OSIR, September 2020, Volume 13, Issue 3, p.90-100

Outbreak, Surveillance, Investigation & Response (OSIR) Journal
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Enhancing Coronavirus Disease (COVID-19) Surveillance System through Information Technology, Thailand, 2020

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Abstract

Coronavirus disease (COVID-19) was designated as a dangerous communicable disease by law in Thailand. However, existing surveillance systems was not timely and accurate. Therefore, we conducted an innovation development research to improve the system. The research comprises two objectives; (i) to describe the existing surveillance system and its challenges, and (ii) to enhance surveillance system through the improvement of information technology. All related stakeholders, from the Department of Disease Control to hospitals, were engaged and communicated to identify the challenges of the surveillance system. Several challenges were reported, for instance, lack of timeliness, overload of verification, inaccessibility of data feedback, and difficulty of cluster identification. To overcome these challenges, five additional features were developed, tested, and implemented. These five features included auto-verification, laboratory reporting, data exporting, data visualization, and integration with the existing event-based surveillance. The system was tested by developers and users and implemented nationwide. The activities were made possible by several communication routes including chat, email, and teleconference. Early engagement of stakeholders, understanding of existing surveillance systems, and utilizing information technologies to solve challenges are substantially crucial. Our study provides a new opportunity for the improvement of the surveillance system during the period of travel restriction in many countries.

Keywords: coronavirus disease, surveillance system, information system, information technology, innovation

Introduction

Shortly after the notification of unknown cause pneumonia cases in China which were later identified as coronavirus disease (COVID-19), on 3 Jan 2020, the Thai Department of Disease Control (DDC), Ministry of Public Health activated emergency operations center to optimize the ability to provide effective and timely outbreak response.[1,2] Several strategies and plans were initiated to mitigate the impact of the disease including specific disease surveillance system which had a direct impact on disease prevention, control, and specific policies implication.[3]

Initially, the COVID-19 surveillance system had been established at the points of entry of the country and hospitals.[2,4,5] The dynamic criteria for identifying a patient under investigation (PUI) including symptoms and specific risk factors were set up and these were changed week by week according to the recent epidemiological characteristics of disease and potential risk factors.[2,6] Besides, laboratory investigation was performed among all PUIs to confirm the diagnosis which could provide opportunities to detect confirmed cases and performed contact tracing.[2,7] Information system had been included in the surveillance system to connect public health decision-makers to appropriate data sources.

Therefore, a reliable and timely disease-specific surveillance system that monitors COVID-19 activity in real-time would help public health institutions deploy timely specific-medication and optimally allocate resources during outbreaks.[8] However, the current information systems in Thailand could not accommodate symptoms, risk factors, cluster of cases data collecting systems, and laboratory reporting system.

In more detail, the current COVID-19 surveillance system could not be applied as a timely and reliable surveillance system due to the complexity of the hierarchical structure of reporting system. Healthcare facilities needed to report PUIs via regional Office of Disease Prevention and Control (ODPC). They could not report the PUI and confirmed case to the surveillance system directly.[2]

At this point, information technology (IT) could be used to support information system of COVID-19 surveillance system.[8,9] Enhancing information system with IT can provide enormous benefits to public health surveillances through improving data quality, data variety, timeliness, ability to understand data and reducing the complex hierarchical structure.[9-15]

However, after February 2020, the situation of COVID-19 had dramatically progressed to become a pandemic. The current COVID-19 surveillance system was not able to handle the massive information which caused several obstacles for DDC response to COVID-19. Thus, DDC decided to design a more comprehensive surveillance system by utilizing information technology.

Therefore, we conducted an innovation development research which consisted of two objectives; (i) to describe COVID-19 surveillance system, focusing on information system during February to April 2020, including roles of stakeholders, and its challenges, and (ii) to redesign and enhance the information system through IT to support COVID-19 surveillance system.

Methods

Operational Definition

SAT: Situation awareness team (SAT) serves as a situation monitoring system. Its main function is to verify, monitor, follow, and evaluate the characteristics and severity of the outbreak, and report such information to the incident commander. The additional heavy task is the verification of PUIs and manually generate SAT code.[2]

PUI criteria: The dynamic criteria for identifying a patient under investigation (PUI) including symptoms and specific risk factors are set up and these are changed week by week according to the recent epidemiological characteristics of disease and potential risk factors.[2,6]

SAT code: The identical number of each PUI who is verified by SAT and compatible with COVID-19 PUI criteria.[2]

Operation team (OP): The team acts as forefront officers to take prompt action against the outbreak which has both roles in the outbreak investigation section and data management section. The data management section gathers information from the outbreak investigation section and summarizes data to the incident commander to ensure the coherence of information.[2]

Strategic response team: The team is responsible for producing applicable operational guidelines for a timely response to COVID-19, based on the state-of-the-art knowledge, considering the strategic directions of the incident commander.[2]

COVID-19 surveillance system: A disease-specific surveillance at the points of entry and hospitals which is established by the Department of Disease Control to monitor, follow, evaluate characteristics and severity of the outbreak.[2]

COVID-19 information system: An information system that is a part of the COVID-19 surveillance system. It gathers information from patients under investigation, case investigation, outbreak investigation, contact tracing, and implications considering the main causal link between information, decision, and action.

Office of Disease Prevention and Control (ODPC): A regional office of the Department of Disease Control, Ministry of Public Health, is responsible for all disease prevention activities within regions. Each ODPC is responsible for 5-12 provinces.

Provincial Health Office (PHO): An identity that is responsible to manage medical resources, prevent and control diseases in their responsible health care facilities in each province. Provincial offices are under the Office of the Permanent Secretary, Ministry of Public Health, Thailand.

Study Overview

An innovation development research consisted of two objectives. Firstly, we conducted a qualitative study to describe the COVID-19 surveillance system, focusing on an information system, roles of stakeholders, and its challenges. Secondly, we redesigned and enhanced information system through IT to support COVID-19 surveillance system.

Describe the Existing System and Identify Challenges

To reach the first objective, we described the existing surveillance system, its information system, and its workflow. All related stakeholders, from DDC to hospitals, were engaged and communicated to identify challenges of the traditional information system. A purposive sampling was conducted to engage stakeholders for each specific setting from DDC and Chonburi Province including ODPC 6, the provincial health office, and the provincial hospital.

We interviewed at least one interviewee from each organization until the results were saturated. For data collecting methods, in-depth interviews with stakeholders through face to face and teleconference were conducted.

Besides, a non-participant observation was performed to observe the activity of the current reporting system. Afterward, we summarized the challenges and workflow of the existing surveillance system.

Identify Solutions, Redesign and Modify Information System

To reach the second objective, we developed the solutions to solve challenges from the first objective. We identified tasks, needed skills of developers, and the number of developers to enhance information systems according to proposed solutions.

Database structures and the hierarchy of data accesses were designed. Each proposed solution was described and transformed into a web-based application. After the information system was enhanced, it was validated by developers and users in the DDC and ODPC 6 to identify more challenges.

We spent one week for a trial period in which we implemented enhanced information system to all ODPCs. After that, the system was re-modified and implemented countrywide. The user supporting team was established to monitor the information system and identify any more challenges in the system (Figure 1).

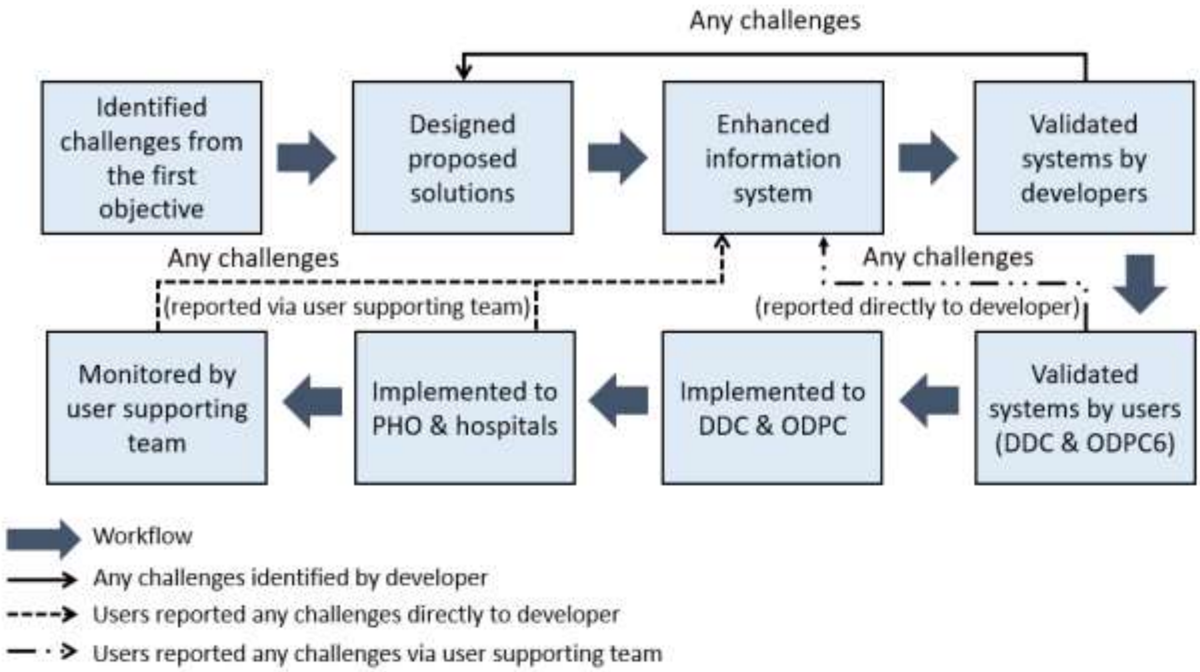

Figure 1. Workflow with the challenges identification process, redesigning process and modification process of the information system

Table 1. Number, roles and types of COVID-19 surveillance system stakeholders

Process	Strategy team	SAT at DDC/ODPC	OP at DDC/ODPC	PHO	Hospitals	Laboratory
1. Create objective and case definition, and identify target population	+					
2. Retrieve patient information		+	+		+	
3. Entry data to system		+	+	+	+	+
4. Extract data from system		+	+	+	+	+
5. Data management and dissemination		+	+			
6. Data usage	+	+	+	+	+	+
Number of stakeholders	3	4	4	2	2	1

Results

Describe the Existing System and Identify Challenges

The COVID-19 surveillance system was designed to be deployed at the national level as disease-specific surveillance, i.e. active, compulsory, and comprehensive surveillance.

The system was designed as a centralized web-based application and functioned as a case-based reporting system. Sixteen staffs from various stakeholders were required to operate the system as described in Table 1.

The workflow was initiated by frontline staff. The information was recorded in a paper-based screening form and forwarded to the SAT staff to verify whether patients were compatible with PUI criteria. If compatible, the SAT code was manually generated, assigned, and sent back to the frontline staff.

At the same time, patient specimens were collected and sent to the laboratory. The test results were notified to the SAT team. The SAT was responsible to record laboratory results into the database and notify the frontline staff.

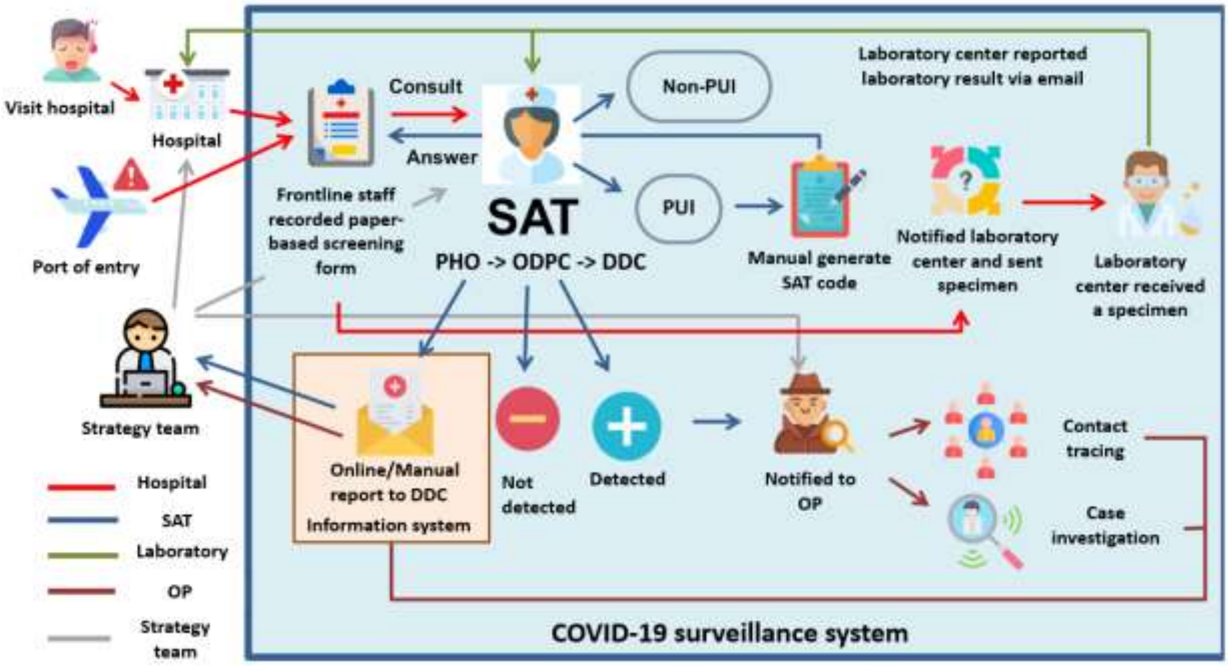

Figure 2. Workflow of the traditional COVID-19 surveillance system reviewed from stakeholders

Note: Blue box illustrates COVID-19 surveillance system; Brown box illustrates information system; Red line illustrates the workflow of the hospital; Blue line illustrates the workflow of the situation awareness team (SAT); Green line illustrates the workflow of the laboratory center; Dark red line illustrates the workflow of the operation team (OP); Grey line illustrates workflow of the strategy team.

Table 2. Summary of challenges and proposed solutions

Challenges	Proposed solutions
1. Overloading of verification processes (SAT code) 2. Time consuming and complexity of verification processes 3. Duplication of record entries by multiple users	SAT code automatic verification system
1. Need to report laboratory result to multiple partners 2. Delayed report and laboratory result 3. Cannot monitor actual number of laboratories tested and new confirmed case (need to check from e-mail)	Laboratory reporting system
1. Cannot identify new confirmed case (need to check from e-mail)	Confirmed case notification feature
1. Cannot monitor real time number and detail of PUI, confirmed case and contact 2. Need to recollect data from lower level (hospitals/PHO)	Data export feature and data visualization
1. Cannot early identify a new cluster of cases 2. Cannot monitor current cluster of cases and event-related patients (active case finding, cluster of cases in local quarantine and state quarantine.	Event-based surveillance system

In case the test result was positive for SARS-CoV-2, the SAT needed to notify the operation team (OP) for investigation and contact tracing. The OP investigation report was also recorded in the database. Lastly, the strategy team extracted data from the information system to support proper policies (Figure 2).

However, several challenges were informed from different stakeholders, for instance, the overburden of verification processes which needed multiple steps of the verification and took a long time, duplication of the patient record, the error of SAT code manually generated, delayed report of laboratory test and confirmed case identification, and difficulty of clustered cases detection and data extraction (Table 2).

Identify Solutions, Redesign and Modify Information System

After challenges were identified, the design team conducted a brainstorming session and proposed the possible solution for each challenge as described in Table 2.

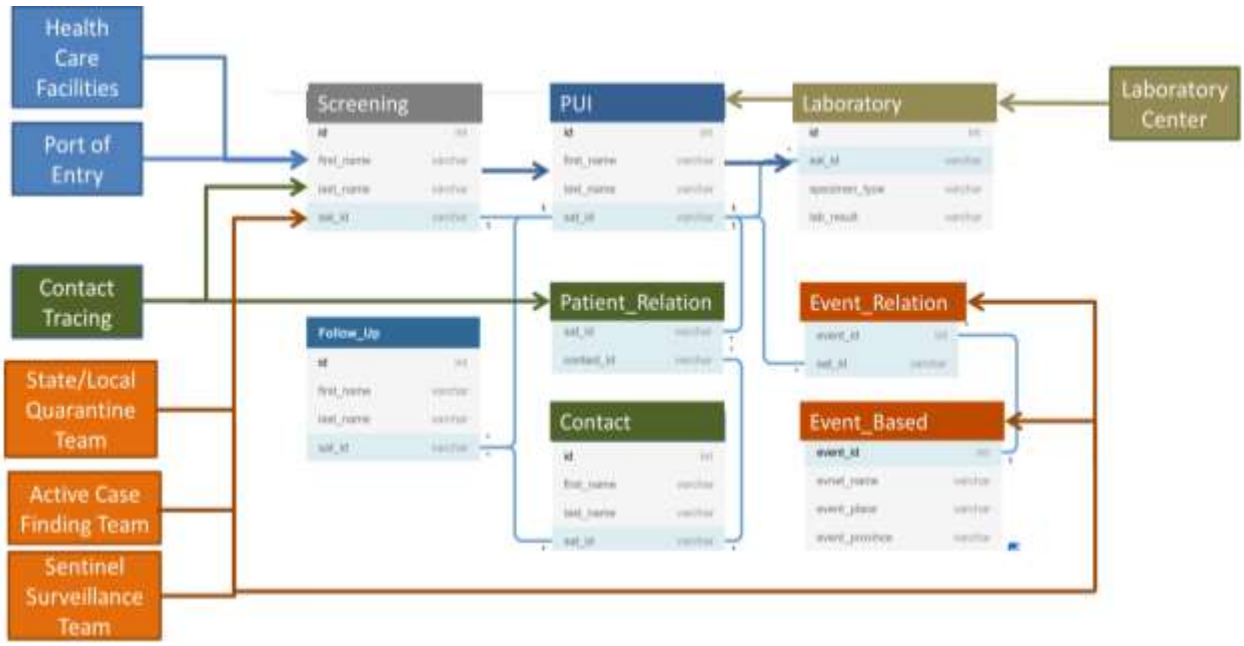

Figure 3. Entity relationship diagram of COVID-19 database structure in COVID-19 enhanced information system

Notes: Blue arrow illustrates data flow from the health care facilities and the port of entry; Green arrow illustrates data flow from the contact tracing team; Brown arrow illustrates data flow from the state quarantine, local quarantine, active case finding team and sentinel surveillance team; Gold arrow illustrates data flow from the laboratory center.

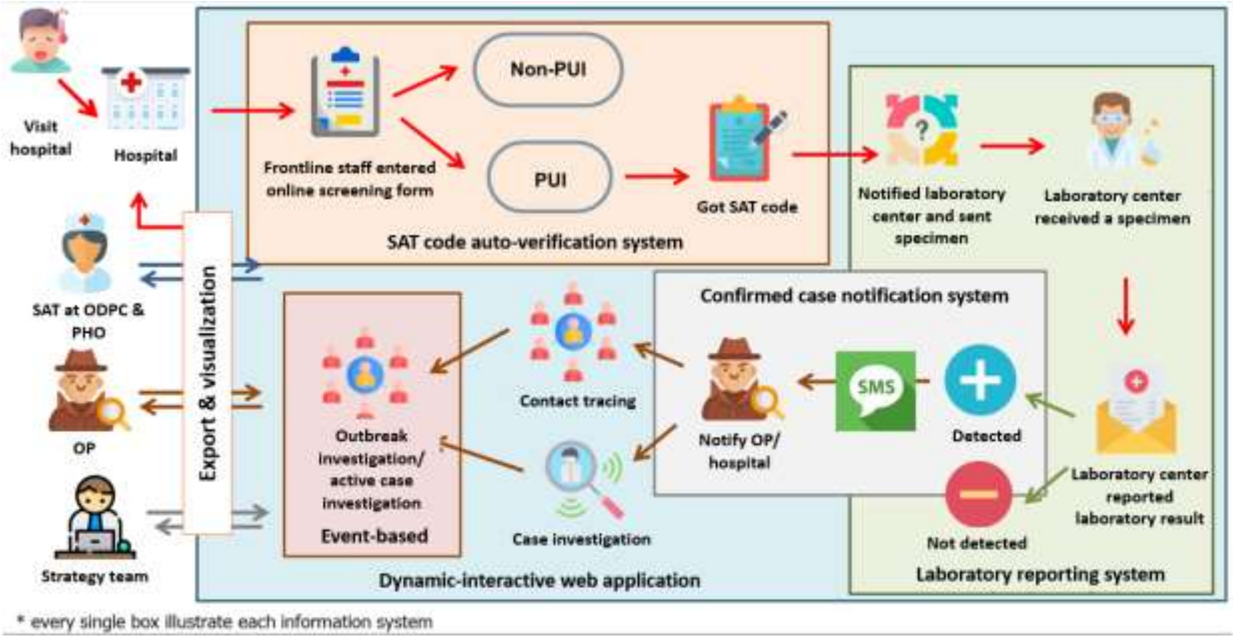

Figure 4. New workflow of the enhanced COVID-19 surveillance system

Note: Blue box illustrates the COVID-19 surveillance system; Red box illustrates the SAT code auto-verification system; Green box illustrates the laboratory reporting system; Gray box illustrates the confirmed case notification system; Dark red box illustrates the event-based reporting system; Red line illustrates the workflow of the hospital; Blue line illustrates the workflow of situation awareness team (SAT); Green line illustrates the workflow of laboratory center; Dark red line illustrates the workflow of operation team (OP); Grey line illustrates the workflow of the strategy team.

In total, 26 staffs and developers from seven different fields of expertise, including two database administrators, six web-application developers, four data analysts, four user supporting staffs, three network and system engineers, one network security consultant, four user supporting staffs and two project managers were recruited to work on the development.

The database was designed based on relational structure and consisted of seven tables including screening, patient, contact, patient contact relation, laboratory, event-based and event-patient relation. (Figure 3).

The user access control (UAC) system was designed based on hospital-level hierarchy. For example, hospital staff could only access their data, the PHO staff could access data of all hospitals under the province authority, ODPC could access data of all provinces under its region and DDC could access national-level data.

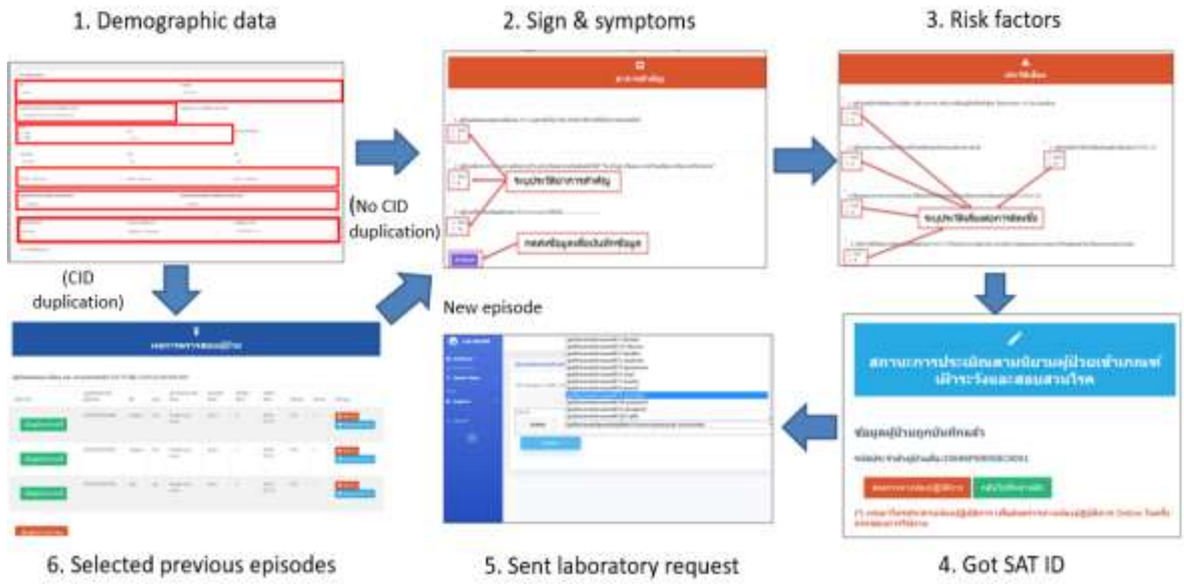

Figure 5. Workflow and example of the user interface of the SAT code verification system

Overall, five additional systems were designed as proposed solutions and were implemented including SAT code automatic-verification system, laboratory reporting system, confirmed case notification system, data export and visualization and event-based surveillance system (Figure 4).

SAT Code Verification System

The system was designed to streamline the SAT verification process. The system received input data from the frontline staff, and categorized patients based on PUI criteria. Patients compatible with PUI criteria were automatically assigned SAT code by the system. Thailand citizen identification number (CID) was required as a master patient index (MPI) across the entire system (Figure 5). Epidemiological linkage and contact tracing were to be identified using the CID of the index cases and contacts (Figure 3).

Laboratory Reporting System

We designed a real-time, electronic-based laboratory reporting system based on two-way communications between frontline staff and laboratory center. After frontline staff get SAT code from the SAT code verification system, they can send laboratory requests to the laboratory center. The specimen status and results will be updated by the laboratory technician through the reporting system.

Confirmed Case Notification System

When the new confirmed case was identified, the notification will be sent to SAT and OP by short message service of the Thai MOPH COLAB application. The notification will be triggered when the laboratory result was updated.

Event-Based Reporting System (EBS)

The event-based reporting system was designed for reporting of clustered events. The system allows the DDC to track the outbreak progress and linkage as one event which can have many patients, and one patient can link with many events. Additionally, the total screening population, confirmed case, and attack rate in those events were automatically calculated.

Data Exporting

We developed a data export feature in which the user could extract data by type of patient and date of the report in Microsoft Excel format according to their hierarchy of data accessibility.

The feature allowed users to export data into Microsoft Excel spreadsheet format. Users can only export data permitted by their level of access and the exporting activity was recorded in the system audit log.

Program Implementation and User Supporting System

A 1-week pilot phase was deployed by trained users via teleconference. An online communication group was provided to gather feedback and for user training. Afterward, the system was deployed to PHO and hospitals. The deployment was supervised by PHO and their networking hospitals. The 24/7 hotline, online chat, and email were established to provide technical assistance during the deployment.

Discussion

The coronavirus disease (COVID-19) surveillance system was designed to be a nation-wide surveillance system aiming to collect all populations related to COVID-19 including PUI, contact, and COVID-19 related signals event. However, several challenges were found in the existing surveillance workflow during the early phase of implementation, January to February. Early engagement with all stakeholders was described as crucial to ensure ownership, increase coordination, and gain a "better understanding of the existing surveillance landscape".[16-19]

This is important as improving the surveillance is also an opportunity to improve workflow, resource utilization, efficiency of the system and outcome of the diseases which was reported in Sydney, Sierra Leone and several previous outbreaks including acute respiratory syndrome (SARS), Middle East respiratory syndrome, and Ebola virus disease.[19-22]

The COVID-19 surveillance system improvement was implemented nation-wide in early April 2020 which had an impact on both data quality and workflow. Before implementing, the health care facility and port of entry needed to notify SAT and wait for multiple steps of verification which might take a long period. This could increase the risk of infection among frontline staff who had long-time direct exposure to large numbers of infected patients.[23-25] This was because SAT spent the majority of its time on the verification processes and missed some opportunities to monitor the situation as its main function.[2] Therefore, the SAT code auto-verification system could speed up the verification processes, diminish incorrectness of SAT code verification and duplication record, and demolish undue burdened personnel with alarming fatigue.

One of the challenges is that the data could not be used to monitor an actual number of confirmed cases and laboratory tested in a timely manner. The reason was the laboratory results were reported via email causing the delay and missing data which leaded to unreliable surveillance systems. Delay in reporting further compromised timely diagnosis, treatment and case isolation which lead to suboptimal disease prevention and control.[20,21] The possible solution was to migrate the laboratory results to the new reporting system.[26,27] Using an automatically trigger of a notification and short message service when tests are being reported could enhance to detect a new confirmed case.[21]

Reporting timeliness is also important for local health authorities to monitor in order to ensure timely intervention and response, which is the very purpose of the disease surveillance system.[28,29] Therefore, data feedback loops are one of the most important parts of the system to fulfill the surveillance cycle which is associated with data quality improvement.[30] Feedback mechanisms to inform stakeholders regarding the situation and performance monitoring were necessary to sustain staff motivation and cooperation.[31]

In the past, we were unable to link the individual patient record to available clustering information to detect epidemiologic linkage systematically. To address the challenge, the existing EBS was integrated into the COVID-19 surveillance system to become the enhanced information system of individual case linkage to the clustering event. EBS was reported to be important in detecting a large scope of events and guiding outbreak response.[31,32] EBS is a valuable source of data that can strengthen the early warning function of national surveillance systems, if it is integrated into existing surveillance and linked to response structures.[31]

According to travel and mass gathering restriction due to the COVID-19 situation, several technologies had been used to support user training processes including teleconference, chat group communication, and comprehensive electronic user manual. Those technologies allowed the DDC to address the gaps in the system and continuously improved the system despite the travel restriction order in Thailand during the COVID-19 epidemic. This provided a new opportunity for surveillance system improvement as the activity was normally conducted by visiting the field in person. Utilizing new technologies that can support epidemiological surveillance has made a positive difference in performance and data quality.[33] Teleconference provides the ability to deliver training to large numbers of people across multiple locations within a relatively short time with reasonable costs.[34]

Due to the COVID-19 situation and its intense control measures, face to face interviews with local stakeholders and direct observation were not performed during the pilot phase which limited our observation and interaction with users to gather essential feedback. Besides, we could not assess the impact of the improvement made in this study given the current COVID-19 situation. Thus, we recommend conducting the surveillance evaluation to compare the performance of the system before and after the improvement.

Public Health Recommendations

During the early phase of IT development, early engagement and comprehensive communicating with stakeholders, both via face to face and teleconference, are strongly suggested to avoid obstacle as it shows an opportunity to gather feedback and address the gaps in the system without the need for the field visiting.

After obstacles identification, integrating information systems, such as laboratory reporting systems and event-based surveillance systems, are suggested to fulfill gaps in the existing surveillance systems. Appropriated helpdesk services and user support have a crucial role to monitor additional challenges from stakeholders and to improve the surveillance system.

Conclusion

The coronavirus disease (COVID-19) surveillance system was designed to be used nation-wide as an active, compulsive, and comprehensive surveillance system. However, the system suffers several limitations, such as lack of timeliness, overload of verification, inaccessible of data feedback loops, and a cluster of case identification. Stakeholders' engagement was made despite the travel restriction order in Thailand to gather feedback and needs from the users. The activities were made possible with several communication routes including chat, email, and teleconference. As a result, several gaps were identified, and improvements were made. Therefore, our study provides a new opportunity for surveillance system improvement to be possible during the travel restriction as implemented in several countries.

Acknowledgments

We would like to thanks for all kinds of support from the Information Technology Unit at the Department of Disease Control, Emergency Operation Center at the Department of Disease Control, Information Center and Technology at Office of the Permanent Secretary, Office of Disease Prevention and Control 6, Chonburi Provincial Health Office Chonburi, and Chonburi Hospital.

Suggested Citation

Wongsanuphat S, Sangwanloy S, Sopha P, Buangsuang W, Denduang S, Thongplean A, et al. Enhancing coronavirus disease (COVID-19) surveillance system through information technology, Thailand, 2020. OSIR. 2020 Sep;13(3):90-100.

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