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Using Syndromic Surveillance for All-Hazards Public Health Surveillance: Successes, Challenges, and the Future

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Fifteen years have passed since the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 called for the establishment of nationwide surveillance and reporting mechanisms to detect bioterrorism-related events.[1,2] In the 1990s, several health departments established surveillance systems to detect prediagnostic (ie, before diagnoses are confirmed) signs and symptoms for the early identification of disease occurrences. However, it was the 2002 act, following the September 11 and anthrax attacks, that provided the impetus and resources for the growth of syndromic surveillance across the country.[3-5] Syndromic surveillance is now a core component of many US health departments' surveillance activities. Public health practitioners use it daily to identify potential events of public health concern, track disease trends, and inform responses to confirmed and rumored events. Syndromic surveillance also provides real-time information for health events that are not supported by case reporting or laboratory reporting, such as injuries and suicidality.

This supplemental issue of *Public Health Reports* contains 18 articles that describe the use of syndromic surveillance for event identification, situational awareness, and enhanced response to diseases, conditions, and activities that affect population health. The data used in syndromic surveillance can come from various sources, but the articles in this supplement focus on the use of electronic health record (EHR) data from clinical settings. The articles describe the value of real-time data for public health decision making and the challenges of collecting and interpreting data that are generated primarily for health care practice and billing purposes.

An All-Hazards Surveillance Approach

Public health agencies have historically partnered with health care delivery organizations to share patient encounter data for public health surveillance. EHR data from hospitals, urgent care centers, and other health care settings can augment traditional public health surveillance methods, such as case reporting, registries, and telephone-based surveys. As EHRs proliferate and electronic data are increasingly available to public health agencies, the secondary use of these data becomes an efficient and cost-effective way to identify and characterize public health threats.

Typically, EHR data transmitted from health care organizations to public health agencies for syndromic surveillance are not filtered or categorized. As a result, public health agencies can use the same data that support delivery of care for an all-hazards surveillance approach. Without additional burden on data providers, public health agencies can monitor, in real time, population health threats ranging from opioid overdoses and suicide-related emergency department (ED) visits to animal bites, influenza-like illness, and emerging infectious disease threats (eg, Ebola).[6-12] The data elements transmitted from EHRs can include free-text chief complaints with signs, symptoms, and reason for visit; vital signs; patient demographic characteristics; triage notes; discharge diagnosis codes (ie, *International Classification of Diseases, Ninth Revision, Clinical Modification* and *International Classification of Diseases, Tenth Revision, Clinical Modification* codes); and, sometimes, laboratory results.[13] Syndromic surveillance practitioners use algorithms to classify chief complaint data and diagnosis codes into routinely monitored syndrome categories (eg, influenza-like illness,

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asthma, heat-related illness, fever and rash, falls) and can also run ad hoc queries of the data to investigate rare health events or the health effects of natural or manmade disasters and disease outbreaks.

Extreme Weather Surveillance

Five articles in this supplement illustrate the use of syndromic surveillance to monitor the health effects of extreme weather. Using ED data from local hospitals, the Philadelphia Department of Public Health found that, during snow and ice events, fall-related injuries occurred more frequently among adults aged 18-64 when compared with younger and older age groups and peaked during the morning commute.[14] Using these findings, the health department determined that alerts and precautions during severe winter weather should be geared to the working-age population, not just the elderly.

A public health team from Ontario, Canada, conducted a retrospective study of cold temperature–related ED visits and examined geographic trends related to ambient temperature to improve the public alerting protocol for cold temperature risks.[15] Two articles on extreme heat events describe methods for refining the heat syndrome case definition to improve the accuracy and value of data informing public health action.[16,17] The inclusion of specific search terms and refined case definitions in these articles will be particularly valuable to syndromic surveillance practitioners in areas of the country that have extreme heat events. An article from the New York City Department of Health and Mental Hygiene shows the public health value of unexpected findings in syndromic surveillance data. After Superstorm Sandy, when the health department was monitoring for injuries, it observed a surge in methadone-related ED visits in a highly affected area. This finding led to an investigation and the discovery of other community postdisaster medical needs, such as dialysis and oxygen.[11]

Characterization of Health Events

Syndromic surveillance is a dynamic practice of continually refining search terms, adjusting aberration detection algorithms, and looking for patterns and anomalies based on previous data.[18] Several articles in this supplement describe how public health practitioners tailored their case definitions and prioritized timeliness and sensitivity over positive predictive value to address health threats. For example, epidemiologists in Cook County, Illinois, used ED visit data to estimate reporting compliance for potential rabies exposures. The authors created a query of chief complaint and discharge diagnosis fields that included terms for contact with wild animals, rabies, and administration of postexposure prophylaxis. They identified substantial underreporting in most participating hospitals that precipitated in an intervention to improve reporting.[8] A flexible, all-hazards surveillance approach allows public health agencies to modify their case definitions to account for changing clinical practices and unforeseen events. This approach has been valuable because public health agencies rely on syndromic surveillance systems to identify drug overdoses and characterize the opioid epidemic in the United States. Three articles in this issue focus on community-level drug abuse trends that are being documented by searches of the chief complaint for terms such as "Narcan" or "naloxone"—medication used to treat opioid overdoses—and for brand-name and street-name drugs that are difficult to monitor with standardized data.[6,7,10]

In another article, epidemiologists from the New York City Department of Health and Mental Hygiene describe the creation of 25 syndromes to identify drug-related ED visits for various legal and illegal drugs. The health department now runs these standardized queries routinely and compares daily counts with baseline data from previous years to detect increased morbidity.[7] Of particular value for control efforts are daily maps that identify neighborhood-level trends. An article from the New Hampshire Department of Health and Human Services describes its use of chief complaints and diagnosis codes in ED data to characterize the state's opioid overdose problem. Using syndromic surveillance data, New Hampshire documented a 70% increase in opioid-related ED visits and an 827% increase in heroin-related ED visits from 2011 to 2015.[6] In another article, the Florida Department of Health in Orange County evaluated 3 data sources for the surveillance of heroin-related morbidity and mortality. The authors found that, compared with medical examiner data and coded ED data captured in hospital discharge databases, syndromic surveillance based on free-text query of the ED chief complaint and discharge diagnosis was timelier and provided earlier warning of health problems in specific communities.[10] The articles from New York City, New Hampshire, and Orange County, Florida, illustrate the ways that state and local health departments are increasingly relying on syndromic surveillance to provide timely data on the health impacts of the opioid epidemic in communities across the country.[6,7,10]

Mass-Gathering Surveillance

The use of syndromic surveillance for situational awareness during mass gatherings is an evolving scientific discipline, as described in a series of reports about monitoring major sports events and large religious gatherings.[19-22] The commentary on mass gatherings in this supplement describes epidemiologic infrastructure requirements that enable the use of syndromic surveillance during an event—for example, integrating new data sources and enhancing ongoing surveillance practices.[23] These principles are illustrated in articles from the Los Angeles County Department of Health, which monitored the 2015 Special Olympics World Games, and the public health agency in Ontario, which monitored the 2015 Pan American and Parapan American Games in Toronto.[24,25] In Los Angeles, the authors augmented their syndromic surveillance system by asking ED registrars to tag Special Olympics attendees proactively with a note in the chief complaint field for faster and more complete detection of

event-associated health outcomes.[24] In Toronto, the syndromic surveillance practitioners developed a risk-assessment tool to evaluate and categorize alerts produced during the monitoring of the Pan American and Parapan American Games to inform more efficient follow-up protocols.[25]

Value and Challenges of Using Real-time Data

The information that health care providers document in the EHR chief complaint field or triage notes about specific scenarios and exposures provides highly useful data to public health practitioners for characterizing disease outbreaks, drug use, disaster-related encounters, mass gatherings, and emerging infectious and noninfectious disease threats. The current movement among many health care organizations to standardize EHR data with drop-down pick lists, including for chief complaint fields, may affect the value of chief complaint data for syndromic surveillance. However, increased standardization of the chief complaint is not the only challenge that public health agencies face in using EHR data. The high-volume, visit-based, real-time EHR data received by syndromic surveillance systems present challenges related to data quality, analysis, and interpretation. EHR systems use different messaging formats, and each patient's ED visit may generate multiple records.[26] Each service provided during the visit (eg, medical history, examination) may generate a new record for a given patient, and these records are individually transmitted to an organization that aggregates the data or to public health agencies. Numerous data transmissions for each health care encounter require processes to link multiple records together, resolve conflicting information for each encounter, and de-duplicate records. The complexity of managing these data requires ongoing data quality monitoring to identify potential messaging errors and to ensure, to the extent possible, data timeliness, completeness, and validity.[27]

Experienced syndromic surveillance practitioners are usually familiar with the idiosyncrasies of their local systems that can affect data quality and have automated processes in place to answer the following questions: (1) Are all of my facilities reporting? (2) Are we receiving the expected volume of data across the different health care settings (ED, inpatient, ambulatory)? (3) Are data elements complete at acceptable threshold levels and coded to expected values? and (4) Are we seeing variation in data content and coding by specific vendors or facilities? Practitioners who operate local systems are also likely to know if local events may have resulted in data transmission delays or changes in reporting by health care sites. When syndromic surveillance data from local systems are shared across jurisdictions or are aggregated at higher levels (eg, state, federal), it is difficult to ensure data quality; as such, the metadata, or information that describes the data (eg, number of hospitals reporting, population coverage, timeliness), become particularly important for analysis and interpretation.

Surveillance Research Agenda

The final article in this supplement, from a task force of the International Society for Disease Surveillance Research Committee, provides a research agenda focused on incorporating novel data sources; eliciting real-time understanding of community-based patterns of disease and conditions; and improving the One Health approach[28] to integrating human, animal, and ecologic data.[29] The agenda calls for new analytic methods and tools, as well as new strategies for building workforce capacity that go beyond the purview of epidemiology. To continue to improve and evolve the use of EHR data for public health, public health agencies require expertise in (1) information system design, (2) analytic data management (including skills in data extraction, transformation, and loading), (3) data quality monitoring and use of data standards (eg, Health Level Seven, *International Classification of Diseases, Tenth Revision, Clinical Modification*, Systemized Nomenclature of Medicine, Logical Observation Identifiers Names and Codes), and (4) data analysis and visualization. For example, natural-language processing techniques that leverage pattern recognition of data over keyword search methods may improve the accuracy of syndrome classification and identify clusters that are missed with current techniques.[29,30] Advanced informatics and data science skills are needed to evaluate, implement, and maintain cutting-edge approaches to data analysis and visualization. Partnerships among public health agencies, academia, and the private sector may address some of these workforce challenges.[31]

Conclusion

In the past 15 years, syndromic surveillance has become a model for electronic data exchange between health care and public health. The articles presented in this supplement provide examples of how EHR data are being used to address health threats in communities. The intent of syndromic surveillance as an early warning system for bioterrorism has expanded to an all-hazards surveillance approach that informs situational awareness, characterization of health events, and response efforts in real time. Continued investment in syndromic surveillance and evolution of methodological approaches will yield benefits to public health through more experienced and knowledgeable interaction with the EHR. The articles in this supplement can be used to inform public health professionals, clinical care providers, and policy makers of the value of syndromic surveillance and can provide syndromic surveillance practitioners with practical advice and lessons learned from their colleagues.

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