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Perspective

Risk assessment for COVID-19 pandemic in Taiwan

Shu-Wan Jiana,1, Chien-Tse Kaoa,3, Yi-Chia Changa, Pi-Fang Chena, Ding-Ping Liuab,*

aEpidemic Intelligence Center, Taiwan Centers for Disease Control, Taipei City, Taiwan
bDepartment of Health Care Management, National Taipei University of Nursing and Health Sciences, Taipei City, Taiwan

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ABSTRACT

Background and objectives: Event-based surveillance and rapid risk assessment for acute public health events are essential in emerging infectious disease control. Since detecting the unusual signal in Wuhan in December 2019, Taiwan has been aligning risk management to policy planning via conducting regular risk assessments to combat the coronavirus disease 2019 (COVID-19). This article aims to provide some insights into Taiwan’s experiences and corresponding actions for the outbreak.

Results: The COVID-19 risk level in Taiwan was raised to “moderate-to-high” in mid-January 2020 when neighboring countries had reported cases and the human-to-human transmission became obvious. The risk level became “high” on 24 January due to China’s escalating epidemic situation and imposed a lockdown in Wuhan. We learned that the commander recognized the importance of risk assessments and considered advice from the experts was crucial in making the correct decision at the early stage of the crisis.

Conclusions: Given the surge of COVID-19 cases globally, understanding the evidence-driven mobilizations via detailed risk assessments in Taiwan may be an example worth considering for other countries. We believe that strengthening a global epidemic intelligence network and sharing information in a timely and transparent manner are essential for confronting new challenges of COVID-19 and other emerging infectious diseases.

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic significantly impacted the global health and economy. By 7 December 2020, there were more than 66 million people confirmed with COVID-19 globally (World Health Organization, 2020). Taiwan was expected to be one of the most affected countries due to its close relationship with China, both geographically and economically (Robert Koch Institute, 2020). Learning from the Severe Acute Respiratory Syndrome (SARS) outbreak, an extensive public health infrastructure has been established in Taiwan. With early detection of the outbreak in Wuhan via the event-based surveillance (EBS) system, followed by the rapid risk assessment and management, Taiwan could respond to COVID-19 early and avoid national lockdown in the following months. This article aims to provide some insight into Taiwan’s epidemic intelligence and risk assessment for the COVID-19 pandemic and how they resulted in proactive risk management.

Event-based surveillance and risk assessment methodology for COVID-19

Taiwan Centers for Disease Control (Taiwan CDC) adopted both manual screening and a real-time public opinion monitoring system (i.e. InfoMiner.io) to monitor international and domestic epidemic news worldwide at the country level and to generate alerts when acute public health events were detected. All relevant information and data detected by the EBS system were gathered from international organizations, government official websites, scientific journals, news, social media, and internet bulletin board from both domestic and international sources. Considering Taiwan’s proximity to China and previous epidemics in China, the EBS for China has been implemented particularly at provincial and city levels. In addition, Taiwan CDC used the risk assessment protocol published by the World Health Organization (WHO) and the European Centre for Disease Prevention and Control (ECDC) as a guide to perform daily risk assessments in response to the...
COVID-19 outbreak (World Health Organization, 2012; European Centre for Disease Prevention and Control, 2019). After filtration and validation of the information, risk assessment was divided into three qualitative aspects: risk of disease importation, risk of community outbreak, and impact on the country. Each aspect was given a low, moderate, or high risk level, and an overall risk level was assigned at the end. Political, economic, social and other factors were also considered in the context analysis. Based on the risk level and context analysis, Taiwan CDC would then devise appropriate responses against the outbreak and discuss with major decision-makers.

Since 18 January 2020, Taiwan CDC conducted daily risk assessments on each province of China based on the following factors: the outbreak magnitude, number of Taiwanese residents, numbers of direct flights to Taiwan, number of confirmed cases, case fatality, number of exported cases to other province(s), status of cluster infection, generation of disease transmission, and weekly traffic volume to-and-from each major city (Bogoch et al., 2020). A level-one epidemic area defines an area with confirmed cases of unknown source and disease exportation to other provinces, implying a sustained community transmission. A level-two epidemic area defines an area with third generation cases, over 400 confirmed cases, or rapid increase in the case volume (eg. doubled case volume from the previous day), implying community outbreak.

Based on the international situation and the understanding of disease transmission, the Central Epidemic Command Center (CECC) has applied scientific approaches to lift border controls gradually since 22 June 2020. Short-term business travellers who arrived from low- and low-intermediate risk countries with no travel history in the past 14 days prior to entering Taiwan were allowed for entry and shortened home quarantine period. Countries with less than ten daily new COVID-19 cases and less than one average daily new COVID-19 case per 1,000,000 in the past 14 days were listed as low risk level. Countries with 10 to 100 daily new COVID-19 cases and 1 to 5 average daily new COVID-19 cases per 1,000,000 in the past 14 days were listed as low-intermediate risk level. In addition, five indicators were used to assess the risk of COVID-19 importation from each country: 1. epidemic magnitude: averaged daily new COVID-19 cases and cases per million in the past 14 days; 2. epidemic trend: the proportion of cases with unknown source and clustering; 3.

Figure 1. The number of COVID-19 confirmed cases in Taiwan by date of reporting (1a) and by date of symptom onset (1b) during 30 December 2019 and 20 March 2020. The arrows show the response activities (1a) and the information supporting risk assessment for COVID-19 at the early stage of the COVID-19 outbreak (1b) in Taiwan, respectively.
Table 1
Risk assessment of COVID-19 between 31 December 2019 and 23 January 2020.

| Factors                          | Evidence and assessment                                                                 |
|---------------------------------|-----------------------------------------------------------------------------------------|
| Time period and risk level      | 31 December 2019 to 15 January 2020: Moderate                                             | 16 January to 23 January 2020: Moderate to high |
| Response in China               | 1. 30 December 2019: An emergency meeting regarding the management of atypical pneumonia of unknown etiology was held at major hospitals in Wuhan (Sina Corporation, 2020). 2. 31 December 2019: National Health Commission of the People's Republic of China appointed a group of experts to lead disease control in Wuhan (Sina Corporation, 2020). This might imply that the outbreak had reached a certain level and the province required help from the central government. 3. 5 January 2020: Every confirmed case was isolated. All medical institutions across Wuhan commenced active case finding and retrospective investigations. It was inferred that the outbreak might be expanding and human-to-human transmission was possible (Wuhan Municipal Health Commission, 2020). 4. 8 January 2020, Hong Kong classified COVID-19 as a notifiable infectious disease. | 1. 17 January 2020: Wuhan began fever screening for outbound passengers at airports, train stations, bus, and ferry terminals (SOHU, 2020). Exit screening is usually a mitigation measure for regions affected by sustained local disease transmissions. Therefore, it was evident that the virus had a certain degree of infectivity as China executed such measures to prevent the disease spread outside of Wuhan. 2. 20 January 2020: Mr. Xi Jinping’s instructions regarding the outbreak indicated a high degree of attention from the central government. He also mentioned that prevention and control measures must be undertaken during the Chinese New Year due to high travel volume in China. |
| Epidemiological evidence        | 1. 15 January 2020: Health officials in Wuhan mentioned that 30% of confirmed cases did not visit the Huanan seafood market. They also stated that infection could be transmitted via suspected cases and a family cluster was reported (Wuhan Municipal Health Commission, 2020), The Beijing News, 2020). Environmental samples in the market also tested positive for the virus. All the information alluded to the fact that transmission via humans was possible (Wuhan Municipal Health Commission, 2020). 2. 11 January 2020: The case with the earliest onset of symptoms was on 8 December 2019, indicating the outbreak has been circulating in the community for a period of time. | 1. 17 January 2020: The Chinese officials stopped mentioning whether confirmed cases had been to the Huanan seafood market and pointed out that cluster infections via human-to-human transmission were possible. 2. 20 January 2020: There were confirmed cases identified in Beijing, Guangdong, and Zhejiang. Some only had a short stay or no travel history to Wuhan. This indicated that the epidemic might have expanded to other provinces and cities. |
| Disease severity                 | 1. 30 December 2019: At least 27 patients with pneumonia were diagnosed with coronavirus at major hospitals (Wuhan Municipal Health Commission, 2020). 2. 11 January 2020: There were 8 (17%) severe infection and mortality cases when the evidence of human-to-human transmission was limited, indicating that the infection had a certain degree of disease severity (Wuhan Municipal Health Commission, 2020). | The whole population in Taiwan was susceptible to the novel coronavirus. If 17% of those infected developed severe symptoms and hospitalised, this could overwhelm the healthcare system. |
| Context analysis                 | Wuhan is a major transportation hub in central China with a population of 11 million. If the epidemic expanded, it could accelerate disease transmission to other provinces and cities. | Taiwan was particularly susceptible to a substantial impact because the timing was close to the Chinese New Year when there is usually a greater number of flight exchanges between China and Taiwan. |
| Property of the virus            | 1. 30 December 2020: Dr. Li Wenliang’s post showed a laboratory diagnostic report from Central Hospital of Wuhan, which identified the patient with pneumonia caused by the coronavirus. 2. 3 January 2020: Respiratory pathogens such as influenza, avian influenza, adenovirus, severe acute respiratory syndrome (SARS), and middle east respiratory syndrome (MERS) have been excluded, indicating the pathogen could be a novel virus (Chinese Center for Disease Control and Prevention, 2020). 3. 8–11 January 2020: The full viral genome sequencing was released on virological.org. This sequence confirmed that the Wuhan strain was a novel coronavirus similar to bat coronaviruses that were a precursor to SARS. The sequence analysis of receptor binding sites indicated that SARS-CoV-2 ACE-2-binding affinity for human respiratory epithelial cell entry was not inferior to SARS-CoV, elucidating the efficient human transmission. (The Wall Street Journal, 2020, Wu et al., 2020) | 20 January 2020: WHO reported the source of 2019-nCoV seems most likely from animals from, with some limited human-to-human transmission occurring close contacts. |
| Risk of case importation from Wuhan | 1. 13 January 2020: Thailand had the world’s first imported case from Hubei Province. The case with febrile illness was detected on the same day by thermal surveillance, indicating symptoms could be mild and patients can still travel (Bureau of Information Office of the Permanent Secretary of Ministry of Public Health, 2020). 2. 14 January 2020: Taipei has one of the greatest volumes of international arrivals from Wuhan following Bangkok, Hong Kong, and Tokyo. The importation of the case from Wuhan to Taiwan could be expected (Bogdans et al., 2020). | 1. 16 January 2020: Japan reported its first imported COVID-19 case from Hubei with no travel history to the Huanan seafood market. This supported the theory of human-to-human transmission. Taiwan and Japan have similar travel volumes to Wuhan, thus increasing the probability of disease importation to Taiwan after Japan reported its first imported case (Ministry of Health, Labour and Welfare, 2020). 2. 20 January 2020: Korea reported its first imported COVID-19 case. The onset of symptoms was on 18 January, indicating the community transmission was not interrupted after the shutdown of the Huanan seafood market in Wuhan. |
| WHO risk assessment              | 1. 9 January 2020: WHO stated that according to Chinese authorities, the novel coronavirus virus in question can cause severe illness in some patients and does not transmit readily | 1. 21 January 2020: WHO stated that cases continue to be reported from Wuhan City and other provinces in China. Additional investigations are needed to determine how the |
surveillance capacity: cumulative number of SARS-CoV-2 laboratory tests per 1,000,000; 4. regional situation; and 5. information transparency.

**Epidemic intelligence and risk assessment since the beginning of the COVID-19 outbreak until the activation of Central Epidemic Command Center (CECC)**

**The risk level from 31 December 2019 to 15 January 2020: Moderate**

On 31 December 2019, the real-time public opinion monitoring system sent an alert regarding a post on an internet bulletin-board that summarized an outbreak of pneumonia of unknown etiology in Wuhan, China. The article was convincing as Wuhan Municipal Health Commission subsequently released an urgent notice on managing the unknown pneumonia. Risk assessment soon commenced in the first week of January 2020 to accurately gauge the degree of response required for disease control (Figure 1). In early January 2020, COVID-19 was classified as a “moderate” risk to Taiwan. The scale of the outbreak would continue to rise, and the severity of the virus could not be underestimated due to multiple factors including epidemiology and context analysis (detailed risk assessment illustrated in Table 1). Back then, the evidence for high viral transmissibility in humans was not strong enough. Nevertheless, as the information was not clear in Mainland China, the disease control measures in Taiwan were all based on the notion that human transmission was possible (Lin et al., 2020). Since 5 January, Taiwan CDC reinforced quarantine practices and defined criteria for disease notification (Taiwan Centers for Disease Control, 2020a).

**The risk level from 16 January to 23 January 2020: Moderate-to-high**

On 16 January, the risk level was escalated to “moderate-to-high” on the risk assessment due to the outbreak expanding to other provinces in China and the detection of imported cases from China to other countries (Table 1). On 15 January, COVID-19 was listed as a notifiable disease. On 20 January, Taiwan CDC announced the activation of CECC. Additionally, disease notification criteria have been updated to include every patient with pneumonia and those who visited China within 14 days prior to the onset of symptoms. One day after the activation of CECC, Taiwan had its very first case of COVID-19.

**Monitoring epidemics in China and subsequent barring of all foreign travellers**

**The risk level from 24 January 2020 onward: High**

Ever since Shenzhen and Shanghai cities reported their suspected cases on 18 January, Taiwan CDC commenced daily risk assessment on each province of China. As China’s epidemic situation was escalating exponentially and Wuhan city officials prohibited all transports in and out of the city on 23 January, Taiwan CDC raised the risk level to “high” on 24 January. Progressively, Taiwan imposed travel restrictions on each province of China to minimise the social and economic impact. Quarantine measures and testing capacity in Taiwan were also improved during the period. Between 2 February and 14 February, Taiwan CDC listed Hubei, Guangdong, Zhejiang, and Henan Provinces as level one epidemic areas. They were classified as notifiable epidemic regions as the community outbreak control would be difficult in those regions. The rest of China was listed as level-two epidemic areas. Travellers coming from level-one or level-two epidemic areas were subjected to home quarantine for 14 days. Taiwan took a series of border control measures and eventually banned the entry of non-citizens who had been to mainland China, Hong Kong or Macau within the past 14 days on 7 February.

Taiwan had a wave of imported cases from Europe and the U.S. since the beginning of March 2020 (Taiwan Centers for Disease Control, 2020b), indicating a pandemic, and the epicenter had gradually moved from Asia to Western nations including the U.S. and Europe. WHO officially described the novel coronavirus as a pandemic on 12 March. The CECC raised travel notice to Level 3 (warning) to all Schengen countries on 14 March and implemented a travel ban on all foreign citizens to minimize the extent of disease importation starting 19 March. All returned travellers are subject to a 14-day period of home quarantine after entering Taiwan.

**Re-evaluation of COVID-19 risk from international arrivals**

Since mid-June, Taiwan has re-opened its border for essential travel and conducted specific quarantine measures for different countries based on the assessment of their importation risks. Based on the five indicators used to assess the risk of COVID-19 importation from each country, the CECC announced the updated list of countries/regions eligible for shortened quarantine periods in Taiwan fortnightly (Figure 2).

**Discussion**

Taiwan had learned valuable lessons from the SARS and H1N1 influenza outbreaks, which enabled Taiwan to better prepare its responses against the COVID-19 pandemic. On 23 January 2020, level 2 of CECC was activated due to the fact that the first case of COVID-19 was confirmed. Dr. Shih-Chung Chen, the Minister of Health and Welfare, served as the commander of the CECC to coordinate and mobilize resources from a cross-ministry perspective, including the ministries of interior, transportation, foreign affairs, economics, labor, education, defense, etc. as well as private stakeholders to fight against COVID-19. The activation of CECC
 enabled the commander to make disease control related policies based on the risk assessments and to coordinate efforts across ministries in a whole-of-government approach. Similarly, South Korea established the Central Epidemic Control Headquarters on the same day to achieve policy coherence and increase efficiency in disease control (Kim et al., 2020). This is important as governments were confronting the pandemic with limited resources and fiscal space. It was also crucial that the commander recognized the importance of aligning risk management to control measures via conducting regular risk assessments by multidisciplinary officials and experts on epidemiology, virology and medicine in order to make difficult decisions under uncertainty at the early stage of the crisis. Furthermore, based on the fact that the serial interval of COVID-19 can be as short as 4 to 5 days (Du et al., 2020), the decision-makers were vigilant that the timeliness of risk assessment, risk management, and further response plans was vital. Before WHO declared that COVID-19 constituted a public health emergency of international concern (PHEIC), Taiwan’s measures were based on the notion that human-to-human transmission was possible and onboard quarantine inspection of direct flights from Wuhan commenced as early as 31 December 2019. The first imported case was identified via this measure. In late January, although it became apparent that novel coronavirus cases were rising rapidly in China, and cases were detected in some countries in Asia, Europe, and America, the risk perception and intervention intensity differed between Asia and the West. Asia’s experience with SARS and MERS could play a key role in this phenomenon. In June, Taiwan progressively lifted international travel measures based on the risk assessments, as countries strove to find a delicate balance between reviving the economy and remaining stringent border control measures. However, as COVID-19 cases have increased exponentially in Europe and other countries since September, Taiwan is considering stricter control measures in response to the new COVID-19 surge. The parameters and metrics for identifying risk levels and the corresponding response may differ between countries depending on the aims of their interventions and the scale of the epidemics.

Robust EBS mechanisms to capture real-time epidemic intelligence were essential throughout Taiwan’s response activities. Given the advantage of similar language and culture between Taiwan and China, the real-time public opinion monitoring system used by Taiwan CDC was customized to screen epidemic information from China. The system generated real-time alerts about the early outbreak in Wuhan right after the first piece of information regarding the outbreak was posted on the Internet. This had led to a series of risk assessments and actions. It also demonstrated the importance of establishing a real-time EBS system, particularly for emerging and unknown diseases. However, language barriers and inadequate epidemic information from distant countries could pose great challenges in epidemic intelligence. For example, Taiwan CDC did not expect the rapid exponential increase of COVID-19 cases in Europe in March. On the contrary, it would be particularly challenging for non-Mandarin speaking nations to gather unofficial information from various media sources from each province/city in China. Strengthening a global epidemic intelligence network and sharing information in a timely and transparent manner are essential for COVID-19 control. A network of EBS systems which share early warning signals and expert opinions of infectious disease with pandemic potential could help early risk detection and response.

Conclusion

During the COVID-19 pandemic, early recognition via the EBS systems and conduction of risk assessment formed the basis of risk identification and management in Taiwan. Importantly, they were used as strong references and prompt decisions were made accordingly. The painful lessons from the past epidemics paved the way for Taiwan’s containment of COVID-19. As the COVID-19 pandemic has persisted for more than half a year, a delicate balance between reviving the economy and keeping stringent border control is a crucial task for every country. We share our experience at the early stage of the pandemic and during de-escalation, with a view of hoping that information sharing and international
collaboration could be reinforced in confronting new challenges of COVID-19 and other emerging infectious diseases in the future.

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The authors declare that they have no known competing financial interests or relationships that could have appeared to influence the work reported in this paper.

**Ethical approval**

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