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Major Article

Systematic review of electronic surveillance of infectious diseases with emphasis on antimicrobial resistance surveillance in resource-limited settings

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Background: Electronic surveillance of infectious diseases involves rapidly collecting, collating, and analyzing vast amounts of data from interrelated multiple databases. Although many developed countries have invested in electronic surveillance for infectious diseases, the system still presents a challenge for resource-limited health care settings.
Methods: We conducted a systematic review by performing a comprehensive literature search on MEDLINE (January 2000-December 2015) to identify studies relevant to electronic surveillance of infectious diseases. Study characteristics and results were extracted and systematically reviewed by 3 infectious disease physicians.
Results: A total of 110 studies were included. Most surveillance systems were developed and implemented in high-income countries; less than one-quarter were conducted in low-or middle-income countries. Information technologies can be used to facilitate the process of obtaining laboratory, clinical, and pharmacologic data for the surveillance of infectious diseases, including antimicrobial resistance (AMR) infections. These novel systems require greater resources; however, we found that using electronic surveillance systems could result in shorter times to detect targeted infectious diseases and improvement of data collection.
Conclusions: This study highlights a lack of resources in areas where an effective, rapid surveillance system is most needed. The availability of information technology for the electronic surveillance of infectious diseases, including AMR infections, will facilitate the prevention and containment of such emerging infectious diseases.

Antimicrobial resistance (AMR) is a major global health problem. It is estimated that 300 million people will die prematurely because of infections as a result of antimicrobial-resistant organisms over the next 35 years (10 million deaths per year), thereby lowering global gross domestic product by 2%-3.5% by 2050.[1] Accordingly, from 2014-2050, the world can expect to lose $60-$100 trillion in economic output if antimicrobial drug resistance is not effectively tackled.[1]

The World Health Organization (WHO) recognizes the global health threat from AMR and over recent decades has urged all member states to combat it.[2-4] The 68th World Health Assembly in May 2015 adopted a global action plan for AMR[5]; among the plan's 5 strategic objectives was reinforcing the knowledge and evidence base through surveillance and research. The WHO recommended that member states should develop a national AMR surveillance system: this should be able to systematically collect and analyze data about the AMR of at least a core set of organisms from both health care facilities and the community. The system should also detect and report newly emerged AMR that could constitute a public health emergency of international concern.

The WHO has also initiated the Global Antimicrobial Resistance Surveillance System (GLASS) to support its global action plan for AMR.[6] To inform decision-making; promote local, national, and regional action; and provide an evidence base for action and advocacy, the goal of the GLASS is to enable standardized, comparable,

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and validated data on AMR to be collected, analyzed, and shared among countries. The GLASS combines patient, laboratory, and epidemiologic surveillance data toward enhancing a grasp of the extent and impact of AMR on populations. In view of the challenges involved in collecting all these data, countries should consider implementing an appropriate surveillance system according to acceptable standards, their priorities, and resources.

Implementing an effective, rapid, efficient surveillance of infectious diseases, including AMR, would appear to require an electronic surveillance system using computer- and Internet-based technology. Electronic surveillance of infectious diseases in hospitals should involve rapidly collecting, collating, and analyzing vast amounts of data from interrelated multiple databases (eg, laboratory information, clinical information, pharmacy information, admission-discharge-transfer databases, online medical records).[7] Many developed countries and some emerging countries have invested in electronic surveillance and efficient real-time early warning systems for infectious diseases. However, an effective electronic surveillance system still presents a challenge for resource-limited health care settings in low- and middle-income countries.

The objectives of this systematic review were as follows: (1) to systematically review articles related to electronic surveillance of infectious diseases, with an emphasis on AMR in hospitals over the previous 16 years; and (2) to provide general principles to guide effective future implementation of electronic surveillance of AMR based on the review results, with a special focus on resource-limited health care settings.

METHODS

Search strategy

We conducted a comprehensive literature search to identify all published or electronically published English-language articles relevant to electronic surveillance of infectious diseases from January 1, 2000-December 31, 2015. We searched the MEDLINE database using a combination of the following terms: ["surveillance" OR "early warning" OR "early detection" OR "real-time" OR "automated"] AND "infectious disease." We obtained the citation title, PubMed identifier, author list, and abstract of each citation. The last search was performed on March 31, 2016.

Literature review

We conducted 3 rounds of review for the articles retrieved from the literature search. All rounds of the literature review were performed by infectious disease physicians. We specifically designed 3 separate quality assessment forms to use for each round of review.

For the first round, an abstract of a given citation retrieved from the literature search was assessed by at least 1 reviewer. We excluded the following citations: (1) unrelated to infectious diseases, (2) only in vitro study, (3) not involving patients or humans, and (4) unrelated to the surveillance of infectious diseases. We automatically included any citation without an abstract in the second round review. We defined an electronic surveillance system as any system that uses electronically available patient data, including clinical, microbiologic, pharmacologic, and administrative patient data. We also considered the following to be electronic surveillance systems: the use of any software or applications, the Internet, mobile phone, landline phone, fax, or Global Positioning System (GPS) applications to collect, transfer, or report data.

For the second round, 2 reviewers independently appraised all the selected full articles that were included according to the selection criteria from the first round review. An article was chosen for the third round review if at least 1 reviewer considered it an original article describing electronic surveillance of infectious diseases or AMR.

For the third round, 3 reviewers independently assessed all the selected full articles that were included according to the selection criteria from the second round review. An article was included in the final analysis if at least 2 independent reviewers considered that it contained electronic system or information technology that could be applied for the hospital surveillance of infectious diseases or AMR. The data to be extracted from each full article included country of the study, targeted infectious disease or organism, details of the electronic system or information technology, resource utilization, and impact of the electronic system or information technology.

Data analysis

The context, study design, study setting, and type of outcomes of included individual studies were different and heterogeneous. Therefore, it was inappropriate to perform a formal meta-analysis of the results from this systematic review of selected studies. However, we summarized the context of all selected studies to determine their overall features. We present the categorized data as numbers and percentages. We performed all statistical analyses using Stata version 14.0/IC (StataCorp, College Station, TX).

RESULTS

Literature and literature review

The flow of the literature and literature review appears in Figure 1. We identified 4,808 English-language citations according to the aforementioned search strategy. We excluded 4,224 abstracts during the first round of review, 455 full-text articles during the second round, and 19 full-text articles during the third round. Accordingly, we included 110 full-text articles in our final analysis. Exclusion details are shown in Figure 1.

Characteristics of full-text articles

The study characteristics are presented in Table 1. Among the 110 selected full-text articles, most studies (73.6%) were conducted in high-income countries[8-91]; 25.5% were performed in low- or middle-income countries; and 0.9% were conducted in multiple countries.[92-116] Only 5 studies (4.5%) took place in WHO Southeast Asia countries: India,[94,108,112] Nepal,[99] and Sri Lanka.[111] Most studies used a locally developed system in their own countries or regional networks. However, WHO-developed surveillance systems were used in 6 studies conducted in Canada,[32] the United States,[30] Argentina,[33,101] France,[73] and Nepal.[99]

The 5 leading conditions of interest or causative organisms were as follows: influenza or influenza-like illnesses (20.0%)[12,13,22,25,32,39,40,42,44,46,48-50,60,62,80,82,85,95,113,114,117]; health care–associated infections or antimicrobial-resistant organisms (16.4%)[8,9,20,23,24,31,56,59,65,67,71,73,78,79,89,97,99,101]; tropical infections (5.5%)[29,77,81,90,105,111]; tuberculosis (3.6%)[34,103,107,112]; and outbreak investigations (2.7%).[30,98,109]

We found 24 studies conducted in only hospitalized patients.[8,9,20,23,24,28,36,52,61,65,67,68,71,73,74,77-80,86,88,91,99,117] Eleven studies were performed in only outpatient settings[18,25,42,44,48,55,57,60,85,89,115] and 28 in only community settings.[12,13,16,35,37,38,41,43,45,46,51,53,58,63,69,72,75,76,82,83,90,92,93,104,105,111,113,114]

After making a comprehensive review of the selected 110 studies, we classified all information technologies used for electronic surveillance of infectious diseases into 4 categories based on the processes in performing surveillance. The results appear in Figure 2.