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An Evaluation of the Enhanced Information System for COVID-19 Surveillance in Thailand, 2020: A Pre-Post Intervention Comparison

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Abstract

With information technology, a traditional coronavirus disease (COVID-19) surveillance system was improved with five additional features including auto-verification system, laboratory reporting system, confirmed case notification system, data feedback loops, and integrated event-based surveillance system. We conducted a surveillance evaluation to compare quantitative and qualitative attributes before and after the improvement. Qualitative and quantitative studies were conducted to measure the effectiveness of enhancing the information system according to the US-CDC framework. Qualitative attributes consisting of simplicity, acceptability, accessibility, flexibility, and stability, and quantitative attributes consisting of timeliness and completeness were investigated and compared between pre-enhanced and post-enhanced information system using the chi-square test. During January to April, there were 74,565 patients under investigation reported to the surveillance system. We interviewed a total of 16 health personnel. After the improvement, we observed statistically significant increases of completeness and timeliness from 55 to 66 and 75 to 96 percent, respectively. Almost all stakeholders (15/16) reported that the system was improved significantly. All qualitative attribute scores were increased including acceptability from 57 to 73, simplicity from 43 to 77, stability from 47 to 80, flexibility from 57 to 73, and usefulness from 50 to 80. In summary, all the qualitative and quantitative attributes were improved significantly (*p*-value<0.01 for the chi-square test). Enhanced information system with careful understanding of the existing workflow and stakeholders could improve performance of the surveillance system in both qualitative and quantitative attributes. Surveillance evaluation process could be used to assess the improvement, gather feedback, and identify the gaps.

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

Introduction

Coronavirus disease (COVID-19) was an emerging infectious disease affecting people worldwide. After received a notification from China, Thai Department of Disease Control (DDC) implemented COVID-19 surveillance system at the points of entry and hospitals since January 2020.[1-3] Public health information systems (PHIS) are major components of public health infrastructure.[4] They have been defined to include a variety of data sources essential to public health action and are often used for surveillance.[4] The COVID-19 surveillance system with the information system was rapidly deployed in February 2020 to

Table 1. Selected variables from COVID-19 screening form and their validity rules

Selected variable	Validity rules
COVID-19 screening form	
Card ID	Must be 13 digits
Sex	Must be Male, Female, Unknown
Age	Must be 0 - 110
Nation	Must be in a valid list of nation codes
Occupation	Must be in a valid list of occupation codes
Address (Sub-district)	Must be a valid sub-district code
Address (Province)	Must be a valid province code
Screening Province	Must be a valid province code
Screening Hospital	Must be a valid hospital code
Screening Date	Must be a valid date format before last update date
Date of Onset	Must be a valid date format before last update date

collect and provide data systematically to all related stakeholders.[1]

Even though the COVID-19 surveillance system was designed to be a passive compulsive surveillance system which could provide rich information to public health authorities, several limitations of the existing surveillance system remained, including reporting delay and poor data quality due to the complexity of the reporting process, and the repetitiveness of multiple stakeholders reporting.[4]

From our previous study, the gap analysis was conducted.[5] Several challenges of the existing surveillance system were identified, including the overburden of case verification, delayed laboratory results, lacking feedback, and case-clustering identification. Therefore, a new electronic surveillance system was designed and deployed in April 2020 by enhancing five important features: (i) auto-verification to verify patient according to screening criteria, (ii) laboratory reporting system which was coordinated with a laboratory center and integrated with the case reporting system, (iii) data exporting, (iv) visualization which was able to fulfill data feedback loops, and (v) integrated event-based surveillance which was developed to address the identified gaps.

To assess the improvement impact, surveillance evaluation was carried out. The surveillance system evaluation is important to promote efficient and effective public health surveillance systems and fulfill the cycle of the surveillance system.[6-7] This could provide opportunities to identify existing difficulties from various stakeholders, access the system effectiveness, monitor data quality, and provide a recommendation to improve the surveillance system. Therefore, we conducted a surveillance system evaluation to assess the improvement of quantitative and qualitative attributes of the newly designed COVID-19 surveillance system.

Methods

Overview

A mixed method, based on the US-CDC Surveillance evaluation framework, was conducted. All reported Patient Under Investigation (PUI) and confirmed COVID-19 cases in the COVID-19 surveillance system during February to April 2020 were obtained nationally from DDC.

Qualitative Study

Firstly, we briefly summarized the improvement made to the surveillance system. We conducted a qualitative study consisted of six attributes namely, simplicity, stability, flexibility, usefulness, and accessibility during February to March 2020 for pre-improvement and April 2020 after the improvement in Chonburi Province, Thailand.

Using purposive sampling method, related stakeholders were interviewed. They included the operation team who acted as forefront officers to take prompt action against the outbreak, situation awareness team who served as a situation monitoring system, strategy response team who was responsible for producing applicable operational guidelines for a timely response to COVID-19, from DDC and Office of Disease Prevention and Control (ODPC), Provincial Health Office (PHO) staffs, hospital staffs, and laboratory technicians.

An in-depth face-to-face interview was conducted during in-person visits and teleconference. After the

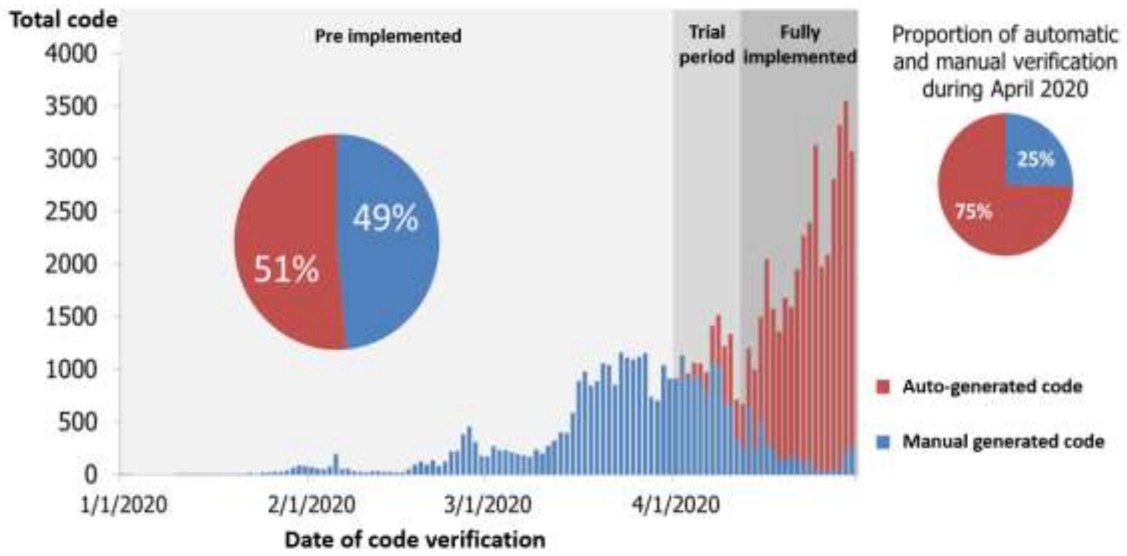

Figure 1. Proportion of the manual and automatic verification system in COVID-19 surveillance system during January to April 2020 (n=74,565)

interview, we asked interviewees to provide a score (0-10) for each attribute. The interview was recorded for coding and transcribe. Lastly, we interviewed each participant twice and conducted the thematic analysis to compare before and after improvement.

Quantitative Study

A quantitative study consisting of 3 attributes including completeness, timeliness, and data quality was conducted and compared before and after improvement of the COVID-19 surveillance system.

Completeness

We calculated the percentage of non-missing data of selected variables from the COVID-19 investigation form including national card ID, sex, age, phone number, nationality, occupation, address, symptom, date of onset, risk factor, screening hospital, and screening province. Additionally, we calculated the proportion of non-missing data for completeness score (maximum of 100). For inferential analysis, completeness during pre- and post-enhancing information system were compared using the Chi square test and its *p*-value.

Data quality

The percentage of valid data of selected variables (the same as completeness) according to validity rules (Table 1) were calculated and compared between before and after improvement with the paired T-test and its *p*-value.

In addition, the percentage of duplicated data of selected variables including exact duplicated first name, last name, and exact duplicated of unique COVID-19 case identifier, the situation awareness team (SAT) code, which was the unique number of each PUI who was verified by SAT, were calculated.

Timeliness

The lag time between the screening date and reported date was calculated with its mean and standard deviation. For inferential analysis, the date of screening was divided into two periods and compared using paired T-test with *p*-values and Kaplan-Meier survival analysis with sub-distribution of hazard approach (Log-rank test with its *p*-values).

Also, the lag time was categorized into the following scores including 0 days (10 scores), 1 day (9 scores), 2 days (8 scores), 3 days (7 scores), 3-7 days (5 scores), 1-2 weeks (4 scores), 2-3 weeks (3 scores), 3-4 weeks (2 scores) and 1-2 month (1 score). The score of pre- and post-enhancing timeliness were calculated according to the given score.

Lastly, the score (maximum of 100) of each attribute including simplicity, stability, flexibility, usefulness, accessibility, completeness, and timeliness for both pre and post enhancing periods were summarized, compared using Chi-square with its *p*-values, and visualized with a radar chart.

Results

There were 74,565 PUIs reported to the COVID-19 surveillance system during January to April. Approximately half or 38,383 cases were reported after the improvements were made. Since the improvement, approximately 700 health care facilities participate in the surveillance system. After the improvement was made in April.

Table 2. Quotation and tone from stakeholders interviewing by qualitative attributes and types of stakeholder before the improvement (February and March 2020)

Stakeholders	Simplicity	Flexibility	Acceptability	Stability	Usefulness
Strategy response team	"Messy data"	"Can adapt"	"Accept it"	"Depend on few people"	"Identify risk population, convince policy"
SAT at DDC/ODPC	"Complicated flow"	"Need to follow PUI criteria and SAT ID pattern"	"We accept it"	"No, if 20% of us got sick"	"Monitor situation"
OP at DDC/ODPC	"Work likes machine"	"Can adapt"	"It's our job"	"Manpower"	"Yes, for news reporting"
PHO	"Multiple steps"	"Always need to update new criteria"	"Work likes messenger"	"Rely on number of staffs"	"Need to collect data from hospital again"
Hospital	"Extremely hard"	"Can adapt with all criteria"	"Not much"	"Depend on number of PUIs/cases"	"No, cannot get data back"
Laboratory	"Need to send result to multiple sector"	"Can adapt if type of specimen change"	"Double work"	"No, if number of tests is increasing"	"Not sure"

Note: Red fonts illustrated a negative tone; Green fonts illustrated a positive tone; Black fonts illustrated a neutral or inconclusive tone.

2020, the number of PUIs were increased almost tripled, from 19,583 in March 2020 to 51,410 cases in April 2020. Figure 1 shows proportions of manual reporting and automatic verification system after the improvement.

Qualitative Study

We interviewed 16 staffs from various parts and roles of the surveillance system. During the pre-improvement period, most of the stakeholders (10/16) reported that the system lacked simplicity and stability. For simplicity, they reported that workflow was complicated, and they needed to do multiple steps for reporting any PUI which took a long time. Additionally, data was not systematically collected with a non-standardized data structure. For stability, most of them (10/16) reported that the system relied on manpower which was only a few stakeholders involved in each process. If the number of PUI were rising, the system might not be able to drive with limited human resources. For acceptability, most of the stakeholders (9/11) in DDC and ODPC accepted it since the pre-enhancing period as it was their primary responsibility. However, most of the stakeholders (4/5) in PHO, hospital, and laboratory center did not accept the system as it was their additional work. For flexibility, some stakeholders (3/16) reported that the system might not be able to adapt with major change such as screening in state quarantine. Additionally, they reported that it was useful to monitor the local situation, identify risked population, and adopted policies. However, various stakeholders (7/16) reported that the data was not fully disseminated. They still needed to collect data from their lower levels repeatedly.

After improving the information system, the reporting system was simpler and required less than 5 minutes. The data was more systematic which could be managed and analyzed easily. For stability, the system was more stable after replacing with information technologies. It required fewer stakeholders to drive in each process. For acceptability, most of stakeholder (4/5) in PHO, hospital and laboratory center accepted the system because it could provide rich information to them. For flexibility, most of the stakeholders (14/16) reported that the system was adaptable to any situation after the improvement (Table 2). Overall, most of stakeholders (15/16) reported that the system was improved significantly.

Quantitative Study

Completeness

Completeness of pre- and post-enhanced information system of selected variables including ID card (pre:

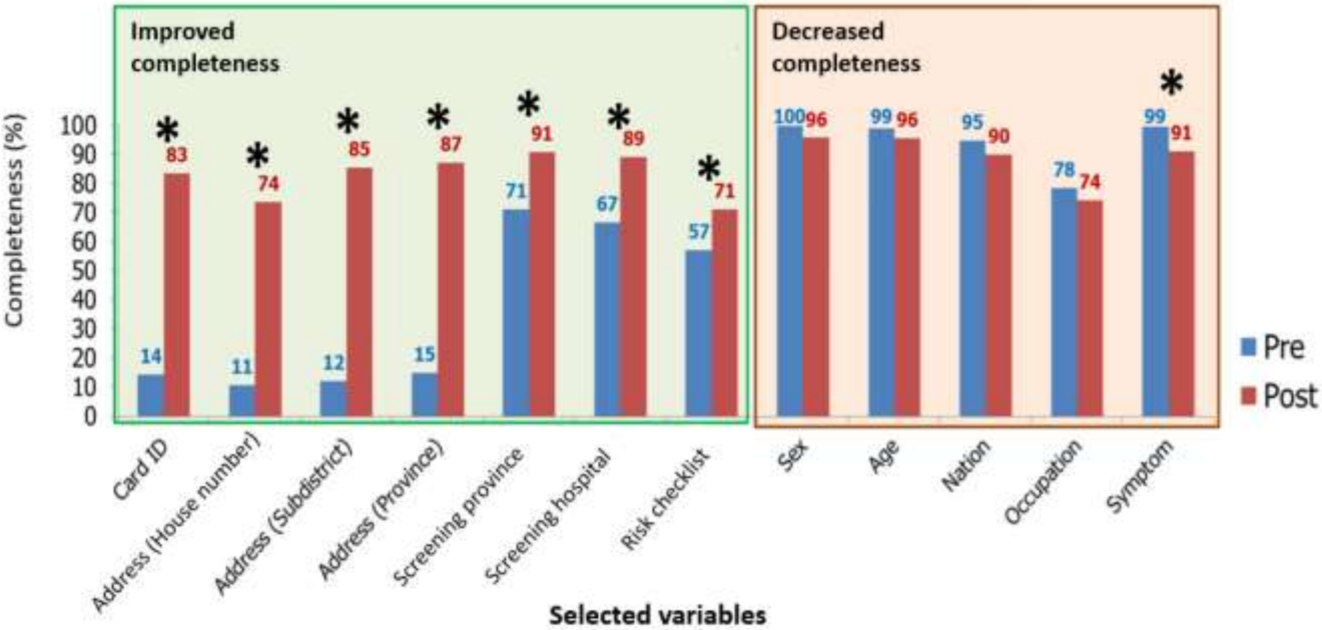

Figure 2. Completeness of selected variables from screening form of COVID-19 surveillance system, comparing pre implementation and post implemented information system period

14%, post: 83%), house number sick address (pre: 11%, post: 74%), sub-district sick address (pre: 11%, post: 74%) and province sick address (pre: 15%, post: 87%), screening hospital (pre: 71%, post: 91%), screening province (pre: 67%, post: 89%), and risk factors (pre: 57%, post: 71%) were improved with statistically significance (*p*-value<0.01). However, variables selected for evaluation of completeness included sex (pre: 99%, post: 96%, *p*-value=0.17), age (pre: 99%, post: 96%, *p*-value=0.17), nationality (pre: 95%, post: 90%, *p*-value=0.18), occupation (pre: 78%, post: 74%, *p*-value=0.50) and symptom (pre: 99%, post: 91%, *p*-value=0.03) were decreased but mostly not statistically significance (Figure 2). The pre and post implementation period score of timeliness were 55 and 66, respectively.

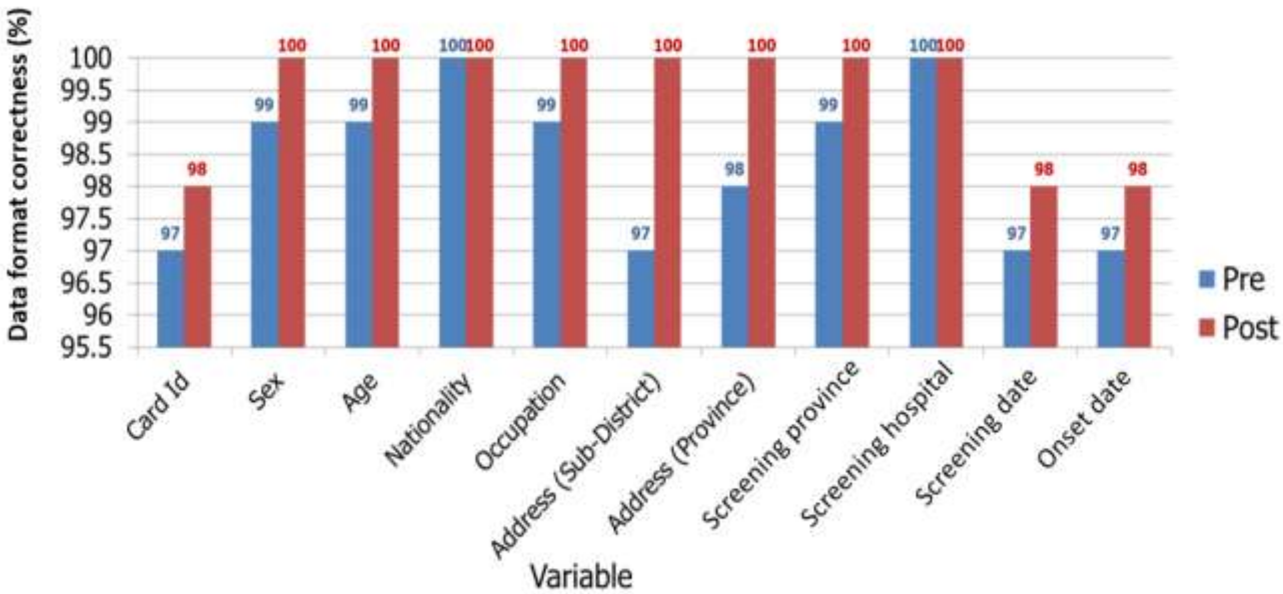

Figure 3. Data format correctness of selected variables from the screening form of COVID-19 surveillance system comparing before and after the improvement

Data quality

Data format correctness of all selected variables were improved without statistical significance at *p*-value>0.05 (Figure 3). In addition, duplication of records, which were checked by both name and surname, and ID card declined from 9.86% to 1.66% and 0.90% to 0.07%, respectively.

Figure 4. Proportion of timeliness of variables in COVID-19 surveillance system comparing pre- and post-enhancing period with its mean and standard deviation

Timeliness

Proportion of 0-day, 1-day, 2-day, the 3-day lag time between screening date and reported date were 31%, 24%, 13%, and 9% before improvement and 88%, 7%, 2% and 1% after improvement, respectively (Figure 4). The mean and standard deviation of lag time between screening date and reported date was 3.99 days and 9.45 days for pre-enhancing, and 0.29 and 1.27 days for the after improvement, respectively. For inferential statistics, the timeliness of the COVID-19 surveillance system was significantly improved. Additionally, from Kaplan-Meier survival analysis, the probability of early reporting to the COVID-19 surveillance system was increased month by month with significant differences according to the log-rank test with *p*-value<0.01 (Figure 5). The timeliness score was 75 and 96 for before and after improvement, respectively.

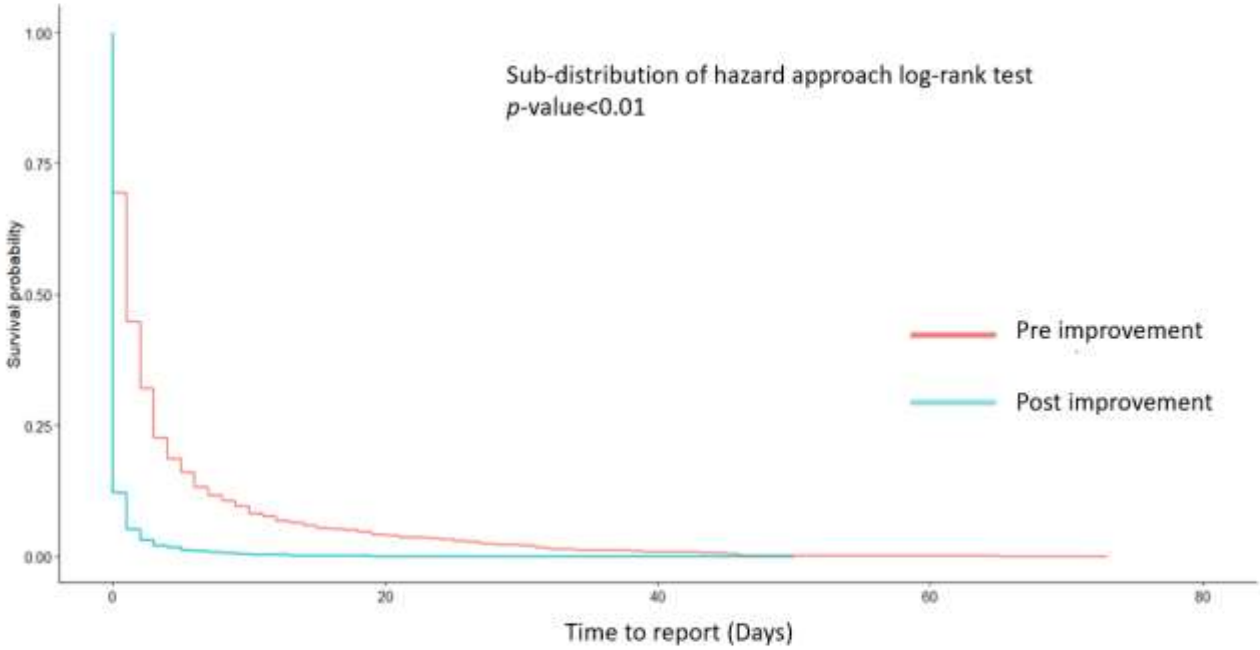

Figure 5. Kaplan-Meier survival analysis for the duration of screening date to reporting date to the surveillance system, comparing pre and post improvement with the log-rank test

In summary, the overall scores of both qualitative and quantitative attributes were improved. For quantitative attributes, completeness and timeliness were improved from 55 to 66 and 75 to 96%, respectively. For qualitative attributes: acceptability, simplicity, stability, flexibility, and usefulness scores were improved from 57 to 73, from 43 to 77, from 47 to 80, from 57 to 73, and 50 to 80 scores, respectively.

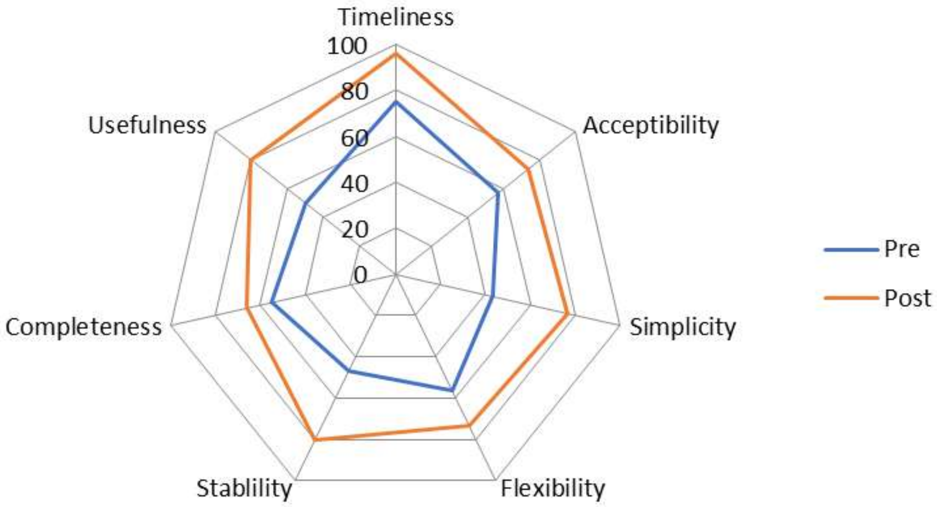

Figure 6. Radar chart illustrates the qualitative and quantitative attributes of COVID-19 surveillance system comparing pre- and post-improvement information system

All those qualitative and quantitative attributes were improved significantly (p-value<0.01) as shown in Figure 6.

Discussion

After the system was improved, the performances in both qualitative and quantitative attributes of the system were also improved significantly. This is because of the better understanding of stakeholder roles and workflows to improve the surveillance system.[8-12] According to the result, approximately 700 health care facilities participated in the surveillance system resulting in a large increase in the reported PUI number.

Several factors including the change in PUI criteria, and the mandate by law that the COVID19 is a dangerous communicable disease since 29 Feb 2020, enforce personnel to report the case to public health authorities within three hours after the suspected case was identified.[13] This might contribute to the improvement. We believe that the better and less complex system also contribute to a better reporting due to an automatic verification feature on the electronic-based platform. Simplification of the system also improves the timeliness by simplifying the reporting process.[14] A similar finding was also reported from Cambodia.[15]

Form our result, we found that both qualitative and quantitative attributes of the surveillance system were improved significantly. To improve the efficiency of the disease surveillance system, many electronic and automated innovations have been tried.[16,17] Additionally, the implementation of electronic-based platforms could be able to improve the simplicity, stability, flexibility, and acceptability of the system by replacing human-required tasks such as SAT code generation. Improving simplicity, stability, and acceptability of the surveillance system could contribute to the observed good quality and completeness of data.[18]

Additionally, data export function and visualization could play an important role to improve the usefulness of the system by providing users the ability to access to the epidemiological data allowing more timely analysis and response.[19-21] This could improve acceptability and cooperation through returning benefits to stakeholders similar to the previous study of influenza surveillance.[16] Additionally, this could improve the data quality as stakeholders were able to validate their data.[22]

Completeness and validity were significantly improved. This was because of the new automated system. It was observed that automated system of disease monitoring and reporting could improve the completeness of variables from several data input validation including the use of the mandatory field, repeatable fields, design logical order of variable and predefined variables. All these could improve the completeness of the system.[23-25]

There were limitations in this study. Firstly, face to face interviewing with local stakeholders was limited. Before the system improvement, our opportunity to gather the system gaps was limited. However, the teleconference was set-up instead and was utilized in the study after the improvement. Secondly, the study did not assess the system reliability (sensitivity and positive predictive value) and representativeness of the surveillance system, which were important attributes of surveillance evaluation.

Public Health Recommendations

Enhancing information system with careful understanding of existing workflow and stakeholders supported by information technologies could improve surveillance system performances in both qualitative and quantitative attributes. This could contribute to better reporting and stakeholders' workload. Additionally, surveillance evaluation process can be used to assess the improvement, gather feedback, and identify the gaps. More attributes of quantitative should be studied, for instance; sensitivity, positive predictive value, and representativeness to better understand the performance of the surveillance system.

Conclusion

With information technology, a traditional coronavirus disease (COVID-19) surveillance system was enhanced. The surveillance evaluation was conducted to compare pre- and post-improvement performance. After implementing enhanced information systems, all selected qualitative and quantitative attributes were improved significantly. Enhancing information system with careful understanding of existing workflow and stakeholders could be used to improve surveillance system performance. Surveillance evaluation process could be used to assess the improvement, gather feedback, and identify the gaps.

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