OVERVIEW

Event-based surveillance: Providing early warning for communicable disease threats

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Abstract

The coronavirus disease 2019 pandemic served as a compelling modern-day reminder of the value of early warning against communicable disease threats in public health. As countries exit the acute phase of the pandemic, there remains a continued need to be vigilant for potential communicable disease threats, particularly as the risk of animal-to-human spillover events is increasing due to climate and land use change. Early warning of emerging threats facilitates earlier public health response, which affords more time to implement public health measures that can help minimize the impact of a particular health threat and protect the health and well-being of the population. One approach to providing early warning for communicable disease and other threats is through event-based surveillance (EBS). However, EBS is not often discussed in the context of public health surveillance. This overview introduces EBS and how it might contribute to providing early warning for communicable disease threats.

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Introduction

The value of early warning about potential threats to public health, such as communicable disease outbreaks, has been known for a long time. An early documented example dates back to the 17th century, during the second plague pandemic (1). As modern disease surveillance systems were not yet in existence, the health authorities of Northern Italy of this era customarily informed each other by letter of news they gathered on health conditions in Europe, North Africa, and the Middle East. In 1652, a letter from the Genoa Health Magistracy notified their counterparts in Northern Italy of several deaths due to the plague on the island of Sardinia. The alarming news from Genoa resulted in swift proclamations by Italian governments to suspend trade and travel with Sardinia to prevent the spread of the plague to their jurisdictions.

Several centuries later, borders would again close, but on a global scale in an attempt to limit the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the novel pathogen that caused the coronavirus disease 2019 (COVID-19) pandemic (2). In this contemporary pandemic context, the value of early warning in public health was again demonstrated with surveillance systems detecting and warning of new SARS-CoV-2 variants, some of which caused new pandemic waves (3,4). These early warnings afforded public health authorities and health systems more time to anticipate and prepare for potential spikes in disease burden by implementing measures to enhance prevention, control the spread of disease, and improve disease outcomes.

As countries exit the acute phase of the COVID-19 pandemic, an important question is when the next pathogen of pandemic potential might emerge, particularly in the 21st century context of increasing animal-human interface as a result of climate and land use change (5). The next pandemic will likely arise in a "hotspot" region of the world (6,7), where public health and surveillance capacity, as well as open, transparent and timely sharing of public health intelligence may be challenges (8). Furthermore, the exact timing and nature of the next pandemic would not be possible to predict; however, public health tools like event-based surveillance (EBS) are expected to play an important role in identifying and alerting potential pandemic signals.

This article provides an overview of EBS, including how it differs from traditional surveillance—also known as indicator-based surveillance (IBS). The Public Health Agency of Canada's Global Public Health Intelligence Network (GPHIN) is highlighted in this article as an example of an EBS system. GPHIN was prototyped in 1997 by the Government of Canada in collaboration with the World Health Organization (WHO) as the world's first EBS system (9). GPHIN has undergone many changes over the years (10,11) and at the time of writing, remains the only state-owned and operated EBS system in the world.

What is event-based surveillance and how is it different from indicator-based surveillance?

Event-based surveillance and IBS are both approaches used to monitor and detect public health threats. However, there are some key differences between the two surveillance systems (see **Table 1** for a summary of these differences). The goal of EBS is to provide early warning signals by identifying and reporting on meaningful signals, while filtering out noise, from open (i.e. publicly accessible) sources. This filtering can be achieved through various methods, including artificial intelligence and human analysis. To identify potential signals, EBS involves the rapid and structured collection, assessment, and reporting of unstructured information (e.g. information that is not organized in a pre-defined manner) about health events that can potentially pose a serious risk to public health (12,13). This information is communicated in a timely fashion to stakeholders (e.g. individual experts, public health authorities, other governmental and non-governmental organizations) for their further assessment and action.

Event-based surveillance systems like GPHIN take advantage of the Internet by web-scraping information from multi-lingual sources, including official sources (e.g. health notices/alerts, press releases/statements, reports), news media, publicly accessible social media and a wide variety of other online media sources (e.g. blog posts, forum posts, scientific publishing). The types of information detected by EBS can be verified (e.g. information from experts, governments, and reputable organizations) and unverified (e.g. rumours, claims, stories) reporting that suggests unusual or heightened disease activity with a potential of public health concern. While GPHIN relies on the Internet to gather information, EBS systems can also leverage other communication technologies, such as telephone, radio, fax and email (12).

Table 1: Differences between event-based surveillance and indicator-based surveillance

Characteristic	Event-based surveillance	Indicator-based surveillance
Objective	To detect health events that can potentially pose a serious risk to public health	To detect disease outbreaks and characterize disease trends and patterns
Scope	Usually takes an all-hazards approach and can report on both known and unknown diseases	Usually focuses on known diseases
Information types	Unstructured information (i.e. information that is not organized in a pre-defined manner), including both verified (e.g. information from experts, governments, and reputable organizations) and unverified (e.g. rumours, claims, stories) reporting	Structured information (i.e. information that meets specific criteria, such as case definitions, and is organized in a pre-defined manner)
Data sources	Official sources, news media, publicly accessible social media, and other online media sources	Health system infrastructure, such as clinical records from the community, hospitals, or laboratories
Outputs	Early warning signals of new, emerging, and re-emerging threats to public health	Indicators or measures related to a particular health issue

Although EBS systems like GPHIN use a set of criteria to determine whether a potential signal is meaningful, signals reported by EBS systems can result in what can be considered "false alarms" or "false positives". Although all public health threats are causes for concern, some signals can result in no, minimal or comparably less public health response due to factors including but not limited to the geographic location of the event, severity of the health threat, availability of resources and countermeasures and potential impact of response. Such events can be considered false positives, but they are not necessarily failures in early warning. These situations may arise because of the need for EBS systems to balance timeliness in providing early warning and waiting for more information to become available.

As an example of a false positive signal, a July 23, 2022 news media report of a cluster of deaths in Tanzania due to an undiagnosed disease involving patients presenting with viral hemorrhagic fever-like symptoms (fever, bleeding, headache and fatigue) was alerted by GPHIN to stakeholders (14). This report raised concern among GPHIN analysts because an outbreak of Ebola virus disease—a severe, often fatal viral hemorrhagic disease that caused an epidemic in West Africa from 2013 to 2016—occurred between April 23 and July 3, 2022 in the neighbouring country of the Democratic Republic of the Congo (15). The cause of the deaths in Tanzania was later verified to be due to leptospirosis, which is endemic in the region (16).

In contrast, IBS involves the collection and reporting of structured information, which is pre-determined indicators or measures that are related to a particular health issue, such as the prevalence of a particular disease or the incidence of certain risk factors. Structured information is usually reported only if specific criteria (e.g. case definitions) have been met and are often presented as counts and/or rates, grouped by important categories for analysis, such as age or sex. Sources of information for IBS rely heavily on data coming from existing health system infrastructure, such as clinical records originating from the community, hospitals, or laboratories. Under IBS, event verification, such as laboratory confirmation, may be a lengthy and required process before the event is communicated to stakeholders.

How does event-based surveillance identify signals of potential communicable disease threats?

For EBS to identify a potential signal, a health event has to be communicated in some way, which is usually through the Internet for EBS systems like GPHIN (13,17). Web-based sources reporting health events have typically been news media or official sources, but social media reporting is becoming increasingly common, due to its ability to facilitate rapid communication and its broad reach (18). A wide range of sources covering multiple languages need to be systematically scanned in order to ensure the detection of potential signals. Given its characteristics, the volume of unstructured information is expectedly large. For example, GPHIN collects thousands of pieces of open-source information on a daily basis as data inputs into the signal identification process (17).

Reported events around the world collected by an EBS system like GPHIN are filtered using automated (e.g. deduplication, categorization by topic) and manual (e.g. assessments of relevancy, public health risk, credibility) approaches to reduce noise and identify potential signals that could be public health threats (13,19). Automation helps organize this large volume of information. To filter all of this information for potential signals, GPHIN's team of multi-lingual and multi-disciplinary analysts rapidly assesses the public health risk of the reported events against the *Annex 2 of the International Health Regulations (2005)* (20) and other considerations (e.g. credibility of the event and source). The International Health Regulations criteria are used to assess whether the event has serious public health impact, is unusual or unexpected, or has a significant risk of international spread or international travel or trade restrictions. Events that are identified as signals are communicated in a timely fashion by GPHIN to stakeholders for follow up, such as further verification, risk assessment and response.

As a hypothetical scenario to demonstrate how an EBS system like GPHIN might pick up a signal, a novel pathogen may emerge in a community as a cluster of illnesses with shared symptoms, somewhat unusual for the region that is noticed by healthcare workers. Local media may pick up the story, describing it as an unknown illness, in the local language. It may take some time for the local public health system to investigate and report on the cluster of illness. It may take even more time for reporting on the event to percolate upwards regionally, nationally and then internationally, through formal or informal channels. By the time an outbreak is recognized by authorities and IBS monitoring is set up, the disease might have already spread internationally. The role of EBS remains the same in this hypothetical scenario as in the real world: to identify a signal from this continuum of information sharing and reporting as early as possible, in order to provide as much lead-time as possible for appropriate public health response.

Why is event-based surveillance a necessary part of the public health toolkit?

Despite their differences, EBS and IBS are complementary components of public health surveillance. Together, EBS and IBS can provide a more complete picture of a particular health issue, by combining information from unstructured and structured sources.

Because of the differences in approach and information sources, EBS reporting can occur earlier than IBS, as well as in populations and geographic regions that are not adequately covered by IBS. Event-based surveillance does not directly rely on healthcare systems, thereby increasing the timeliness and comprehensiveness of public health surveillance. The trade-off for this timeliness is that the events identified by EBS as signals often require further verification by reliable sources (e.g. experts on the ground, formal/informal communications with responsible public health authorities, laboratory testing) in what can be a time and resource-intensive process and could result in false positives.

Thematically, EBS can take an all-hazards approach, in that health events of interest are not limited to known communicable diseases, but extend to unknown, emerging, and re-emerging diseases, and other chemical, biological, radiological and nuclear events. In comparison, IBS usually focuses on known diseases and modes of transmission, as specific case definitions are intrinsic to this type of surveillance. While EBS detects acute events or occurrences reactively, IBS allows for the monitoring of diseases over longer time periods and can provide more detailed information on trends and patterns.

Is event-based surveillance successful in providing early warning about public health threats?

Not all signals identified by EBS are indications of major outbreaks, epidemics or pandemics. Due to the nature of EBS, signals identified by EBS are often based on reporting that is preliminary, incomplete or unverified. The vast majority of these signals end up being assessed as non-events or posing low risk to public health after further verification, as new information emerges, or as a result of public health intervention. Sporadically, however, there are signals that are linked to serious threats to public health. **Table 2** provides a snapshot of such early warning signals for outbreaks of emerging communicable diseases identified by GPHIN in the past two decades, including the COVID-19 pandemic. The specific impacts of these signals on the outcomes of public health response, such as morbidity and mortality, have not been investigated.

As a source for all-hazards intelligence, signals identified by GPHIN are not limited to communicable diseases. The GPHIN identified early signals of the outbreak of renal disease in China in 2008 that was associated with the consumption of melamine-adulterated; powdered infant formula; the nuclear accident at the Fukushima Daiichi nuclear power plant in Japan in 2011 that was triggered by a tsunami; the multi-state outbreak of fungal meningitis in the United States in 2012 that was caused by injections with contaminated medication; and the emerging evidence of severe pulmonary illness associated with vaping in the United States in 2019. These early warning signals provided lead time for risk assessment and response by relevant authorities. For example, after GPHIN reported on vaping-associated severe pulmonary illness in the United States on August 2, 2019, the Public Health Agency of Canada mobilized resources to monitor the emerging disease pattern and support case finding activities, with the first confirmed Canadian case detected in September 2019 (17).

Table 2: Examples of Global Public Health Intelligence Network's successes in providing early warning signals for emerging communicable diseases

Disease	Date of first signal detected by GPHIN	Country where signal was detected	Type of source (Language of source)	Description of signal	Date of first report in the WHO Disease Outbreak News	Date of WHO declaration as a PHEIC	Date of first case confirmed in Canada
2002—2004 SARS outbreak	November 27, 2002	China	International media report (Chinese)	Cases of pneumonia-like illness in Guangdong, China	February 11, 2003	Not applicable (PHEIC declaration developed after the SARS outbreak)	February 23, 2003
2009 H1N1 pandemic	April 1, 2009	Mexico	Local media report (Spanish)	Outbreak of respiratory illness in La Gloria, Mexico	April 24, 2009	April 26, 2009	April 26, 2009
2012 MERS-CoV outbreak	April 19, 2012	Jordan	Local media reports (Arabic)	Outbreak of an unknown disease in Zarqa, Jordan	February 11, 2013	Not declared	Not applicable
2014 Ebola virus disease outbreak in West Africa	March 19, 2014	Guinea	International media report (English)	Outbreak of hemorrhagic fever in southeast Guinea	March 23, 2014	August 8, 2014	Not applicable
2015—2016 Zika virus disease outbreak in the Americas	March 24, 2015	Brazil	Local media reports (Portuguese)	Cases of unidentified mosquito-borne illness in Recife, Brazil	October 21, 2015	February 1, 2016	December 2015
COVID-19 pandemic	December 31, 2019	China	International media reports (English)	Cases of viral pneumonia of unknown origin in Wuhan, China	January 5, 2020	January 30, 2020	January 25, 2020
2022 mpox outbreak	May 7, 2022	United Kingdom	Government health notice (English)	Confirmed case of mpox in London, England	May 16, 2022	July 23, 2022	May 19, 2022

Abbreviations: COVID-19, coronavirus disease 2019; GPHIN, Global Public Health Intelligence Network; MERS-CoV, Middle East respiratory syndrome coronavirus; PHEIC, Public Health Emergency of International Concern; SARS, severe acute respiratory syndrome; WHO, World Health Organization

Conclusion

Finding the signal for the next significant public health threat as early as possible is a challenge for public health surveillance. Although public health has a robust suite of IBS tools available, the signal might be missed or delayed due to inherent limitations behind existing surveillance systems that range from active to passive forms of surveillance and laboratory or syndromic-based reporting styles (21). There are also multitudes of barriers, such as a lack of expertise, data management systems and laboratory capacity, in implementing these surveillance tools in many countries, particularly in low and middle-income countries (22) and in preventing vigilance atrophy (i.e. the relaxation of vigilance over time in the absence of manifestations of further incidents) (23).

As the risk of animal-to-human spillover events increases due to climate and land use changes, it will be increasingly important to remain vigilant of these communicable diseases and other emerging threats to provide timely early warning for public health response. Although it is impossible to predict when the next threat to public health will occur, EBS systems like GPHIN will play a vital role in public health surveillance by complementing IBS systems. To best fulfil its unique role in providing early warning, EBS systems will need to continue to evolve and increase in sophistication, as advances in technology will change the way humans share information and how meaningful signals can be identified from this information.

Authors' statement

TN — Conceptualization, writing–original draft, writing–review and editing
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Competing interests

None.

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