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.

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Journal of the Formosan Medical Association xxx (xxxx) xxx

Available online at www.sciencedirect.com
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journal homepage: www.jfma-online.com

Review Article

Preventing and controlling intra-hospital spread of COVID-19 in Taiwan — Looking back and moving forward

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Received 22 February 2023; accepted 18 May 2023

KEYWORDS
Infection prevention and control;
Access control;
Isolation;
SARS-CoV-2 testing;
Case investigation;
Contact tracing

COVID-19 has exposed major weaknesses in the healthcare settings. The surge in COVID-19 cases increases the demands of health care, endangers vulnerable patients, and threats occupational safety. In contrast to a hospital outbreak of SARS leading to a whole hospital quarantined, at least 54 hospital outbreaks following a COVID-19 surge in the community were controlled by strengthened infection prevention and control measures for preventing transmission from community to hospitals as well as within hospitals. Access control measures include establishing triage, epidemic clinics, and outdoor quarantine stations. Visitor access restriction is applied to inpatients to limit the number of visitors. Health monitoring and surveillance is applied to healthcare personnel, including self-reporting travel declaration, temperature, predefined symptoms, and test results. Isolation of the confirmed cases during the contagious

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https://doi.org/10.1016/j.jfma.2023.05.018

Please cite this article as: K.-Y. Lin, S.-C. Pan, J.-T. Wang et al., Preventing and controlling intra-hospital spread of COVID-19 in Taiwan — Looking back and moving forward, Journal of the Formosan Medical Association, https://doi.org/10.1016/j.jfma.2023.05.018

period and quarantine of the close contacts during the incubation period are critical for containment. The target populations and frequency of SARS-CoV-2 PCR and rapid antigen testing depend on the level of transmission. Case investigation and contact tracing should be comprehensive to identify the close contacts to prevent further transmission. These facility-based infection prevention and control strategies help reduce hospital transmission of SARS-CoV-2 to a minimum in Taiwan.

Introduction

Coronavirus disease 2019 (COVID-19), emerging in December 2019 from China, has become pandemic within 3—4 months and affected more than 755 million confirmed cases, including more than 6 million deaths, as of 31 January 2023.[1] COVID-19 exposed the weakness of national public health and healthcare infrastructure, and also threatened national economy and healthcare capacity. The impact of COVID-19 varied widely among countries or regions because the initial anti-epidemic interventions differed. For example, the US and Taiwan confirmed the first imported COVID-19 case on January 21, 2020. While 33 states and territories in the US had issued mandatory stay-at-home orders to control widespread community outbreaks as of April 1, 2020,[2] Taiwan only reported 348 cases (1.46/100,000 population) as of April 3, 2020 and only 13.8% of them were indigenous cases.[3] The Taiwan Central Epidemic Command Center (CECC) deployed containment strategies to reduce the impact of COVID-19 to a minimum,[4—8] and achieved low excess deaths without city lockdown, workplace closures, or curfews.[9] Therefore, proactive, strong, and decisive coordinated action is imperative at the global, national and institution levels.

COVID-19 is highly transmissible from person to person via a respiratory route (mainly droplet transmission), direct contact of infected individuals (symptomatic, pre-symptomatic, or asymptomatic), or indirect contact of droplet- or secretion-contaminated environmental surfaces (fomite transmission).[10] To effectively control the COVID-19 epidemic needs a bundle of active interventions. Fig. 1 shows the concept map of national strategies and key measures to combat COVID-19 in Taiwan. Before availability of etiology-specific resources, such as testing, vaccine, or antiviral therapy, non-pharmaceutical interventions (NPIs) are key measures for surviving at the first encounter of human and pathogen.[11] The implemented NPIs include border control, which is only applicable to imported diseases, as well as transmission prevention in the community and healthcare settings.[5,12—14] While public health measures aim to prevent and control spread of SARS-CoV-2 in the community, infection prevention and control (IPC) measures in the healthcare settings are an extension of public health interventions and important along the path of the COVID-19 pandemic. However, IPC in the healthcare settings can be a challenging and complicated task due to the segregation of vulnerable individuals who share common space and facilities. Furthermore, patients and their accompanying persons are not familiar with and prepared to do so in compliance with national and institution policies.

In 2003, an outbreak of severe acute respiratory syndrome (SARS) in a regional hospital affecting 113 patients and 37 healthcare personnel (HCP) led to a whole hospital quarantined.[15] That event was really a crisis of the Taiwanese government and the society.[15] Therefore, the government and people in Taiwan become alert to the threat of emerging infectious diseases and willing to act coordinately.[16,17] When facing a newly emerging infection with limited information, it is reassuring to have mechanisms to detect unusual events in place as a part of the IPC programs in hospitals. These mechanisms can help promptly detect the first encounter through the identification of unusual clusters of cases, as was demonstrated in a teaching hospital in Taiwan in March 2003.[18] Furthermore, no HCP who involved in the care of the first five SARS cases was infected despite a substantial number of exposures which relied just on adherence to standard precautions in HCP's daily practice on the ground.[18]

Numerous COVID-19 outbreaks occurring in the healthcare settings can amplify transmission, endanger vulnerable patients, threaten occupational safety, and hamper the healthcare capacity.[19—23] The surge in COVID-19 cases increases the demands of healthcare capacity while the capacity remains limited and difficult to promptly increase. In addition, hospitalized COVID-19 cases might transmit the disease to HCP and other inpatients, which would further compromise the healthcare systems. During the early phase of the COVID-19 pandemic, two case series in China estimated that the proportion of hospital-acquired SARS-CoV-2 infection was 44%.[24] In a hospital in South Africa a single unsuspected COVID-19 case involved 80 HCP and 39 patients in 5 wards and an outside nursing home and dialysis unit.[21] The large extent and a high mortality rate of 38.5% among infected patients underline the devastating consequences of hospital transmission of SARS-CoV-2. Moreover, the affected hospital services, wards, and buildings of hospital outbreaks had been temporarily closed to reduce transmission.[21,22,25]

Therefore, IPC policy, strategy and practice in the healthcare settings are paramount important for national security, HCP and patients' health and safety, and preservation of healthcare capacity. In this article, we review the COVID-19 outbreaks in the healthcare settings and the corresponding IPC strategies to prevent intra-hospital spread of SARS-CoV-2 in Taiwan, and provide the rationale

which may facilitate decision making at the institution level in the future.

Beyond personal protective equipment

Universal masking and appropriate personal protective equipment (PPE) are effective in reducing intra-hospital spread of SARS-CoV-2.[26] However, a prospective cohort in the UK and the US demonstrated that HCP with adequate PPE remained at increased risk of acquiring COVID-19 and underscore the challenges in availability and appropriate use of PPE.[27] Outbreak investigations have repeatedly demonstrated intra-hospital spread of SARS-CoV-2 despite fully equipped PPE.[28] The findings indicate that healthcare systems should develop further IPC measures to protect HCP from COVID-19, along with ensuring PPE quality, availability, and appropriate use.

Intra-hospital spread of COVID-19 in Taiwan

In Taiwan, the combination of NPIs and high degree of public adherence have contributed to successful COVID-19 control in the early stages of the COVID-19 pandemic.[4] As of 30 April, 2021, only 1163 COVID-19 cases were reported, with >90% being imported cases.[29] Nevertheless, hospital outbreaks were detected and increased parallel to the surge of COVID-19 cases in the community. Fig. 2 illustrates the number of confirmed COVID-19 cases and corresponding hospital outbreaks from January 2020 to July 2021 in Taiwan. The first intra-hospital outbreak occurred in February 2020 despite

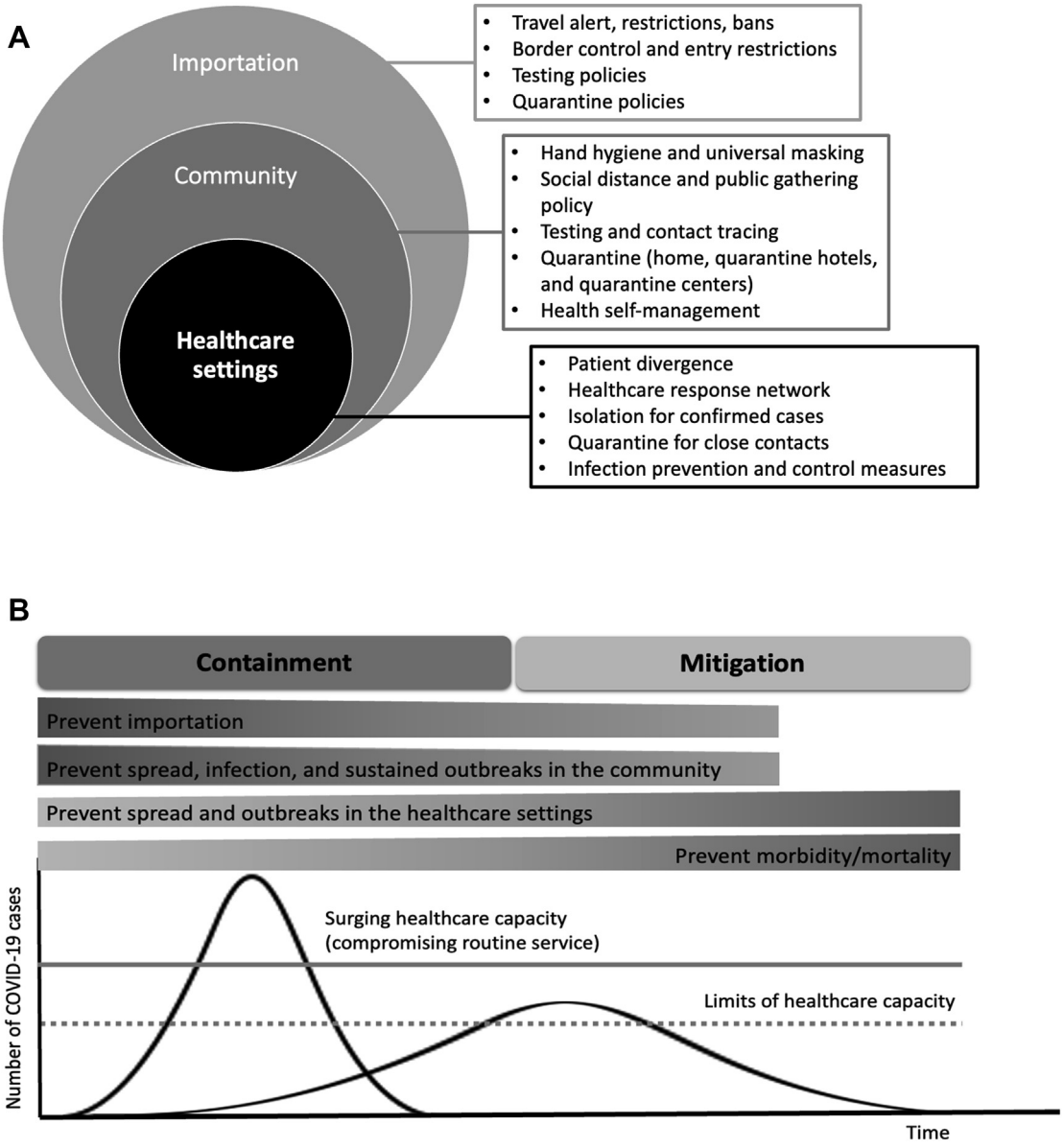
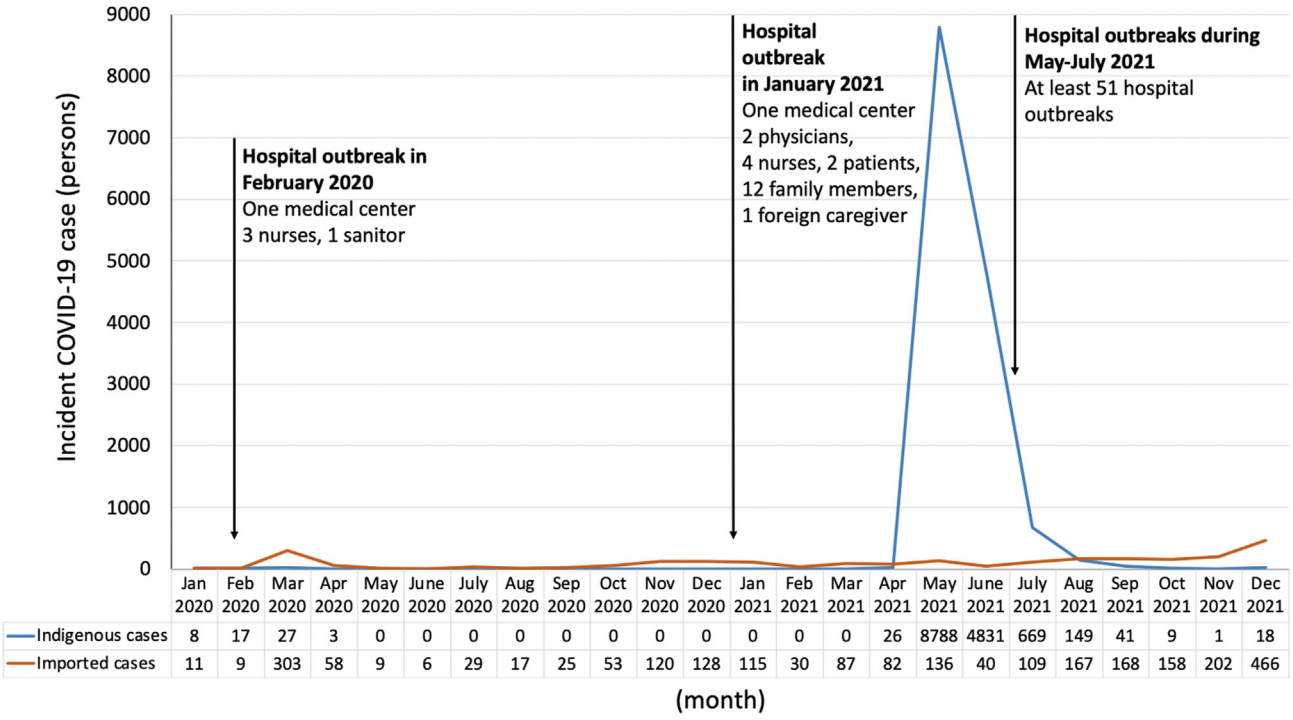


Figure 1 The concept map of national strategies and key measures to combat COVID-19 in Taiwan. (A) Three tiers of containment strategies. (B) Timely adjustment by risk and resources from containment to mitigation.



	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	June 2020	July 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021	June 2021	July 2021	Aug 2021	Sep 2021	Oct 2021	Nov 2021	Dec 2021
Indigenous cases	8	17	27	3	0	0	0	0	0	0	0	0	0	0	0	26	8788	4831	669	149	41	9	1	18
Imported cases	11	9	303	58	9	6	29	17	25	53	120	128	115	30	87	82	136	40	109	167	168	158	202	466

Figure 2 Number of COVID-19 cases by date of report and corresponding hospital outbreaks.

implementing triage, access control, and other measures.[30] The index case, who was an inpatient without COVID-19 related symptoms and a travel, occupation, contact, and cluster (TOCC) history at admission, developed pneumonia and was diagnosed with COVID-19 by SARS-CoV-2 PCR 10 days later. A total of four HCP were infected subsequently. The second outbreak occurred at a designated COVID-19 hospital in January 2021, and involved 21 cases (6 HCPs, 2 patients and 13 accompanying persons).[28] The index case triggering the investigation was a physician, who was wearing appropriate PPE while taking care of an imported case in a COVID-19 unit. The hospital immediately established the incident command team, and the Taiwan Centers for Disease Control (CDC) deployed personnel to facilitate outbreak management which included restriction of admissions and visitor access, PCR testing for all HCP, 14-day single-room quarantine of the close contacts, traffic control bundling, wards segregated based on the COVID-19 risk, and thorough environmental cleaning and disinfection.

Following a cluster of infections in Wanhua District, Taipei City, a surge of COVID-19 cases occurred mainly in northern Taiwan during May to July 2021.[31] An undiagnosed resident from Wanhua resulted in a cluster of COVID-19 cases in a nearby medical center.[32] Overall, a total of 26 hospitals among 495 hospitals in Taiwan reported 54 outbreaks of COVID-19 with 512 confirmed cases between January 2020 and July 2021.[19] The confirmed cases included HCP (19.5%), patients (39.3%), and accompanying persons (41.2%). The median number of affected cases per outbreak was 6 (interquartile range [IQR], 2—12), and the median outbreak duration was 12 days (IQR, 4.3—17.0). Accordingly, the Taiwan CDC has strengthened IPC strategies for preventing transmission from community to hospitals as well as within hospitals (Table 1). The detailed IPC measures other than PPE are described below.

Access control measures

Before the COVID-19 pandemic, there is no access control in the hospitals in Taiwan except during nighttime hours. The Taiwan CECC announced the access control policy to prevent the intrusion of SARS-CoV-2 into hospitals. In addition to universal masking and alcohol hand sanitizer, a triage area is established at the designated entrance (including emergency departments) to screen fever, respiratory symptoms, and history of TOCC.[33] To translate this policy, sustain these measures, and expedite entry into hospitals, several novel designs or devices have been implemented. These include temperature measurement using non-contact thermal imaging cameras,[34] on-site digital reading the National Health Insurance cards,[35] and automated triage and appointment systems which are incorporated into the hospital's existing web-based appointment system and deployed along with its on-site counterpart to expedite entry into hospitals.[36] Both automated triage and appointment systems query COVID-19 risks (international travel, confirmed cases, close contacts) through web-based database maintained by the National Health Insurance Administration, which integrates data from the Immigration Agency and CDC. Visitors or patients with relevant histories are denied registration or entry; on the other hand, they are referred to either epidemic clinics or outdoor quarantine stations of emergency departments based on their medical needs.[30,37]

The epidemic clinic is designated to provide medical service to patients who are suspected of having COVID-19 or

Table 1 Facility-based infection prevention and control measures beyond personal protective equipment in the context of COVID-19 in Taiwan.

Measures[a]	Comments
Patient divergence	- Avoiding the risk of transmission before hospital visits or before entry based on the government- or institution-based policies, which are officially announced at the hospital's website or through media, on-site posters, auto-remind messages[d] - Pre-screening of the TOCC history[d] via the web-based National Health Insurance Administration system for scheduled hospital admission, outpatient procedures or clinics, and visits - Designated services to mitigate the risk of transmission including epidemic clinics, testing clinics/centers/station, triage at emergency services, teleclinics - Avoiding the three Cs: crowded places, close-contact settings, confined and enclose spaces with poor ventilation[58]
Access control	
Triage[b]	- Triage at the designated entrance (emergency room and other hospital entry)
Entry control[b]	- Masking requirements and hand hygiene - Temperature measurement - Screening fever, respiratory symptoms, and the history of TOCC
Visitor access restriction[b]	- Applied to visitors and bedside accompanying persons of inpatients - Applied to those with risk for COVID-19 - Policies are adjusted based on the level of community transmission, which are applied to all visitors during the large-scale outbreak.
Source control	
Isolation and quarantine[b]	- Isolation for the confirmed cases during transmission period; quarantine for the close contacts during incubation period - Accommodation includes single negative isolation rooms or single rooms if the capacity is limited. - Policies are adjusted based on epidemiological characteristics, availability of vaccination and antiviral agents, resource, and feedback from the frontline execution. - Capacity surging and patient divergence in the community relieve the burden of hospital service.
Testing and tracing	
Health monitoring and surveillance[b,c]	- Applied to HCP, also inpatients and their accompanying persons - Surveillance and reporting systems - Self-reported travel declaration, temperature, predefined symptoms, and test results
SARS-CoV-2 testing strategies[b,c]	- Government-funded free testing including SARS-CoV-2 PCR and later, rapid antigen testing - Testing strategies are adjusted according to epidemiological characteristics, capacity, level of transmission, and turnaround time. - Four tiers of target populations include: (1) Individuals with COVID-19 related symptoms and signs, or those at risk based on a TOCC history; (2) Individuals suspected of having COVID-19 based on clinical judgement; (3) Active screening for target populations regardless of symptoms or exposure risk; (4) Mass screening for outbreak management
Case investigation and contact tracing[b,c]	- Evaluating COVID-19 cases for the potential of intra-hospital spread and incident event management - Index case is placed in a single isolation room and a contact elicitation window of 3 days is used. - Close contacts should undergo a SARS-CoV-2 PCR test and 14-day quarantine, and risk contacts should monitor themselves for symptoms consistent with COVID-19 for 14 days. - Environment cleaning and SARS-CoV-2 surveillance
Basic IPC measures	Measures implemented before and more important during the pandemic
Standard precaution[7]	- Used for all patient care based on a risk assessment to protect HCP from infection and prevent the spread of infection from patients to patients[59] - Hand hygiene with emphasis of 5-moment opportunity - PPE use whenever there is an expectation of possible exposure to infectious materials - Properly handle, clean, and disinfect patient care equipment, instruments, and devices - Clean and disinfect environment appropriately - Handle textiles or laundry carefully

(*continued on next page*)

Table 1 (*continued*)

Measures[a]	Comments
Universal vaccination[b,c]	Preventive mass immunization campaign or an outbreak-response vaccination campaign[60,61]
Partnership[b,c]	The patient/public empowerment and engagement as the new normal through continuous education and encouragement residents, patients and their accompanying persons to help stop the spread of COVID-19, and keep one another safe by getting vaccinated and tested

Abbreviations: HCP, healthcare personnel; IPC, infection prevention and control; PPE, personal protective equipment; TOCC, travel, occupation, contact, cluster.

[a] IPC measures are designed along the path of individuals who enter and share the public space and shared facilities to protect the right, health and safety of all stakeholders (healthcare personnel, patients and their accompanying persons, and visitors). The challenges are how to translate the theory, policies, government requests, professional recommendations, stakeholders' anticipations, and frontline feedback, while considering the reality which includes the gaps and limitations of environmental, resource, and human factors. All IPC measures should be integrated into daily practice or standards of procedures, and checked and then revised to be feasible, practical, and sustainable. For hazard control, these include PPE, engineering control, and administrative control.

[b] Measures aim to prevent transmission from community to hospitals.

[c] Measures aim to prevent transmission within hospitals.

[d] Information technologies are applied to facilitate IPC measures and provide user-friendly platforms.

are at risk of SARS-CoV-2 infection; therefore, it is usually located in an independent building or at the corner of one hospital building, preferably separate from other clinics and with an independent entrance and air-conditioning circuit. Since the COVID-19 pandemic, the triage of emergency departments is moved outside for screening fever, respiratory symptoms, and history of TOCC. Patients at risk for COVID-19 are diverted to the outdoor quarantine stations, where physicians visit them after wearing proper PPE. Those patients undergo SARS-CoV-2 PCR testing, medical examination, and corresponding treatment in the outdoor quarantine stations until meeting the criteria for releasing from isolation. Furthermore, a double triage and telemedicine protocol are developed to triage suspected COVID-19 cases and minimize HCP's exposure to this disease.[38]

Visitor access restriction

The Taiwan CECC has announced visitor restriction policies, which are applied to inpatients to limit the number of visitors and time staying at bedsides and also to those with risk for COVID-19; the policies are adjusted based on the level of community transmission.[39] Exception to these restrictions are clearly defined for ethical consideration, such as key family members of patients undergoing emergent care, invasive procedures, or hospice care. Following the large-scale community outbreak, visitors are required to provide a negative SARS-CoV-2 PCR or antigen test result before entering the hospitals. Visitors could be exempted from screening for SARS-CoV-2 if they have received the full COVID-19 vaccination at least 14 days before or have a history of previous COVID-19 within three months.[40]

Isolation and quarantine

Integrated with early identification of confirmed cases and comprehensive contact tracing, isolation of the confirmed cases during their contagious period and quarantine of the close contacts during the incubation period are critical measures to prevent transmission and contain clusters of infectious diseases with high transmissibility such as COVID-19, particularly when pharmaceutical interventions are absent, unavailable, or limited in efficacy. This policy is aligned with the recommendations of the US Centers for Disease Control and Prevention.[41] Quarantine policy was initiated at the beginning of COVID-19 pandemic in Taiwan with rolling updates according to the epidemiological evidence, resource, and feedback from the frontline execution.

To surge capacity for this mission, hospitals are required to allocate a certain proportion (up to 30% at the peak in northern Taiwan) of inpatient units or beds as isolation units to provide acute and intensive care of COVID-19 cases.[37] The isolation units are generally located away from the main hospital building, with incorporating contaminated, transition, and clean zones.[42] Hospitalized patients are transported through specific routes to minimize contact with other patients and HCP, and placed in adequately ventilated single rooms or negative pressure isolation rooms.[41] The portable high efficiency particulate air (HEPA) cleaners have been confirmed to be effective in removing SARS-CoV-2 particles from the air, and thus are used to increase the filtration of aerosol particles in single rooms without modifying the existing ventilation systems.[43,44] Physicians and nurses working in the isolation units receive comprehensive PPE training and are not allowed to work in other patient-care areas.

To cope with the surge in COVID-19 cases from the community or confirmed after hospitalization with the difficulty in transferring cases to other hospitals, hospitals respond accordingly by transforming routine inpatient units into dedicated COVID-19 units. A medical center near Wanhua increased the COVID-19 units from 1 unit (11 negative pressure isolation beds) to 5 units (138 beds without negative pressure designs) and ICU capacity from 1 unit (10 beds) to 4 units (58 beds) within 3 weeks in 2021.[32]

At the national level, the central and local governments work together to divert asymptomatic or mild COVID-19 cases in the community to preserve hospital capacity for severe cases and routine healthcare. These include home

isolation or quarantine which is integrated with hospital-based supporting system sponsored by local governments. In addition, hotels are recruited and transformed into quarantine hotels for inbound traveler or into enhanced quarantine centers equipped with HCP and medical resources.[45] These capacity surging and patient divergence in the community significantly relieve the burden of over-stretched hospital service, which indirectly result in subsequent reduction in hospital outbreaks and preserve capacity of routine health care.

Health monitoring and surveillance

For occupational health and safety, HCP's right, and protection of vulnerable populations in the healthcare settings, early identification of SARS-CoV-2 infection among HCP has been emphasized and can be achieved through a surveillance and reporting system.[46] Syndromic surveillance can be conducted using passive or active methods according to the COVID-19 transmission risk.[47] A weekly passive syndromic surveillance has been routinely performed after the SARS epidemic in Taiwan; HCP self-report to the designated staff in their unit or department if they experience any predefined symptoms, such as fever, cough, and other airway symptoms. In response to the evolving COVID-19 outbreak, the systems have been rapidly scaled up, and the predefined symptoms were expanded to include dysosmia and dysgeusia as well.[48] HCP measure their temperature at least once daily on arrival for their shift. Requirement to daily report their health status causes additional burden on HCP who are already stretched by the excess load of COVID-19; therefore, REDCap or other one-stop intranet platforms are developed to actively remind HCP for self-reporting travel declaration, temperature, predefined symptoms, and test results. The corresponding management for HCP with predefined symptoms are established based on their SARS-CoV-2 infection risk.[46] The policies for testing, quarantine accommodation, sick paid leave are well defined and announced at the national and institution levels.

The effectiveness of enhanced surveillance and reporting systems had been evaluated between January and June, 2020 in Taiwan[46] and from January to February, 2020 in Singapore.[49] None of the HCP were found to be infected with COVID-19. The results highlight that a surveillance and reporting system in place can be rapidly enhanced to prevent HCP from infection during the COVID-19 outbreak.

SARS-CoV-2 PCR testing strategies

Before the etiology causing emerging infectious disease is identified and efficient testing is available and accessible, syndromic surveillance is conducted based on case definition for notification. However, the following cases may be missed by syndromic surveillance: patients with early stage of the disease, mild infections, atypical symptoms, co-morbidities, extreme age, co-infections, uncommon routes of transmission, and infections from various virus variants.[30,50] With the advance in science and technology of viral kinetics of SARS-CoV-2, laboratory testing plays a key role in early case finding (including symptomatic, pre-symptomatic, and asymptomatic patients) and guiding risk-adjusted and transmission-based IPC measures. The national laboratory network was established and strengthened through the recruitment of medical centers and regional hospitals distributed throughout most geographical regions of the country in January 2020; later, the network expanded the available testing supply and maximized testing capacity.[51]

National and institutional SARS-CoV-2 PCR testing strategies have been developed and implemented since the emerging COVID-19 pandemic. The government-funded, free testing strategies are adjusted timely according to epidemiological characteristics, capacity of testing, level of transmission in the community or institutions, and turnaround time from sampling to data feedback. The target populations for SARS-CoV-2 PCR and rapid antigen testing have been expanded stepwise (Table 1). With an increasing level of community transmission, SARS-CoV-2 testing has been applied to all patients scheduled for hospital admission, surgery, dialysis or other procedures, as well as their accompanying persons. Given the higher risk of infection, HCP are recommended to be prioritized for SARS-CoV-2 testing[47] following exposure to virus or periodically (e.g., weekly). The later was initially applied to HCP at high-risk units, such as triage, emergency departments, or COVID-19 units. The testing frequency depends on the level of transmission within a hospital and surrounding areas, and mass screening has been applied to all HCP periodically for outbreak management or until HCP are fully vaccinated.[22,25,32] After implementing universal testing for newly admitted patients and their companions, as well as periodic testing of HCP in high-risk areas, there was a significant decrease in hospital outbreaks.[19]

With the advanced facility, large-scale SARS-CoV-2 PCR testing is doable. Nevertheless, self-performed rapid antigen testing is feasible and sustainable for repeated testing and can be used as an effective intervention for countries transitioning from pandemic mitigation to endemic COVID-19 though the impact of testing varies depending on test sensitivity and frequency.[52,53] Besides, in the absence of government subsidy, the feasibility and sustainability of these testing strategies will depend on the costs of the tests.

Case investigation and contact tracing

Taiwan's response to the COVID-19 pandemic was unique in the world, as it acted promptly at the very beginning and conducted precisive contact tracing and testing to achieve very low proportion of indigenous cases using a reasonable number of testing. As of March 27, 2021, total number of COVID-19 cases per million population was 42 in Taiwan and 63 in China, and total number of tests per million population was 19,256 in Taiwan and 111,163 in China, whereas more than 90,000 cases per million population and more than 1,000,000 tests per million population were reported in the US and Israel. As of 29 January, 2023, Taiwan reported 399,263 COVID-19 cases per million population (rank 46 among 229 countries and territories), including 683

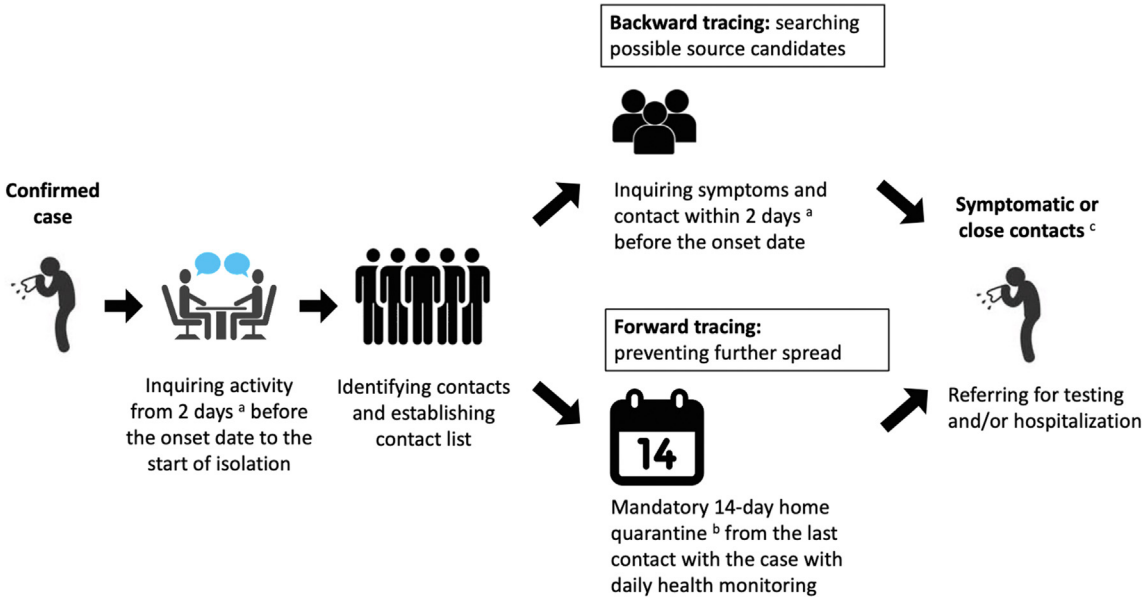


Figure 3 The framework of bi-directional contact tracing (a) a contact elicitation window of 2 days is used to ensure more infected contacts are identified, thus day 0 is considered as 2 days prior to the date of symptom onset or specimen collection for SARS-CoV-2 testing for the index case.[62,63] (b) close contacts are defined as individuals with face-to-face contact (within 2 m) for a period of $\geq$15 min or direct exposure to aerosols or respiratory secretions without proper personal protection equipment from 2 days before the onset date of index case to the start of isolation. (c) The quarantine period of contacts is adjusted from 14 days to balance the public health risks and benefits against the social and economic impact.

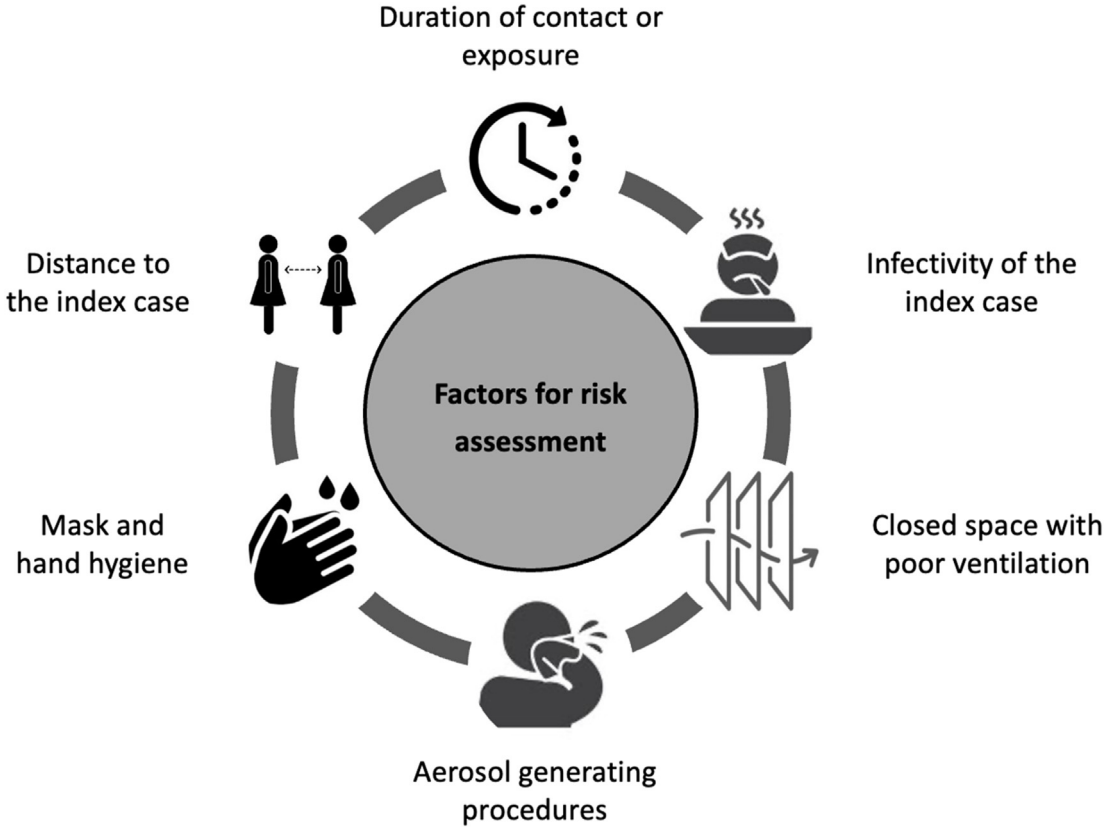


Figure 4 Factors considered in the risk assessment for possible transmission to contacts in the absence of transmission-based isolation precaution and appropriate personal protective equipment.

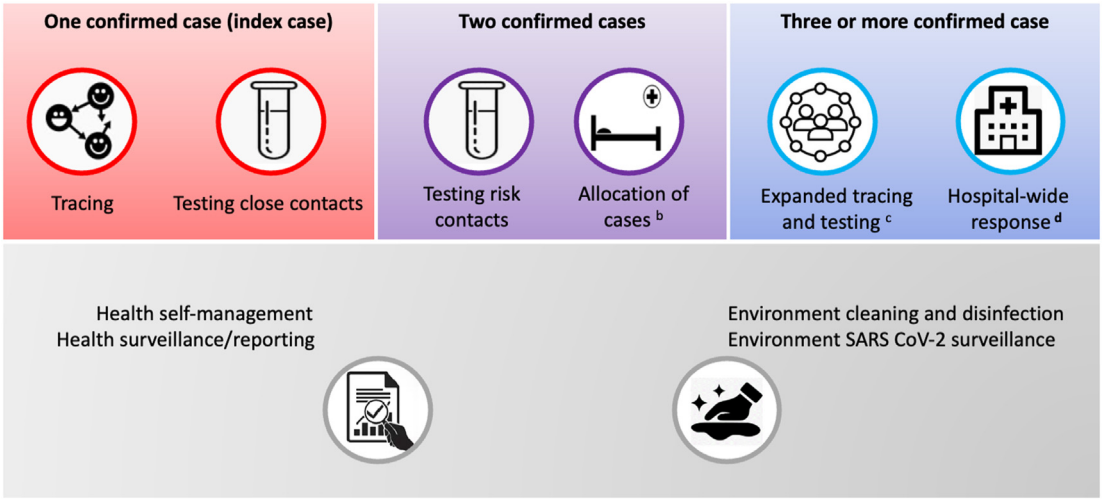


Figure 5 The core elements of responding to COVID-19 confirmed cases who are hospitalized outside of dedicated COVID-19 wards or beds, and in the absence of COVID-19 specific precaution according to the Taiwan CDC recommendations (a) the guidance was first released on February 26, 2020 by the Taiwan CDC.[55] (b) Isolation of confirmed cases and quarantine of those close contract in single rooms in designated COVID-19 units or in index units after cleaning. (c) In addition to the index case, there are additional 2 confirmed cases among those close contacts or risk contacts in inpatients units or additional 3 cases in outpatients or administrative units. In this situation, risk contacts are managed as close contacts. (d) Hospital-, campus- or building-wide responses are mandatory if there are a total of 3 or more confirmed cases (including the index case), or confirmed cases are distributed across more than one unit. These responses include active monitoring of health condition, mass screening, segregation of wards, and traffic control bundle. If deemed necessary, restrictions or delays of scheduled admissions or procedures may be implemented to reallocate capacity for isolation or quarantine purposes. For example, the facility may need to allocate manpower to support the index unit(s) to manage the outbreak.

deaths per million population (rank 120), and conducted 1,259,685 tests per million population (rank 92).[54]

In the healthcare settings, case investigation and contact tracing should be comprehensive for the close contacts since getting infected could potentially affect many people, including those at higher risk for severe diseases and critical infrastructure workers. To achieve zero healthcare-acquired COVID-19 in a teaching hospital, infection control nurses evaluate every COVID-19 case for the potential of intra-hospital spread immediately after receiving the automated messages of positive results of SARS CoV-2 PCR or notification from the frontline HCP.[46] If the case has not been reported as COVID-19 before or stayed in the hospital outside the dedicated COVID-19 units without COVID-19 specific isolation precaution, the incident event management is initiated according to the Taiwan CDC recommendations with minor modification.[55]

Fig. 3 shows the framework of bi-directional contact tracing and testing. The index case is placed in a single isolation room and interviewed for comprehensive information on the history of SARS-CoV-2 testing and results, date of symptom onset, potential source of illness, activity history, and the list of close contacts.[41] A high-risk contact (i.e., close contact, as defined in Fig. 3) should undergo a SARS-CoV-2 PCR test and 14-day quarantine. On the other hand, low-risk contacts (i.e. risk contacts) should monitor themselves for symptoms consistent with COVID-19 for 14 days. The risks of exposure are accessed based on several factors, as described in Fig. 4. In addition, the risks of subsequent infection following exposure vary by vaccination status and host factors.

In addition to those described in Table 1, other measures implemented include escalating SARS-CoV-2 testing policies, restriction or delay of scheduled admissions or procedures, segregation of wards, and traffic control bundle according to the Taiwan CDC recommendations (Fig. 5).[55] All these intensive aggressive interventions allow the outbreak to be declared over quickly.[56] To proactively prevent COVID-19 acquisition and spread in the healthcare settings, the importance of hand hygiene, environmental cleaning, and other elements of standard precaution (Table 1) cannot be overemphasized as SARS-CoV-2 may be transmitted indirectly through contaminating the hospital environment.[57]

Conclusions

The early and aggressive implementation of NPIs in Taiwan has successfully contained COVID-19 prior to the widespread availability of effective vaccines and antiviral agents. In the healthcare setting, IPC measures are important during the initial phase of pandemics as well as transition to endemics since HCP and patients face higher risks of SARS-CoV-2 infection than individuals in the community. In view of the lessons learned from the SARS outbreak in 2003, hospital outbreaks of COVID-19 during community surges were controlled by strengthened, multipronged integrated IPC measures. In addition to appropriate use of PPE, access control, visitor restriction, dedicated isolation units, hospital-wide health surveillance and reporting system, and extensive case findings and contact tracing have been deployed during the COVID-19 pandemic.

These IPC measures prevent intra-hospital spread of SARS-CoV-2 to a minimum and protect HCP and patients in Taiwan.

Funding

YC Chen was supported by National Taiwan University Hospital intramural fund (NTUH 109-P14). The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the manuscript.

Declaration of competing interest

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

Acknowledgments

Thanks to Dr. Hao-Hsin Wu, Taiwan Centers for Disease Control, for suggestion and preparing Figs. 4 and 5. We are grateful to infection control personnel for their commitment and contribution and healthcare personnel for their engagement and collaboration to protect patients, caregivers, and colleagues during the COVID-19 pandemic. We also appreciate all personnel in local and central governments who involve in pandemic control to secure a safe and healthy society for three years.

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