

Use of Information Communication Technology in communicable disease surveillance

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Abstract

Panic set out by newly emerging and re-emerging communicable diseases is taking a global dimension. A functional surveillance system is essential in all countries to provide the necessary information required for preventive action against communicable diseases and to make decisions on public health related issues. This article discusses the importance of such communicable disease surveillance systems (CDSS) and problems with existing CDSS. Most of the studies conducted were related to the attributes such as accuracy and speed of communicable disease notification. As a solution to overcome the difficulties experienced by the existing systems, some countries have introduced computerised systems for the surveillance of communicable diseases. Studies focused on the evaluation of these electronic systems reported improvements in the quality of the systems with respect to the previous systems. During the last few years, studies were directed towards the development and evaluation of 'early warning systems' and 'syndromic surveillance systems' for early detection and monitoring of epidemics and bioterrorism-initiated infectious disease outbreaks. The WHO envisages an integrated approach to communicable disease surveillance and this strategy has been recognised by all member states and is being adopted in the African region and activities are under way in the Eastern Mediterranean region, Europe and South-East Asia.

Keywords - communicable disease surveillance; disease notification; infectious diseases; electronic reporting.

Introduction

Newly emerging and re-emerging infectious diseases and its consequences are in the spotlight. Since 1995, the World Health Organisation (WHO) Secretariat has given it high priority and is responding with determination towards infectious diseases⁽¹⁾. Even though the world today is largely characterised by tremendous globalisation, connectivity and speed, control of communicable diseases is still a challenge. These diseases are a leading cause of morbidity and mortality around the world. Furthermore, these diseases have an adverse effect on the economic and social development of countries too⁽²⁾.

Prevention and control of communicable diseases depends on effective response systems which could be run successfully with helpful disease surveillance activities. In all countries, surveillance activities on communicable diseases are operated via functional surveillance systems which provide necessary information. It also plays a vital role in public health decision-making⁽³⁾.

Public health surveillance systems for communicable diseases

Effective and efficient delivery of health care services through the implementation of cost-effective health strategy is ensured by the information provided by public health surveillance systems⁽³⁾. The World Health Organisation's definition of public health surveillance, proposed under resolution WHA58.3⁽⁴⁾ as: "Surveillance means the systematic ongoing collection, collation and analysis of data for public health purposes and the timely dissemination of public health information for assessment and public health response".

Assessing the health status of a population and controlling the disease outbreak through effective disease prevention and control activities are the main components of public health surveillance⁽⁵⁾. This is largely supported by surveillance systems for communicable diseases.

These systems identify disease outbreaks, analyse the long-term trend of a particular disease and hypotheses are formulated as to the nature of the problem based on the information provided⁽⁶⁾. Recent events like the SARS epidemic and avian influenza have drawn worldwide attention and have also increased the potential for bioterrorist attacks. These events have highlighted the importance of these types of surveillance systems^(4,7).

Around the world, surveillance activities have evolved in an irregular manner. Individual countries handled the problem of infectious diseases and the threats posed by them in their own way⁽³⁾. At present, except for three internationally notifiable diseases (cholera, plague and yellow fever), the list of reportable diseases differs from country to country, and even within each country it would change over time.

Many countries in the world today have state laws and regulations for reporting of communicable diseases of public health importance⁽⁸⁾. In these countries, notification of infectious diseases is a legal duty of the physician or medical practitioner who treats the person with the reportable disease and also the healthcare institutions^(9,10). Rutherford⁽¹¹⁾ stated that in addition to medical practitioners, other healthcare professionals, medical laboratories and public could also notify. It is important that notification of infectious diseases should be made or directed to a 'proper officer' at a local public health authority. This is because the goals of notification such as taking appropriate steps to control further spread of the disease, carrying out an investigation of the reported cases and supplying of data for local and national surveillance will be accomplished only if the notification reaches the correct person on time⁽¹²⁾.

Surveillance activities in many countries are targeted to monitor the progress of surveillance programmes enforced by the national or international organisations. In addition, they aim to detect the incidence of epidemic prone diseases and monitor the more prevalent infectious diseases in a particular community⁽³⁾. Surveillance of communicable diseases is primarily based on the notifiable disease reporting systems. Some of the distinct features of these reporting systems are promoting epidemiological investigations, monitoring disease trends, detecting epidemics, and assessing disease surveillance programmes⁽¹³⁾. Despite the importance of these, on most occasions the surveillance data collected via these systems are not helpful in decision making. This is because they become incomplete, inaccurate, untimely, obsolete and unrelated to priority tasks at the time it reaches the healthcare personnel⁽¹⁴⁾.

Problems with existing communicable disease surveillance systems

Studies undertaken to examine the barriers to notification of infectious diseases have identified certain strategies to improve the notification process. Further, except for the studies on accuracy and speed of reporting, it is hard to find any literature related to other attributes (such as simplicity, flexibility, acceptability, representativeness, predictive value) used for the evaluation of surveillance systems for communicable diseases.

Under reporting (incomplete reporting) of infectious diseases, remains a major problem in communicable disease surveillance. Several studies indicate that a surveillance system based solely on traditional passive reporting by healthcare providers may lead to substantial under

reporting of certain diseases^(15,16,17,18). This clearly reveals that the importance of notification has not been understood by the medical practitioners. This is partly because some of them are not aware of the reportable diseases and/or because of ignorance or the fact that they had forgotten to notify⁽¹⁹⁾. In addition, lack of awareness of legal obligations to report and unfamiliarity with the notification procedures also contribute to under reporting^(20,21,22, 23). As a solution to this problem and to increase the number of reported cases, it was suggested to obtain information from other sources such as laboratories^(24,25), infection control units in hospitals, record room personnel⁽¹⁷⁾, nurses, midwives and health visitors⁽¹⁸⁾. Reports from these sources should never replace the requirement for reporting by physicians or medical practitioners and will lead only to the identification of unreported cases and monitoring of reporting rates⁽¹⁷⁾.

Moreover, a study carried out in Malta revealed that General Practitioners (GP) are expected to notify the hospital, when a case is transferred to a hospital from a GP practice. This leads to a certain amount of uncertainty among medical practitioners regarding authority of notification, whether it has to be done by the referral doctor or the hospital physician who confirms the case and finally ends up under reporting⁽²⁶⁾. An analytical review of published literature on the completeness of notifiable disease reporting in the United States revealed that completeness of reporting is strongly associated with the type of disease being reported⁽²⁷⁾. Voss⁽²⁸⁾ pointed out that one reason for under reporting could be that proper emphasis has not been given to notifiable disease reporting in medical education at undergraduate and postgraduate levels. The importance of notification and the legal obligations of medical practitioners should be stressed at every level of medical training^(17, 28). Furthermore, studies revealed that payment to doctors has a tendency to increase their participation in notification of infectious diseases^(23, 29). In contrast, Gauci *et al.*⁽²⁶⁾ suggested that rather than being remunerated, doctors prefer acknowledgement for their notification in the form of awarding points for their progress in medical education. In addition, it was felt that communication between public health authorities and clinicians on surveillance activities carried out based on the notifications, and regular feedback on communicable disease issues (including outbreaks) will improve the attitudes of clinicians regarding notification^(26,30). Simmons *et al.*⁽³¹⁾ also emphasised the importance of feedback as an effective way to motivate general practitioners to notify.

Speed is considered as one of the key measures in any surveillance system and needs to be assessed periodically^(5,32,33). Many studies carried out in relation to speed of surveillance systems focused on the time lag or problems that appeared at each surveillance step^(5, 34, 35, 36). Further, studies also compared clinical and laboratory surveillance^(23,37), and electronic and conventional methods used in surveillance systems^(24, 36, 38). It is also observed that efficiency and involvement of public health systems could be affected by the delay in notifying infectious diseases. Studies reporting on speed of notification of infectious diseases found that notification delay varied between diseases. It depends on the relative number of cases for a particular disease, severity of the disease, and diagnostic difficulties of the disease^(35,39). According to Allen and Ferson⁽²³⁾, leaving notification to the laboratories will accelerate the notification.

Application of ICT in communicable disease surveillance

The contribution of ICT to overcome the difficulties experienced in the existing systems is apparent. Invention of electronic tools and techniques has influenced the changes in the way surveillance activities are performed. Conventional paper based surveillance systems are being increasingly replaced by electronic reporting of surveillance data, initially by means of diskettes⁽⁴⁰⁾ and now using web based reporting mechanisms⁽³⁶⁾. With the help of electronic databases, surveillance data can be analysed rapidly and easily. In addition, geographical

information systems (GIS) support the mapping and analysis of geographical information. Such advancements in information communication technology have given new opportunities to improve the existing surveillance systems while reducing the burden on health workers to report.

Epi Info (URL: <http://wwwn.cdc.gov/epiinfo>), statistical software for epidemiology developed by the Centers for Disease Control and Prevention (CDC) could be considered as one of the earliest attempts in this line. It was designed to assist the medical and public health professionals in surveillance activities. It facilitates the functions such as, developing questionnaires, customising data entry process, entering data into the developed questionnaire quickly and analysing the data with the help of analytical tools. Further, it produces epidemiological statistics, tables, graphs, and maps instantly, based on the data. Initially, Epi Info 1 was introduced in 1985, as an MS-DOS batch file on 5.25" floppy disks. In 2001, first Windows-compatible version of Epi Info, named as Epi Info 2000 was released. This was written in Microsoft Visual Basic and by adapting the Microsoft Access database format, it has changed the way in which data was stored. Epi Info 7 is the latest version written in Microsoft C#.NET and is supported by both Windows and Linux operating systems. It was released in 2009. A pilot study carried out in Tuscany, Italy with the implementation of Epi Info 5.0 software demonstrated that computerisation will improve the quality of the surveillance system to a certain extent⁽⁴⁰⁾. Further, an analysis carried out in 2003 by CDC has documented that there were 1,000,000 downloads of Epi Info from over 180 countries⁽⁴¹⁾. This indicates the current shift towards electronic reporting from conventional methods.

Worldwide, current threats of bioterrorism and infectious diseases caused by emerging pathogens have resulted in increased pressure to improve the quality and speed of routine communicable disease surveillance systems⁽⁴²⁾. The WHO also supports such activities through their strategy called 'integrated approach to communicable disease surveillance', introduced in 2000. As a result, countries have initiated projects to strengthen their existing communicable disease surveillance systems, particularly by means of electronic data interchange (such as NEDSS of United States, OSIRIS of Netherlands, CIDR of Ireland, SmiNet of Sweden, SurvNet@RKI of Germany, NNDSS of Australia). Some of these systems are reported below:

Case studies

Sweden was supposed to be one of the pioneers in this field and introduced a computerised reporting system, called SmiNet in 1997. The main objectives of SmiNet were to enhance the quality of communicable disease surveillance by simplifying the reporting process, as well as improving the sensitivity and speed of reporting. A study which assessed the sensitivity of the Swedish statutory surveillance system revealed that sensitivity improved through parallel reporting by clinicians and laboratories in counties (16 out of 21) where SmiNet system was implemented⁽²⁴⁾. Parallel to this, a programme called SmittAdm was developed by the Department of Communicable Diseases Control and Prevention, in the Stockholm county for electronic reporting and was used in five more counties since 1998. This programme was also built in Lotus Notes (LN) and supplemented SmiNet for certain functions performed at county level.

In contrast to SmiNet, SmittAdm permits the integration of patient records with the LN on contact tracing and outbreaks, as well as facilitating working at county level. The SmiNet system was later upgraded with an internet based version called SmiNet-2, in 2004. The new system allows clinicians to report cases with notifiable conditions directly via internet and also receives

notifications directly from laboratory data systems via the internet. Thereafter, clinical and laboratory notifications are merged automatically to case records by the system, with the help of a unique personal identification number. Major advantages of SmiNet-2 are speed in dataflow (up to national level), complete integration of clinical and laboratory notifications, and capacity to handle more than 50 diseases within one single system. Regarding the technological aspects, the system maintains a common central server at national level. In addition separate county servers are kept at each county to support functions such as outbreak investigations, case management and contact tracing⁽⁴³⁾.

In Lithuania, establishing an electronic reporting system for the surveillance of communicable diseases was a project initiated by the public health centre in Kaunas county, with the collaboration of Swedish Institute for infectious disease control (SMI) and Department of Communicable Diseases Control and Prevention of Stockholm county in Sweden, in 2002.

In 2004, SmittAdm software was acquired from the Department of Communicable Diseases Control and Prevention, Stockholm county and adopted in Lithuania, resulting in a software called ULISAS, which was very similar to SmittAdm. IBM Lotus Domino and Lotus Script and Java programming languages were used for the development of ULISAS. A major advantage of this software was the possibility to work offline, which was an essential requirement since internet access is not available in all public health institutions in Lithuania. Further, server requirement at county level was 2GHz, 2GB RAM, 36GB HDD, whereas at national level was 3 GHz, 4GB RAM, 300GB HDD. Moreover, it is Lotus based software, running Notes Domino 6.5 or higher versions on Linux or Windows servers, and Windows computers as workstations. Initially, the system was implemented in two counties in 2004, and central server at the national level was installed and connected to the system during late 2005. Then, the system was extended to include all remaining counties, during the period 2006 and 2007. Even though, surveillance activities of the public health sector are computerised, still the system receives notifications from physicians and laboratories, via mail, e-mail or fax. Hence, it is intended by the Lithuanian authorities to computerise the clinical and laboratory reporting, develop web application (when internet access is available at all levels), and establish alert system for outbreaks⁽⁴⁴⁾.

SurvNet@RKI, an electronic reporting system for notifiable infectious diseases surveillance was implemented in 2001 in Germany. Major objective of introducing such system was to ensure the flow of surveillance information between local, state and federal institutions in Germany. This system was developed by the Robert Koch-Institut (RKI) with the collaboration of an external IT company and was used in 431 Local Health Departments (out of 439 LHDs), 16 State Health Departments (SHD), and the RKI (national agency for infectious disease epidemiology), in 2006. The software for SurvNet@RKI was written in MS Access 97 and Visual Basic, and it supports MS Access and MS SQL Server database management systems depending on the volume of data. The database is designed as a dynamic relational database, which consists of 73 reporting categories with more than 600 fields and about 7000 pre-defined entry values.

However, difficulties experienced at implementation level, necessitated certain changes in the system. In 2006, it was decided to change the platform to Microsoft C#/.NET and replace the transport file format to XML in order to overcome those difficulties encountered with the previous system⁽⁴⁵⁾. In the meantime a web interface called SurvStat@RKI (URL: <http://www3.rki.de/SurvStat>) was introduced in 2004 which allows the public health workers to

access surveillance data whenever necessary and permit them to analyse the epidemiological data held by the system, in an interactive manner⁽⁴⁶⁾.

In 2000 the National Electronic Disease Surveillance System (NEDSS) project was initiated in the United States with federal funding. Previously, state health departments received notifications by mail. Subsequently case details were entered into computer systems and then surveillance reports were prepared and sent out from the states to CDC. In order to transmit these surveillance reports to CDC, different states have adopted different methods, due to incompatibility in exchange of data between different systems used. The NEDSS project introduced in 2000 was aimed at strengthening the public health surveillance by introducing uniform standards to exchange relevant information required for surveillance and intervention, in addition to improving the speed and accuracy of disease surveillance. In April 2005, it was recorded that 27 state health departments and two municipal health departments were using this secure, internet based system for reporting notifiable diseases. NEDSS also supported Electronic Laboratory Reporting (ELR). In 2005, it was documented that a total of 26 state health departments obtained laboratory reports via ELR, whereas the remaining 24 states were at various stages of development⁽⁴⁷⁾.

Electronic Laboratory Reporting system (ELR)

In the meantime, studies were also directed towards the development of ELR, in which the laboratory computer system automatically sends an electronic message to the public health system regarding the lab findings of the notifiable conditions under surveillance. Laboratory reporting is necessary for conditions where diagnosis can be based solely on positive results of laboratory tests. But in the public health context, clinician's responsibility to report a notifiable disease based on clinical diagnosis cannot be replaced by laboratory reporting⁽⁴⁸⁾. Laboratory reporting is also helpful in early detection of communicable disease outbreaks⁽⁴⁹⁾ and identifying non-communicable diseases (laboratory-diagnosed)⁽⁵⁰⁾.

Generally, conventional methods of laboratory reporting by means of mail, facsimile or telephone, require active participation by laboratory staff. Further, it was found that communicable disease cases reported via these conventional methods are relatively low than the cases diagnosed at these laboratories^(51,52,53). As a result, research was focussed on an alternate method of laboratory reporting on infectious diseases. Studies on electronic laboratory based reporting of notifiable diseases revealed that electronic reports were faster, accurate and detailed when compared to conventional reports^(38,54). Moreover, Effler *et al.*⁽⁵⁴⁾ reported that accuracy and speed of notifiable disease reporting has increased with the introduction of ELR.

Even though, ELR has the potential to improve the quality of communicable disease surveillance, Wurtz and Cameron⁽⁴⁸⁾ pointed out that existing ELR systems are not functioning effectively due to poor electronic data interchange. These systems currently use "local codes" (developed at institutional level) which are not internationally recognised to indicate the test ordered and its result. Therefore, it is crucial to adopt universally shared definitions and methods for transmitting information, or take necessary steps to map available local codes to standard codes, in order to comply with automated electronic data transmission. Efforts are underway to develop inter-operable tools and systems to support notifiable disease surveillance, by improving the seamless interaction between clinical, laboratory and public health interfaces^(55,56).

In addition, research is now progressing to modify the health care vocabulary standards (eg. LOINC, SNOMED) to meet the public health requirements, and developing the mapping of tables to serve as the basis for mapping local codes to standard codes⁽⁵⁷⁾. Further, Health Level 7 (HL7) is the most widely accepted rule for the syntax of health related messages. Studies reveal how it can be used in notifiable disease surveillance data interchange⁽⁵⁸⁾. On standardisation of the meaning and the structure of the message to be transmitted, then the manner in which the message has to be delivered to be identified, which is known as ‘messaging protocol’ or ‘transport protocol’. Usually it is decided, based on the type of information systems which are interacting and the desired level of security. Currently, secure file transport protocol (SFTP) and public health information network messaging system (PHIN MS) are available for electronic surveillance data interchange. Further research is required for natural language processing and development of automated software applications to analyse electronic data in medical records and laboratory reports in order to detect and report notifiable conditions which are of interest to public health authorities.

Conclusion

It is generally agreed that current surveillance systems need to be improved in order to cope with emerging and re-emerging infectious diseases. The need for better and novel infectious disease surveillance systems have been highlighted by the recent epidemics like the SARS (2002-2003) and Swine flu (2009) epidemics and the increased potential for bioterrorist attacks. Improvement in sensitivity and speed of surveillance systems are required to face these problems successfully.

During the last few years, there has been a surge in the development of surveillance systems to satisfy these needs. Recent studies were directed towards the development of ‘early warning systems’ (based on syndromic surveillance), which could be used in early detection and monitoring of disease outbreaks^(7,59,60,61,62). These systems will gather information on epidemic prone diseases, with a view to initiating prompt public health interventions. Collection of such surveillance data will be syndrome-based and focused on illnesses with certain signs and symptoms, for example, fever with rash, watery diarrhoea, dysentery, fever with abdominal symptoms and headache, and other diseases of unknown origin. Studies undertaken to develop and evaluate such early warning systems have shown promising results^(59,60,61). However, these systems do not depend exclusively on typical methods, such as statistical methods to detect changes in disease trends or sentinel events required for such interventions. In most occasions, epidemiologists are expected to do an in-depth review on collected surveillance data, currently which is not practised in a systematic way⁽⁶²⁾. Further, these systems are most likely to be based on electronic reporting and internet technologies.

Current trend towards web based or internet based reporting of communicable diseases is anticipated to fulfil the intention of the ‘integrated multi disease national surveillance and response system’ recommended by the WHO. Web based communicable disease reporting system is likely to enhance the speed of dataflow up to national level, facilitate the integration of parallel reporting systems, and have the capacity to handle a large amount of data within a single system⁽⁴³⁾. Such systems are developed and introduced in certain countries to check its feasibility.

A study carried out at Fujian province, China showed that a significant increase in speed of reporting has been observed after medical practitioners started online notification. This study

also suggested that speed can be further improved by taking certain measures, such as ensuring internet accessibility to all hospitals, providing training to health staff and maintaining better hospital management systems⁽⁶³⁾. This is supported by several other studies too, which confirmed that accuracy and speed of notification can be improved significantly with web based reporting^(36,43). But, it has to be borne in mind that web based reporting becomes a reality for developing countries, only if adequate internet access is made available for all the healthcare providers engaged in communicable disease surveillance activities.

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