Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Original Article

Prospective health surveillance for COVID-19 among health care workers at a university medical center in Taiwan, January to June 2020

Sung-Ching Pan a,b, Mu-Ching Hsusb, Hsin-Hsin Chang b, Jann-Tay Wanga,b, Yu-Ling Lai c, Pau-Chung Chenc,d,e,f, Sui-Yuan Chang g,h, Wang-Huei Sheng a,i, Yee-Chun Chen a,b,i,*; Shyr-Chyr Chen j,k, Shan-Chwen Chang a,i

a Department of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan
b The Center for Infection Control, National Taiwan University Hospital, Taipei, Taiwan
c Office of Occupational Safety and Health, National Taiwan University Hospital, Taipei, Taiwan
d Department of Environmental and Occupational Medicine, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan
e Institute of Environmental and Occupational Health Sciences, National Taiwan University College of Public Health, Taipei, Taiwan
f National Institute of Environmental Health Sciences, National Health Research Institutes, Miaoli, Taiwan
g Department of Laboratory Medicine, National Taiwan University Hospital, Taipei, Taiwan
h Department of Medical Technology, College of Medicine, National Taiwan University, Taipei, Taiwan
i Department of Medicine, College of Medicine, National Taiwan University, Taipei, Taiwan
j Department of Emergency Medicine, National Taiwan University Hospital, Taipei, Taiwan
k Department of Emergency Medicine, College of Medicine, National Taiwan University, Taipei, Taiwan

Received 25 March 2021; received in revised form 7 July 2021; accepted 15 July 2021

KEYWORDS
COVID-19; Infection control; Occupational safety; Health surveillance

Background: Healthcare personnel (HCP) at the front line of care are exposed to occupational hazards that place them at risk for infection, which then endanger patient safety and compromise the capability of the healthcare workforce. As of March 8, 2021 more than 420,170 HCP in US had been infected with SARS CoV-2 with 1388 deaths. In two Taiwan hospitals COVID-19 outbreaks involved HCP and resulted in shutdown of service. This report describes our prospective health surveillance of the HCP and COVID-19 containment measures in a teaching hospital in Taiwan during Jan. 1 through June 30, 2020.

* Corresponding author. Department of Internal Medicine, National Taiwan University Hospital, No. 7 Chung-Shan South Rd, Taipei, 100, Taiwan. Fax: 886 2 23971412.
E-mail address: yeechunchen@gmail.com (Y.-C. Chen).

https://doi.org/10.1016/j.jfma.2021.07.018
0929-6646/© 2021, Formosan Medical Association. Published by Elsevier Taiwan LLC. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Methods: We prospectively monitored incidents, defined as an HCP with the predefined symptoms, reported by HCP through the web-based system. HCP were managed based on an algorithm that included SARS CoV-2 RNA PCR testing. Infection prevention and control policy/practice were reviewed.

Results: This hospital took care of 17 confirmed COVID-19 cases during the study period and the first Case was admitted on January 23, 2020. Among the 14,210 HCP, there were 367 incident events. Of 283 HCP tested for SARS CoV-2, 179 had predefined symptoms. These included 10 HCP who met the national case definition for COVID-19 infection and 169 based on Extended COVID-19 Community Screening program. The other 104 asymptomatic HCP were tested based on hospital policy. All of them had tested negative.

Conclusion: We attribute our success in preventing COVID-19 infections among HCP to rapid, proactive, decisive, integrated national and institutional response in the early stages of the epidemic.

Introduction
Taiwan has experienced epidemic/pandemic due to the novel coronaviruses SARS and novel influenza H1N1 and H7N9. Healthcare personnel (HCP) are at the front line of care and are exposed to occupational hazards that place them at risk for infection. Among 8096 SARS cases reported to World Health Organization (WHO) in 2003, 21.0% were in HCP. As of March 8, 2021 The US CDC reported that more than 420,170 HCP had been infected with COVID-19 with 1388 deaths. This report probably underestimated the number of cases since there was no systematic surveillance and reporting of infection in HCP.

Contagious infectious diseases are not only occupational hazards for HCPs, but also endanger patient safety and compromise the capability of the healthcare workforce. A WHO report in 2020 emphasized the rights of HCP in addition to their roles and responsibilities. The WHO and the International Labor Organization released a comprehensive manual in 2018 that provides guidance to protect HCP and respond to public health emergencies. National and international recommendations for risk assessment and management of hospital HCP working with patients infected with SARS-CoV-2 are detailed and publicly available. However, there is limited guidance on how to establish national and institutional policies to protect HCP in the context of COVID-19 pandemic. In this report we described our experience on implementing specific infection prevention and control (IPC) policy and practice (P&P) at a large teaching hospital in Taiwan during the first 6 months of the epidemic.

Materials and methods
Study design
This study was conducted at the National Taiwan University Hospital (NTUH). NTUH is a teaching hospital located in Taipei, Taiwan with a total of 2632 beds that provides both primary and tertiary care. We described control measures, reviewed and analyzed health surveillance incidence reports from 14,210 HCP and the results of COVID-19 testing from January 1, 2020 through June 30, 2020. The study protocol was approved by the Research Ethics Committee of the hospital and complies with the category of exempt review.

Infection prevention and control policies and practices
The Incident Command Center for COVID-19 pandemic has established since January 23 at NTUH. Superintendent chaired daily briefing since Lunar New Year holiday and multidisciplinary or cross sector policies were made efficiently. The IPC P&P had escalated based on the information and requests from the government and hospital surveillance data and is outlined in Table 1. This includes control at the source, control along the path, control at the person level, and engineering and environmental controls.

Prospective, hospital-wide health monitoring and surveillance
The Center for Infection Control (CIC) and the Occupational Safety and Health Office (OSHO) at the NTUH are responsible for IPC P&P for occupational safety and health. The health status of the HCP is monitored through a web-based hospital-wide health surveillance and reporting system. HCP surveyed include full-time personnel and outsourcing personnel. The coordinator of each department reports to OSHO all HCP who develop predefined symptoms during the reporting interval. These symptoms are structured to detect potential emerging infectious diseases or epidemiologically important endemic contagious diseases. They include fever (>38 °C), cough of unknown cause ≥5 days, diarrhea for 12 h, and skin rash > 2 days. The predefined symptoms were modified and included taste or olfactory disorder in the context of COVID-19 pandemic. The head nurses are responsible to daily monitor HCP with close contact to a COVID-19 confirmed Case and report the findings to the CIC.
Infection control personnel contact the head nurse or chief of the unit to clarify additional information concerning adequacy/appropriateness of personal protection equipment (PPE) and compliance of hand hygiene, the health of other colleagues in the same unit and provide interim suggestions such as environment cleaning accordingly.

The risk-based management algorithm for HCP with predefined symptoms is shown in Fig. 1. HCP are placed on a compulsory sick leave and stay at home, health self-management, and be tested by SARS CoV-2 RNA PCR at the emergency room (ER) or COVID-19 clinic, or be admitted for isolation or quarantine. Table 2 provides the policies regarding SARS CoV-2 RNA PCR targeted testing and HCP returning to the workplace.

### Case finding and contact tracing

The government started border quarantine rapidly after detecting the possible COVID-19 cluster news at Wuhan. COVID-19 is announced as category V notified diseases on January 15 and any patient who fulfilled Case definition should be reported to Taiwan Centers for Infection Control (CDC) within 24 h. CDC case definitions were modified based on global and local situations very frequently in the early phase of COVID-19 pandemic. Patients who fulfill COVID-19 notified case definition are managed as confirmed case which include traffic control during transfer, hospitalization at special units, HCP PPE, environment cleaning protocol, and de-isolation based on predefined criteria. Infection control personnel and public health

| Table 1 | The infection prevention and control policy and practice implemented or strengthened at National Taiwan University Hospital to protect safety and health of healthcare personnel (HCP) and patients in the context of COVID-19 pandemic. |
|---|---|
| Category | Policies and Practices<sup>a</sup> |
| **Control at the source** | Early Case finding and aggressive contact tracing  
SARS CoV-2 RNA PCR targeted testing  
Isolation for the sick and quarantine for those at risk  
COVID-19 specific isolation precaution implemented preemptively and deescalated based on risk and testing results  
HCP health surveillance and reporting |
| **Control along the path** | Double triage at emergency service entry<sup>20</sup>  
Universal masking, hand hygiene, temperature check and visitor restriction at hospital entry  
Information technology-assisted risk assessment of COVID-19 exposure for patients with scheduled admission and selected outpatient services  
Telehealth for patients at risk  
Dedicated path for at-risk patients indicated for emergence/urgent healthcare  
Universal masking of all personnel in hospitals |
| **Control at the person** | Hand hygiene is emphasized and alcohol hand rubs are widely provided at hospital entry and hospital wide.  
Rational selection and appropriate use of PPE  
Buddy system and/or tele-monitoring for IPC compliance of HCP who enter the room of COVID-19 confirmed cases  
Hospital web-based education and technique training and buddy system for PPE; monthly training for residents in the dedicated COVID-19 units  
30-min policy for HCP in negative pressure room<sup>1</sup>  
Policy for clean zones such as dining area and meeting room, etc.  
Environment surveillance of SARS CoV-2 contamination |
| **Others** | Stockpile and rationing of PPE  
N95 respirator reuse policy<sup>b</sup>  
Symptomatic patients with risk of COVID-19 (notified cases) are empirically isolated individualized in negative pressure rooms or in single-bed rooms. Asymptomatic patients with risk of COVID-19 are quarantined in single-bed rooms. Aforementioned patients are allocated in dedicated units or rooms.  
Portable HEPA filtration at high-risk area such as COVID-19 clinics, dedicated single room for COVID-19 notifiable cases in the absence of negative pressure room |

<sup>a</sup> This 30-min policy reminds HCP not to stay in negative pressure rooms for more than 30 min. In order to implement this policy HCP need to integrate bedside activities and proper design the workflow and involve appropriate HCP numbers. For example, two HCP work together as a team for chest care. This policy was developed based on SARS experience<sup>1</sup> in order to prevent risk of infection due to inadequate protection. This may occur after intensive bedside care which results in sweating and loosening of previously well-fitted N95 respirators.

<sup>b</sup> Due to shortage of N95 respirator, we cover N95 with a surgical mask and remove surgical mask when leaving patient room and N95 is discarded after one shift (8 h).

Abbreviation: HCP, healthcare personnel; PPE, personal protection equipment.
personnel work together to trace every contact (including HCP, patient and their care givers) for every COVID-19 confirmed cases and adopt risk based stepwise infection control measures based on Taiwan CDC’s suggestion. Emergency Department physicians and infection control personnel cross talked for joined decision, updated and announced the policy by 8 am every day. We adapted CDC policies with modification regarding SARS CoV-2 RNA PCR testing and patient isolation/quarantine. This is because the physicians at the front line are more sensitive to the evolution of epidemiology or clinical presentation of the disease. Our practices and findings are efficiently feedback to Taiwan CDC for modifying case definition or other polices accordingly.

Indications for SARS CoV-2 RNA testing

SARS CoV-2 RNA PCR testing was established at NTUH on January 21. There are six indications for COVID-19 testing for HCP at NTUH in addition to national policies, three for those with symptoms and three for those without symptoms (Table 2). Nasopharyngeal swabs for SARS CoV-2 testing are collected in dedicated area equipped with portable HEPA filters. The HCP take a sick leave and go home wearing surgical mask and avoid public transportation system. Home isolation and prevent contact with household members are suggested before result is available or other suggestion. For indication 1 (staff with symptoms after exposure to confirmed Case), admission was arranged if the primary care team judged as high risk for COVID-19 infection or home isolation was not feasible. The CIC pursue the report and inform the HCP. The policies for returning work place are well defined by the government and hospital.

Outbreak or other IPC adverse events investigation

Considering the limitation of hospital wide health surveillance system and limitation of predefined symptoms, the hospital provides a blame-free environment in which HCP can report an incident, including a suspected clustering of
infection in the unit, exposures to blood or bodily fluids, or inadequate compliance of PPE or other IPC during taking care of COVID-19 patients. In addition, the head nurse or chief of each hospital services should inform the CIC immediately if any suspicion of clustering of infection occur involving HCP or patients or bedside care giver in that unit. The CIC will initiate investigation immediately. Reporting tightly incorporated into investigation and management.

The government has announced guidance for the situation that any inpatient is diagnosed as COVID-19 during hospitalization or HCP is diagnosed as COVID-19.20

Patient triage and traffic control bundles

During epidemics, identifying and separating patients with exposure risk at first point of contact with the healthcare system is particularly important to prevent and minimize exposure risk of HCP, other patients, their companion or visitors. Patients are triaged outside the emergency rooms21 and at hospital entry of outpatient clinics. Patients were managed based on risk of COVID-19 at emergency rooms or COVID-19 clinics where dedicated environment design, PPE, and standardized management algorithm.

### Table 2

| Policy Category | Symptoms | Indication or clinical scenario | Prerequisite for returning to work place |
|-----------------|----------|-------------------------------|-----------------------------------------|
| COVID-19 notified cases | Yes | Close contact to a notified Case without appropriate precaution (PPE and hand hygiene) | If test is negative twice performed 24 h apart and symptoms resolve, HCP can return to workplace after 14 days of isolation and 7 days of self-health management. |
| Extended COVID-19 Screening program | Yes | Pneumonia (national policy since February 16); any symptoms and physicians deem indicated for testing (NTUH policy in late January which has become national policy since March 30) in the concern of community spread of COVID-19. | Test negative twice, and afebrile for more than 24 h in the absence of antipyretic, and improvement of respiratory symptoms. |
| Hospital policies | No | Close contact to a confirmed COVID-19 Case without appropriate precaution (PPE and hand hygiene) | a. Test negative  

b. According to clinical judgment of risk of exposure |
| | | Returning from an overseas travel whose departure occurred before government announce travel ban/restriction (oversea travel before March 19) | Test negative after 14 days of home quarantine |
| | No | Compulsory self-health management according to national policy | Test negative after 14 days of self-health management |

Abbreviation: PPE, personal protection equipment; TOCC, travel, occupation, contact or cluster.

a Definitions COVID-19 notified cases are modified timely.

b Report to Taiwan CDC within 24 h and budget of SARS CoV-2 RNA PCR testing and hospitalization is provided by the government.

c Symptoms are the clinical criteria of COVID-19 notified cases and include fever (≥38 °C) or symptoms of acute respiratory tract infection; abnormal sense of smell, abnormal sense of taste, or diarrhea of unknown etiology; community-acquired pneumonia highly suspected to be COVID-19 by doctors.

d For national surveillance definition, the exposure among healthcare setting was defined as exposed to confirmed COVID-19 patients while HCPs did not wear surgical mask or HCPs who did not wear N95 while perform aerosol inducing procedures for the confirmed patients. https://fightcovid.edu.tw/cdc-guidelines/clinical-management (Accessed August 5, 2020).

e The management algorithm for notified COVID-19 cases https://www.cdc.gov.tw/File/Get/t7wzp6abxPz7rfngl30h4w (Accessed August 5, 2020).

f The management algorithm for HCP in the Expanded COVID-19 Screening Program. https://www.cdc.gov.tw/File/Get/gf4KQji5h2Du49KW-sQgA. "The management algorithm for general population in Expanded COVID-19 Screening Program" https://www.cdc.gov.tw/File/Get/8PIAUhmzG6izC6ehj44Jg. (Accessed August 5, 2020).

g Return to work Guideline for Healthcare Workers (HCW) Involved in Expanded COVID-19 Screening Program. https://fightcovid.edu.tw/cdc-guidelines/return-to-work-guidelines-for-healthcare-worker (Accessed August 5, 2020).
Hospital entry control

Before this pandemic almost all of the hospitals in Taiwan had very limited if any control at hospital entry point except during 9pm and 6am. Three measures are implemented stepwise at hospital entry sites, wearing masks, temperature check, and restricted hospital visits. The government requests all should wear face masks when enter hospital since Jan 31. Temperature check for all patients and visitors is conducted using infrared thermal imaging cameras and/or forehead thermometers. The government restricted hospital visits stepwise to protect healthcare settings. These restrictions include the number and duration of visitors or bedside caregivers. The hospital is responsible to keep the name and contact information of these care givers and visitors for 28 days just in case that they will be informed if a clustering of infection occurs in the unit. Any patient, visitor or HCP who has potential risk such as overseas travel in the preceding 14 days is not allowed to enter the hospital with exemption.

Information technology-aided risk assessment

Risk assessment is conducted for patients or visitor to restrict the hospital entry. For more stringent control and avoid intentional deny important epidemiologic history, the personnel information for international travel and contact of confirmed cases are integrated with the National Health Insurance (NHI) database by the government. We designed working stations at hospital main entry sites and check every visitor’s NHI card to confirm aforementioned information. Alternatively, TOCC information is collected using a questionnaire. The patient lists for scheduled admission or selected outpatient service are checked the night before and at 7am at the scheduled day for any COVID-19 risk based on aforementioned database. Scheduled procedure or admission is subjective to postpone and reschedule. Patients with COVID-19 risk and indicated with emergent or urgent healthcare are referred to the emergency department for further management.

Personal protection equipment

The government announced the policy regarding wearing face masks in the community and PPE use in the healthcare settings, rationing of PPE and surge capacity of PPE production. Nevertheless, shortage or unstable supply of PPE occurred during the first few months. The hospital rationing and prioritization of PPE use. PPE use is based on risk categories, due to both the scientific evidence and also the supply. The PPE reuse policy is clearly defined. N95 fit test and seal check are emphasized.

Engineering and environmental control

Notified cases were isolated in negative pressure room or single room with portable HEPA filters before PCR confirmation. The high risk or confirmed cases were allocated in COVID-19 wards. The low risk patients were allocated in negative control pressure room in general wards before test result were available.

Environmental cleaning was strengthened, particularly in dedicated high-risk areas. These include personnel assignment and training, frequency and protocol of cleaning. The quality of cleaning was assured at COVID-19 care area using a fluorescent marker and/or SARS CoV-2 RT PCR.

Policy for clean zones

The government announced restriction or precaution for outdoor mass gathering or indoor meeting. On-site meeting is limited to 50 persons or less. Webinar or teleconference are encouraged. Participants wear masks and/or keep social distance for 1 m or more. Along with minimal numbers of individuals in any given space, screens were set up to prevent droplet transmission while HCP are unmasked and in close proximity in dining area. All these P&P avoid cross transmission between HCP.

Education

During epidemics the government announces update guidance and visits the hospital to check their performance. For example, the government requested the hospital to provide education for all HCP for COVID-19 within one month and visited NTUH in February to check triage process, traffic control and the dedicated units for taking care of patients with suspect COVID-19. Under the challenge of COVID-19 pandemic, CIC organized PPE training on NTUH on-line education system again. To minimize the risk of exposure and spread, clinical care should at all times adhere to standard precautions including hand hygiene. PPE education is included in orientation training course for new employee. Dedicated COVID-19 PPE training is conducted for residents who rotate to intensive care units or COVID specific wards. All residents who would rotate in the ICUs (mainly resident year 2–5) were asked to field exercise putting on and removing PPE under the instruction of their colleague (senior residents or senior nurse practitioners) as a buddy system. In addition, CIC arranged PPE training for HCP of radiology, respiratory care and other supporting personnel and conducted simulations of contaminated PPE removal using a fluorescent marker.

Data collection and analysis

The following data were prospectively collected for the HCP: predefined incident events reported through health surveillance system, results of SARS CoV-2 RNA PCR tests, and HCP admission for isolation or quarantine. An incident event reported is defined as an HCP with one or more predefined symptoms during a reporting interval (weekly or daily).

Results

Seventeen patients with confirmed COVID-19 infection were admitted to NTUH during the study period. The first confirmed Case was a traveler from Wuhan, China. She was admitted on January 23 through a dedicated emergency department path for COVID-19. All patients survived. The final patient was discharged on June 18, 2020.
Among the 14,210 HCP there were 367 incident events (2.6%), with a median of 2 events per day (range, 0–13). The number of HCP incident reports at the NTUH and concurrent confirmed cases of COVID-19 in Taiwan are shown in Fig. 2A. There was only a small proportional spike among the HCP during the peak of the epidemic.

A total of 283 HCPs were tested for COVID-19 during the course of the study, Fig. 2B. Of these 179 had predefined symptoms and 104 were asymptomatic, but at risk of acquiring infection. Many of the tests, 169/283 (59.7%), were performed as part of the Extended COVID-19 Screening Program. Ten of the 169 (5.6%) HCP with predefined symptoms met the Case definition for COVID-19 infection. The 104 asymptomatic HCP were tested based on hospital policy. These included exposure to confirmed cases before isolation in a negative pressure room (n = 29), overseas travel (n = 64) and a national self-health management regulation (n = 11). None were found to have a positive RNA PCR. Of 64 HCP who were hospitalized for isolation or quarantine, all had mild symptoms and all recovered.

Discussion

Taiwan is a crowded country and close proximity to China, the epicenter of COVID-19. Nevertheless, it is one of the few countries with the lowest number of cases. As March 9, 2021, there have been only 977 cases in Taiwan (41 cases per million population), most of which, 861 (88.1%), were imported from abroad. The national infection control program along with our IPC and prospective health surveillance practices in NTUH have achieved zero COVID-19 Case among our HCP. Another small surveillance (n = 195) conducted at a medical center in Taiwan also revealed negative infection among HCPs. We attribute the current success to Taiwan’s experience to the SARS epidemic in 2003. Besides, we used a hospital-wide web-based health surveillance integrated with a risk-based management algorithm and molecular testing of asymptomatic HCP. This allowed us to rapidly identify HCP at risk of infection and prevent spread to other HCP and patients.

HCP could acquire SARS-CoV-2 at work through direct or indirect contact with infected patients or other HCP, or as a result of ongoing community transmission. Lai X et al. described spread of SARS-CoV-2 to HCP during the early stage of the outbreak in a tertiary care hospital in Wuhan. The major routes were contact with infected patients (59%), colleagues (11%), and from the community (13%). Cheng et al. used a bundled approach to escalate the infection control response in Hong Kong. Similar to what we have done, these included active and enhanced laboratory surveillance, early airborne infection isolation, rapid molecular diagnostic testing, and contact tracing for HCP with unprotected exposure in the hospitals. On the other hand, a recent data based on whole-genome sequencing of SARS-CoV-2 collected from patients and HCP during the first two weeks in three hospitals in the Netherlands suggested multiple introductions into the hospitals through community-acquired infections. Thus, one of the key

Figure 2  The numbers of healthcare personnel reported with one or more predefined symptoms through web-based hospital-wide health surveillance system (A) and those received SARS CoV-2 RNA PCR testing at National Taiwan University Hospital as of June 30, 2020 (B).
factor to support safety and health of HCP (as well as patients and visitors) is the control of COVID-19 at the source at national level. In addition to border control, travel restriction/ban, contact tracing and home isolation/quarantine in the community, the government recommended the universal use of mask in the healthcare settings and encouraged wearing mask for the public early in the pandemic which might prevent potential asymptomatic or presymptomatic transmission.22

Several major hospitals in Taiwan had to be completely or partially shut down because of spread of SARS to patients, caregivers and HCP.37 The epidemic exerted a severe negative impact on the economy and trust in government. This led to development of a national initiative to conduct nationwide annual hospital IPC audits. The audits emphasized and strengthened organization, P&P, hand hygiene, bundle cares, health surveillance, outbreak investigation, and EID preparedness. Hand hygiene and wearing masks for respiratory hygiene and cough etiquette were promoted to the public particularly during the influenza season. In addition, the government announce P&P to prevent influx of cases into medical centers. Notified cases were treated at dedicated hospitals well distributed nationwide and transfer need preapproval by commander of regional medical network. Thus, as of June 30, 2020 only 17 (3.8%) of 447 confirmed cases in Taiwan were hospitalized at this hospital. This is contrast to the situation during SARS epidemic in 2003 that NTUH reported 270 cases and 13 patients with COVID-19 became infected. A study from Korea showed that none of 184 HCP exposed to 13 patients with COVID-19 was infected based on molecular testing.41 A recent review based on available data from 41 countries showed the median HCP infection percentage among total cases was 10.04% (range 0–24.09%) and countries in Asia seem to have lower infection rates among HCPs (<3%).42 This could possibly be attributed either to the readiness of these countries to deal with outbreaks. The third limitation is that the diagnosis of COVID-19 infection in this study is based on RT-PCR for HCP with symptoms or epidemiological risk. Some may argue there may have asymptomatic infection among the HCP remained undiagnosed in the absence of periodical mass screening program. Through another cross sectional study in this hospital during July 1 to Aug. 31, 2020, all of the participated HCP (n = 194) were seronegative, too.43 Thus, the finding is in line with our study to demonstrate the importance of an IPC policy and practice in the hospital level and national level.

Conclusions

Early initiation and full implementation of a timely risk-adjusted, integrated national and institutional IPC policy and practices were successful in protecting HCP from COVID-19 infections.

Author contributions

YC Chen had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: YC Chen. National and institutional policy: YC Chen, SC Chen, SC Chang. Laboratory support: SY Chang. Acquisition, analysis, or interpretation of data: MC Hsu, HH Chang, YL Lai. Drafting of the manuscript: YC Chen, SC Pan. Critical revision of the manuscript for important intellectual content: all other authors.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

The authors thank Calvin M. Kunin for his insightful thoughts towards improving the manuscript. YC Chen has received funding from the National Taiwan University Hospital (109-
P14). The funding source played no role in study design and conduct, data collection, analysis or interpretation, writing of the manuscript, or the decision to submit it for publication.

References

1. Chen YC, Chen PJ, Chang SC, Kao CL, Wang SH, Wang LH, et al. Infection control and SARS transmission among healthcare workers, Taiwan. Emerg Infect Dis 2004;10:895–8.
2. Chen YC, Huang LM, Chan CC, Su CP, Chang SC, Chang YY, et al. SARS in hospital emergency room. Emerg Infect Dis 2004;10:782–8.
3. Wu UI, Wang JT, Chang SC, Chuang YC, Lin WR, Lu MC, et al. Impacts of a mass vaccination campaign against pandemic H1N1 2009 influenza in Taiwan: a time-series regression analysis. Int J Infect Dis 2014;23:82–9.
4. Lin PH, Chao TL, Kuo SW, Wang JT, Hung CC, Lin HC, et al. Viriological, serological, and antiviral studies in an imported human Case of avian influenza A(H7N9) virus in Taiwan. Clin Infect Dis 2014;58:242–6.
5. World Health Organization. Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003. https://www.who.int/csr/sars/country/table2004_04_21/en/, 2003. [Accessed 5 August 2020].
6. Centers for Disease Control and Prevention. Cases & deaths among healthcare personnel. https://covid.cdc.gov/covid-data-tracker. [Accessed 9 March 2021].
7. World Health Organization. Coronavirus disease (COVID-19) outbreak: rights, roles and responsibilities of health workers, including key considerations for occupational safety and health. https://www.who.int/publications-detail/coronavirus-disease-(covid-19)-outbreak-rights-roles-and-responsibilities-of-health-workers-including-key-considerations-for-occupational-safety-and-health, 2020. [Accessed 19 March 2020].
8. World Health Organization and the International Labour Organization. Occupational safety and health in public health emergencies: a manual for protecting health workers and responders. Geneva, https://www.who.int/occupational_health/publications/safety-health-public-health-emergencies/en/, 2018. [Accessed 5 August 2020].
9. Bielicki JA, Duval X, Gobat N, Goossens H, Koopmans M, Tacconelli E, et al. Monitoring approaches for health-care workers during the COVID-19 pandemic. Lancet Infect Dis 2020;20:5473–3099(20). https://doi.org/10.1016/S1473-3099(20)30458-8. 30458-8.
10. Wang CJ, Ng CY, Brook RH. Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. J Am Med Assoc 2020;323:1341–2.
11. Huang YS, Wang JT, Huang IC, Huang YH, Sheng WH, Chen YC, et al. Infection prevention and control of coronavirus disease 2019 (COVID-19) in hospital settings. J Intern Med Taiwan 2020;31:247–53.
12. Giacomelli A, Pezzati L, Conti F, Bernacchia D, Siano M, Oreni L, et al. Self-reported olfactory and taste disorders in SARS-CoV-2 patients: a cross-sectional study. Clin Infect Dis 2020;71:889–90.
13. Chen YH, Fang CT. Combined interventions to suppress R0 and border quarantine to contain COVID-19 in Taiwan. J Formos Med Assoc 2021;120:903–5.
14. Taiwan Centers for Infection Control. COVID-19. https://www.cdc.gov.tw/Disease/Subindex/H6XvF41YP9CXYdBD0kNSJ9A. [Accessed 9 March 2021].
15. Taiwan Centers for Infection Control. Recommendations for COVID-19: case definition, specimen collection, and diagnostic tests. Updated April 16, https://www.cdc.gov.tw/Category/MPage/np0we4f4ijY9hvb8wnQoQ. [Accessed 9 March 2021].
16. Taiwan Centers for Infection Control. Infection prevention and control guidelines in the health care settings. https://www.cdc.gov.tw/File/Get/Th0Qm5-uHgpCKVVs3wzwFwA. [Accessed 9 March 2021].
17. Chien LJ, Su CH, Wu HH. Recommendations on contingency operations for hospitals in response to COVID-19 cases identified in inpatients - Taiwan. J Formos Med Assoc 2020;119:1572–4.
18. Liu WD, Chang SY, Wang JT, Tsai MJ, Hung CC, Hsu CL, et al. Prolonged virus shedding even after seroconversion in a patient with COVID-19. J Infect 2020;81:318–56.
19. Taiwan Centers for Infection Control. Return to work guideline for healthcare workers (HCW) involved in expanded COVID-19 screening program. https://fightcovid.edu.tw/cdc-guidelines/return-to-work-guidelines-for-healthcare-worker. [Accessed 9 March 2021].
20. Taiwan Centers for Infection Control. Contingency recommendations for hospitals in response to COVID-19. https://fightcovid.edu.tw/cdc-guidelines/contingency-recommendation. [Accessed 9 March 2021].
21. Lien WC, Wu JL, Tseng WP, Ko PCI, Chen SY, Tsai MS, et al. Fight COVID-19 beyond the borders: emergency department patient diversion in Taiwan. Ann Emerg Med 2020;75:786–7.
22. Taiwan Centers for Infection Control. Recommendations for visitor and caregiver in the healthcare settings. https://www.cdc.gov.tw/File/Get/1reunNTY3u1pyBPVZCRM9W. [Accessed 9 March 2021].
23. Lee PC, Chen SC, Chiu TY, Chen CM, Chi CH. What we can learn from Taiwan’s response to the covid-19 epidemic. BMJ Opin 2020. https://blogs.bmj.com/bmj/2020/07/21/what-we-can-learn-from-taiwans-response-to-the-covid-19-epidemic/. [Accessed 26 July 2021].
24. Chiang CH, Chiang CH, Chiang CH, Chen YC. The practice of wearing surgical masks during the COVID-19 pandemic. Emerg Infect Dis 2020;26:1962.
25. Taiwan centers for Infection control. https://www.cdc.gov.tw/File/Get/FB7NTBw8xg84Rjycy-6Y50w. [Accessed 9 March 2021].
26. Chiang CH, Chiang CH, Chiang CH. Maintaining mask stockpiles in the COVID-19 pandemic: Taiwan as a learning model. Infect Control Hosp Epidemiol 2020;42:244–5.
27. Hung IC, Chang HY, Cheng A, Chen MW, Chen AC, Ting L, et al. Implementation of human factors engineering approach to improve environmental cleaning and disinfection in a medical center. Antimicrob Resist Infect Contr 2020;9:17.
28. Taiwan Centers for Infection Control. Instructions in response to COVID-19 outbreak: community management. https://fightcovid.edu.tw/cdc-guidelines/community-management. [Accessed 9 March 2021].
29. Taiwan Centers for Infection Control. Taiwan CDC guidelines. https://fightcovid.edu.tw/cdc-guidelines. [Accessed 9 March 2021].
30. Tomas ME, Kundrapu S, Thota P, Sunkesula VC, Cadnum JL, Mana TS, et al. Contamination of health care personnel during removal of personal protective equipment. JAMA Intern Med 2015;175:1904–10.
31. Worldometer. Reported cases and deaths by country, territory, or conveyance. https://www.worldometers.info/coronavirus/. [Accessed 9 March 2021].
32. Taiwan centers in infection control. Situation report. https://www.cdc.gov.tw/. [Accessed 9 March 2021].
33. Chan MC, Cho TJ, Chang FY, Lin JC. Surveillance for coronavirus diseases 2019 (COVID-19) among health care workers at a medical center in Taiwan, March to August 2020. J Formos Med Assoc 2021;120:1025–6.
34. Lai X, Wang M, Qin C, Tan L, Ran L, Chen D, et al. Coronavirus Disease 2019 (COVID-19) infection among health care workers
35. Cheng VCC, Wong SC, Chen JHK, Yip CCY, Chuang VWM, Tsang OTY, et al. Escalating infection control response to the rapidly evolving epidemiology of the coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in Hong Kong. *Infect Control Hosp Epidemiol* 2020; 41:493–8.

36. Sikkema RS, Pas SD, Nieuwenhuijse DF, O'Toole Á, Verweij JJ, van der Linden A, et al. COVID-19 in health-care workers in three hospitals in the south of The Netherlands: a cross-sectional study. *Lancet Infect Dis* 2020; 20:1273–80.

37. Schwartz J, King CC, Yen MY. Protecting healthcare workers during the Coronavirus Disease 2019 (COVID-19) outbreak: lessons from Taiwan’s severe acute respiratory syndrome response. *Clin Infect Dis* 2020; 71:858–60.

38. Chen YC, Chen MF, Liu SZ, Romeis JC, Lee YT. SARS in a teaching hospital, Taiwan. *Emerg Infect Dis* 2004; 10:1886–7.

39. Ran L, Chen X, Wang Y, Wu W, Zhang L, Tan X. Risk factors of healthcare workers with Corona Virus Disease 2019: a retrospective cohort study in a designated hospital of Wuhan in China. *Clin Infect Dis* 2020; 71:2218–21.

40. Yang JR, Liu MT, Huang HJ, Teng HJ, Chen JH, Li SY. Building the national SARS-CoV-2 laboratory diagnostic capacity in Taiwan. *Health Sec* 2020; 18:383–91.

41. Jeon YW, Park ES, Jung SJ, Kim Y, Choi JY, Kim HC. Protection of healthcare workers against COVID-19 at a large teaching hospital in Seoul, Korea. *Yonsei Med J* 2020; 61:631–4.

42. Papoutsi E, Giannakoulis VG, Ntella V, Pappa S, Katsaounou P. Global burden of COVID-19 pandemic on healthcare workers. *ERJ Open Res* 2020; 6:195–2020.

43. Pan SC, Huang YS, Hsieh SM, Chen YC, Chang SY, Chang SC. A cross-sectional seroprevalence for COVID-19 among healthcare workers in a tertiary care hospital in Taiwan. *J Formos Med Assoc* 2021; 120:1459–63.