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Original Article

Strategies for Minimizing Intra-Hospital Transmission of COVID-19 among Health Care Workers in a Hospital Setting during a COVID-19 Pandemic

Chang-Pan Liu^{a,b,c}, Ching-Hsiang Leung^d, Chien-Feng Kuo^{a,b,c}, Hung-I Yeh^{b,c,e*}

^a Division of Infectious Diseases, Department of Internal Medicine, MacKay Memorial Hospital, Taipei, Taiwan, ^b Department of Medicine, MacKay Medical College, New Taipei City, Taiwan, ^c Committee of Infection Control, MacKay Memorial Hospital, Taipei, Taiwan, ^d Division of Endocrinology and Metabolism, Department of Internal Medicine, MacKay Memorial Hospital, Taipei, Taiwan, ^e Division of Cardiology, Department of Internal Medicine, MacKay Memorial Hospital, Taipei, Taiwan

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SUMMARY

Background: SARS-CoV-2 infection initially occurred in December 2019 and spread rapidly into a pandemic. The aims of this study were to assess the efficacy of measures taken to minimize intra-hospital transmission of COVID-19 at our hospital.

Methods: An outdoor fever screening station and outdoor COVID-19 screening station were initially set up to isolate people with suspected COVID-19 infection from those within the hospital. Another outdoor outpatient department (OPD) was set up later in the pandemic for people visiting the hospital following 14 days of quarantine, during the next 15 to 30 days, or residents from high incidence areas. Rogers' model of diffusion of innovations was applied to the promotion of COVID-19 vaccination.

Results: From 18 March 2020 to 17 April 2020, 10 newly confirmed cases at our hospital were detected at the outdoor COVID-19 screening station, and no health care workers (HCWs) in the hospital contracted COVID-19. From May 2021 to November 2021 during the outbreak in Taiwan, there were 191 confirmed cases and 2 HCWs had COVID-19. Promoting COVID-19 vaccination led to 98.2% of employees receiving two doses by November 2021 and zero COVID-19 infection in HCWs from June to the end of November 2021.

Conclusion: Having outdoor fever and COVID-19 screening stations and an "outdoor OPD" service to isolate patients suspected of or at risk of COVID-19 were effective strategies to minimize the risk of intra-hospital transmission. Promotion using Rogers' model resulted in nearly all employees receiving two doses of COVID-19 vaccine.

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1. Introduction

Severe acute respiratory syndrome (SARS) coronavirus-2 (SARS-CoV-2) infection (COVID-19), was first detected in Wuhan, China in December 2019,^{1,2} followed by rapid and extensive spread worldwide. The World Health Organization (WHO) first declared the COVID-19 outbreak a Public Health Emergency of International Concern and then a pandemic in early 2020.^{3,4} Taiwan is in close proximity to China and in recent years receives millions of travelers annually from China.^{5,6} Person to person transmission was confirmed on 23 January 2020⁷ and Taiwan was regarded at high risk for being the next epicenter. In 2003, SARS-CoV caused an epidemic of SARS and Taiwan was severely affected; with a high fatality rate^{8–10} and case clusters in nine hospitals involving 120 healthcare workers (HCWs).¹¹ This made Taiwan strengthen its preparation for the next episode, which included having an adequate stockpile of N95 masks and other personal preventive equipment (PPE) in all medical centers which was checked annually by the government since 2004.¹²

On 19 March 2020, Taiwan CDC stipulated that persons who

contact with a confirmed case or arrived from abroad were required to be in quarantine for 14 days, calculated from the date of contact or arrival.¹³ The daily number of imported cases in Taiwan increased markedly on 18 March 2020.¹³ Taipei MacKay Memorial Hospital (MMH) was one of the hospitals designated to treat COVID-19 patients. HCWs were known to be at high risk for COVID-19 infection and death.¹⁴

The COVID-19 vaccines were first approved for use by the public in December 2020¹⁵ and reduced the severity COVID-19 infection.¹⁶ Many countries have implemented phased distribution plans for COVID-19 vaccines that prioritize those at highest risk, such as the elderly and HCWs.⁷ Vaccination of HCWs, including those in MMH commenced in March 2021 in Taiwan and only the Oxford-AstraZeneca (AZ) vaccine was available initially. There was initial reluctance for vaccination among HCWs of MMH due to concern about rare but serious side effects such as thrombocytopenia with thrombocytopenia syndrome¹⁷ and reduced efficacy compared to mRNA vaccines.¹⁸ Hence there was an urgent need to quickly increase vaccine coverage of employees to reduce intra-hospital transmission of COVID-19 in our hospital.

This observational study aimed to explore the effectiveness of the strategies taken to control the spread of COVID-19 infection in

* Corresponding author. Department of Internal Medicine, MacKay Memorial Hospital, No. 92, Zhongshan N. Road, Taipei, Taiwan.

E-mail address: hiyeh@mmh.org.tw (H.-I. Yeh)

our hospital. The first aim was to explore the effectiveness of having an outdoor COVID-19 screening station and an outdoor outpatient department (OPD) as a new strategy to control COVID-19 infection during the early stage of the COVID-19 pandemic. The purpose was to reduce infection risk by separating persons visiting the hospital with risk of COVID-19 from those within the hospital premises, as large numbers of patients visit our hospital and space is limited. In some other hospitals, persons visiting the hospital were allowed to enter into the hospital without initial categorization at the hospital entrance for COVID-19 risk.

The second aim was to evaluate effectiveness of promotion of vaccination among Taipei MMH HCWs using the Rogers' model of diffusion of innovations¹⁹ following the outbreak in Taiwan in May 2021.

2. Materials and methods

This study was conducted from 18 March 2020 to 30 November 2021 at Taipei MMH, a medical center and tertiary teaching hospital in northern Taiwan with approximately 1,000 beds and 4,000 employees. More than 30,000 patients usually visited the OPD weekly, and although there was a decrease of over 50% from late May to June 2021, nevertheless weekly attendance was over 12,000 patients.

2.1. Preventive measures

On 25 January 2020, temporary stations for fever and COVID-19 screening were set up in the outdoor area of the hospital beside the Emergency Department as an infection prevention measure early in the pandemic. People who had fever but not suspected of having COVID-19 were sent to the outdoor fever screening station for management. The fever screening station was previously set up indoors. This was for separation of those at risk of COVID-19 visiting the hospital from those within the hospital premises. Cases suspected of having COVID-19, travel abroad to a high-risk area within two weeks or had contact with confirmed cases of COVID-19 within two weeks were defined as high risk and sent to the outdoor COVID-19 screening station for testing and initial management.

The increased number of newly confirmed cases of COVID-19 in Taiwan in March 2020 impelled us to develop a new strategy of setting up an "outdoor area" to provide outdoor OPD service for people at moderate risk of COVID-19 visiting the hospital: people after 14 days quarantine, during the following 15 to 30 days (Figure 1) or residents of high COVID-19 incidence communities. All other visitors were defined as low risk and allowed to entrance into the hospital.

The outdoor OPD, implemented on 18 March 2020; was initially within a fabric tent building which was replaced a month later by a modular building. Management stations were set up on both sides of the main entrance of our hospital where information from the National Health Insurance cards of all persons visiting the hospital were checked. After processing the information, visitors were directed to different areas for service according to the risk category for COVID-19.

2.2. Confirmation of COVID-19 infection

Nasopharyngeal or throat swab technique for collection of specimens for COVID-19 were performed at the fever and COVID-19 screening stations and in negative pressure isolation rooms only by designated well-trained physicians. According to the policy of the Taiwan CDC, reverse transcriptase polymerase chain reaction (RT-PCR) tests were performed on persons undergoing 14 days quarantine (due to contact with a confirmed case or a travel history to a high-risk area) or suspected cases having symptoms or signs of COVID-19.

Confirmation of diagnosis COVID-19 at MMH was by the RT-PCR method which was approved by the Taiwan CDC. The primers used for RT-PCR were according to the protocol of Corman et al.²⁰ Patients who tested positive for COVID-19 at our hospital were immediately isolated for treatment.

2.3. Promotion of vaccination

COVID-19 vaccines were first available in March 2021 at MMH. In response to a low initial COVID-19 vaccination rate of HCWs at our hospital, we applied Rogers' model of the five stages (knowledge stage, persuasion stage, decision stage, implementation stage and

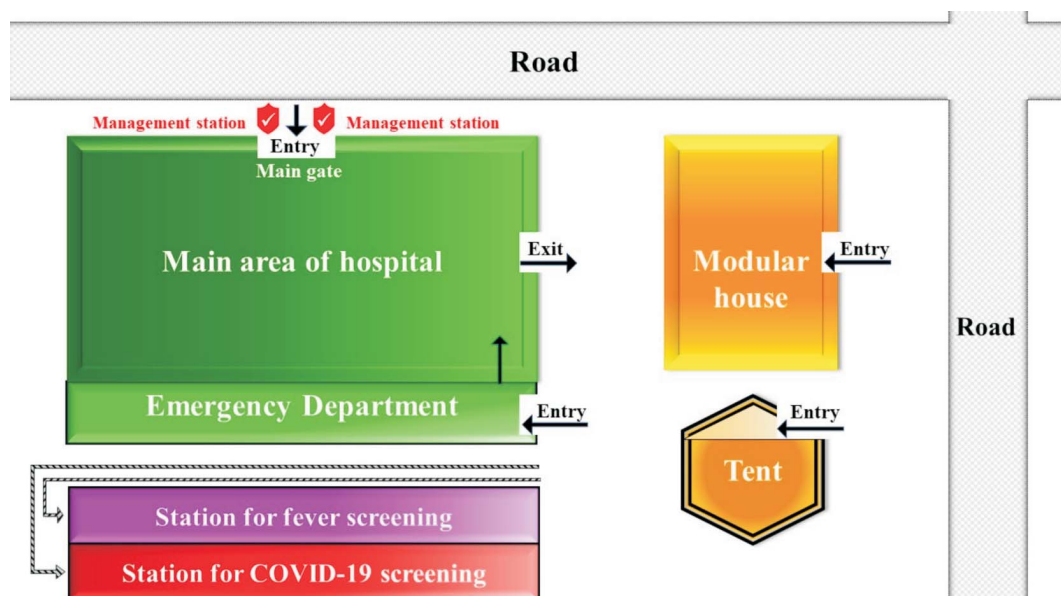


Figure 1. The "outdoor area for OPD" (modular house and tent), stations for fever screening and COVID-19 screening in the outdoor area beside the Emergency Department and the management stations at both sides of the main gate of the MacKay Memorial Hospital.

confirmation stage) of diffusion of innovations to the promotion of COVID-19 vaccination among MMH HCWs.

2.4. Statistical analysis

Categorical variables were analyzed using the chi-squared test or Fisher's exact test as appropriate, especially for nonparametric statistics. All biological variables with a two-tailed p value < 0.05 were considered significant. All data were analyzed using the SPSS software version 21.0 (SPSS Inc., Chicago, IL, USA).

3. Results

The first episode when the number of COVID-19 cases increased markedly in our hospital was from 18 March 2020 to 17 April 2020. During this period, 790 patients met the criteria for COVID-19 testing, including 188 having a history of travel to a high-risk area and 602 with symptoms or signs suggestive of COVID-19. During the same time period, there were 318 confirmed cases in Taiwan (290 imported and 28 local, which reached a peak on 19 March 2020 with 27 new cases and decreased to zero on 17 April 2020) and 5 deaths. Of these, the 10 cases diagnosed at our hospital were all detected at the outdoor COVID-19 screening station. In parallel, medical service was provided for 480 persons in the outdoor area of the hospital. Once the incidence of COVID-19 was low, the outdoor OPD was discontinued, with the plan to be implemented again whenever the need arose in the future. No HCWs in the hospital contracted COVID-19 during the first episode.

The second episode where there was a high incidence of COVID-19 in our hospital was from 1 May 2021 to 30 September 2021. The outdoor OPD was reopened in May 2021 and enhanced by telemedicine (remote clinics) during the second episode. The function of the outdoor OPD was extended to provide medical service from May 17 to June 17, 2021 for people living in areas with a high incidence of COVID-19 within Taipei city and New Taipei city. Strategies taken during the study period and the number of admitted and confirmed cases of COVID-19 to our hospital from March 2020 to November 2021 are shown in Table 1. During the second episode, 12,995 persons (2.27%) were treated at the fever screening station, 38,688 (6.76%) at the COVID-19 screening station, 3,266 (0.57%) at the outdoor OPD and 3328 (0.58%) by telemedicine (remote clinics), while another 513,635 visited the indoor OPD.

Rogers' model of the innovation-decision process was applied to the measures taken to promote COVID-19 vaccination. Information collected in the knowledge stage included persistence of the pandemic, new waves of COVID-19 despite implementation of preventive measures, occurrence of new variants, and that COVID-19 vaccines were safe and effective in preventing symptomatic and severe infection and decreased hospital admissions and mortality. When

COVID vaccines first became available in Taiwan, the initial vaccination rate of HCWs at our hospital was low. From March to April 2021, there were no confirmed cases of COVID-19 and only 13% (542/4168) HCWs in our hospital received the first dose of COVID-19 vaccine. Reasons for the low vaccination rate among HCWs included a low incidence of COVID-19 in Taiwan during the period between the 2 episodes and thus a perceived low risk of infection, concern about serious adverse events, and preference to wait for mRNA vaccines as only AZ vaccine was available initially.

A rapid and sharp increase in incidence of COVID-19 occurred in Taiwan in May 2021. Twenty-one confirmed cases were admitted to Taipei MMH in May, 102 cases in June, 48 cases in July and 17 cases in August 2021 (Figure 2). During the persuasion stage, this second episode of high incidence of COVID-19 was used as an opportunity to promote and encourage COVID-19 vaccination among unvaccinated HCWs as a preventive strategy to reduce the incidence, severity of infection, mortality from COVID-19, and to decrease intra-hospital transmission of infection. Information promoting vaccination was sent by the Hospital Information System.

In the decision stage, participation and lead of early vaccination were taken by the high-ranking directors of the hospital, including chairmen of the infection control committee, chief of center of infection control and directors of pediatric and adult division of infectious diseases to encourage vaccination in all employees.

During the implementation stage, special vaccine OPDs for hospital employees were set up for 2 months. Information was provided on dates and times for registration of vaccination. Vaccination was made convenient by group vaccination during working hours in areas that could accommodate large numbers of employees. Vaccination could be completed quickly within 25 minutes, including history taking, physical examination, and injection within 10 minutes plus an observation period of 15 minutes without disrupting routine work. An implementation team was set up to supervise the process. Social reinforcement from vaccinated colleagues helped to encourage those reluctant to be vaccinated. Data collected in the confirmation stage on vaccination coverage of employees for first and second doses of COVID-19 vaccine are shown in Figure 2. From May to June 2021, there were 123 confirmed cases of COVID-19 at our hospital, 94.9% (3964/4177) of HCWs had received the first dose of vaccine and 5.2% (217/4177) had received the second dose. From July to August 2021, there were 65 confirmed cases of COVID-19, 98.4% (4087/4153) HCWs had received the first dose and 93.3% (3875/4153) the second dose. During the period from September to October 2021, there were 3 confirmed cases of COVID-19, 99.2% (4041/4074) of HCWs had received the first dose while 97.3% (3964/4074) had received the second dose of COVID-19 vaccine. In November 2021, there were no confirmed cases of COVID-19, 99.6% (4029/4045) of HCWs had received the first dose and 98.2% (3972/4045) had received the second dose.

Table 1
Number of admitted and confirmed cases and strategies taken for the prevention of COVID-19.

Period	Episode 1	Between Episode 1 & 2	Episode 2	After Episode 2
	Mar 18, 2020~Apr 17, 2020	Apr 18, 2020~Apr 30, 2021	May 1, 2021~Sep 30, 2021	Oct 1, 2021~Nov 30, 2021
Admitted and confirmed new cases	4	2	191	0
Strategies				
(1) Outdoor screening station	Yes	Yes	Yes	Yes
(2) Outdoor OPD-Tent	Yes	NA	NA	NA
(3) Outdoor OPD-Modular house	NA	Yes	Yes	Yes
(4) Management station at main gate	Yes	Yes	Yes	Yes
(5) Application of Roger's model	No	No	Yes	Yes
Intra-hospital transmission	0	0	2 HCWs	0

Abbreviation: HCWs, health care workers; NA, not available; OPD, outpatient department.

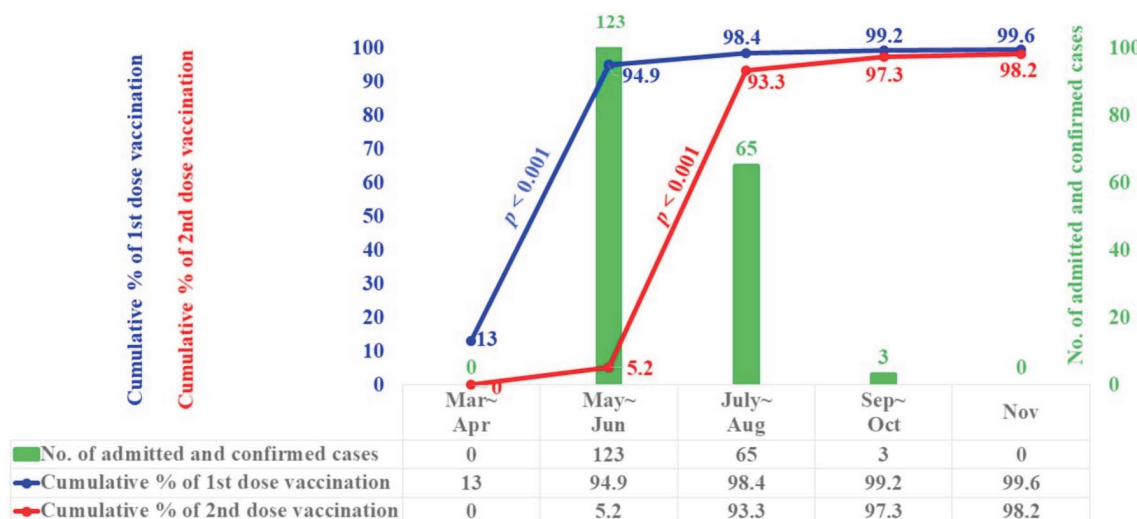


Figure 2. Number of admitted and confirmed cases of COVID-19 and cumulative % of COVID-19 vaccination of HCWs at Taipei MacKay Memorial Hospital.

Before May 2021 no HCW in the hospital were infected with COVID-19 infection. In May 2021, during the period of community spread in Taipei, 2 HCWs had intra-hospital COVID-19 infection with complete recovery without complications. After June 2021, following the increase in vaccination rate, no HCWs in the hospital had COVID-19, till the end of the study period.

4. Discussion

The concept of a temporary outdoor area for OPD service to keep the SARS-CoV-2 battle outside the hospital was the core of the main principle. It is important that measures to prevent or reduce transmission should be implemented in populations at risk.²¹ Diverting persons suspected of or at risk for COVID-19 to designated outdoor areas for initial medical service prevented contact with the large numbers of persons inside the hospital. Despite increased knowledge regarding methods of transmission, multiple and extensive preventive measures and availability of rapid diagnostic tests, the COVID-19 pandemic continues to spread worldwide. Infection in HCWs due to COVID-19 is inevitable, and HCWs taking care of COVID-19 patients have been reported infected and some have died.^{14,22} Our strategy to minimize intra-hospital transmission of COVID-19 was to keep the virus outside the hospital prior to detection. This was achieved by risk stratification of visitors. Those suspected of COVID-19 were kept in the outdoor area of the hospital for initial screening and detection, and an “outside” OPD service was provided for persons at moderate risk of COVID-19, including those during the next 15 to 30 days period following 14 days of quarantine and residents of high incidence areas. These measures were effective in preventing COVID-19 infection of HCWs and others within the hospital during Episodes 1 and 2. Additionally, the provision of telemedicine (remote clinics) during Episode 2 protected the frail and elderly patients who sought hospital treatment from contact with those at risk of COVID-19.²³

Since the start of the pandemic up-to the end of April 2021, no HCWs were infected with COVID-19. In May 2021, two HCWs at different districts in the hospital had COVID-19 during the outbreaks of community infection in Taiwan, which were thought to be intra-hospital infection. A nurse in the emergency room and another nursing assistant in a medical ward had contact with confirmed cases of COVID-19 despite wearing adequate PPE. Both had received only the first dose of vaccine. After investigations and contact tracing measures, no other infection sources were detected. Thus, the de-

contamination process was regarded as the possible source of COVID-19 in these two HCWs. The potential risk of contamination when removing PPE exists and could be a cause of intra-hospital transmission among HCWs treating COVID-19 patients. Hence, HCWs should be familiar and comply with all the standard procedures for prevention of infection. We took measures to ensure that all HCWs, especially those treating patients with COVID-19 complied with all the standard procedures and took special care when putting on and removing PPE, especially during the de-contamination process.

In the present study, application of Rogers’ model of the innovation-decision process showed that promotion of COVID-19 vaccination greatly increased the vaccination rate among hospital employees over a short period, which reduced the risk of intra-hospital transmission of infection. We applied Rogers’ model of diffusion of innovations in our study since it has been often used in diffusion research, including COVID-19 vaccination²⁴ and was of low cost and easy to implement compared to other models.

Safety and effectiveness of COVID-19 vaccines has made vaccination a major prevention measure against COVID-19 infection,^{25,26} hence promoting COVID-19 vaccination in HCWs is an extremely important infection prevention strategy.

4.1. Study limitation

This study was conducted over short periods in a single medical center in Taiwan. The total number of confirmed cases of COVID-19 during the study periods was relatively low in Taiwan compared to many other countries and applicability in other hospitals with large numbers of cases remains to be determined. It would be interesting to see whether application of our strategies elsewhere could have similar results and help to bring the pandemic under control.

5. Conclusion

In this study, setting up of an outdoor fever screening station, keeping suspected cases at an outdoor COVID-19 screening station for RT-PCR testing, and having an outdoor OPD service for patients at risk of COVID-19 who visited the hospital during the next 15-to-30 days period following 14 days of quarantine or residents from high incidence areas during periods of community spread were strategies taken to minimize the risk of intra-hospital transmission of COVID-19. Only 2 HCWs acquired COVID-19 infection in May 2021 when the COVID-19 vaccination rate in the hospital was low; and intra-hospital

transmission was suspected. HCWs should be familiar and comply with all the standard procedures for prevention of infection, especially when putting on and removing PPE. Promoting COVID-19 vaccination led to 98.2 % employees receiving 2 doses by November 2021 and zero COVID-19 infection in HCWs and intra-hospital transmission from June 2021 to the end of the study period. Application of similar strategies in hospitals could decrease the risk of intra-hospital transmission of COVID-19 during the ongoing COVID-19 pandemic.

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Ethics approval and consent to participate

This study was approved by the MacKay Memorial Hospital Institutional Review Board (Protocol number: 21MMHIS029e).

Competing interests

The authors declare that they have no conflicting interests.

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