Chapter 4: Healthcare-Associated Infections and Antimicrobial Resistance Outbreak Detection and Reporting
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PREFACE

Surveillance is a key component to detecting the spread of disease and identifying outbreaks. For healthcare-associated infections (HAIs) and antimicrobial resistant (AR) pathogens, disease surveillance identifies some clusters and outbreaks, but public health agencies also rely on healthcare facilities, astute clinicians, and sometimes other partners and the public to report potential outbreaks to them. The spectrum of communicable disease outbreaks that can occur within a healthcare system or community outbreaks of pathogens typically found in healthcare is extremely broad. Unlike more long-standing areas of communicable disease epidemiology, not every pathogen and condition that might indicate a healthcare outbreak are reportable in all jurisdictions. To detect outbreaks, public health depends on both excellent surveillance (including advanced laboratory testing) and reports from facilities and clinicians.

4.0 Introduction

In the context of healthcare delivery, the primary purpose of detecting clusters and outbreaks is to protect patients and staff from avoidable harms. The detection of HAI/AR outbreaks might occur via signals detected through surveillance, via reporting by healthcare partners, or during other prevention activities such as infection control assessments or investigation of infection control breaches. This represents the first and most essential step in a chain of investigation and response. When surveillance activities detect outbreak signals, they set in motion a cascade of events aimed at assessing the situation, implementing control measures, halting disease transmission, and preventing new cases. Secondary benefits of outbreak detection include recognizing opportunities for future prevention of infections, gaining experience in responding to novel outbreak situations, and providing knowledge to the greater public health and healthcare community. This chapter focuses on the methodology to detect outbreaks and ways HAI/AR outbreak identification can be improved. Section 4.1 provides an overview of healthcare outbreak detection and reporting. Section 4.2 describes specific reporting systems for potential outbreaks to be communicated to public health

agencies, while section 4.3 examines the use of routine surveillance systems for outbreak detection. The chapter concludes with section 4.4, which provides considerations for detecting and reporting multi-facility and multi-jurisdictional outbreaks.

4.1 Overview

Suspected outbreaks can be detected by a variety of agencies and partners, including healthcare facilities, healthcare providers, laboratories, public health agencies, and other associated agencies. Public health and healthcare facilities share responsibility for outbreak detection and investigation, and, as described in Chapter 3, relationships and communication among partners that detect and respond to outbreaks are essential to protecting patients' and the public's health. In this section we review definitions for the terms "cluster" and "outbreak" that will be used throughout the guidance and describe methods to detect outbreaks.

Table 4.1 Potential Methods of Outbreak Detection by Healthcare Facilities and Public Health Agencies

	Sources of Outbreak Reporting	Data Sources for Outbreak Detection	Additional Activities that Might Result in Outbreak Detection
Healthcare Facility	Healthcare providers Infection Preventionist Other healthcare facilities Clinical laboratory	Facility tracking systems (e.g., electronic medical records)	Infection prevention rounds Microbiology rounds

	Hospital epidemiologist Public health agencies Patients Members of the public Media and social media	Admission, readmission, and transfer reports Clinical laboratory data	
Public Health Agency	Healthcare facilities Healthcare providers Clinical laboratories Public health laboratories Other public health agencies Members of the public Other agencies (e.g., state survey agency, Centers for Medicare and Medicaid Services [CMS], accrediting organizations) Media and social media	Reportable conditions (including pathogens and HAIs as well as general outbreak reporting requirements) Public health laboratory data Other public health surveillance systems (e.g., sentinel surveillance systems, disease registries) Other data sources (e.g., hospital discharge data)	Infection control assessments Prevention collaboratives Other public health initiatives and stakeholder engagement

4.1.1 Outbreak Detection Pathways

Outbreaks can be detected by public health and healthcare facilities via direct reporting (section 4.2), using surveillance data for cluster detection (section 4.3), or by other means (Table 4.1). Reporting of suspected outbreaks should occur within healthcare facilities as well as to public health agencies; all suspected outbreaks should be reported to public health. Reports of suspected outbreaks might come to local, state, territorial, or tribal public health agencies, or to CDC; public health agencies communicate these reports among involved agencies (e.g., CDC to state public health agency, local public health agency to state).

One of the primary reasons for systematic collection of selected HAI and AR pathogen data via surveillance is to identify transmission events. Surveillance data can be used by healthcare facilities and public health agencies to detect clusters and suspected outbreaks by recognizing patterns. Systematic review of surveillance data or using software programs can automate the cluster detection process. Identification of clusters or outbreaks might be accomplished by identifying similar cases within a facility, across multiple facilities, within the community, or across a region. Understanding endemic rates of a disease via surveillance, which can vary across institutions and jurisdictions, is often a key component of determining if an outbreak is occurring.

Public health agencies might learn about outbreaks during other public health activities, such as infection control assessments or prevention collaboratives with healthcare facilities. In the

recent past, public health agencies have dramatically increased expertise and capacity in the field of infection prevention, and one result of this is increased capacity to detect and respond to outbreaks. Significant infection control breaches are now more likely to be reported to public health agencies when detected by state survey agencies due to a requirement from the Centers for Medicare and Medicaid Services (CMS) to do so,[1] or by accreditation partners; investigation of these events can result in detection of previously unknown or unreported outbreaks.

4.1.2 Cluster and Outbreak Definitions

A "cluster" is defined as two or more cases of disease linked by place, time, pathogen subtype, or other characteristic. A cluster is the initial signal that there might be transmission of disease and should be the threshold to trigger further investigations to determine if the cluster represents an outbreak.

When initial epidemiologic or laboratory evidence indicates possible transmission, we consider this a suspected outbreak. A suspected outbreak is the threshold for additional investigation and reporting to public health. The Centers for Disease Control and Prevention (CDC) Field Epidemiology Manual defines the terms "outbreak" and "epidemic" as follows: "An outbreak is defined as 'the occurrence of more cases of disease than expected in a given area or among a specific group of people over a particular period of time.' When there are clearly many more cases than usual that are distributed across a larger geographic area, the term epidemic can be used."[2] In healthcare settings where certain types of infections are common and, in fact, might be the reason for a patient's admission to a healthcare setting, it can be challenging to recognize transmission and identify outbreaks. One definition that has been commonly employed is an increase above what is considered endemic, or above the baseline of disease.[3] There are several challenges in using this definition. First, baselines will vary from facility to facility, among healthcare settings, and among regions of the state or country. Second, baseline levels within a particular healthcare setting might reflect inadequate control of ongoing transmission of pathogens.

Baselines are not always determined for all pathogens, and in some instances the occurrence of even a single case can reflect a departure from baseline or expected levels. For example, a single case of a bloodborne pathogen infection, such as hepatitis C virus or HIV, occurring as a result of a healthcare exposure exceeds the expected level; this is often sufficient to prompt an investigation. Likewise, reports of unusual pathogens, unexpected infection types, or unusual combinations of pathogens/infections can be useful in revealing a larger issue or outbreak. Examples of unusual situations that were reported to public health agencies and that were the initial signals of larger outbreaks include non-tuberculous mycobacteria (NTM) infections following cardiothoracic surgeries using heater-cooler devices,[4] a cluster of *Elizabethkingia anophelis* infections,[5] and fungal meningitis primarily due to *Exserohilum rostratum* among patients following injections of a compounded medication.[6]

Determining a single definition for "outbreak" that fits all HAI/AR situations can be challenging, and often it can be beneficial to have pathogen-specific reporting thresholds and outbreak definitions. The Council for Outbreak Response: HAIs and AR Pathogens (CORHA, www.corha.org) has developed and continues to develop outbreak definitions for selected pathogens and conditions. Pathogen/condition-specific outbreak definitions found on the CORHA website are structured to include categories for the threshold for facilities to begin

investigation, the threshold for facilities to report to public health, and the definition of an outbreak.

Thresholds for investigation and reporting are critical for triggering a rapid response. For pathogens or conditions that do not have specific thresholds for reporting to public health, determining when a situation warrants public health reporting should follow these general principles:

- When there is a reasonable suspicion that disease transmission occurred among two or more individuals based on preliminary epidemiologic and laboratory evidence.
- When there is a reasonable suspicion that two or more cases of disease were acquired from a common source based on preliminary epidemiologic and laboratory evidence.
- Suspected outbreaks include the above criteria for infectious diseases as well as illnesses due to non-infectious conditions (e.g., toxins, chemicals).
- Single cases of unusual pathogens, unexpected infection types, and novel or rare conditions should be treated as sentinel cases and investigated as potential outbreaks; a similar rationale applies to suspected medical product contamination and serious infection control breaches (e.g., syringe reuse).

REPORTING CLUSTERS AND OUTBREAKS

4.2 Reporting of Clusters and Outbreaks

4.2.1 Purpose

Nearly any type of outbreak that can occur in the community can also occur within healthcare settings. Healthcare settings are also unique and complex settings that lend themselves to types of outbreaks that can only occur within healthcare. For these reasons, there are a multitude of types of HAI/AR outbreaks that can occur. Many of these outbreaks are not routinely detected via public health surveillance since surveillance is usually limited in scope (e.g., to specific infections or pathogens). Therefore, reporting of clusters and outbreaks to public health is a critical pathway for public health to become aware of outbreaks within a healthcare setting. The healthcare community plays an essential role in the detection of not only outbreaks within facilities, but community outbreaks as well. Reporting by healthcare facilities, astute clinicians, and community partners plays an essential role in the detection of community-based outbreaks, including AR pathogens and other pathogens typically found in the healthcare setting.

4.2.2 Background

Reporting a suspected outbreak within a healthcare facility and to the public health agency as soon as it is detected is critical to outbreak response. See Table 4.1 for a list of possible reporting sources for each organization type. Although this chapter focuses primarily on public health outbreak detection, understanding the components of outbreak detection within healthcare facilities is also discussed to some extent for context.

4.2.2.1 Reporting within a Healthcare Facility

Healthcare facilities of all types should have systems in place for staff to notify a designated person or team when a cluster or outbreak is recognized. Outbreaks are usually reported to

an infection control team, which in some facilities might be a large team consisting of infection preventionists, medical epidemiologists, and other experts. In other facilities it might be one person with multiple duties, including infection prevention. Within a healthcare facility, clinicians, staff, and laboratories are typically the most common sources of outbreak reports. The culture of the healthcare facility should be such that internal reporting is an open process, where staff feel empowered to make a report and supported when a notification is made. Although there might be situations where patients, the public, or the media might report an outbreak to a healthcare facility, this is not a common way a facility is notified of an outbreak. Public health agencies might detect an outbreak within a facility that the facility is not aware of, either detected using surveillance data or from a report that comes from outside the facility. When this situation occurs, public health should contact the healthcare facility as soon as the outbreak is detected, both to ensure that the facility can immediately respond and gather additional information.

4.2.2.2 Reporting to Public Health

Entities that report to public health are described in the next section and in Table 4.1. Processes should be established to receive, triage, and respond to reports of suspected outbreaks. These processes should be clearly communicated to outside partners that report, as well as internally to staff that respond to outbreaks. The easier it is for an entity to report, the more likely they are to do so.

Requirements for what should be reported and who should report outbreaks varies among jurisdictions. Public health jurisdictions should ensure that all outbreaks are reportable to public health, including suspected outbreaks, outbreaks that occur within a healthcare setting, and any situation that might indicate illness from a common exposure including within healthcare. Requirements for reporting single cases of novel or rare conditions that might be sentinel events should also be included. Healthcare facilities and other reporting entities should report suspected outbreaks and should not wait until an outbreak is confirmed before reporting to public health. Although all suspected outbreaks should be reported to public health, not all suspected outbreaks reported will require active response or extensive investigation; passive monitoring may be sufficient in some instances and is itself a form of surveillance. Prioritization of investigations of suspected and confirmed outbreaks is covered in additional detail in Chapter 5.

Public health agencies should collaborate with healthcare facilities and other reporting entities to improve the reporting of suspected outbreaks to public health. Strategies that public health agencies can use to encourage reporting of suspected outbreaks might include:

- Encouraging healthcare facilities to report anything they feel is unusual and maintaining open communication to allow for discussion of unusual situations between the public health agency and the facility;
- Striving for increased visibility among healthcare facilities and partners, such as giving presentations or attending meetings and local conferences;
- Implementing an effective triage and prioritization process that allows for reporting of suspected outbreaks with a full public health investigation only when indicated;
- Establishing and maintaining relationships among public health agencies and reporting entities.

Perceived barriers to reporting suspected outbreaks can include the following:

- Concern of the facility that reporting might trigger additional work or regulatory action;
- Uncertainty regarding reporting requirements or procedures;
- Uncertainty of the threshold for reporting;
- Previous negative experiences with reporting.

Public health agencies should be familiar with reporting barriers in their jurisdiction and collaborate with facilities to overcome reporting barriers.

4.2.3 Reporting Entities

Reporting to public health can come from a variety of sources, including the healthcare facility (from the infection prevention team, directly from staff, or from a clinical laboratory), from laboratories (public health laboratory, reference laboratory, community laboratory), or from community sources (public, media, other government agencies or other organizations). The public health agency receiving the report could be at the local, state, territorial, tribal, or federal levels, and public health agencies that receive these reports should notify other impacted agencies as appropriate. If a healthcare facility contacts CDC directly, CDC staff will advise them of the need to coordinate with the state or local public health agency. The entities reporting outbreaks, and those required to report, might vary across jurisdictions.

4.2.3.1 Healthcare Facilities and Providers

Most reports of HAI/AR suspected outbreaks are made to public health agencies by healthcare facilities and providers, who are the front line in identifying conditions, pathogens, and suspected outbreaks to public health, including outbreaks that occur in the community. See Table 4.1 for information on how outbreaks come to the attention of facilities and public health.

4.2.3.2 Laboratories

Clinical laboratories and public health laboratories might detect clusters or suspected outbreaks upon producing test results that might indicate links between similar test results. Laboratories might detect clusters using automated processes and laboratory information systems, or astute laboratorians might identify clusters during testing. Laboratories that identify clusters and suspected outbreaks should notify their healthcare facility, if applicable, and suspected outbreaks should be reported to public health.

4.2.3.3 Public, Patients, and Media

Less often, members of the public, including patients within a healthcare facility, might identify a cluster or suspected outbreak based on similarity of disease and/or exposure. Members of the public might call the health department directly; public health agencies might also identify suspected outbreaks on social media. Reports might come to public health via the media if either the media reports a story regarding a suspected outbreak or the media calls public health to request information about an outbreak. In these situations, public health should initiate a brief investigation to see if there is a suspected outbreak that has not been reported yet.

4.2.3.4 Other Government Agencies

Various other government agencies at the local, state and territorial, and federal levels might become aware of and report outbreaks to public health agencies. For example, state facility licensing agencies might identify a suspected outbreak during a routine survey of a healthcare facility, or during an investigation of a complaint. In addition to concerning cases or clusters, serious infection control breaches also might be identified by state facility and provider licensing agencies, or other regulatory partners. State facility licensing agencies should report suspected or potential outbreaks to the public health agency. In some circumstances CMS might identify a suspected outbreak, through its own activities or those of an accrediting organization, and report to public health. State agencies that license healthcare providers might also identify potential outbreaks (including serious infection control breaches) during their investigations or by receiving complaints from consumers and should report these to public health. In turn, public health agencies should have protocols and appropriate authority to receive and share information on potential outbreaks, including infection control breaches.

4.2.3.5 Other Partners

Other partners that work with healthcare settings might also be positioned to identify suspected outbreaks.

- Accrediting organizations might identify and report a significant infection control breach or suspected outbreak to public health authorities.
- Law enforcement might identify concerns that they report to public health during criminal investigations.
- Other organizations that have roles in HAI/AR prevention, such as hospital and long-term care associations, member organizations, and quality improvement organizations, might identify suspected outbreaks.

These partners might not have specific requirements to report; however, public health agencies should develop relationships with these entities, opening the door to communication when partners identify concerns.

4.2.4 Epidemiology Process

When an initial report of an outbreak is received, there should be a pre-established process for intake as well as assigning an appropriate staff member for the initial assessment. Information should be gathered from easily available sources to make a preliminary assessment and triage an appropriate level of response; see Chapter 5 for a detailed discussion of information to be gathered and determining the level of a response.

For each report received, consideration should be given to the possibility it might be linked to other reports or surveillance data. Linking clusters, outbreaks, and single cases of public health interest detected can be done within the jurisdiction and is aided by having an outbreak investigation tracking system (see section 4.2.9) in place along with regular communications among surveillance and response staff. This can also be accomplished nationally via communication through Epi-X, list-serves such as the Infectious Diseases Society of America's (IDSA's) Emerging Infection Network (https://ein.idsociety.org), or via

communication with CDC. These sources can be checked to ensure there is not a larger, broader outbreak.

4.2.5 Laboratory Process

When receiving an initial report of a suspected outbreak, epidemiology staff should communicate with their public health laboratory colleagues to share initial information and allow them to prepare for upcoming laboratory activities that may be indicated as part of the investigation. In some instances, the public health laboratory will receive the first communication regarding a potential outbreak. For example, a hospital might contact the laboratory for assistance with specialized testing to assess the relatedness among isolates or samples as part of the hospital's internal investigation of a cluster of infections. At other times, the public health laboratory might detect a possible healthcare outbreak as part of its regular testing activities. In either case, laboratory staff should relay this information to their epidemiology colleagues. The key is to ensure clear communication and coordination between epidemiology and laboratory staff.

4.2.6 Strengths and Limitations of Outbreak Reporting Systems

4.2.6.1 Strengths

Strengths of outbreak reporting systems include the following.

- A healthcare outbreak reporting system provides the surest and fastest method for public health to learn about suspected outbreaks.
- All manner of outbreaks and infection control breaches can be reported, including outbreaks where the pathogen is unknown and where pathogens/conditions are not included in surveillance.
- During the reporting process, additional communication can occur between the reporter and public health staff.
    - Public health gains information quickly about outbreak scope and infection control measures already in place.
    - Initial recommendations for prevention measures can be communicated during the initial report when appropriate, allowing for rapid intervention that can prevent cases. See Chapter 5 for additional details.
    - Healthcare facilities and providers have overlapping expertise with public health professionals, leading to a widespread system of experts that can identify clusters and outbreaks across the continuum of care.

4.2.6.2 Limitations

Outbreak reporting systems also have limitations.

- Defining and communicating clearly what should be reported can be challenging.
- Dependence on a wide variety of reporters with inconsistent understanding, interpretation, and practice related to surveillance and reporting.
- Signal fatigue can occur.

- Recognition of multi-facility outbreaks can be delayed or missed if not all facilities involved report.

4.2.7 Key Determinants of Successful Outbreak Reporting Systems

A successful outbreak reporting system is one where criteria for suspected outbreaks are as clearly defined as possible, entities reporting are clear on when and what to report, reporting is systematic and complete, processes for handling reports are pre-established, and, when indicated, rapid investigation is initiated as a result.

4.2.7.1 Sensitivity of Detection

Identification of a suspected outbreak using the reporting process might occur when a suspected outbreak is reported or when individual reports of conditions of interest, such as an unusual pathogen/infection combination, are made and the public health agency has a method for compiling reports to identify a cluster or suspected outbreak. The sensitivity to detect an outbreak using an outbreak reporting system is dependent on the ability of a healthcare facility/provider (or other reporter) to identify a cluster or suspected outbreak and the awareness of how to report suspected outbreaks. The sensitivity to detect an outbreak when individual cases are reported is dependent on the healthcare facility/provider (or other reporter) identifying that an individual case might be of interest to public health,

the awareness of how to report the case, and the resources of the public health agency to recognize that cases are part of a cluster as well as to perform enough of an investigation to confirm the cluster as an outbreak. Multi-facility and product-related outbreaks can be more difficult to detect as often individual reports need to be linked by the public health agency or agencies.

4.2.7.2 Prevalence of Disease

The prevalence of a pathogen or infection type (or infection/pathogen combination) impacts the ability of a healthcare facility/provider or public health agency to identify a cluster. When the background prevalence of a disease is low, it is generally much easier for a case or cluster to stand out and be recognized as a suspected outbreak. Conversely, when the background prevalence of a disease is high, it can be challenging to discern a potential outbreak from background rates of sporadic disease occurrence. This can lead to delayed recognition and under-reporting with missed opportunities for intervention and outbreak control. It can also lead to over-reporting of suspected outbreaks, additional work for healthcare facilities and public health, and depletion of resources. Similarly, during an investigation involving a pathogen with a higher background prevalence, inclusion of cases that are not actually part of the outbreak (i.e., misclassification) can lead to challenges finding the cause of the outbreak.

4.2.7.3 Relationships

The quality of relationships between the reporting entity and the public health agency can impact the willingness of the entity to report. If there is trust, mutual respect, and an understanding of the expertise and importance of each entity, entities are much more likely to actively engage in reporting and jointly investigating suspected outbreaks. It is critical to

develop relationships prior to an outbreak, as discussed in detail in Chapter 3. Each outbreak response experience can have an impact on future reporting. Public health agencies can improve reporting by demonstrating sensitivity to the burden experienced by healthcare facilities and providers during a public health response to an outbreak; however, this should not be at the expense of a complete investigation when warranted.

4.2.8 Model Practices for Outbreak Reporting Systems

4.2.8.1 Required Reporting

Public health agencies should have clear requirements for the reporting of outbreaks, including suspected outbreaks, outbreaks occurring in a healthcare setting, and novel or rare conditions that might be sentinel events. The method for setting forth requirements for reporting varies among states and territories. Public health should have clear authority to initiate an investigation into any cluster or suspected outbreak, including those occurring in healthcare settings, and authority to conduct all activities needed to stop the outbreak.

4.2.8.2 Ensuring Timeliness

Suspected outbreaks should be reported to public health upon initial identification. Reporting entities should not wait until an outbreak is "confirmed" or an internal investigation has been completed prior to reporting to public health. Public health agencies should have a clear and easy reporting process as described below and develop relationships with reporting entities to maintain open lines of communication.

4.2.8.3 Clear Reporting Process

Public health agencies should work to ensure that entities that report understand reporting requirements in their jurisdiction and should communicate reporting requirements frequently to reporting entities. Thresholds for reporting clusters and suspected outbreaks, especially for outbreak types that are less common, can be challenging to define. Guidance for what to report can be challenging for public health agencies to clearly communicate. Public health agencies can remove barriers to reporting by helping interpret guidance, communicate expectations, and making the reporting process as simple as possible. When possible, processes for reporting suspected outbreaks should be clearly written and easily available, and include:

- Clear guidance on timing of reporting;
- What information will be needed when making a report;
- Clear, easy-to-locate, information on the reporting method, which could be via phone (with numbers that are easy to locate, including a 24/7 afterhours number) and/or via systems for electronic reporting, such as a web- or text message-based system;
- Guidance for what to expect during and after the reporting process.

Public health staff should have a clear understanding of the reporting process for entities reporting, and there should be a clear, written internal process for standardized intake and triage of reports. Ideally the reporting intake process should be centralized, so that one or limited persons conduct the intake, or one person reviews reports to identify commonalities.

4.2.8.4 Useful Tools

Useful tools for an effective outbreak reporting system include clear written processes for intake, recording, and reviewing outbreak reports to guide the systematic collection of reports. An intake form can be helpful to ensure that information is collected systematically each time. Alternatively, an electronic system with required fields for filing outbreak reports can make it easy for the entity reporting, as outlined in the next section.

Reports of outbreaks can be checked against other data systems, depending on the type of outbreak, including state survey reports on facilities involved; Epi-X, the IDSA Emerging Infection Network list-serve (https://ein.idsociety.org), and other reports of ongoing national outbreaks; and public health surveillance systems that might identify additional cases.

Knowledge of healthcare facility systems and patient transfer patterns can be a useful tool to detect multi-facility outbreaks and understand the potential scope of an outbreak. If public health agencies have the expertise and resources, a model practice is to create and maintain a network analysis of facility transfer patterns to apply to detected outbreaks.

4.2.8.5 Outbreak Tracking

As described in Chapter 3, each agency should track all outbreak reports and response activities, including clusters, suspected outbreaks, confirmed outbreaks, sentinel events, and infection control breaches. CORHA has developed a HAI/AR Outbreak Investigation and Response Tracking System and associated data dictionary for this purpose, found on the CORHA website (www.corha.org/resources-and-products/?filter_cat=data-management).

DETECTING CLUSTERS AND OUTBREAKS THROUGH SURVEILLANCE

4.3 Detecting Clusters and Outbreaks through Surveillance

4.3.1 Purpose

By using surveillance data, public health agencies can systematically detect outbreaks of pathogens and conditions that are under public health surveillance. This is an essential public health activity that complements the direct outbreak reporting pathways reviewed in section 4.2. When every case is reported, patterns suspicious for an outbreak can be recognized not only within a single facility, but across multiple facilities and within the community. Pattern recognition can be via manual review of surveillance or laboratory data or in an automated fashion using specific software for data mining and cluster detection. Public health agencies that rely on the detection of outbreaks using both surveillance data and outbreak reporting systems will detect more outbreaks than either system alone. Of note, while this section primarily takes the point of view of public health surveillance, many of the activities and principles reviewed here can also apply to healthcare facilities, especially larger hospital-based systems.

4.3.2 Background

Disease surveillance is an established practice in public health. By receiving reports of every case of a specific condition or pathogen, surveillance can be comprehensive, and by using various techniques, patterns in the data can be recognized. It can be helpful for public health agencies to review surveillance data daily, including a review of the reporting facility and the address of the patient, to identify healthcare facilities that might be associated with the case. In some situations, review of case information in an electronic health record or health information exchange can be helpful to identify characteristics that might be indicative of a cluster or sentinel event. Review of every case using these methods might not be feasible, and so public health agencies should prioritize these methods based on local epidemiology and priorities.

Two techniques that can assist with detecting patterns within surveillance data are laboratory typing and the use of automated systems to detect clusters. These methods can be employed within healthcare facilities and by public health. An example of cluster detection methodology can be found in routine enteric disease surveillance methods using systematic typing of all isolates of specific conditions. For example, when all *Salmonella* isolates undergo whole genome sequencing (WGS), a technique now employed more routinely in foodborne surveillance, clusters are identified based on the similarity of the isolates based on single nucleotide polymorphism (SNP) differences. A cluster of three *Salmonella* isolates with no SNP differences might lead to an investigation to find the link among the cases. HAI/AR programs within the U.S. have begun to implement similar laboratory testing approaches for pathogens related to healthcare settings, particularly those which represent emerging AR threats (see Section 4.3.5). When available, cutting edge laboratory technologies provide powerful methods for enhancing outbreak detection. The use of automated systems, such as cluster detection software tools, applied to surveillance data is another method by which clusters and outbreaks might be detected. This method is described in additional detail below (see Section 4.3.4).

4.3.2.1 Detection within a Healthcare Facility

Public health agencies should be aware of surveillance systems in place in healthcare facilities in their jurisdiction, including barriers facilities might experience in implementing surveillance systems. Surveillance systems used might vary widely across facilities and healthcare settings, and might include electronic health records, infection prevention systems, laboratory systems, or even basic line lists in small or lower-resourced facilities. Facility surveillance systems cross paths with public health when such systems are used to collect and report conditions under public health surveillance, and when a system results in the detection of a cluster or outbreak that triggers public health reporting requirements.

Healthcare facilities should have surveillance systems in place for selected pathogens, conditions, and syndromes; an essential function of facility surveillance systems is to detect situations that might indicate disease transmission within their facility. There is not a single approach to surveillance that will fit all healthcare facilities, and facilities should design surveillance procedures and systems based on their population, priorities, and objectives, as well as any applicable regulatory requirements.[7] Recommendations for surveillance within healthcare facilities are outside the scope of this guidance, but other resources are available for this purpose.[7,8]

4.3.2.2 Detection by Public Health

HAIs and healthcare-associated pathogens, including AR pathogens, are reported to public health agencies according to state, territorial, tribal, and local regulations. Public health agencies establish lists of conditions for public health surveillance that are reportable by healthcare providers, healthcare facilities, and/or laboratories. Conditions to report might be pathogen-specific or based on infection type, described below, or some other criteria. Isolates or clinical material are often required to be submitted in conjunction with the report. Additional information on surveillance practices can be found in Chapter 2. Reporting requirements by state can be found at www.cste.org/group/SRCAQueryRes. Conditions that are notifiable to CDC on a national level can be found at wwwn.cdc.gov/nndss/conditions.

4.3.3 Types of Surveillance Data

It is important to understand the different types of HAI/AR surveillance data collected by public health agencies, and what their advantages and limitations are. Two types of surveillance used extensively by health department HAI/AR programs are population-based surveillance and healthcare facility-based surveillance. Population-based surveillance involves identifying cases that meet a specific surveillance definition within a defined population, typically residents of a certain jurisdiction, such as a state or a county. For some conditions, surveillance occurs at the healthcare facility level rather than the population level; each healthcare facility may be expected to report conditions for their facility, either to the local/state public health agency or to a national system such as NHSN (which in turn may transmit back to or be accessed by local/state public health). See Chapter 2 for additional information on these surveillance practices.

When a cluster is detected using a specific data source, understanding the strengths and limitations of the surveillance system will lead to a more accurate interpretation of the significance of the cluster. An outbreak might be detected using either population-based surveillance or healthcare facility-based surveillance, or other surveillance systems that might be in use. One example of the latter might be antibiogram data, which might indicate increasing levels of a particular pathogen or resistance pattern. Antibiogram data can also be used to understand the baseline prevalence of a pathogen or resistance pattern for organisms that might not be under routine surveillance.

4.3.4 Epidemiology Process

Once cases of a condition under surveillance are received by the public health agency, individual cases might be reviewed to gather additional epidemiologic data, depending on the priorities of the public health agency, local epidemiology, and characteristics of the condition. Gathering additional epidemiologic information might be accomplished via discussions with the healthcare facility, medical record reviews, and/or interviews of patients. The level of additional data gathered for each case and the methodology employed is highly variable among jurisdictions and among specific pathogens or conditions reported; broadly speaking it covers the “who, what, where, when” and sometimes also includes aspects of the “why/how.” Resource limitations typically do not allow for complete data collection for every case for every pathogen and condition for which reports are collected. Public health agencies should prioritize individual case investigation based on local epidemiology and priorities. Routine collection of selected information should occur as soon as possible after public health receives a case report to maximize the possibility of cluster

detection. For more information on descriptive epidemiology, see Chapter 5 and CDC's Principles of Epidemiology in Public Health Practice, 3rd Edition, here: www.cdc.gov/csels/dsepd/ss1978/lesson1/section6.html.

As epidemiologic information accrues, these data can be reviewed for possible linkages among cases in terms of etiology, person, time, and place. Manual review of cases is one method to identify any clusters that might need additional investigation. Reviews might identify clusters associated with a particular facility or facility network, among patients with similar healthcare conditions or exposures to procedures, among patients with similar community exposures, or other unique exposures. This works well if the condition under surveillance has a fairly low prevalence and the reviewer has a solid understanding of the data. If the prevalence of the condition is high, manual review of cases might be too labor-intensive and subjective to employ routinely.

More automated methods can be used to detect clusters using surveillance data, particularly when a high prevalence of disease is too cumbersome for manual review. Some public health agencies, as well as hospital systems, also use automated methods, such as the application of data mining and cluster detection software, to identify clusters among surveillance data. Automated technologies can speed up the process of detecting clusters and can combine data across data sources. Advantages of using automated cluster detection include speed, efficiency, accuracy, reduction of staff time, and potential to detect more clusters and

prevent more disease.[9,10] Additional resources are needed to implement such processes, such as information technology support, staff training, and software acquisition. Use of automated systems by public health agencies to detect clusters varies greatly by jurisdiction; in a recent survey, 36% of respondents indicated that their agency did not use automated methods for cluster detection. The most commonly reported barriers to automated methods for cluster detection included lack of resources, perceived lack of timeliness, lack of access to data, and a lack of expertise.[11] It can be challenging to set parameters that provide enough sensitivity to detect every cluster that truly represents an outbreak without being so sensitive that more clusters are identified than can be investigated practically (including many which may not represent true outbreaks, representing a poor signal-to-noise ratio); a recent review found that sensitivity of detection algorithms could vary between 17 and 100%.[12]

4.3.5 Laboratory Process

Electronic laboratory reporting for conditions under public health surveillance supports complete and accurate reporting; complete surveillance reporting assists the detection of clusters and outbreaks. When unusual pathogens, testing results, and pathogen/specimen combinations are detected, astute laboratory staff are in a prime position to detect clusters and report potential outbreaks to clinical and public health partners. Laboratory information systems and other laboratory databases also can be sources of data to detect clusters and suspected outbreaks.

Clinical laboratories forward isolates or clinical specimens to the public health laboratory according to local regulations as part of surveillance. For AR pathogens, as well as other healthcare-associated pathogens (e.g., group A *Streptococcus*), it is important to receive isolates for confirmation (e.g., organism genus and species, antimicrobial susceptibility) and additional testing to further characterize the isolate (e.g., molecular testing). For example,

identification of mobile genetic elements of interest to public health, such as carbapenemases and *mcr*-1 genes,[13] is important to identify clusters and suspected outbreaks; such additional characterization helps focus epidemiologic investigations on selected cases that truly might be related and avoid case misclassification. Additionally, some jurisdictions might prioritize AR pathogens with specific characteristics, such as carbapemase-producing CRE. Epidemiology should be aware of what testing is performed routinely on isolates submitted to the public health laboratory, turn-around time, and how results are communicated to healthcare facilities. Communication of results to epidemiology and the healthcare facility should be rapid and part of an established process. Laboratory processes that support surveillance also support the detection of clusters; epidemiology should be able to act quickly on single cases and clusters detected.

In 2016 CDC established the AR Laboratory Network (AR Lab Network), which led to expansion of the capability of facilities and public health agencies to detect emerging AR threats and support coordinated local responses to prevent their spread. It also functions as a surveillance entity with the capacity to provide information on national trends and detect outbreaks. More information on the AR Lab Network can be found in Chapter 2 and here: https://www.cdc.gov/drugresistance/laboratories.html.

4.3.6 Strengths and Limitations of Surveillance for Outbreak Detection

4.3.6.1 Strengths

Using surveillance data to detect clusters and suspected outbreaks has several strengths.

- It is potentially more thorough and systematic than relying on passive reports.
- When epidemiologic information is available on cases, the signal-to-noise ratio and sensitivity can be high.
- It supports complementary processes (manual and automated). The manual process of outbreak detection relies on personnel to review surveillance data and make connections among cases; with experienced personnel and less common conditions, this methodology should identify most outbreaks of diseases and conditions under surveillance. Using data mining and cluster detection software can supplement and automate this process.

4.3.6.2 Limitations

Limitations of outbreak detection using surveillance data include the following.

- Reliance on surveillance data to detect outbreaks only works for conditions under surveillance.
- Outbreak detection using surveillance data is typically slower than outbreak reporting to public health. It is dependent on the timing and completeness of individual case reports, additional testing performed and reported, and the time it takes for staff or automated processes to flag a cluster.
- Manual review of surveillance cases can miss clusters, is subject to human error, and can be very time-intensive.

- Automated cluster detection minimizes risks of human error but adjusting thresholds to achieve effective signal-to-noise ratio can be tricky when the condition is common. Signal fatigue could occur if the signal-to-noise ratio is low.
- Using software for automated detection requires information technology resources and staff expertise.

Incorporating both outbreak reporting systems and use of surveillance data to detect outbreaks capitalizes on complementary strengths and minimizes limitations of each system. Public health agencies should consider options for improving and optimizing their use of both types of systems to detect clusters and outbreaks.

4.3.7 Key Determinants of Successful Outbreak Detection via Surveillance Systems

Successful use of surveillance to detect outbreaks is dependent on rapid surveillance with complete data, targeted and specific information collected on cases that supports epidemiologic linkage and cluster detection, and rapid and systematic identification of clusters using the data collected. Here are the key determinants.

4.3.7.1 Completeness of Reporting

In order to use surveillance data to detect clusters, cases must be reported in a complete, accurate and timely fashion. Public health agencies can support this by ensuring requirements for reporting within their jurisdiction include rapid timeframes for reporting and clear

requirements as well as clear communication with entities reporting cases for surveillance. Electronic laboratory reporting is systematic and ensures complete and timely reporting for entities using it and should be used when possible. Additional epidemiologic information gathered on each case should be limited to what is needed and specific to assisting the detection of outbreaks and not superfluous, which diverts resources. Laboratory testing performed by the reporting entity should be communicated to public health. The capacity of the public health laboratory to perform additional laboratory testing (e.g., confirmation of clinical laboratory test results, advanced laboratory testing including molecular testing) may determine if cases can be linked based on laboratory data; any testing performed by the public health laboratory should be completed in a timely manner and shared with epidemiologic staff responsible for performing cluster detection.

4.3.7.2 Sensitivity of Detection

Surveillance might only represent a sampling of the true number of cases in the population, depending on the pathogen or condition, and the completeness of reporting of the true number of cases directly impacts the ability of public health to detect a cluster. With some HAI conditions, under-diagnosis and under-reporting can decrease the sensitivity of case detection. Pathogen-specific surveillance, particularly for AR pathogens, might provide an incomplete picture because of the presence of colonized individuals in the population or differential approaches to testing. Similarly, if isolates and clinical material are not routinely submitted for confirmation and additional testing, included cases might not represent the true scope of an outbreak. WGS is extremely promising to help define the scope of outbreaks; however, this technique is not yet widely applied to a wide array of reportable conditions.

4.3.7.3 Prevalence of Disease

As described previously, the prevalence of a disease often has an inverse relationship to the ease with which an outbreak can be detected. When the prevalence of disease is high, determining additional characteristics of the pathogen (e.g., mechanism testing, molecular typing such as WGS) and collecting additional epidemiologic data can be helpful in distinguishing cases that might be part of a cluster. For example, if a healthcare facility identifies two cases of CRE in an intensive care unit, it might be difficult to determine if this is a likely outbreak. However, if additional testing is performed and both isolates harbor a carbapenemase that has not yet been identified in the facility, it is much more likely that this will be identified as a cluster and possible outbreak.

4.3.7.4 Speed of Detection of Diseases and Conditions under Surveillance

It is advantageous to detect outbreaks as soon as possible, so that investigation can proceed, if warranted, with swift implementation of control measures. Rapid outbreak detection and response depend on the speed of the reporting, which can be affected by local requirements for reporting, ease of reporting processes in place, and the speed of gathering additional information from the facility, medical records, or interviews.

4.3.8 Model Practices for Detecting Outbreaks through Surveillance

4.3.8.1 Case Reporting

To support rapid detection of outbreaks, surveillance requirements and processes should reflect the need for timely case detection and reporting. Public health agencies can do the following:

- Make local timelines for reportable conditions commensurate with the urgency to detect outbreaks involving that specific disease or condition;
- Put processes in place to make reporting easier for entities reporting (e.g., support electronic laboratory reporting), and support those entities by providing education, being available for questions, and communicating frequently and clearly the methods for reporting;
- Ensure that case information collected is limited to what is needed for effective surveillance, outbreak detection, and other public health needs, ensuring judicious use of resources;

4.3.8.2 Submission and Characterization of Isolates

Public health agencies often issue requirements for submission of isolates and clinical material in connection with communicable disease case reporting. This is especially useful when additional confirmatory testing and further testing will assist with the identification of clusters and outbreaks. Clearly communicating the rationale and mechanisms for isolate submission helps ensure that this process happens quickly and reliably. Providing additional guidance, as needed, to affected laboratories helps ensure that case reporting and isolate submission can happen simultaneously. On the public health laboratory side, awareness of

local epidemiology, supported by communication between epidemiology and the laboratory, allows them to prioritize testing of pathogens as needed. Outbreak detection should be a strong consideration for prioritization of testing. Epidemiology staff should understand the testing practices and timelines of their laboratory partners.

When detecting clusters using surveillance data, establishment of etiology is a critical component. Laboratory testing frequently plays a key role in determining and confirming the diagnosis. For example, public health laboratories often will confirm the testing results performed at the clinical laboratory, especially when the etiology is in question. It is best practice to enlist the assistance of a reference laboratory with capacity to perform advanced laboratory testing, such as the public health laboratory, when attempting to determine if isolates or specimens are related.

Resources do not always allow for every isolate or specimen to undergo advanced laboratory testing. The ideal practice would be to perform molecular typing on all isolates submitted. Detecting clusters via assessments of relatedness (e.g., sequencing, isolate typing), and confirmation of relatedness of isolates when suspected transmission is occurring, would add to the ability of public health to detect clusters, confirm outbreaks, and ensure that cases identified as part of an outbreak investigation are not mis-classified. Routine typing of isolates submitted as part of surveillance is progressing and remains an important long-term goal for the HAI/AR field.

4.3.8.3 Standardized Processes for Cluster Detection

Processes to identify clusters using surveillance data should be as rapid as possible, regardless of whether they are conducted manually or using an automated method. Public health entities might choose to implement manual cluster identification or automated cluster detection depending on the pathogen or condition and resources available. Public health agencies should have processes in place, preferably written, that are standardized as much as possible to ensure consistent identification of clusters and outbreaks.

4.3.8.4 Communication

Laboratory staff should understand local epidemiology and be kept informed of clusters and outbreaks; epidemiology staff should understand the testing practices, constraints, and timelines of the laboratory. It is critical that laboratory and epidemiology staff communicate regularly to accomplish this. There should be established, routine procedures for communicating general practice information (such as regular meetings), as well as procedures for rapidly communicating the day-to-day work of surveillance data, test results, cluster and outbreak detection, and local epidemiology patterns.

4.3.8.5 Useful Tools

Free software is available for use with surveillance data to automate cluster detection; one such tool is SaTScan, which can be used in combination with data sources to detect clusters of disease using space, time, and space/time data. WHONET was developed to manage microbiology data, focusing on antimicrobial susceptibility test results, and has the capability to develop descriptive statistics and graphs which can be reviewed to detect possible

clusters. WHONET can be used in combination with SaTScan. See whonet.org and www.satscan.org.

Knowledge of healthcare facility systems and patient transfer patterns can be a useful tool to detect multi-facility outbreaks and understand the potential scope of an outbreak. Public health agencies can consider creating and maintaining network analyses of facility transfer patterns to apply to detected outbreaks. Surveillance data can be applied to facility network maps to understand patterns that might indicate clusters or to identify facilities that might be at risk.

4.3.8.6 Outbreak Tracking

As described in Chapter 3, each agency should track all outbreak responses, including to clusters, suspected outbreaks, confirmed outbreaks, sentinel events, and infection control breaches. CORHA has developed a HAI/AR Outbreak Investigation and Response Tracking System and associated data dictionary for this purpose, found on the CORHA website (www.corha.org/resources-and-products/?filter_cat=data-management).

MULTI-FACILITY AND MULTI-JURISDICTIONAL CONSIDERATIONS

4.4 Multi-Facility and Multi-Jurisdictional Considerations

Complete and timely reporting and detection of outbreaks is the gold standard for public health to aspire to. Detection of multi-facility and multi-jurisdictional outbreaks, a key component of complete detection of outbreaks, is highly dependent on robust reporting of conditions under surveillance, suspected outbreaks, as well as unusual pathogens/infections. For example, major multi-facility and multi-jurisdictional outbreaks with high morbidity and mortality have been detected due to reports of a non-reportable condition that originated from a single healthcare facility or provider.[6,14,15]

Multi-facility and multi-jurisdictional outbreaks can result from contaminated medical devices or drugs, a common healthcare provider, or some other shared infection source that is present in multiple facilities or jurisdictions. Recognizing this type of outbreak is challenging because the initial signals can manifest as a collection of seemingly isolated case reports. While healthcare facilities and healthcare providers play important roles in helping to identify multi-facility outbreaks, public health agencies have the advantage of being able to monitor and link reports across facilities and even across jurisdictions. Cluster detection using surveillance data can help identify multi-facility and multi-jurisdictional outbreaks that would otherwise go undetected. Public health agencies should employ methods to detect outbreaks via reporting and using surveillance data as described throughout this chapter to detect multi-facility outbreaks and maintain a low threshold for sharing concerns regarding a potential multi-jurisdictional outbreak with other state public health agencies or relevant federal agencies including CDC and the US Food and Drug Administration (FDA).

CORHA Keys to Success

Maximizing Outbreak Detection

Receiving Reports

- Perform surveillance for HAIs and AR pathogens which includes mandatory reporting and submission of isolates and clinical material when applicable.
- Ensure mandatory reporting includes reporting of suspected outbreaks and novel or rare conditions that might represent sentinel events.
- Establish processes for reporting that are clear to reporting entities, easy to follow, and allow for rapid reporting.
- Establish thresholds for reporting suspected outbreaks that are clearly defined. Under circumstances when suspected outbreaks are not easily defined, make guidelines for reporting as clear as possible.
- Ensure that entities that do not report regularly can easily find methods for reporting when they identify a suspected outbreak, building relationships with a variety of partners that might report.

Detection of clusters and outbreaks

- Use multiple methods to detect HAI/AR outbreaks, including, at a minimum, receiving reports of clusters and outbreaks and using surveillance data to detect clusters.
- Ensure processes are in place to detect clusters and outbreaks using surveillance data, which might include review of surveillance data by experienced personnel, data analysis to identify clusters and outbreaks, or automated processes using data mining and cluster detection methods.
- Ensure public health laboratory testing practices support the detection of outbreaks, including prioritization of testing based on local epidemiology and ability to perform advanced laboratory testing, with regular communication between epidemiology and laboratory.

Communication

- Ensure reporting entities receive detailed communication regarding reporting requirements with a frequency that maximizes sharing of information without overload.
- Clearly communicate thresholds and guidelines for reporting suspected outbreaks to reporting entities.
- Ensure clear and regular communication regarding local epidemiology and laboratory testing practices between laboratory and epidemiology public health staff. Processes for rapid communication of test results should be in place.

Evaluation

- Use an outbreak tracking database to monitor reports and investigations of clusters, suspected outbreaks, sentinel cases of public health interest, infection control breaches, AR-containment responses, and other healthcare outbreak responses; use this information to identify areas for improvement.
- Periodically evaluate processes for outbreak detection and refine and enhance them when needed.

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