MEDINFO 2017: Precision Healthcare through Informatics
A.V. Gundlapalli et al. (Eds.)

doi:10.3233/978-1-61499-830-3-808

Toward Automatic Reporting of Infectious Diseases

Hsiao-Mei Tsao[a], Chi-Ming Chang[b], Jen-Hsiang Chuang[b,c], Ding-Ping Liu[b], Mei-Lien Pan[a], Da-Wei Wang[a]

[a] Institute of Information Science, Academia Sinica, Taipei, Taiwan, China
[b] Epidemic Intelligence Center, Centers for Disease Control, Taipei, Taiwan, China
[c] Institute of Biomedical Informatics & Institute of Public Health, National Yang-Ming University, Taipei, Taiwan, China

Abstract

Accurate, complete, and timely disease surveillance data are vital for disease control. We report a national scale effort to automatically extract information from electronic medical records as well as electronic laboratory systems. The extracted information is then transferred to the centers of disease control after a proper confirmation process. The coverage rates of the automated reporting systems are over 50%. Not only is the workload of surveillance greatly reduced, but also reporting is completed in near real-time. From our experiences, a system sustainable strategy, well-defined working plan, and multifaceted team coordination work effectively. Knowledge management reduces the cost to maintain the system. Training courses with hands-on practice and reference documents are useful for LOINC adoption.

Keywords:

Public Health Surveillance; Electronic Health Records; Logical Observation Identifiers Names and Codes

Introduction

Infectious disease surveillance has been a cornerstone of disease control. In order to have effective surveillance systems, we need to obtain timely, accurate, and complete data. In the past, data collection process used to rely on the physicians and Infection Control Nurses (ICNs) to manually report via telephone or faxing to the health authorities. The manual reporting process is not only time-consuming and labor-intensive, but also error-prone. With the adoption of web-based information systems, reporting time has greatly reduced and data quality has significantly improved. Information systems have transformed from a supportive role for public health to a proactive one in the last two decades. In 1995, the first syndromic surveillance systems were established to detect outbreaks of waterborne illness [1]. In addition, the US government started promoting a National Electronic Disease Surveillance System (NEDSS) in 2000. Hospitals were encouraged to develop electronic reporting systems to achieve stage 1 of Meaningful Use [2]. In 2004, the Public Health Information Network (PHIN) integrated the information systems to meet public health functional needs [3]. These all improved case detection and lead to prompt responses to an outbreak.

Currently, the major surveillance systems in Taiwan are the notifiable disease reporting system, laboratory surveillance system, school surveillance system, populous institutions surveillance system, and Taiwan Real-time Outbreak and Disease Surveillance (Taiwan RODS) system [4]. Among them, the notifiable disease system is the most important one. Physicians and ICNs are mandated to report notifiable diseases through this web-based system. That is to say, they need to look up all the information from hospital information systems and then type information into the notifiable reporting system. According to Taiwan's regulations, there are more than seventy notifiable diseases. For each disease, plenty of data needs to be collected. Thus, collecting surveillance data comprises heavy workloads for physicians and ICNs. In addition to the notifiable disease system, Taiwan RODS is also important for infectious diseases surveillance. Taiwan was severely struck by the SARS epidemic, and subsequently, the government has made a lot of progress in disease surveillance. Taiwan RODS was launched to automatically monitor several syndromes through emergency departments since 2004. Taiwan RODS was easily adapted to monitor an outbreak of red eye syndrome and has shown its effectiveness in situational awareness [4]. Now, it monitors influenza-like illnesses, enterovirus infections, red eye syndrome, and diarrhea. However, before conducting this project, Taiwan had not yet implemented any electronic laboratory reporting (ELR) system. We could only obtain pathogen information from sentinel physicians through the laboratory surveillance system to characterize the subtypes of influenza virus and enterovirus infections.

In the past decade, the Taiwanese government has aggressively promoted Electronic Medical Record (EMR) systems and Health Information Exchanges (HIE). There are 406 out of 501 hospitals that have implemented EMR systems and are capable of interchanging EMRs among institutions [5]. Given this basis, Taiwan Centers for Disease Control (TCDC) launched the National Epidemic Prevention and Control (NEPC) project to improve the efficiency and effectiveness of surveillance in 2014 [6]. This project comprises two programs. One is the "automated reporting via EMR" program (EMR program for short), which aims to accomplish the automatic machine-to-machine reporting of notifiable diseases from hospitals' EMR systems to TCDC. The other is the ELR program, the goal of which is to report positive laboratory test results of 20 selected pathogens from hospitals (directly from the laboratory information system). In this article, we report Taiwan's experiences of its implementation strategies and current achievements in promoting the NEPC project.

Methods

Implementation strategies

The initial step of the NEPC project was amending the regulation by the authority to make automatic extraction and reporting acceptable. A committee was formed to design the system architecture and establish program workbooks that contain all the necessary information to implement such systems. The data format as well as the semantics of required data elements of each notifiable disease and an accompanying specification using HL7 [7] Green Clinical Document Architecture (GCDA) [8] were also included.

The three-year NEPC project took an expanding-and-maintaining strategy in three rounds. For each round, which took one year, there were three stages: the recruitment stage, development stage, and evaluation stage. The first two months were the recruitment stage. TCDC announced the latest program workbooks and recruited hospitals. The incentives for hospitals to join the project included funding for system construction and bonus points for hospital accreditation. The recruitment stage ended with a signed contract, and the seven-month development stage began. During this stage, the participating hospitals followed the program workbooks to develop the reporting system and had to pass the system testing at the end. The last three months were evaluation stage. Data completeness and system stability were evaluated at this stage. In order to encourage the participating hospitals to report complete data and maintain system stability, an extra bonus was given based on the results of the evaluation stage. It is worth mentioning that hospitals joining in earlier rounds were actively engaged and this was the maintenance art of the strategy.

In order to run the project smoothly, TCDC organized a multifaceted team, which consisted of a policy instruction committee, an information technology (IT) support group, and a project coordination office. The team meeting was held weekly to monitor the progress and to assist all the hospitals for implementation issues. The details of the development and evaluation stages for the EMR and ELR programs are as follows.

EMR program

The EMR reporting system is designed to utilize hospital EMR to report notifiable diseases. A schematic view of the EMR reporting system is shown in Figure 1. We selected participating hospitals according to the reporting quantity. The participating hospitals have to develop a reporting module, XML generation module, and digital signature module. The reporting module extracts cases from EMR systems; the XML generation module creates reports conform to the defined XML schema; the electronic signature module adds digital signatures to the reports. After physicians or ICNs review the data, the hospitals report the cases to TCDC. For each hospital, we compute a weighted sum of the ratios of all notifiable diseases cases reported by that hospital divided by the national total and this is the coverage rate of the hospital. We can then add all the coverage rates of all participating hospitals as the coverage rate of the project. Furthermore, system maintenance is estimated by the EMR reporting rates and successful reporting rates. The reporting rates of each participating hospital have been monitored since the systems were launched. We also surveyed how frequently the participating hospitals send the reports.

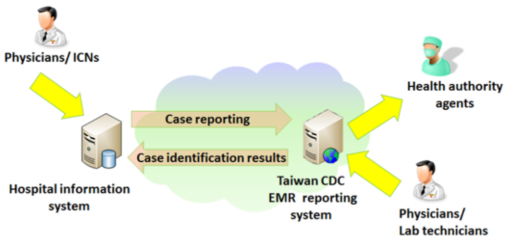

Figure 1–Schematic view of the EMR reporting system

ELR program

The Laboratory Automated Reporting System (LARS) is designed to monitor trends in 20 selected pathogens such as hepatitis virus, influenza virus, and Salmonella, to name a few. A schematic view of the LARS is shown in Figure 2. There are two objectives when selecting participating hospitals: the reporting quantity, and balance of area. The participating hospitals were asked to send positive laboratory test results to TCDC. There are three steps for system development, including gateway setup, Logical Observation Identifiers Names and Codes (LOINC) [9] mapping, and data transmission. The IT support group assisted the hospitals to setup the gateway. The positive laboratory test results were then sent to TCDC. Because there is no reference data for LARS, we used the notifiable disease reporting rates of all hospitals participating in the ELR program in 2015 as a proxy for the coverage rate. The total coverage rate and the district coverage rates were calculated. (Taiwan is divided into six districts according to geographic location.) We adopted the international standards for the laboratory test results, LOINC, as well as the coding system for LARS. Therefore, the first step is to map the hospital local codes to LOINC codes. When the project was initiated, LOINC was not commonly known in Taiwan. Medical technologists (MTs) were not familiar with LOINC. TCDC provided LOINC mapping training courses to all the participating hospitals on the second month of the development stage in each round. The courses contain the introduction of basic knowledge of LOINC, mapping procedure demonstration, and hands-on practice. RELMA® [10] was chosen as the mapping tool.

In addition to the training courses, TCDC keeps auditing data to ensure the data quality and the auditing results are fed back to the hospitals. The six parts of LOINC are compared with the mapped LOINC codes to see whether they are matched to each other. The LOINC mapping rates are then calculated. LOINC mapping rate is also one of the items in auditing.

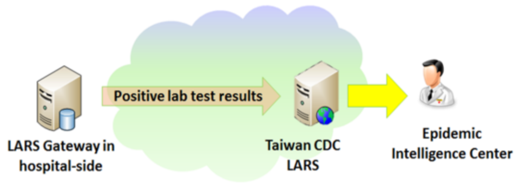

Figure 2–Schematic view of LARS

Results

There are now a total of 47 and 53 participating hospitals in the EMR and ELR programs and the coverage rates are 52% and 59%, respectively. The characteristics of the participating hospitals are shown in Table 1. In the first year, medical centers had higher priority. In the end, all the medical centers in Taiwan joined this project.

Table 1–Hospital levels of the participating hospitals

Program	Hospital level	2014	2015	2016
EMR	Medical center	14	3	2
	Regional hospital	6	6	16
ELR	Medical center	15	2	2
	Regional hospital	5	7	22

EMR program

The implementation strategies of all the EMR program participating hospitals can be categorized into self-developing and outsourcing. Most medical centers (84%) developed their own EMR reporting systems. On the contrary, 75% of the regional hospitals tended to outsource to vendors (Table 2). We conducted a chi-square test with Yates' continuity correction to compare the implementation methods between the two groups and the finding revealed a significant difference with $p < 0.001$. These regional hospitals are served by four health information companies, which is an advantage to the project because the vendors can serve many hospitals.

From our experience, we found that self-developing hospitals were more likely to fall behind schedule. Every year, there are always 1 or 2 hospitals having trouble keeping up with the schedule. Thus, we set up milestones for program progress and carefully monitored the progress of every hospital. Any hospital that was 30 days behind schedule was arranged to be met by the project coordination office. Moreover, it takes a longer time for the self-developed systems to revise the program. This April, the case definition of syphilis was amended; it took about one month to update the program for the self-developed systems, whereas less than two weeks was enough for the outsourced, developed systems to update the program.

Table 2–Characteristics of the EMR program participating hospitals

Hospital level	Self-developed (%)	Outsourced developed (%)
Medical center	16 (84)	3 (16)
Regional hospital	7 (25)	21 (75)
Total	23	24

The EMR program has achieved three marked effects: high reporting rates, near real-time reporting, and decreased workloads.

1. High reporting rates:

   All the EMR program participating hospitals were monitored for the EMR reporting rates and successful EMR reporting rates. The average EMR reporting rates were constantly maintained around 93%. Some hospitals had a reporting rate below 60% because they did not develop a reporting module for diseases that rarely occur there. Hospital 41 (H41) is a small hospital. It missed one case, and had only one reporting failure after the system was launched at the end of this September.

2. Near real-time reporting:

   The EMR reporting system can automatically extract data from EMR systems. After ICNs examine the reporting data, the data can be sent. Among these participating hospitals, 25 out of 47 hospitals can send data in real-time. The others send data via a scheduled program. The reporting intervals are shown in Table 3. In the future, with enough evidence, the workflow can be further streamlined; the confirmation of the ICNs can be a parallel process with the machine-to-machine reporting. Undoubtedly, the status data will be classified as to-be-confirmed and confirmed. This modification can partially mitigate the potential issue that ICNs become the bottleneck in the process.

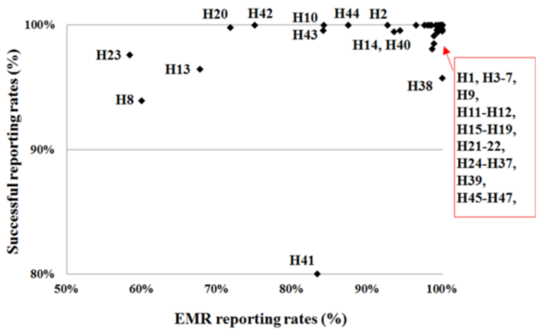

Figure 3–Reporting rates and successful reporting rates of the EMR program participating hospitals

Table 3–Reporting intervals of the EMR program participating hospitals

Reporting interval	No. of hospitals (%)
Real-time	25 (53)
<4 min	15 (32)
4-10 min	6 (13)
11-30 min	1 (2)
Total	47 (100)

3. Decreased workloads:

   The most important benefit of the EMR reporting system is the reduction of ICNs' workloads. Because the ICNs' role changes from entering the data to reviewing them for confirmation only, it reduces the reporting time from 8 minutes per case to 3 minutes, as mentioned by a senior ICN from a medical center [11].

ELR program

Compared with the traditional laboratory surveillance system, which collects data from only a few contracted laboratories, LARS gathers data directly from hospital laboratory information systems. On average, TCDC received around 13,000 positive laboratory tests of the 20 selected pathogens per week from the 53 participating hospitals. The coverage rates of LARS for each of the six districts ranged from 44%-69%.

From our experience, with the help of knowledge management, LOINC mapping training courses are the most effective way to promote LOINC adoption. The average LOINC mapping rate was about 50% in 2014, and has improved steadily since. It has now reached 82% in 2016. In the first year, only basic knowledge and RELMA demonstration were provided in the training courses and the average mapping rates were low. More efforts were made to correct the data. Therefore, we added hands-on practice in the second year and the average LOINC mapping rates increased to 72%. In addition, we extracted knowledge from data auditing and reached a consensus for LOINC mapping rules from expert panel discussions. The knowledge was documented as LOINC mapping rules, the LOINC mapping FAQ, and the most frequent LOINC combinations. These documents became the teaching materials in the third year.

Here, we used the influenza virus data as an example to represent the system effects of LARS. Figure 4 shows the number of positive influenza virus tests during the period from the 40th week, 2015 to the 48th week, 2016. In this figure, it clearly shows a peak spanning from the 2nd week, 2016 to the 16th week, 2016. Type A influenza virus accounted for the most positive test results. LARS can detected an unusual signal two weeks earlier than traditional laboratory surveillance systems (data not shown). Based on the pathogen data collected by LARS, TCDC was able to make a timely decision and respond promptly for flu control.

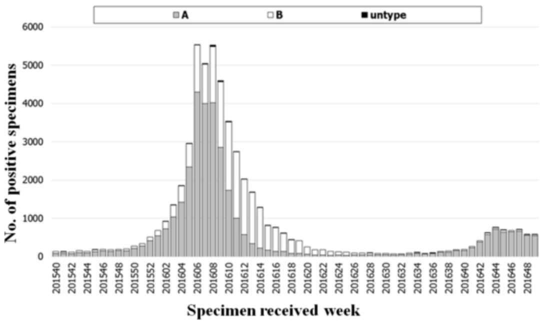

Figure 4–Positive influenza virus tests collected by LARS

Discussion

The NEPC project was successfully executed under a limited funding budget. TCDC has made the coverage rates of both programs reach more than 50%. Besides, the implementation of the EMR reporting systems has greatly reduced the workloads of ICNs. Thus, the reporting rates have been constantly maintained above 90%. The LARS collects positive test results of the selected pathogens and provides further information for infection control efficiently. The experience of the NEPC project provides an operational roadmap for implementing a successful strategy for enhancing national infectious disease surveillance systems, which adopt HIE. From our experience, we have extracted the following three lessons to share.

1. System sustainability:

   TCDC makes a tremendous effort to make the operation sustainable. From a policy perspective, the first step is to have a legal basis and then bring in incentives. Hence, the Infectious Disease Control Act and Implementation Regulation for Epidemic Surveillance and Alert System were amended. Thereafter, a one-year grant jumpstarted the program. Further, the maintenance strategy included providing feedback to the hospital and awarding outstanding hospitals. Hospitals also can earn extra bonus points during hospital accreditation. From an implementation perspective, knowledge management is an effective way to maintain the system with limited resources. In this case, we documented each of the issues encountered during the project. As for TCDC, it helps them to provide continuous support to the hospitals. As for the participating hospitals, it is also useful when the personnel change. In addition, the EMR reporting system directly benefits ICNs by reducing their workloads. This makes hospitals more than willing to participate in this project. We have heard that several hospitals were actually persuaded by their infection control departments. Some of the healthcare networks even voluntarily implemented the EMR reporting system in their member hospitals without any funding.

2. Project implementation:

   A well-defined working plan and schedule management help the project run on schedule. A full-year detailed working plan and schedule were determined at the beginning with a thorough communication process. The project coordination office monitors the progress in accordance with this plan closely, in order that any delay can be detected earlier. The noted delay triggers a coordinated effort to speed up the progress. Therefore, all of the participating hospitals can finish system construction, testing, and evaluation on schedule.

   Furthermore, keeping the project running smoothly requires multifaceted team coordination. There are multiple stakeholders in the project: the hospital, IT support group, project management office, and TCDC. We note that when hospitals need help, the best approach is to have all stakeholders work together to resolve issues. We note that cases in which only IT support group is involved may focus on technical details regardless of administrative support issues, and thus, delay the progress. It seems to be a trivial observation, but when there are several hospitals asking for help, it soon becomes a daunting effort. Furthermore, bilateral efforts soon become the norm if multilateral collaboration is not mandatory. Besides, we note that the needs of the hospitals vary dramatically. For example, medical centers usually have their own in-house software development teams, and the trouble usually comes from inter-departmental communication, especially between the infection control departments/laboratory departments and software teams. The project also has to compete with other projects in the hospital; therefore, an early warning to the project leader, usually the deputy director of the hospital, is very important. For hospitals that do not have in-house software teams, the trouble usually stems from the interaction between two IT vendors, one from the hospital and one from the CDC. The detection of early warning signs and timely intervention from the project office are vital.

3. LOINC adoption:

   Although training courses are an effective method to introduce LOINC, only teaching basic knowledge of LOINC is not enough. Hence, we held two expert panel discussions and reached a consensus for LOINC mapping. Thus, overall LOINC mapping rules have been created and incorporated into teaching materials for the next training courses. Online videos for LOINC mapping were also provided. Given the clear instructions and online videos, MTs are able to map LOINC effectively. Because laboratory data change with time, continuous auditing is important. We extracted knowledge from data auditing, and documented the mapping FAQ and the most frequent combinations of LOINC parts.

Conclusion

The NEPC project's success is two-fold: 1) the EMR reporting system greatly reduces the workloads of ICNs and shortens the reporting time of notifiable diseases; 2) LARS collects positive test results of 20 selected pathogens to complement the existing surveillance systems. These achievements have made the surveillance more efficient and effective. From our experiences, we have learned lessons for system sustainable strategy, project implementation, and LOINC adoption. A system sustainable strategy includes having a legal basis and adequate incentives. Knowledge management reduces the cost to maintain the system. Further, a well-defined working plan, schedule management, and multifaceted team coordination work effectively for project implementation. Training courses with hands-on practice and reference documents are useful for LOINC adoption. Reference documents include the overall mapping rules, mapping FAQ, and the most frequent combinations of LOINC parts.

Acknowledgements

This work was supported by Taiwan CDC (MOHW104-CDC-C-114-000801, MOHW105-CDC-C-114-000401), and by Multidisciplinary Health Cloud Research Program: Technology Development and Application of Big Health Data. Academia Sinica, Taipei, Taiwan. The authors declare that there is no conflict of interests regarding the publication of this article.

References

[1] R. Heffernan, F. Mostashari, D. Das, M. Besculides, C. Rodriguez, J. Greenko, L. Steiner-Sichel, S. Balter, A. Karpati, P. Thomas, M. Phillips, J. Ackelsberg, E. Lee, J. Leng, J. Hartman, K. Metzger, R. Rosselli, and D. Weiss, New York City syndromic surveillance systems, MMWR Suppl 53 (2004), 23-27.

[2] C. Centers for Disease and Prevention, Progress in improving state and local disease surveillance--United States, 2000-2005, MMWR Morb Mortal Wkly Rep 54 (2005), 822-825.

[3] J.W. Loonsk, S.R. McGarvey, L.A. Conn, and J. Johnson, The Public Health Information Network (PHIN) Preparedness initiative, J Am Med Inform Assoc 13 (2006), 1-4.

[4] J.H. Chuang, A.S. Huang, W.T. Huang, M.T. Liu, J.H. Chou, F.Y. Chang, and W.T. Chiu, Nationwide surveillance of influenza during the pandemic (2009-10) and post-pandemic (2010-11) periods in Taiwan, PLoS One 7 (2012), e36120.

[5] Y.C. Li, J.C. Yen, W.T. Chiu, W.S. Jian, S. Syed-Abdul, and M.H. Hsu, Building a national electronic medical record exchange system - experiences in Taiwan, Comput Methods Programs Biomed 121 (2015), 14-20.

[6] H.-M. Tsao, M.-L. Pan, E.-W. Huang, and D.-W. Wang, Experience from National Medical Informatics Policy: Using the Example of Epidemic Prevention and Control Project, Journal of Taiwan Association for Medical Informatics 25 (2016), 1-12.

[7] HL7 International, Introduction to HL7 Standards, Available from http://www.hl7.org/implement/standards/index.cfm?ref=nav (2016).

[8] R. Worden, Introduction to Green CDA, Retrieved from http://docslide.us/documents/introduction-to-green-cda-cda-forum-17-th-january-2013.html (last accessed 16 Dec, 2016).

[9] Regenstrief Institute, LOINC, Available from http://loinc.org (2016).

[10] Regenstrief Institute, RELMA, Available from http://loinc.org/downloads (2016).

[11] iThome, CDC launched the NEPC project, Available from http://www.ithome.com.tw/news/94172 (2016) (in Chinese).

Address for Correspondence

Da-Wei Wang

Address: 128 Academia Road, Section 2, Nankang, Taipei 11529, Taiwan (Institute of Information Science, Academia Sinica)

Email: wdw@iis.sinica.edu.tw

Tel: 886-2-2788-3799 #1729

Fax: 886-2-2782-4814