International Journal of Infectious Diseases 101 (2020) 348–352

Contents lists available at ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Perspective

Contact tracing with digital assistance in Taiwan's COVID-19 outbreak response

Shu-Wan Jian[a], Hao-Yuan Cheng[a], Xiang-Ting Huang[b], Ding-Ping Liu[a,c,*]

[a] Epidemic Intelligence Center, Taiwan Centers for Disease Control, Taipei, Taiwan
[b] Taipei Regional Control Center, Taiwan Centers for Disease Control, Taipei, Taiwan
[c] Department of Health Care Management, National Taipei University of Nursing and Health Sciences, Taipei, Taiwan

ARTICLE INFO

Article history:
Received 14 August 2020
Received in revised form 27 September 2020
Accepted 30 September 2020

Keywords:
Contact tracing
COVID-19
Digital tool
Outbreak response
Coronavirus

ABSTRACT

Aim: Comprehensive case investigation and contact tracing are crucial to prevent community spread of COVID-19. We demonstrated a utility of using traditional contact tracing measures supplemented with symptom tracking and contact management system to assist public health workers with high efficiency.
Methods: A centralized contact tracing system was developed to support data linkage, cross-jurisdictional coordination, and follow-up of contacts' health status. We illustrated the process of how digital tools support contact tracing and management of COVID-19 cases and measured the timeliness from case detection to contact monitoring to evaluate system performance.
Results: Among the 8051 close contacts of the 487 confirmed cases (16.5 close contacts/case, 95% CI [13.9–19.1]), the median elapsed time from last exposure to quarantine was three days (IQR 1–5). 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 via contact tracing (88%) might reduce the R0 to under one and minimize the impact of local transmission in the community.
Conclusion: Comprehensive contact tracing and management with complementary technology would still be a pillar of strategies for containing outbreaks during de-escalation or early in the next wave of COVID-19 pandemic.

Background

As of September 21, 2020, over 30.6 million coronavirus disease 2019 (COVID-19) cases and 950,000 deaths have been reported globally (World Health Organization, 2020a) Case detection and contact tracing were essential components to control the spread of COVID-19. Taiwan government has enhanced notifiable disease reporting and laboratory surveillance since January 2020 by testing the respiratory specimens from various sources for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), including patients who were reported as cases of severe or novel influenza infection, clusters of upper respiratory disease/fever of unknown origin, and patients with respiratory infections via the sentinel surveillance. Because of the concerns about pre-symptomatic/asymptomatic transmission, contacts in high-risk settings (i.e. households, healthcare settings, and long-term care facilities) were tested for COVID-19, regardless of symptoms. By the aforementioned approaches, we avoided the large scramble and the massive resources devoted to universal testing in the community.

By August 26, 2020, of 173,081 specimens tested for SARS-CoV-2, 487 persons were positive in Taiwan. No locally acquired cases were registered since mid-April. Approximately 76% (370/487) of the COVID-19 cases were previously quarantined inbound travelers or quarantined close contacts of confirmed cases (Figure 1). The outbreak was temporarily contained by measures such as border control, case identification and isolation, contact tracing, and home quarantine for returning travelers and close contacts, jointly with the traditional non-pharmaceutical interventions such as face mask use, personal hygiene measures, and physical distancing (Lin et al., 2020). In Taiwan, digital tools have been introduced to support the contact tracing efforts. This report illustrated the process of how digital tools support contact tracing and management of COVID-19 cases. We described the characteristics of close

* Corresponding author at: Epidemic Intelligence Center, Taiwan Centers for Disease Control, Taipei, Taiwan.
E-mail addresses: swjian@cdc.gov.tw (S.-W. Jian), drhao@cdc.gov.tw (H.-Y. Cheng), xiang@cdc.gov.tw (X.-T. Huang), dpliu@cdc.gov.tw (D.-P. Liu).

https://doi.org/10.1016/j.ijid.2020.09.1483
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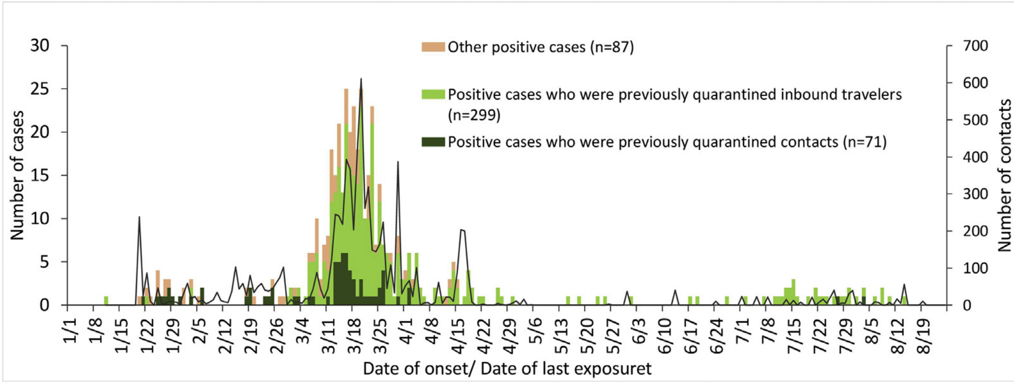

Figure 1. Distribution of 457 COVID-19 cases and 8,051 close contacts by the time of symptom onset for cases and the time of last exposure for close contacts, Taiwan, January 11–August 26, 2020. The figure does not display 30 asymptomatic confirmed cases.

contacts and calculated the timeliness from case detection to contact monitoring to evaluate system performance.

Process for contact tracing and the following managements for COVID-19 outbreak in Taiwan with information system

Inspired by the lessons learned of the Ebola outbreak in West Africa (Polonsky et al., 2019), the Taiwan Centers for Disease Control (TCDC) developed a national contact tracing platform named TRACE in 2017, to link other data systems, monitor health status of contacts, and support management of contacts via compiling daily descriptive analysis and relevant performance indicators (Appendix 2, development concept of TRACE) (Taiwan Centers for Disease Control, 2020). The modules in TRACE were applicable for all notifiable diseases in Taiwan, and they have been implemented for contact tracing in diseases such as measles and rubella, and health monitoring of individuals exposed to animals with avian influenza. For the COVID-19 outbreak response, we developed the COVID-19 module in mid-January 2020 to support contact tracing. To ensure confidentiality, the database that contained contacts' personal information would be deleted in six months and could not be used for other purposes.

The contact tracing efforts for COVID-19 in Taiwan included: case investigation, contact list generation, health monitoring, and quarantine measures of close contacts (Figure 2B).

Case investigation

After being reported to the National Notifiable Disease Surveillance System (Jian et al., 2017), suspected COVID-19 cases should be hospitalized or self-isolated until test results were obtained. A laboratory-confirmed case would be personal/phone-interviewed by case investigators from the local health departments using the standardized case investigation form. The investigation should be completed within 24 h (Figure 2B). Furthermore, movement records of patients with unknown infectious origin could be retrieved from the police and the telecommunication companies to assist the investigation if necessary.

Contact list generation

Close contacts were defined as individuals who had unprotected physical contacts with a confirmed case within two meters for 15 min from two days before the onset of symptoms until the date of isolation. They had to undertake 14-day home quarantine followed by additional 7-day self-health monitoring after their last exposure. The local health departments in the jurisdictions of places that the patient has visited strove to line-list contacts and submitted the list to TRACE, which was the most labor-intensive part of contact tracing. TRACE provided a platform for designated representatives of exposure settings (e.g. restaurant owners, workplace managers, clinic physicians) to upload contacts' personal information to facilitate this workflow. TCDC generated the list of inflight contacts and updated the residential information for those who could not be outreached by the local public health officers via linking to other data systems such as the Household Registration Information System.

Health monitoring and quarantine measures of close contacts

Two distinct methods of health monitoring were devised to ensure completion of twice-daily follow-up, namely, telephone calls or home visits by public health workers and self-reporting via automatic text-message or web-app. Both designated representatives and contacts could update their health status using the web-app. From April 5, 2020, the Central Epidemic Command Center (CECC) collaborated with telecommunication companies via TRACE to send automatic two-way text messages and receive responses (e.g. no symptoms, COVID-19 related symptoms, or other symptoms) from the contacts during the 21-day health monitoring. Cross-jurisdictional coordination, health-status follow-up, and key performance indicators monitoring such as the proportion of contacts tracked and proportion of symptomatic contacts and their symptoms were accomplished in TRACE to ensure the sustained quality and completeness of contact tracing. TCDC and the local public health departments would manage symptomatic contacts such as arrangements for treatment, case reporting, and testing suspects.

In the meantime, CECC also set up a smartphone-based real-time locating system to track contacts' phone signals and alert local authorities if anyone left their designated location or switched off their phone. Authorities would contact or visit those who triggered an alert within 15 min in person.

Results

As of August 26, 487 laboratory-confirmed COVID-19 cases, with 8,051 close contacts, were identified (16.5 close contacts/case [95% CI 13.9–19.1]). Because all inbound passengers should undertake 14-day home quarantine after arrival since March 21, 2020, the number of tracked contacts increased with the growing number of confirmed cases before mid-March and then decreased thereafter (Figure 1). The distribution of confirmed cases aligned with the trend of the number of close contacts over time, which supported the message of a timely contact tracing effort.

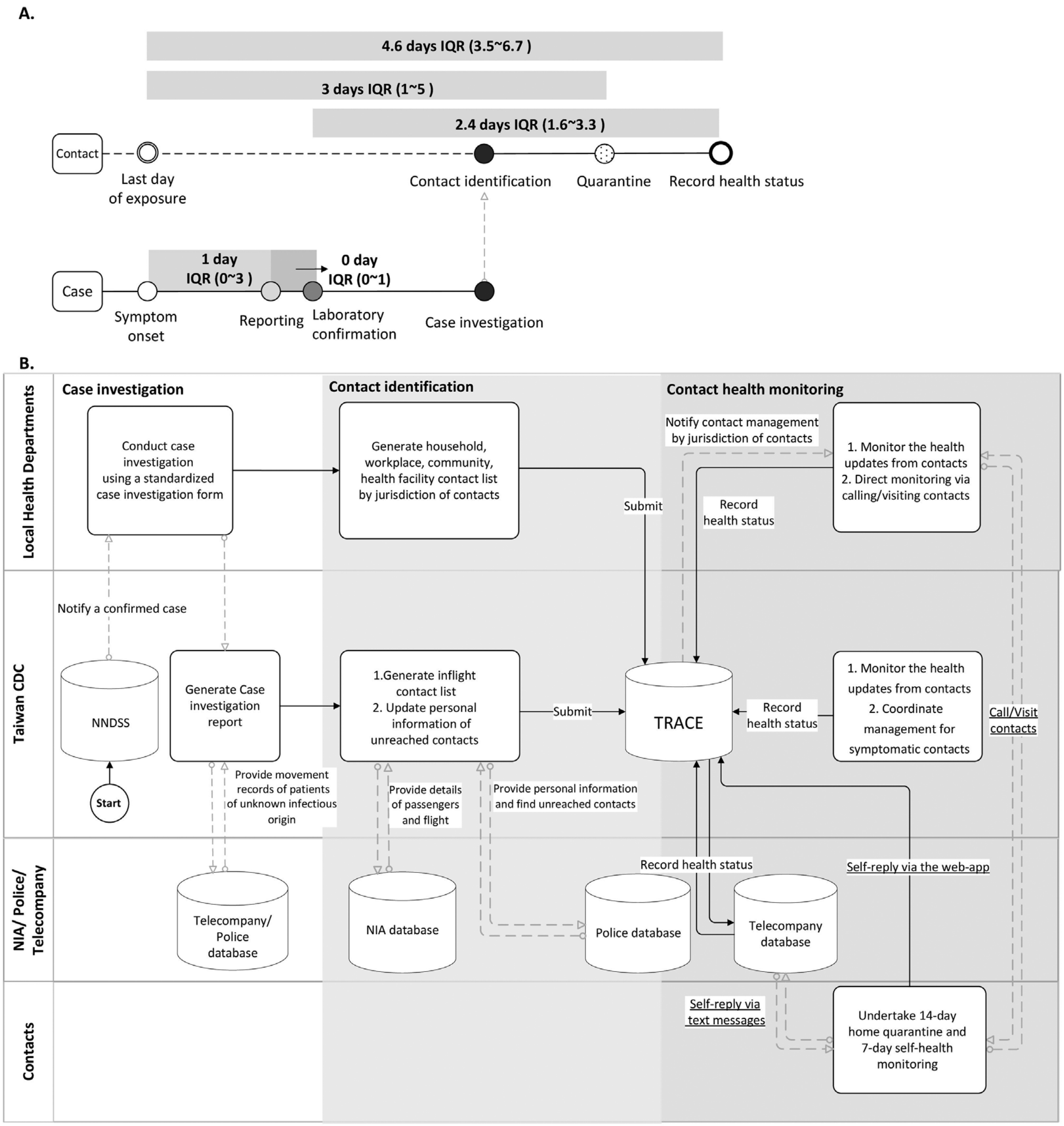

Figure 2. Timeline from symptom onset to contact follow-up and the information flow during COVID-19 contact tracing in Taiwan. (A) The median time and IQR (interquartile range) between steps from last day of exposure to contact quarantine and the start of health status reporting. The dashed line represents that the timeline between the last day of exposure and the day of contact identification was made retrospectively. (B) Information flow from case confirmation to contact health status monitoring during contact tracing activities. Arrows with a dashed line represent information flow via emails/text messages/calls. NIA: National Immigration Agency; NNDSS: National Notifiable Disease Surveillance System; TRACE: Infectious disease contact tracing platform and management system.

Among the 487 cases, 42 were secondary cases, among whom 37 (88%) were detected via contact tracing. Of the 8051 contacts, 1411 (17.5%) were reported to be symptomatic during the 14-day home quarantine and 147 (1.8%) were confirmed to have COVID-19 infection. Of the 147 cases found from the contacts, 81 out of 110 imported cases were in the clusters from the same tour groups, and 37 were confirmed to be secondary cases through the epidemiological review. Most close contacts were aged 20–29 years (34.7%), followed by 30–39 (19.3%) and 40–49 (12.4%) years. The median duration of quarantine was 11.3 days in close contacts (interquartile range [IQR] 10.0–14.0) (Table1). The median elapsed time from the last day of exposure to quarantine start was 3 days (IQR 1–5) (Figure 2A), which has reached the target proposed by WHO that over 80% of contacts quarantined within 4 days of exposure to index case (World Health Organization and Regional Office for the Western Pacific, 2020)

After the active implementation of self-reporting via automatic text-message or web-app from April 5, 2020, health updates of close contacts via self-reporting increased from 22.5% (27,008/120,232) to 61.5% (26,989/43,851). This greatly reduced the workload for public health workers (Appendix Table 1).

Discussion

In Taiwan, all close contacts identified would undertake home quarantine for 14 days immediately after their exposure to the confirmed cases, including asymptomatic persons. In this way, we could prevent presymptomatic transmission, which is not achievable by symptom-based or test-based quarantine measures (Arons et al., 2020). Satisfactory timelines are also pivotal to the successful implementation of contact tracing as a control measure, as shown in previous modeling studies (Hellewell et al., 2020; Peak

Table 1
Characteristics of close contacts of confirmed COVID-19 patients, Taiwan, January 11–August 26, 2020.

Status of index case	Imported	Locally-acquired	Total
Characteristics of close contacts (n)	6616	1435	8051
Years of age, n(%)			
0–9	122(1.9)	85(5.9)	207(2.5)
10–19	416(6.3)	74(5.1)	490(6.1)
20–29	2470(37.3)	323(22.5)	2793(34.7)
30–39	1305(19.7)	251(17.5)	1556(19.3)
40–49	810(12.2)	192(13.4)	1002(12.4)
50–59	677(10.2)	133(9.3)	810(10.1)
60–69	401(6.1)	112(7.8)	513(6.4)
70+	127(1.9)	120(8.4)	247(3.1)
NA	288(4.4)	145(10.1)	433(5.4)
Gender, n(%)			
Female	3874(58.6)	831(57.9)	4705(58.4)
Male	2689(40.6)	562(39.2)	3251(40.4)
NA	53(0.8)	42(2.9)	95(1.2)
Hospital/clinic contacts, n(%)			
Yes	79(1.2)	544(37.9)	623(7.7)
No	6537(98.8)	891(62.1)	7428(92.3)
Flight contacts, n(%)			
Yes	3523(53.2)	0(0.0)	3523(43.8)
No	3093(46.8)	1435(100.0)	4528(56.2)
Duration of quarantine, day (IQR)	12.0 (10.0–14.0)	12.0 (9.0–14.0)	11.3 (10.0–14.0)

COVID-19 = coronavirus disease 2019; IQR = interquartile range.

et al., 2020). Because the transmission can occur from a person that is infected even two days before showing symptoms, the delay between case detection and contact tracing has to be very short to prevent onward transmission in the community (He et al., 2020). Compared to a study in China (Luo et al., 2020), the median elapsed time from last exposure to quarantine (3 days) in Taiwan was short. With a combination of the timely and comprehensive contact tracing and the corresponding home quarantine measures, the probability of ongoing community transmission could be minimized (Hellewell et al., 2020).

Our experience suggested that contact tracing is still vital in the next phase of the coronavirus pandemic in the world. Nevertheless, traditional contact tracing efforts require skill training, massive resources, and labor-intensive process of interviews and detective works. In Taiwan, the capacity faced significant challenges when the number of imported COVID-19 cases surged in March because of the escalating pandemic. In the context of contact tracing, since the activation of self-reporting in April 2020, more than half of the daily health-monitoring records were received through self-reporting to TRACE, which allowed for real-time monitoring and reduced the workloads. The public health agencies could preserve more capacity at investigating newly confirmed cases to determine potential epidemiological linkage to previously confirmed cases. Currently, the contact tracing workforce of COVID-19 in Taiwan was about 400–600 persons at peak capacity. Compared to 190 contact tracers in New Zealand and 9000 in Wuhan, the number of individuals conducting case investigation and contact tracing activities was lower in Taiwan (Johns Hopkins Center for Health Security, 2020). Thousands of contacts' information could be efficiently managed by a limited number of public health workers by TRACE. Furthermore, Taiwan has notified more than 500 COVID-19 case contacts with foreign nationals to the national focal points of 31 countries via emails in compliance with the International Health Regulation (IHR). It would be more practical to develop a secured global platform that allows sharing of COVID-19 case information among countries and sends exposure notifications across borders. This may improve the timeliness of international case and contact management.

Several countries have begun to discuss the development of digital tools for contact tracing(World Health Organization, 2020b) European Union has implemented contact tracing apps that identify close contacts via Bluetooth connections and aim to work seamlessly when users travel to other participating countries. This approach could facilitate cross-border contact tracing. However, the effectiveness of risk notification on the apps based on the decentralization approach also needs assessment (European Centre for Disease Prevention and Control, 2020). In addition, South Korea has adopted a rigorous contact-tracing program and tracked contacts by linking large databases like credit card transactions to mitigate the pandemic (Park et al., 2020). New Zealand also found success through the use of aggressive traditional contact tracing supplemented with the NZ COVID Tracer app. (New Zealand Government, 2020). However, mobile apps can complement but never replace traditional contact tracing efforts. Because transmission of COVID-19 mainly occurred in household and close contacts, a documentary tool for more extensive casual contacts might not help to identify others with a higher risk (Lin et al., 2020). Besides, proximity tracing tools only solve the first issue of contact tracing: point out a possible contact. They cannot replace rigorous contact identification, listing, and interviews to maintain trust with the contacts, and adjudication on who should quarantine.

An integrated contact tracing system like TRACE may not be feasible for countries without an existed relational database from various sources such as case notification, laboratory, and contact tracing. It was most useful in initial outbreak response and cluster investigation during the containment stage or preparedness for the next wave of COVID-19. Besides, digital tools require costs for developers, hardware and software development, training, and continuous user support. In addition, successful case investigation and contact tracing for COVID-19 depend on a robust and well-trained public health workforce. Over 90% of the contact tracers involved in current contact tracing tasks in Taiwan were experienced public health workers. Education programs of using TRACE for contact tracing have been provided for local governments every year since 2018. In 2020, TCDC is developing skilled and knowledge-based training to enhance the knowledge and skills of the contact tracers essential to the COVID-19 pandemic response.

Conclusion

In summary, the experience of comprehensive contact tracing in Taiwan can help devise potential approaches for controlling the COVID-19 outbreak. Management tools like TRACE can augment the capacity, decrease the workloads of contact tracers, and improve contact tracing effectiveness. Before the anonymized proximity tracing approach has proven to be effective in slowing the spread of transmission and with the satisfying response rate from contacts, traditional contact tracing with an integrated management system may still be the key in responding to the next wave of COVID-19.

Conflict of interests

None declared.

Funding source

None declared.

Ethical approval

We conducted this study as a legally mandated public health investigation under the authority of the Taiwan Centers for Disease Control and the Communicable Disease Control Act. Ethical approval was not required for this research.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2020.09.1483.

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