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Review Article

Early Prompt Response to COVID-19 in Taiwan: Comprehensive surveillance, decisive border control, and information technology support

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Since the COVID-19 outbreak was detected in Wuhan in December 2019 by the event-based surveillance of Taiwan Centers for Disease Control, Taiwan has been aligning risk management to policy planning with the assistance of comprehensive surveillance and regular rapid risk assessments. Taiwan Central Epidemic Command Center (CECC) promptly initiated stepwise border control for major cities and provinces in China, European and American countries, and eventually expanded it to the whole world in March 2020. With stringent quarantine measures, the early response not only successfully blocked the first wave of imported cases, but also slowed down subsequent large local outbreaks. Digital technologies including digital fencing and government database linkage were adopted to facilitate the application of public health interventions and data collection. The experience of Taiwan’s prompt and comprehensive response at the early stage may contribute to the preparedness for the next disease X outbreak.

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Introduction

After the discovery of SARS-CoV-2 in Wuhan, the pandemic outbreak has continued for more than 2 years, resulting in over half a billion of patients worldwide.\(^1\) As one of the nations that first detected the news of the disease outbreak in Wuhan, China, successful early response in Taiwan not only blocked the first wave of imported cases,\(^2\) but also slowed down subsequent large outbreaks locally. During the first year of the COVID-19 pandemic, only 56 locally-acquired cases and few small clusters occurred in Taiwan, mostly in households and hospitals, and there were 253 consecutive days without locally-acquired cases detected until 22 December 2020.\(^3\) The first large community outbreak in Taiwan did not occur until May 2021.\(^4\) The experience of Taiwan’s prompt and comprehensive response at the early stage may contribute to the preparedness for the next disease X outbreak. This article aims to document Taiwan’s response during the early stage of the COVID-19 pandemic and the key elements for success.

Comprehensive surveillance and risk assessment

After the SARS outbreak in 2003, Taiwan Centers for Disease Control (Taiwan CDC) established a comprehensive framework for disease surveillance, both for international epidemic intelligence and domestic disease surveillance.\(^5\)

In the era of social media, the event-based surveillance constructed by Taiwan CDC was also expanded to cover commonly used social media websites, including local electronic bulletins, Facebook, and the commonly used social media website in other countries, such as Weibo. In the beginning, the collection depended on real people to scan the posts on news and social media websites. In recent years, a web crawler system was introduced to automatically collect the posts or news using keywords about infectious disease, for example, an outbreak of unknown disease, influenza, or Ebola virus. The framework of Epidemic Intelligence in Taiwan is illustrated in Fig. 1.

Capture of the Wuhan event and alert to the public

In the early morning of 31 December 2019, a medical officer of the Epidemic Intelligence Center, Taiwan CDC, caught a post on an electronic bulletin that mentioned an outbreak of undiagnosed pneumonia in Wuhan, China. This is the beginning of the whole pandemic story. As the surveillance system and risk assessment process has been operating for years, the message was reviewed in the morning meeting of Taiwan CDC on the same day. The message was considered as an unusual event because it clearly pointed out the outbreak location and some clinical information of the patients. In the following hours, Taiwan CDC sought verification and further information from the World Health Organization (WHO) and the Chinese government. Although the outbreak was confirmed and the message was soon sent out on other epidemic notification services like PubMed, no additional information was provided at that time. The report of the atypical pneumonia cluster in Wuhan from the Chinese government was not published on the Epidemic Information Site (EIS) of the WHO intranet until 5 January 2020.

![Figure 1](image)

**Figure 1** Framework of epidemic intelligence systems in Taiwan CDC. Footnote: ER: emergency room; Lab: Laboratory; OPD: outpatient department; SMS: Short Message Service; Sys: System.
Because of the experience of the SARS outbreak and the concerns about the transparency of epidemic information provided by the Chinese government, Taiwan CDC decided to initiate early response by activating the emergency response mechanism immediately. In the following months, Taiwan CDC continued to use the event-based surveillance system to monitor the Chinese local media and official websites, to capture local outbreak information, and to obtain some important epidemiological characteristics of the epidemic before formal scientific reports were published. On 12 January 2020, Taiwan CDC sent Taiwanese experts to Wuhan to commence an investigation; according to the intelligence they received from the Chinese government, human-to-human transmission was presumed as some household contacts of persons with pneumonia of unknown cause were infected without having been to the Huanan Seafood Wholesale Market, the place thought to be the common exposure of the initial cases.

Risk assessment for proactive actions

Despite sensitive surveillance systems, the linkage from information to action was the key to successful response. Since detecting the unusual signal in Wuhan in December 2019, Taiwan has been aligning risk management to policy planning via conducting regular risk assessments. The COVID-19 risk level in Taiwan was raised to “moderate-to-high” in mid-January 2020 when neighboring countries has reported cases and the human-to-human transmission became obvious; Taiwan CDC subsequently listed COVID-19 as a notifiable disease on 15 January and activated the Central Epidemic Command Center (CECC) on 20 January. The risk level was adjusted to “high” on 24 January because of the lockdown in Wuhan and the growing regional threats.

Since mid-January 2020, Taiwan CDC had conducted daily risk assessments for each province of China based on not only outbreak magnitude, the situation of clusters and their progress, but also the numbers of Taiwanese residents in China, direct flights to Taiwan, and weekly traffic volume among major cities. The epidemic risk of the province/municipality was classified as two epidemic areas: level-one and level-two, with corresponding quarantine measures, and the traveling history of the level-one epidemic area was included in the epidemiological criteria of the COVID-19 case definition. The corresponding actions by the CECC included travel restrictions on each province in China, health declaration requirements for international arrivals, the ban of face masks exportation, and guidance for suspected cases and contacts. These plans and responses were implemented much earlier than the declaration of Public Health Emergency of International Concern (PHEIC) by WHO on 30 January 2020.

Decisive border control

Because of the proximity to China and the high volume of air travel between China and Taiwan, the risk of importing COVID-19 was considered to be very high and soon, when the outbreak was spreading to other countries. As a result, CECC initiated stepwise border control for major cities and provinces in China. During 2 February and 14 February, Hubei, Guangdong, Zhejiang, and Henan Provinces were listed as level one epidemic areas subsequently; and the rest of China was listed as level two epidemic areas. Travelers coming from epidemic areas were subjected to home quarantine for 14 days. On 7 February, Taiwan banned the entry of non-citizens with history of traveling to China within the past 14 days. Similar principles of risk evaluation and border control measures were also applied to other countries, for example, Italy, Spain, and other European and American countries, when the pandemic spread to those continents in March.

The surge of the number of imported COVID-19 cases peaked with the surge of the pandemic but decreased soon after timely prohibition of entry by foreign citizens on 19 March and the announcement of level 3 travel alerts for the whole world on 21 March 2020 (Fig. 2).

Although border control effectively decreased the number of imported COVID-19 cases, cases imported before the application of strict border control still caused several local outbreaks of COVID-19 in Taiwan. To rapidly detect and respond to the possible local outbreak, Taiwan CDC adopted the exiting framework of infectious disease surveillance for the detection of COVID-19. After case detection, contact tracing and quarantine for close contacts were applied for all confirmed cases to contain further transmission.

Since mid-June 2020, Taiwan has re-open its border for essential travel and conducted specific quarantine measures for different countries based on the assessment of their disease importation risk. The indicators for re-evaluation of COVID-19 risk from international arrivals included epidemic magnitude/trend, surveillance capacity, regional situation, and information transparency. CECC announced the updated list of countries/regions eligible for shortened quarantine periods every two weeks. With a comprehensive public health mix approach in the following months, there were no community outbreak in Taiwan for nearly one year.

Database linkage and information technology support

Public health interventions usually required great manpower to assure compliance, for example, following the quarantine requirement, and monitoring the health status of close contacts. In Taiwan, CECC adopted innovative digital technologies and big data analytics to facilitate the application of those non-pharmaceutical interventions (NPIs) and the data collection.

For case containment, inbound travelers who were asked to be quarantined at home or quarantine facilities, a digital fencing system using mobile phone signals was designed to monitor if the quarantined people breach the protocol. Additionally, the National Health Insurance Administration (NHIA) integrated the information from the National Immigration Agency and the CECC and updated the cloud database daily, helping the medical providers to identify patients with travel history of affected areas or infection/contact history, and take appropriate protection measures in time.
CECC to track back all doctor visits and medical contacts of confirmed and suspected cases. For contact tracing and the following health monitoring for close contacts, an electronic contact tracing system (TRACE) was adopted to assist public health workers with high efficiency.11,15 The system was developed to support data linkage, cross-jurisdictional coordination, and follow-up of contacts’ health status. By implementing the approach of self-reporting using automatic text messages and web-app, the percentage of health status updates from self-reporting increased from 22.5% to 61.5%. The high proportion of secondary cases detected (88%) via comprehensive contact tracing with digital support proves the value of information technology in identifying and monitoring exposed contacts, and thus help to decrease further transmission in the community.

For detection of potential close contacts, two innovative strategies were taken-the 1922 SMS Contact Tracing system and Taiwan Social Distancing App.16,17 All residents were required to scan a QR Code before entering public places, including stores, hospitals, government buildings, etc. and send a mobile text message to a central database. Using these records, CECC could inform specific customers with potential exposure. The system is different from the “name registration” in other countries: no personal information (ex. name) other than mobile phone number was collected; the reason is to avoid deliberately concealment of exposure history because of privacy concerns.18 A contact tracing app using exchanged Bluetooth identification code with contacts and compare it with the list of diagnosed Bluetooth identification code (from COVID-19 confirmed cases) in the cloud was also developed. Users received feedback every day to make sure whether they have close contact with cases. However, the effectiveness of the App depends on the user coverage in the community.19

When the CECC was trying to promote face mask use as a population-based intervention, the most important issue was the distribution of face masks of limited quantity. Therefore, the CECC established a digital system linked with the National Health Insurance IC Card to effectively and equally distribute the face mask for everyone.20,21 This system reduced the effort of acquiring face masks for daily use and prevent unnecessary stockpiles.

**Discussion**

The keys for successful early response in Taiwan include comprehensive and sensitive surveillance, rapid risk assessment, decisive action for border control. Event-based surveillance would be an important tool for detecting disease X. For novel diseases without vaccines or prophylaxis, NPIs will still be essential for early phase response. Healthy behavior surveillance, which means the monitoring and evaluation of the compliance and effectiveness of NPIs like contact tracing, quarantine, and other population-based measures like face mask use, will be an important issue for next-generation surveillance systems.

Precise risk assessment provides early alerts for timely decisions including expanding laboratory and mask production capacities for long-term response and classifying the risk level to prioritize the targets for action when resources have not yet in place. Most countries in the world were informed about the COVID-19 outbreak in Wuhan soon after the outbreak occurred. However, travel restrictions were not considered because of different assessment for the pandemic outbreak and the impacts caused by COVID-19. For far Asian countries, such as Singapore, South Korea, and Taiwan, took more proactive actions on COVID-19 outbreak because of the experience of SARS or MERES outbreak and the following response made the difference.22
The experience of Taiwan’s successful response demonstrates the importance of border control and quarantine which might play crucial roles in the early stage of a novel outbreak, especially when the reliable laboratory methods, effective treatment or vaccine have not been in place. Except for the immediate benefit of closing border, 14-day quarantine for inbound passengers not only help to isolate the imported cases in advance but also deterred unnecessary international trips; it might be one of the reasons why imported case numbers still remained low after lifting the border control in mid-June, 2020. How to use these measures to spare more time for the development of pharmaceutical interventions, should be a major issue in future pandemic outbreak preparedness and response strategy. Many studies showed quarantine will be more effective when implemented early and combined with other public health measures.\textsuperscript{23–25} The effectiveness to decrease case numbers depends on rapid and comprehensive case detection, compliance to the quarantine measures, and government’s enforcement.\textsuperscript{26} However, maintaining the high stringency of border control and quarantine policies always requires tremendous economical and societal costs, how to balance the benefits and impacts would be another task.

The direct involvement of digital technologies for infectious disease control may cause issues about violating human rights and privacy.\textsuperscript{27} The use of novel technologies should take a least human right-invasive approach, for example, the exposure notification systems established IOS and Android systems, or using technology to facilitate the data collection and monitoring. Furthermore, collection and use of these data should be stringently restricted to disease control purposes only, and the access period and destruction mechanism must be well formulated. In the very early beginning of outbreak response, the emergent actions might lack of comprehensive legislative support. However, more normalized legislative process and ethical discussion should be required when a long fight against COVID-19 pandemic would be expected.

Additionally, the experience of the Wuhan outbreak also emphasizes the value of the sharing and communication of epidemic intelligence on an international scale. To facilitate international public health risk information sharing and intelligence communication, Taiwan had constructed the International Health Regulation (IHR) Focal Point Office in 2007, which has been recognized by the WHO Director-General Office since January 2009. In the following years, Taiwan has been sharing information and reporting/referring cases with the WHO (IHR Office, Geneva) directly and international national focal points (NFP) such as the USA, Japan, the Republic of Korea, Canada, South-East Asian, and European countries through this channel, including reporting the event in Wuhan on 31 December 2019. Additionally, during the COVID-19 pandemic, an investigation summary of each imported case in Taiwan was sent to the NFP of affected countries for further analysis and investigation. Under this mechanism, Taiwan CDC has helped to detect early importation and subsequent spread of the virus in Europe.\textsuperscript{28} The development of Taiwan’s early response strategy also benefits from the sharing of the crucial epidemic intelligence and discussion with surrounding partners like Japan and the Republic of Korea.

Conclusion

After the SARS outbreak in 2003, Taiwan established comprehensive surveillance systems and play a key role in detecting the COVID-19 outbreak in Wuhan and the following early response. Timely border control and quarantine policy successfully slow down the domestic outbreak and saves more time for further preparedness. However, closing border with high social and economic impacts could not be a long-term solution when the pandemic outbreak continues. How to transit from early response to more sustainable strategies would be Taiwan’s challenge at the next stage.

Declaration of competing interest

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

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