluid was performed once a day in the general wards, and twice a day in the intensive care units. PPE used by HCWs included facemasks, isolation gowns, and gloves. When HCWs performed aerosol-generating procedures, such as sputum suction or endotracheal tube intubation, the use of N95 respirators and disposable face shields was suggested. Additionally, HCWs were educated on practicing hand hygiene using an alcohol-based hand sanitizer, containing 70% ethanol or isopropanol. If their hands were visibly soiled, washing with water and an antiseptic agent was preferred. Emphasis was laid on scrubbing hands for an optimal duration at all available opportunities. We also provided all HCWs with job-specific education and training, emphasizing the correct method of putting on and removing PPE. Both the guidelines of the TCDC and the United States CDC are similar except that of the TCDC suggested handwashing of at least 40 seconds compared to the US CDC of 20 seconds. Also, the US CDC suggested the use of respirators or N95 face masks for the airway protection during high-risk work contrary to the TCDC guideline on using only N95. We followed the guidelines of the TCDC first.

This retrospective observational study was approved by the institutional review board of our hospital (09-X-035 and 09-X-041) and conducted in accordance with the principles of the amended Declaration of Helsinki. The institutional review

board waived the requirement for informed consent because the study was retrospective and the data were anonymized.

Data on demographic and clinical characteristics, contact history, PPE use, clinical symptoms (including rhinorrhea, cough with or without phlegm, sore throat, dyspnea, dysosmia, abnormal taste, and diarrhea), and throat swab SARS-CoV-2 RT-PCR test results were collected, as previous descriptions[5].

HCWs were categorized into different risk groups with help from physician from TCDC. At that time, the policy of 14-day isolation at home was decided for the "high-risk" exposure group. The "low-risk" exposure group comprised HCWs who had worn suitable PPE during contact with infected patients, whereas the "high-risk" exposure group comprised HCWs who had contact with infected patients, particularly during high-risk procedures such as those involving aerosol production, without suitable PPE. PPE use was divided into four categories: "no protection," referred to HCWs who did not wear masks; "partial protection," those who wore masks but did not use other PPE; "general protection," those who wore surgical masks and other PPE, such as gloves, or who washed their hands; and "standard protection," those who wore N95 masks and other PPE such as gloves or a waterproof gown. Medical treatment, delivered to the patients, was divided into three categories: the "aerosol production" group referred to those involved in aerosol-generating procedures such as bronchoscopy, nebulizer inhalation, and sputum suctioning; the "ward close contact" referred to nursing care in a general ward in close daily contact for ≥15 minutes; and the "OPD short contact," to contact with patients for <15 minutes, including OPD visits or for health education.

No cases of infection in HCWs were detected. The basic reproductive number (R_0) was calculated for comparisons between different groups. The R_0 may be influenced by virus infectivity and use of personal airway protection.

Previous studies have shown that populations differ in the observed attack rates. Using Cheng's data from Taiwan[8], we calculated the R_0, which represents the average number of secondary cases associated with exposure to the index case within a population[9]. Calculations were performed using a standard implicit equation, which relates the attack rate to R_0, as ar=1-exp(-R_0*ar). This formula was previously used by Haw[10].

Continuous data were expressed as mean ± standard deviation. Categorical data were expressed as frequencies and percentages. The occupational characteristics were compared using the Student's t-test for high- and low-risk exposure groups. The Fisher's exact test was used for comparing 2 × 2 categorical variables. $P<0.05$ was considered to indicate statistical significance.

Results

Participants' clinical and demographic characteristics, PPE use, and clinical outcomes were compared between high- and low-risk groups (Table 1). There were significant between-group differences in contact status. Moreover, the high-risk group had a lower rate of PPE use, including partial, general, and standard PPE use (p=0.001) than the low-risk group. All of the HCWs who were exposed to nine household members at least, wore masks. The high-risk group was also more likely to have contact time >1 hour than the low-risk group, with rates studied for > 1 hour, ≤ 1 hour, and < 15 minutes (p=0.001). The high-risk group was more likely to engage in aerosol-production tasks, close ward contact, and OPD short contact (p<0.001) than the low-risk group. The symptoms (including rhinorrhea, sore throat, or cough) during quarantine were significantly higher in the high-risk group than in the low-risk group (p=0.018). Nevertheless, there were no cases of hospital-acquired COVID-19 among HCWs

Table 1. Characteristics, personal protection equipment use, and clinical outcomes of medical team members in contact with COVID-19 patients

Exposure	High-risk n=70 (%)	Low-risk n=68 (%)	p-value	Household n=9 (%)
Characteristics				
Sex (Female)	52 (74.3)	41 (60.3)	0.058	6 (66.7)
Age (years)	32.18±9.50	33.56±9.51	0.407	37.33±22.6
Work duration			0.293	
<1 year	9 (12.9)	14 (20.6)		NA
1-5 years	38 (54.3)	27 (39.7)		
6-10 years	15 (21.4)	15 (22.1)		
11-15 years	8 (11.4)	12 (17.6)		
Occupation			0.237	
Doctor	11 (15.7)	14 (20.6)		NA
Nurse	39 (55.7)	31 (45.6)		
Paramedic	14 (20.0)	17 (25.0)		
Cleaning staff	6 (8.6)	6 (8.8)		
Flu vaccination	55 (78.6)	46 (67.6)	0.104	3 (33.3)
Contact characteristics				
PPE			0.001*	
No mask	0	0		9 (100)
Partial (mask only)	27 (38.6)	46 (67.6)		0
General (mask with other)	36 (51.4)	14 (20.6)		0
Standard (N95 with other)	7 (10.0)	8 (11.8)		0
Contact time			0.001*	
>1 hour	12 (17.1)	0 (0)		9 (100)
≤1 hour	21 (30.0)	21 (30.9)		0
<15 minutes	37 (52.9)	47 (69.1)		0
Medical services for patients			<0.001*	
Aerosol production	36 (51.4)	4 (5.9)		NA
Ward closed contact	30 (42.9)	46 (67.6)		
OPD short contact	4 (5.7)	18 (26.5)		
Clinical outcomes				
Symptoms during quarantine	8 (11.4)	1 (1.5)	0.018*	3 (33.3)
SARS-CoV-2 RT-PCR positive	0	0	NA	5 (55.6)

"With other PPE" refers to gloves or a waterproof gown.

Paramedics included clinical operation technicians (n=5), respiratory therapist (n=9), radiology technician (n=11), medical secretary (n=2), social worker (n=1), nutritionist (n=1), nutritionist trainee (n=1), medical hairdresser (n=1); 2-by-2 variables are examined with the Fisher's exact test; two continuous variable groups were compared using the independent t test. Mean ± SD: means with standard deviation.

Abbreviations: COVID-19: coronavirus disease; NA: Not applicable; OPD: outpatient department; PPE: personal protective equipment; SARS-CoV-2 RT-PCR, severe acute respiratory coronavirus 2 reverse transcription polymerase chain reaction.

* $p<0.05$.

in either group.

At a single hospital, the overall attack rate was higher than that observed throughout Taiwan; however, this difference was not significant (3.4% vs. 1.5%, p=0.168) (Table 2). In household comparisons, the single hospital attack rate was higher than that in Taiwan (55.6% vs. 4.6%, p<0.001). In comparisons of HCWs, the single hospital attack rate was zero, without significant differences in Taiwan (0 vs. 0.8%, p=0.597). In Taiwan, the risk of infection among HCWs was 0.8% (0.18-1.55%), and the estimated R_0 was 1.00. Conversely, in this single hospital, the attack rate was 0 (95% CI, −8.34 to 8.34).

Discussion

Six members of a single household were either admitted to or visited our hospital without any HCWs getting infected with COVID-19. These findings contrast with Taiwan's experience 17 years ago when SARS infected 668 people, resulting in 181 deaths (mortality rate 27%)[1]. The sudden and rapid transmission of SARS-CoV in the 2003 coronavirus epidemic was Taiwan's first encounter with this kind of a pathogen. An estimated 137 HCWs were infected, with 26 deaths recorded in one hospital[1]. Masks, hand washing, and environmental disinfection were useful in preventing nosocomial infection[2,3,11]. Since then, donning of masks and PPE along with hand washing have become a standard part of anti-infection procedures, as outlined in the TCDC guidelines. Adherence to the guidelines may help prevent outbreaks (Table 1); especially, masks may prevent immediate infection. In reality, before the accidental finding of the index case, the HCWs did not wear suitable PPE that adhered with the guidelines, and only 68 individuals were defined as having low-risk exposure.

Detailed examinations and therapy for critical patients with pneumonia of unknown cause may increase the risk of HCWs contracting COVID-19. A high rate of upper respiratory infection symptoms during quarantine periods of high-risk HCW, work stress and high-risk contacts were confirmed among hospital staff during the COVID-19 pandemic in Taiwan.

The use of masks by medical staff in high- and low-risk groups prevented infection spread. However, this study has some limitations including recall bias regarding the use of PPE, especially since this is a retrospective investigation. Another limitation was that no antibody was detected in HCWs such that the possibility of false-negative results cannot be excluded completely. Nevertheless, unlike most of Taiwan (Table 2), where the estimated R_0 value was 1, the estimated R_0 value in our hospital was 0, indicating that the outbreak was contained. Adherence to guidelines on infection prevention might account for this finding.

Table 2. Attack rate and estimated basic reproduction number (R_0) in different populations in Taiwan

Exposure	Case/contact	p-value	AR %	95% CI	Estimated R_0
In single hospital	5/147	0.168[a]	3.4	0.47 to 6.33	1.01
Household	5/9	<0.001[b]	55.6	22.5 to 87.5	1.46
Healthcare worker	0/138	0.597[c]	0	−8.34 to 8.34	0
In Taiwan	13/848		1.5	0.71 to 2.36	1.00
Household	7/151		4.6	1.28 to 7.99	1.02
Healthcare worker	6/697		0.8	0.18 to 1.55	1.00

[a] Overall attack rate comparisons between "in single hospital" and "in Taiwan" setting.
[b] Household attack rate comparisons between "in single hospital" and "in Taiwan" setting.
[c] Healthcare worker attack rate comparisons between "in single hospital" and "in Taiwan" setting.
Abbreviations: AR: attack rate; CI: confidence interval; R_0: basic reproduction number. Fisher's exact test is used for comparisons of categorical variables in attack rate.

Conclusion

Use of masks might help prevent nosocomial infection transmission of SARS-CoV-2. The R_0=0 in HCWs of a single hospital exposed to 1.46 in household. Further study is needed to compare rates of infection spread between different hospitals following different protection guidelines.

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Transparency declarations

Conflict of Interest: The authors declare that they have no conflicting interests.

Authors' contributions

WLS, IST, SJL collected the data. WLS, IST conceived the idea and drafted the paper. MCY, SJL, PSW, YCC reviewed the paper. All authors read and approved the final manuscript.

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口罩可預防醫護同仁新冠病毒感染 - 台灣某家準醫學中心臨床照護經驗為例

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摘 要

2003年SARS流行之後，台灣疾病管制署(TCDC)制定了醫院感染控制指南。隨著2019年底另一次新冠病毒疫情(COVID-19)的爆發，醫院獲得感染的風險成為新冠病毒傳播的重要問題。因此，本研究旨在估計醫院的疾病侵襲率(attack rate)和基本再生數(R_0)。於2020年1月14日至2020年3月7日，台灣某一家準醫學中心總共138名醫護人員(HCW)在醫療服務工作中接觸新冠病毒感染(COVID-19)的個案，根據其暴露風險分為兩組比較。所有醫護人員兩次接受咽拭子新冠病毒SARS-CoV-2 RT-PCR檢測。醫院遵從常規的感染控制政策，包括疾病管制署制定指南進行環境消毒，使用個人防護設備(PPE)和遵從手部衛生。並且依照實際家庭群聚與醫護同仁的感染情形計算出估計的疾病侵襲率和基本再生數。與“低風險”暴露組相比，“高風險”暴露組執行醫療業務時使用完整PPE的可能性較小，較多接觸時間超過1小時，執行“氣霧生成”業務的可能性較高，並且在隔離期間較多出現呼吸道症狀，然而兩組的所有HCW均無感染COVID-19；分析所有醫護人員在執行醫療業務都戴著口罩，並進行了常規環境清潔；家庭傳染和醫護人員傳染模式的估計R_0分別為1.46和0，這表明該院照顧COVID-19患者並未傳播新冠病毒。醫護人員使用口罩可能有助於預防醫院獲得新冠病毒感染。