Enhancing Data Linkage to Break the Chain of Coronavirus Spread: The Taiwan Experience

Wei-Cheng Lo, Fu-Chung Wang, Li-Yin Lin, Hong-Wei Jyan, Hsuan-Chien Wu, Yao-Liang Huang, I-Ming Parng, Hung-Yi Chiou

Submitted to: Journal of Medical Internet Research
on: September 13, 2020

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Abstract

Digital technology has been widely used in health care system and disease management, as well as controlling the spread of coronavirus. As one of the most successful countries in fighting against COVID-19, Taiwan greatly and successfully use digital technology to strengthen the COVID-19 epidemic prevention. Since we have a well-established National Health Insurance System (NHIS), which provides a great opportunity to develop a nation-wide data linkage model in an agile way. This Viewpoint provides an overview of the application of data linkage models in COVID-19 combat strategies in Taiwan, including NHIS centralized data linkage systems and “from border to community” information-driven data linkage systems during the COVID-19 pandemic. Also, we discuss that science technologies play a dual role of being an “enabler” and a “driver” in early prevention. Lastly, Taiwan’ experience in applying digital technology to enhance COVID-19 control will highlight lessons and opportunities for other countries.

(JMIR Preprints 13/09/2020:24294)
DOI: https://doi.org/10.2196/preprints.24294

Original Manuscript

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Summary word count: 152 words
Text word count: 3467 words
Tables: 1; **Figures:** 4

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Summary

Digital technology has been widely used in health care system and disease management, as well as controlling the spread of coronavirus. As one of the most successful countries in fighting against COVID-19, Taiwan successfully use digital technology to strengthen the COVID-19 epidemic prevention. Since we have a well-established National Health Insurance System (NHIS), which provides a great opportunity to develop a nation-wide data linkage model in an agile way. This Viewpoint provides an overview of the application of data linkage models for strategies in combating COVID-19 in Taiwan, including NHIS centralized data linkage systems and “from border to community” information-driven data linkage systems during the COVID-19 pandemic. Also, we discuss that science technologies play a dual role of being an “enabler” and a “driver” in early prevention. Lastly, Taiwan’ experience in applying digital technology to enhance COVID-19 control will highlight lessons and opportunities for other countries to handle the COVID-19 situation better.

Introduction

Worldwide, the novel coronavirus disease 2019 (COVID-19) pandemic has led to 60 million confirmed cases, 1.4 million confirmed deaths as of November 30th, 2020, and the numbers are still rising to date. When China had its first reported COVID-19 outbreak, an early study conducted by Johns Hopkins University in January had forecasted the number of imported cases arriving at each airport inside and outside mainland China, and indicated that Taiwan would be the second most affected country by the COVID-19 virus due to the close economic and transportation links with mainland China [1]. However, Taiwan has defied those expectations. Up until November 30th, 2020, Taiwan had only 679 COVID-19 cases, 7 confirmed deaths, and only 1.03% case fatality rate (CFR). Taiwan has been performing well in combating COVID-19 hitherto and this may be attributed to the hard lessons learned from the 2003 Severe Acute Respiratory Syndrome (SARS) outbreak. The SARS experience had prepared the Taiwanese government and citizens to respond to the COVID-19 pandemic more promptly and cautiously. Countries who had experience with SARS pandemic prevention prior (with over 100 confirmed cases and over 10% CFR) also performed well in combating the coronavirus this time [2, 3].

During the 2003 SARS outbreak in Taiwan, the infected persons hided their travel history to outbreak areas to escape the quarantine thus being a loophole at the border control. Furthermore, there was no regulation to prevent potentially infected people from entering hospitals without declaring their risk, resulting in the shutdown of a regional hospital and partial service closure at a medical center [4, 5]. Furthermore, the face mask supplies in the market also faced a shortfall and caused panic in face mask purchasing in the community. The devastating experience with the SARS outbreak had led Taiwan to be extremely cautious when China initially announced its COVID-19 outbreak on Jan.20th, 2020. Taiwan quickly established the Central Epidemic Command Center

(CECC). The well-developed infrastructure of the CECC allows quick strategic planning, epidemic analysis, and prevention, as well as unifying medical resources to successfully contain the outbreak and minimize the infection [6]. Meanwhile, digital technology (DT) plays an essential role in combating the COVID-19 pandemic, especially its dual roles as an “enabler” and “driver”, provided tremendous help in containing the COVID-19 virus, which was not well exploited during the SARS pandemic.

In the face of the coronavirus pandemic, all countries worldwide deployed public health strategies including border control, control of community transmission, enhance personal hygiene, and prevent nosocomial infection, and Taiwan was no exception. This article aims to illustrate how data linkage was used to strengthen epidemic prevention and to explore the role of DT plays in public health and disease control strategy. Based on Taiwan’s successful pandemic control experience, two major data linkage models were proposed in COVID-19 control. Furthermore, the application of data linkage models will be discussed.

Apply current National Health Insurance System (NHIS) to enhance epidemic prevention and control.

Taiwan’s National Health Insurance System (NHIS) initially rolled out in 1995 with the National Health Insurance Administration (NHIA) being the only insurer. Since the NHIS was completely information-driven, 90% of the hospitals and clinics had used the electronic-based reporting system to claim medical expenses. Currently, these services are fully automated and have been running smoothly for years. For security reasons, the virtual private network (VPN) is used to strengthen data security while the information is being processed by the internet. Once the NHIA had collected reported and complied all medical expenses into the “centralized database”, big data was used to automatically review and process all medical claims received from hospitals and clinics. As a benefit, Taiwan was able to be the country with the lowest administration cost for NHIS worldwide [7, 8]. In addition, NHIA issues National Health Insurance IC cards (NHI IC card) as an insurance certificate. In general, the Taiwanese citizens present the NHI IC card during doctor’s visits. The NHI IC card enables physicians to obtain the most recent medical records regarding the patient. Moreover, detailed past medical records and medication use can also be accessed by linking to a medical cloud information exchange system, the MediCloud. Under the NHIS, two important pandemic preventive features were established: travel history tracking and the mask-rationing plan for purchase as shown in Figure 1.

Travel History Tracking

At the early stage of the CECC establishment, the presence of fever, cough, as well as other respiratory symptoms, travel history, occupation, contact history, and cluster exposure were used as the criteria for case reporting and screening. In addition to the existing pandemic reporting and screening procedures, towards the end of January 2020 (also known as Lunar New Year for Asian-Pacific areas), the CECC decided to utilize the MediCloud system from NHIS to provide inquiring service regarding patient's travel history. MediCloud system (previously known as PharmaCloud) had been expanding its services and functions to provide patient information (i.e. disease diagnosis, examinations, laboratory testing, and medication) to hospitals and clinics since its initiation in 2015. After years of promotion and system advancement, the usage of MediCloud is currently over 99% and MediCloud has become the essential platform for information sharing among medical institutions. Once the interface linkage was established between the National Immigration Agency (NIA, belonged to Ministry of the Interior) and NHIA, the travel information database was integrated with medical records within just a few days. Now the NHIA has been able to provide inquiring service of travel history in infected countries or regions. In response to the progression of the COVID-19 pandemic, the features of querying wider ranges of travel history and occupations were included (Figure 2). These features contribute greatly to the prevention of nosocomial infections and enable timely screening to prevent the pandemic outbreak. Front-line medical workers are able to spot potential infected individuals based on patients' travel history and reported symptoms with the aid of real-time alerts from the integrated information system and take appropriate steps to adequately protect themselves from COVID-19 virus.

Name-based mask-rationing system for purchase

At the beginning of February 2020, the CECC announced that daily production of face masks was around 2 million, which was way below the total population of Taiwan (around 23 million). Meanwhile, China also proceeded with purchasing large amounts of face masks in response to the COVID-19 pandemic. Since the Taiwanese people had experiences with the SARS pandemic, people in some areas started stocking up face masks at home to avoid shortage [9]. In response to the face mask shortfall, the government began to increase face mask production to ensure all citizens have equal access to good-quality face masks. The policy that the government deployed "name-based mask-rationing system", was inevitable to ensure fair distribution of face masks in the community. Since all insurees (including legal foreign workers in Taiwan) obtain an NHI IC card, the CECC commanded the NHIS to contract pharmacies to link with MediCloud system so that the policy of "three face masks per week per individual" can be executed for all that are insured. The policy

utilized the information that the NHI IC card provides to verify and control the allocation of face masks to ensure that everyone has access to face masks for basic protection against COVID-19. Furthermore, at the beginning of March, the CECC had announced a payment mechanism where the public can utilize kiosks to reserve face masks, pay the fees, and pick up the face masks in preference to either local convenience stores or pharmacies. The Taiwanese local manufactures have been able to increase face mask production; hence, the purchasing policy was modified by the CECC to "nine face masks every two weeks per individual" in early May. Starting on June 1st, the public was allowed to make more purchase if needed besides the primary rationing.

The current NHIS's infrastructure allows the aforementioned functions such as travel history tracking and executing a "name-based mask-rationing system" policy thus all pandemic prevention strategies given by the CECC can be implemented in a timely manner. The establishment of the NHI IC card, MediCloud, and VPN were mostly completed after the SARS outbreak in 2003. The original purpose was not for pandemic control, but for the Taiwanese citizens to utilize medical services at their convenience. The original purpose of the establishment of the NHI IC card was to avoid medical service abuse by the public and to enhance medication safety by using information technologies to share information amongst hospitals, clinics, and pharmacies rather than pandemic control. Meanwhile, this "centralized" data linkage structure becomes the key enabler for the government to carry out epidemic prevention strategies.

Establish a pandemic preventive system from border to community

Towards the end of January 2020, the CECC decided to asked passengers coming from China, Hong Kong, and Macau to follow home quarantine procedures. The procedure requires that passengers receive a home quarantine notice once they reach the border (both traveling by air and sea). Both the civil affairs department and the health department could be informed with lists of people who require home quarantine in their responsible areas. The civil affairs personnel will check on those who are in home quarantine regarding basic living and health needs, and the health department will arrange medical treatments if needed.

Information-driven system planning

Due to the lack of assistance from DT, the manpower required to carry out those surveillance duties was tremendous and ineffective in the beginning. For instance, the airport staff needed to identify those who require home quarantine within the 70,000 passengers entering the country each day.

Therefore, the airport needed to recruit a large number of health officers or temporary assistants to carry out verification duties. According to the infectious disease prevention and treatment law, the duty of performing home quarantine is fulfilled by civil affairs personnel from the Ministry of Home Affairs and local government. The health officers who are responsible for COVID-19 testing at the airport collected all the information on paper, performed online data entry, and the information was sent out from the health department to the Ministry of Home Affairs and then passed on to the local government. The local government passed the information regarding COVID-19 testing results to the chief of the village and the chief will check and assist those who are in home quarantine. Those who violate home quarantine procedures are subject to administrative penalties by the health administrative system. Many government employees are under extreme pressure about mishandling COVID-19 related tasks and causing loopholes in the epidemic prevention system during the pandemic. The delay of information received by the local government employees, misinformation regarding personal information such as telephone number and address, quality of information, and efficiency may all contribute to the pressure felt by the government employees.

By the end of January 2020, the CECC had begun to improve data quality and efficiency and try to improve sharing correct personal information such as home address, phone number, cell phone number, and the start date of home quarantine between different government departments. As an information center, the CECC has established both the information flow and relevant application system to allow information circulating from the border to the community. Due to the fact that 80% of Taiwanese people are smartphone users, smartphones were being used as the main tool to keep track of individuals. A mobile app was not a choice for the application selection regardless of the smartphone system (iOS or Android) since it may take a considerable time for approval. Nevertheless, more time may be required for program correction. Therefore, the option of using a mobile app was eliminated as it was time-consuming during the critical outbreak.

Establishment of the information-driven system

The information-driven system was ready for launch after 2 weeks of brainstorming ideas to the completion of the entire system. In the middle of February of 2020, the information system became available and allowed data linkage among border control and local government services with Advance Passenger Information System (APIS) from NIA and Household Registration Information from the department of household affairs (also belonged to the Ministry of the Interior) for the management of home quarantine cases (Figure 3). For instance, the information system will ask all inbound passengers to use smartphones to scan a specific QR code prior to departure and fill out

personal information, health status, travel history, cell phone number, and public transportation needs. Before the aircraft reaches the gate, passengers will receive text messages regarding the information on home quarantine notice and health declaration certificate. If passengers report symptoms related to COVID-19 under health status, the health personnel will proceed with testing immediately and arrange for medical treatment. If passengers indicate the need for public transportation, the arrangement will be made. At present, there are on average 40,000 travelers arriving in Taiwan every day and our information system has been working well in entry control.

The immigration information can be delivered timely to the home quarantine management system, which is based on the regional joint defense concept to directly assign people who require home quarantine to the village, which avoids lengthy process of information transfer. In the beginning when the system was established, issues such as the submission of incorrect contact information appeared. The village-based civil affairs personnel (such as village officials) are responsible for confirming if the individual has returned to the correct home quarantine location; if not, all the other possible addresses or phone numbers may be used to track the individual down. If needed, the civil affairs personnel will check on the individual in person to ensure the individual stays at the designated quarantine location. The civil affairs personnel from different villages will also assist each other to carry out the surveillance duty. During the 14-day home quarantine period, the civil affairs personnel will provide home care services to the quarantined individuals based on the address and contact number that appear in the system. The home care services provided by the civil affairs personnel are often delivered to the individual through smartphones, which will allow a trace of records for future reference. If there is an incidence of violation of the home quarantine case, the CECC can work with phone service providers to send out timely text messages to remind the individual to return to their designated home quarantine location.

Merging of information-driven system and instant messaging apps

As the system is functioning better each day and the accuracy of information continues to improve, yet, to initiate full border control still remains a challenge. On March 19th 2020, CCEC announced that all travelers entering Taiwan will need to fulfill the home quarantine requirement. Although on average there were only around 7,000 travelers entering Taiwan each day, the number of home quarantine cases was still rising significantly (maximum 50,000 people/day to be monitored), and this certainly adds tremendous pressure on the local civil affairs personnel (Figure 4). The CCEC used the media as a channel to advocate and invite the citizens to use the instant messaging app (LINE) and add LINE Bot as a friend. Once obtained the consensus from the home quarantine cases,

the local civil affairs personnel then can use LINE app to follow up on home quarantined individuals regarding self-health management and personal needs on a daily basis. According to a survey done in mid-May 7100 home quarantined Taiwanese people using the LINE app were sampled. It showed that chatting with LINE Bot and chatting with local civil affairs personnel each scored 8.68 and 8.56 respectively on a scale of 10 (0 being complete unsatisfactory and 10 being very satisfied).

Until June 30th 2020, within the confirmed 447 cases, 356 cases (80%) were imported, and only 55 local cases (12%) plus 36 confirmed cases (8%) from navy clusters. For the imported cases, 141 infected individuals tested positive at border arrival, 150 infected individuals tested positive during 14-day quarantine, and the rest of 65 individuals tested positive during cluster quarantine, home quarantine, or isolation (Table 1). The information-based epidemic control system was the main "driver" to successfully block the COVID-19 virus at the border and away from the community. The local rate for being penalized for violating the home quarantine policy was lower than 0.5% (720/175,720 people).

Recommendation and Discussion

From the perspective of using data linkage to enhance pandemic control, the success of COVID-19 control in Taiwan was analyzed and that could be attributed to two main data linkage models. These two main models enhance and improve four key public health strategies in Taiwan, including border control, eliminate community outbreak, enhance personal hygiene, and avoid nosocomial infections. Through data linking among NHIS and other departments, Taiwan was able to secure the supply of face masks and avoid nosocomial infections, which have been described by previous studies [10, 11]. The efficiency of the "centralized" data linkage model can be optimized as long as the integrity of the database is sufficient. Moreover, the range of travel history and the traveler's identity can be expanded as the pandemic progresses. The amount of allowance to purchase face masks and participating vendors can also be adjusted as needed. Overall, it is much feasible to have the aforementioned flexibilities in a country like Taiwan where the national health insurance system demonstrates great functionality/performance. Unlike Taiwan, the United States has multiple insurance systems. Nevertheless, it's still feasible to use existing online medical networks to create similar data linkages after additional works. From the border to the community information-oriented prevention system is considered as a type of "downstream supply chain" of data linkage, and the key to success is attributed to the accuracy and timeliness of the data [6, 12]. For instance, for people who require home quarantine, within the first hour or two after arrival, the information should be sent directly to the civil affairs personnel of the appropriate residential area. The process can significantly ensure information is received in a timely manner and avoid any flaws in epidemic

prevention. It is essential to implement the correct system at the right time to reinforce border management and prevent community outbreak. Therefore, using the agile approach instead of the traditional approach in building the correct system is preferable during the COVID-19 outbreak.

Similar to other countries that rely heavily on information technologies, it is essential to find a balance between pandemic prevention and personal data protection. Although in general the public agrees and obeys necessary pandemic control policies despite the concern of personal data protection. Unlike Taiwan, South Korea implements a law allowing the government to reduce the level of protection for personal data during - critical pandemic [13]. What the Taiwanese government does is apply the current Infectious Disease Control Act and Personal Data Protection Act and openly disclose the prevention measures that are required to be followed by all travelers entering Taiwan. On May 28th, 2020, CECC has announced guidelines for contact-information-based measures and data collection in response to the COVID-19 outbreak to ensure personal data protection and facilitate outbreak investigations. On the other hand, Taiwan chooses to use a less privacy-sensitive DT approach, such as using smartphone base station tracking instead of real-time GPS technology to monitor people who are in home quarantine or home isolation. Furthermore, a proposal of eliminating all the unnecessary electronic records and linkages after the pandemic has been approved/endorsed/authorized at the legislature, which can also be adapted by other countries.

Currently, Taiwan has been free from local COVID-19 days for more than 200 days. The CECC cautiously reopened the economy step by step. As the restrictions on social activities are being lifted gradually, the “from border to community” information-driven prevention system continues to strengthen border control, ensuring foreign confirmed cases can be isolated immediately to minimize contact with others and compiling information on the number of screenings performed and the number of confirmed cases at the airport daily. Furthermore, the system can also help to analyze and understand the changes in confirmed cases overseas once border restrictions are lifted and adjustments are made to border control policies accordingly. Also, in the post-COVID era, new technology-driven practices will now form part of ‘the new normal’. Government and organizations need to adopt new DT systems during the pandemic and think about how to normalize these new practices. These new technology-driven work practices are usually implemented during the most severe time under highly pressured conditions and often without former experience or training. Taiwan’s experience therefore can be considered as a valuable reference for other countries to better understand how DT can be embedded within the government practices and form the ‘new normal’ in the post-COVID era.

In conclusion, the integrity, accuracy, and timeliness of data linkage and DT infrastructure ensure that the essential public health interventions, such as border control, quarantine, case detection, contact tracing, and universal surgical mask-wearing can be effectively implemented, and become the foundation of the highly successful COVID-19 pandemic response in Taiwan.

Acknowledgments

We appreciate the support from Department of Information Management and Centers for Disease Control at the Ministry of Health and Welfare, Department of Cyber Security of Executive Yuan, and National Immigration Agency at the Ministry of the Interior.

Competing interests

None to declare

Authors' Contributions

All authors contributed substantially to the work presented in this paper. IMP and HYC conceived and designed the study. HWJ, HCW, and YLH prepared the figures and tables. WCL, FCW, and LYL wrote the first draft of the manuscript. All authors contributed to the interpretation of data, critically revised the manuscript, and approved the final manuscript.

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Figures

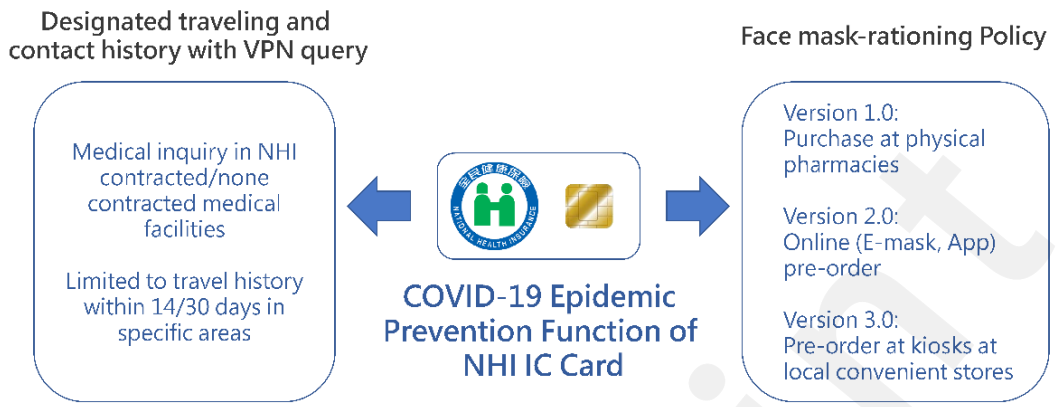

Figure 1. Diagram of the NHI IC Card usage in COVID-19 epidemic prevention

NHI IC card: National Health Insurance IC cards

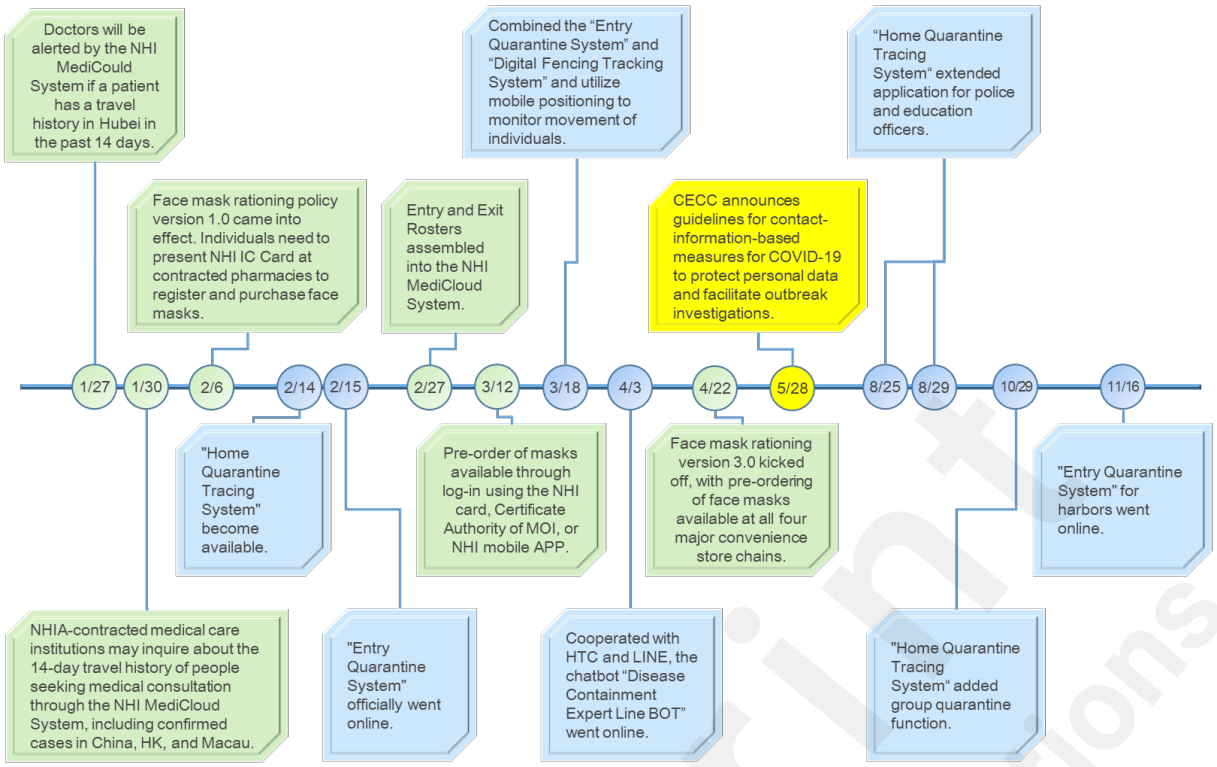

Figure 2. Timeline of technology usage in COVID-19 epidemic prevention in Taiwan.

Green blocks represent the launching date of travel history inquiry system and name-based mask-rationing system, blue blocks represent the procedures and services for border control and home quarantine system, and yellow block is the date of that CECC announces guidelines for contact-information-based measures and data collection.

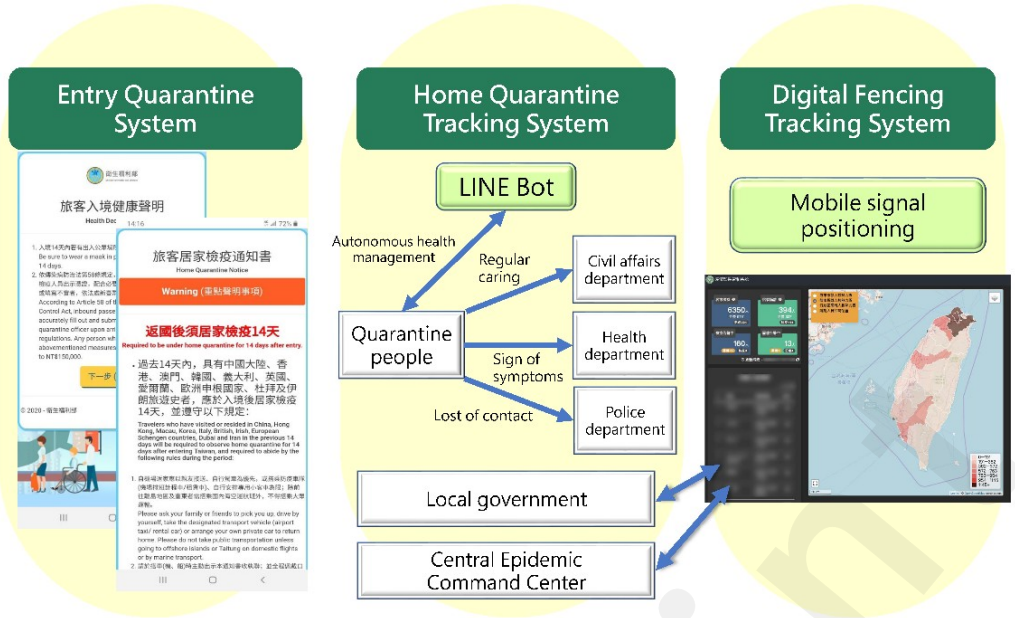

Figure 3. Diagram of border control and home quarantine system

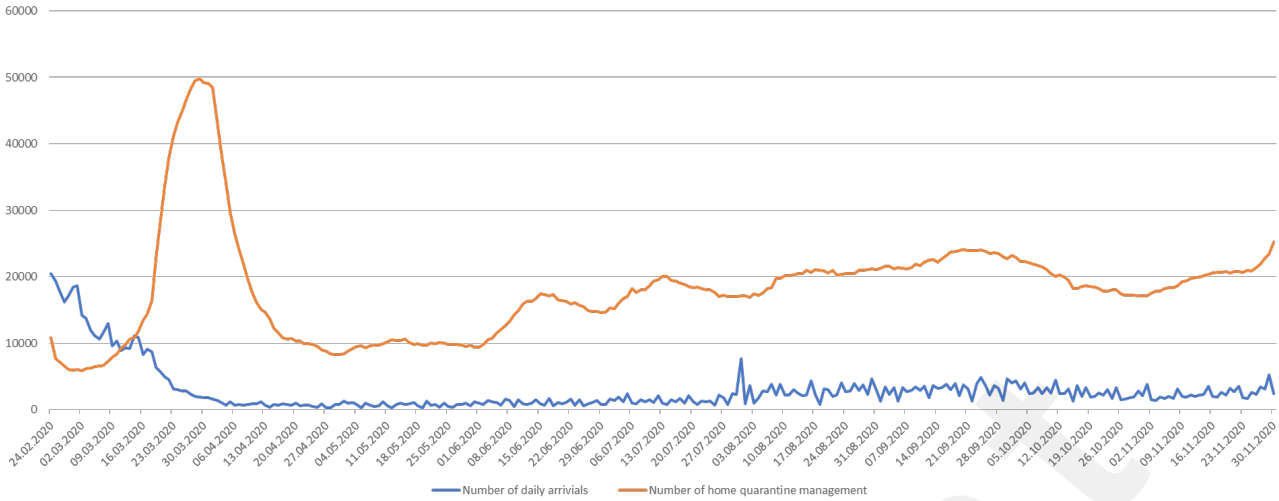

Figure 4. Number of daily arrivals and home quarantine management in Taiwan. (Data was collected until November 30th, 2020)

Table 1. Source of confirmed COVID-19 cases in Taiwan

Data was collected until November 30th, 2020

Number of Testing	Confirmed cases (test positive rate)	Imported cases (percent of total confirmed cases)	Locally acquired (percent of total confirmed cases)	Navy crew members aboard the Panshi Fast Combat Support Ship (percent of total confirmed cases)

110,685	679 (0.6%)	588 (86.6%)			55 (8.1%)	36 (5.3%)
		Immigration testing	During home quarantine	Others		
		232 (39.5%)	207 (35.2%)	149 (25.3%)		

Supplementary Files

Figures

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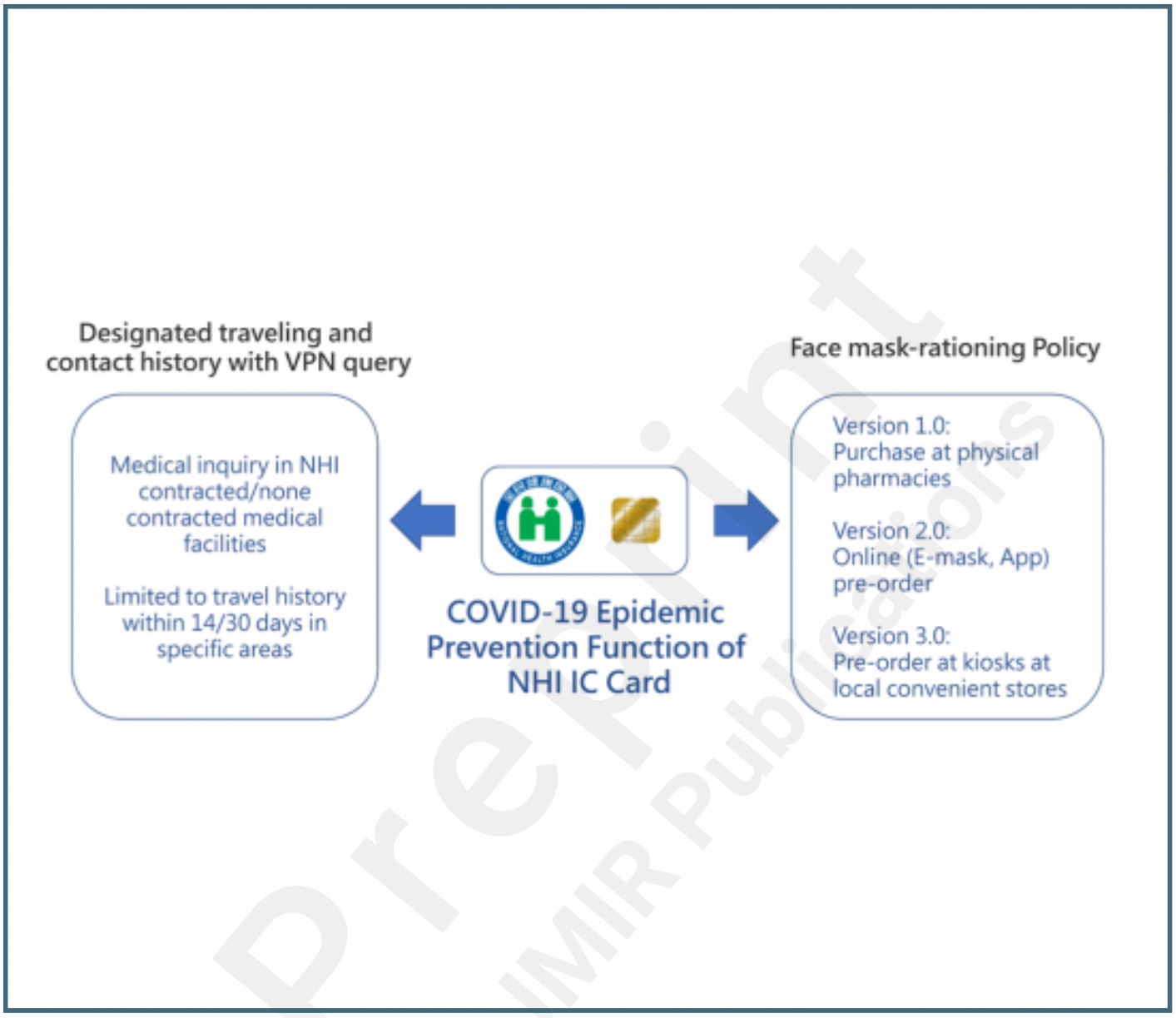

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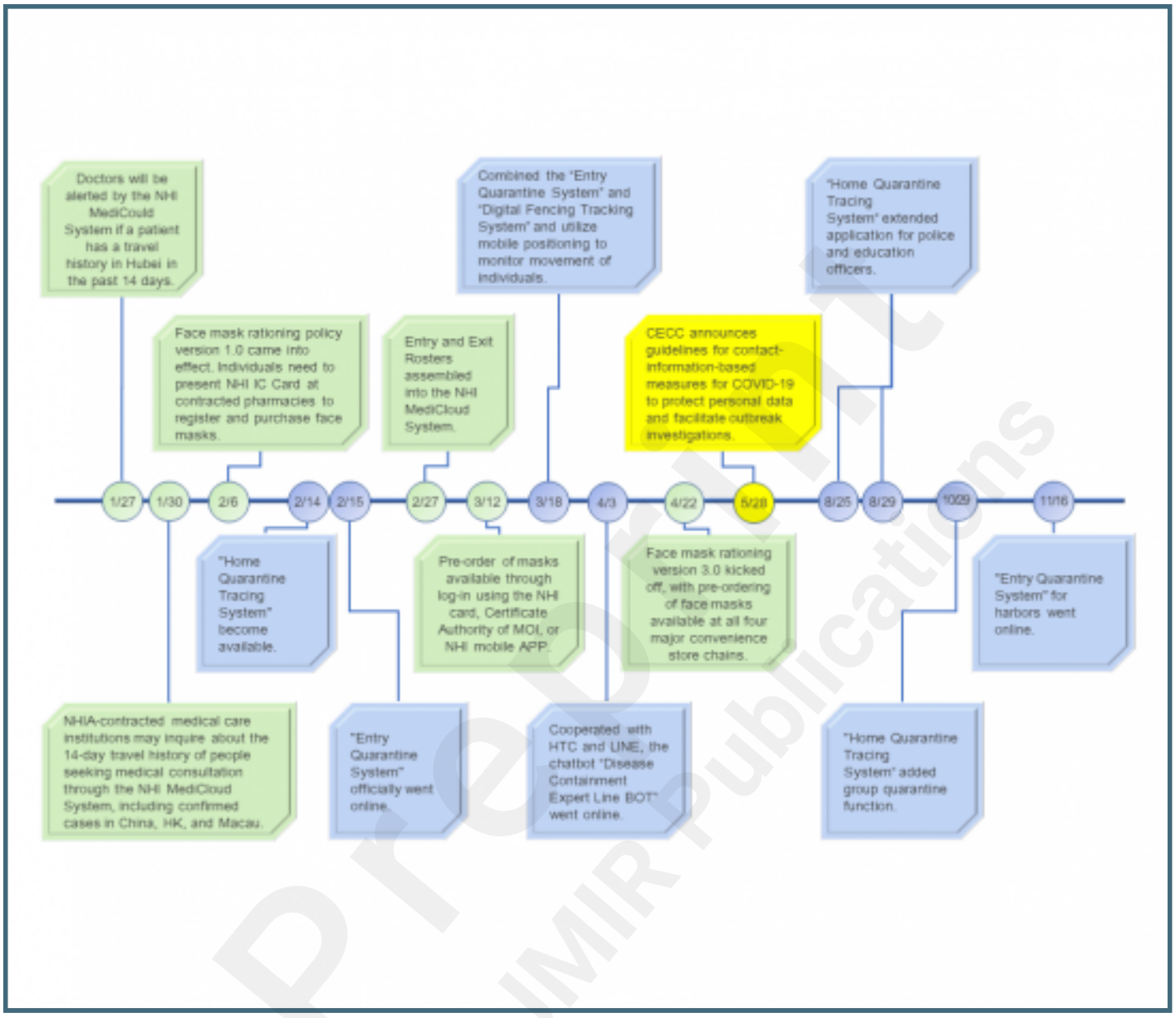
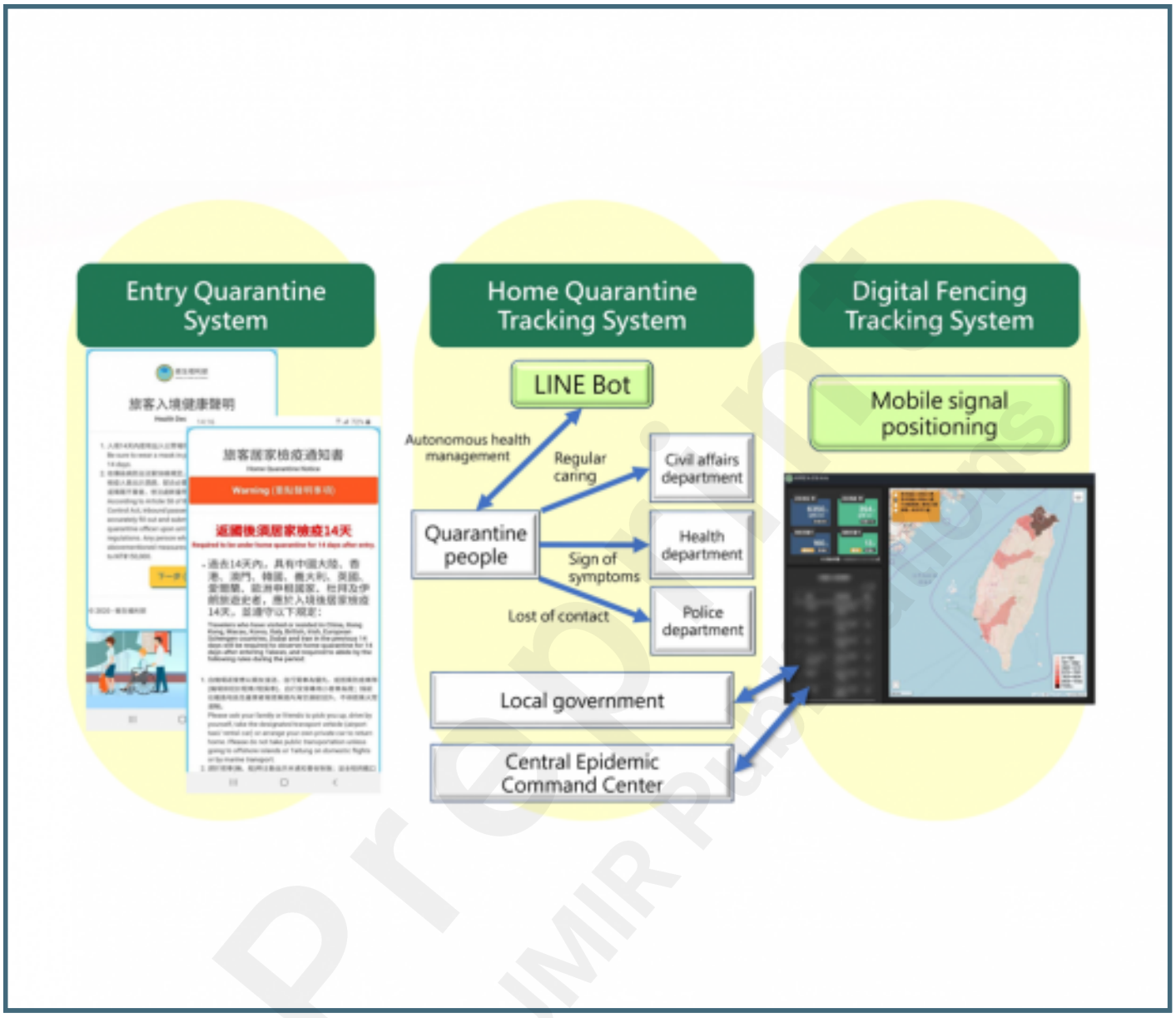

Doctors will be alerted by the NHI MediCould System if a patient has a travel history in Hubei in the past 14 days.
Face mask rationing policy version 1.0 came into effect. Individuals need to present NHI IC Card at contracted pharmacies to register and purchase face masks.
Entry and Exit Rosters assembled into the NHI MediCloud System.
Combined the "Entry Quarantine System" and "Digital Fencing Tracking System" and utilize mobile positioning to monitor movement of individuals.
CECC announces guidelines for contact-information-based measures for COVID-19 to protect personal data and facilitate outbreak investigations.
"Home Quarantine Tracing System" extended application for police and education officers.
1/27
1/30
2/6
2/14
2/15
2/27
3/12
3/18
4/3
4/22
5/28
8/25
8/29
10/29
11/16
"Home Quarantine Tracing System" become available.
Pre-order of masks available through log-in using the NHI card, Certificate Authority of MOI, or NHI mobile APP.
Face mask rationing version 3.0 kicked off, with pre-ordering of face masks available at all four major convenience store chains.
"Entry Quarantine System" for harbors went online.
NHIA-contracted medical care institutions may inquire about the 14-day travel history of people seeking medical consultation through the NHI MediCloud System, including confirmed cases in China, HK, and Macau.
"Entry Quarantine System" officially went online.
Cooperated with HTC and LINE, the chatbot "Disease Containment Expert Line BOT" went online.
"Home Quarantine Tracing System" added group quarantine function.

Untitled.


Entry Quarantine System
旅客入境健康聲明
旅客居家檢疫通知書
Warning
返國後須居家檢疫14天
Home Quarantine Tracking System
LINE Bot
Autonomous health management
Regular caring
Civil affairs department
Quarantine people
Health department
Sign of symptoms
Lost of contact
Police department
Local government
Central Epidemic Command Center
Digital Fencing Tracking System
Mobile signal positioning

Untitled.