CHAPTER

5

Investigation of Clusters and Outbreaks

Outbreaks of foodborne illness are detected by recognition of similar illnesses among persons with a common exposure that leads to a complaint or notification of health officials or by identification of case clusters through pathogen-specific surveillance. Although complaints are responsible for the detection of approximately 75% of foodborne disease outbreaks, the development of pathogen-specific surveillance through public health laboratories has enabled the detection of widely dispersed outbreaks caused by commercially distributed food products. These outbreaks are initially recognized as clusters of cases defined by subtype characteristics. Distribution of cases by time, space, and personal characteristics provides important clues about whether the cases are likely to represent an outbreak from a common source of exposure. However, only a systematic investigation of the cluster can confirm whether it actually is an outbreak and, if so, whether it is a foodborne disease outbreak. Identifying the route of transmission is critical for implementing effective control measures (see Chapter 6) but is not always possible through agent identification or clinical presentation.

5.0. Introduction

When a potential foodborne disease outbreak is first detected or reported, investigators will not know whether the disease is foodborne, waterborne, or attributable to other causes. Investigators must keep an open mind in the early stages of the investigation to ensure that possible causes are not prematurely ruled out. Even though these Guidelines focus on foodborne disease, many of the investigation methods described in this chapter apply to a variety of enteric and other illnesses, regardless of source of contamination.

5.1. Characteristics of Outbreak Investigations

5.1.1. Importance of Speed and Accuracy

Speed and accuracy are the two key qualities of all outbreak investigations. The investigation team cannot afford to sacrifice one for the other. The team motto should be *Fast and Right*. The importance of speed and accuracy are illustrated below.

- "Removing the pump handle." Stopping an outbreak in its tracks and preventing illnesses are the most obvious goals of outbreak investigations. From this perspective, there are three types of outbreaks.
  - *A localized one-time event, such as a specific food-preparation error or ill food worker at a food-service establishment*. By the time these outbreaks are recognized, the event may be over. However, ensuring an ill worker does not continue to spread disease or preventing secondary spread from initial cases might be possible.
  - *Widespread distribution of a perishable commodity, such as spinach or tomatoes.* Because product may still be in the marketplace when the outbreak is detected, the faster the source can be identified, the more likely the possibility that the commodity can be recalled, preventing further illness from that source. Given the large quantities of contaminated product often involved in these events, even a limited recall could significantly benefit public health.
  - *Contamination of shelf-stable commodities, such as canned or frozen foods or peanut butter, or persistent environmental contamination at a farm, food-processing facility, or restaurant.* The speed with which the source is identified and the effectiveness of a recall are directly related to the number of people exposed to the contaminated commodity and the ultimate size of the outbreak.
- Preventing future outbreaks by identifying the circumstances that led to contamination. Without a prompt, complete, and accurate investigation, the circumstances that led to contamination may not be identified, and the opportunity to prevent future outbreaks will be lost.
- Identifying new hazards. Outbreak investigations identify new agents, new food vehicles, new agent–food interactions, and other unsuspected gaps in the food-safety system. Prompt and thorough investigations while memories are fresh and specimens are available are much more likely to successfully rule out known hazards and identify new hazards. Presenting the information to the sector of the food industry involved can be critical for encouraging changes in procedures, resulting in primary prevention of sporadic illnesses and outbreaks.
- Maintaining the public's confidence. Foodborne disease outbreaks undermine the public's confidence in the food supply and in the public health system established to ensure food safety. Rapidly identifying outbreaks, determining their source, and limiting their scope are critical to restoring

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confidence in the food supply and food-safety system. On the other hand, inaccurate conclusions about the source undermine public confidence and harm food producers not involved in the cause of the outbreak. For example, strawberries from California were implicated as the source of a multistate outbreak of cyclosporiasis that actually was caused by raspberries from Guatemala. Media reports based on the erroneous conclusion led to millions of dollars in lost strawberry sales, even though the error was rapidly corrected. This situation probably could have been avoided if investigators had considered results from simultaneous investigations in other localities. Maintaining close communication and coordination among members of the investigation team and with other public health officials is the best way to avoid this type of error without delaying the investigation. Early communications with industry representatives may also help to clarify possible misconceptions in data analysis. See section 6.1 for additional discussion about the importance of collecting sufficient information before taking action.

- Empowering the public. Even though releasing premature and incorrect conclusions to the public can be disastrous, and alerting the public about food-safety concerns too often can lead to warning fatigue, withholding or delaying the release of information the public may need to protect itself is inadvisable. Public health agencies are obligated to inform the public or others who need to know as quickly as possible. Generally, ask yourself,
  - "Will the release of this information enable consumers to take steps to protect themselves?"
  - "If the wrong product is identified, what will the negative impact be on public health, as well as on the industry and consumer confidence?"

Making decisions with imperfect information in the context of an ongoing outbreak is challenging, and judgments should favor protecting the public while keeping in mind the significant negative impact the announcement of an incorrect association can have on an industry. However, as new information becomes available, recommendations must be rapidly revised and communicated. For example, in 2011, a large outbreak of hemolytic uremic syndrome caused by a novel *Escherichia coli* O104:H4 strain occurred in Germany.[1] Within a week after outbreak detection, results of preliminary investigations led German public health officials to advise consumers to not eat fresh tomatoes, cucumbers, or lettuce. However, ongoing investigations during the next 2 weeks implicated consumption of sprouts, and the previous advisory was promptly retracted.[2]

5.1.2. Principles of Investigation

5.1.2.1. Outbreak detection

Outbreaks typically are detected through two general methods: complaint systems and pathogen-specific surveillance (see Chapter 4). After receipt of a complaint about suspected foodborne illness associated with a particular event or establishment or detection of an unusual cluster of isolates through pathogen-specific surveillance, a preliminary investigation should be conducted to determine whether the reported illnesses may be part of an outbreak.

5.1.2.2. Investigation leadership

During an investigation, the focus of activities might shift between roles described below. They also might shift between levels of government in accordance with authority and the availability of resources to carry out the required tasks, as follows:

- Laboratory studies to identify an agent, including microbiological studies and applied food-safety research;

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- Epidemiologic studies to identify transmission routes, exposure sources, or food vehicles and risk factors for disease;
- Regulatory investigations of food-production sources and distribution chains to identify where, during production of the food, contamination occurred and facilitate recall of food items;
- Environmental assessments of food production, processing, and service facilities to identify routes of contamination, contributing factors, and environmental antecedents; and
- Communication of investigation findings to the public and the food industry to support control and prevention measures.

Investigations initiated at a local level might be more effectively coordinated or conducted at a state level if multiple jurisdictions are involved. Similarly, federal agencies might be needed to effectively coordinate and investigate multistate outbreaks. Conversely, state or local agencies with sufficient resources to investigate clusters within their jurisdictions should be encouraged to do so, even if the cluster was recognized at the federal or state level (see Chapter 7).

5.1.2.3. Communication and coordination

Coordinate activities and set up good lines of communication between individuals and agencies involved in the investigation. To avoid mixed messages and incomplete information or misinformation, each investigation should have a consistent point of contact. Guidelines for coordinating multijurisdictional investigations are summarized in Chapter 7. Investigations are rarely linear. Although most procedures for investigating outbreaks follow a logical process—from determining whether an outbreak is occurring to identifying and controlling the source—most actual investigations feature multiple concurrent steps. In addition, the focus of the investigation may need to shift as the situation warrants. For example, a key to solving the *Salmonella* Typhimurium outbreak associated with peanut products produced by Peanut Corporation of America was the recognition that subclusters of cases had common institutional exposures. This led to an investigational shift from individual case exposures to institutional food purchases.[3] Maintaining close communication and coordination among members of the outbreak investigation team is the best way to ensure concurrent activities do not interfere with each other and important investigation steps are not forgotten.

5.1.2.4. Hypothesis generation

To narrow the focus of an investigation and most effectively use time and resources, investigators should begin to generate hypotheses about potential sources of the outbreak during the earliest stages of the investigation and refine them as they receive information. Key steps in this process include the following:

- Review previously identified risk factors and exposures for the disease;
- Examine the descriptive epidemiology of cases to identify person, place, or time characteristics that might suggest a particular exposure; and
- Interview in detail the affected persons or a sample of affected persons to identify unusual exposures or commonalities among cases.

On the basis of this information, investigators can identify possible exposures for further evaluation by epidemiologic, laboratory, or environmental studies. In practice, the generation and testing of hypotheses is an iterative process, with the hypothesis modified as more information is obtained. For example, an outbreak involving a high proportion of cases among preschool-aged children might suggest exposure to a food product marketed to young children, such as a cereal product or snack food. Identification of a specific product, such as a certain vegetable

5.1. Characteristics of Outbreak Investigations

powder–coated snack, by several cases should prompt re-interview of other cases to identify previously unrecognized exposures to the product. Concordance of exposures among a substantial proportion of cases could lead directly to recall or product testing or a focused epidemiologic study to confirm the association.

Although hypothesis generation seeks to narrow the focus of the investigation, high-risk exposures that are easy to forget should not be ruled out just because a low proportion of cases report the exposure. If reason exists to suspect that a particular food item might be the source of the outbreak, that item should be included in further epidemiologic studies, regardless of whether a majority of cases recalled it. Interviews should include questions that specifically try to identify consumption of the suspected food item, especially if it is an ingredient.

5.1.2.5. Standardized data collection forms and processes

The use of standardized forms for collecting exposure histories ensures that pertinent information is collected from all cases. Consistently asking about high-risk exposures (e.g., sprouts, raw milk, ground beef, leafy greens) makes data easier to share among jurisdictions and commercial product outbreaks easier to resolve quickly. In addition, use of a standardized interview form with which the interviewer is familiar will decrease time spent on staff training and decrease errors in data collection. Similarly, use of standardized forms for environmental investigations provides comparable data for investigations that might involve multiple establishments. Because good forms take time to develop and format, developing templates *before* a crisis is critical to their rapid deployment (see also Chapter 4, section 4.3.9). The CIFOR Clearinghouse (www.cifor.us/ clearinghouse/keywordsearch.cfm) provides examples of questionnaires used by various health departments to collect exposure information for different pathogens and might be useful in template development. The Environmental Health Specialists Network (EHS-Net) website (www.cdc.gov/nceh/ehs/EHSNet/) can be referenced for models of environmental assessment forms and consumer complaint forms.

Interviewers should be trained in the use of the standardized interview forms and techniques and have demonstrated proficiency in their use during previous investigations. Interviews can be conducted by one interviewer or by multiple interviewers. Although one interviewer might recognize uncommon exposures mentioned by multiple persons, completing these hypothesis-generating interviews might take several days. Multiple interviewers can interview cases simultaneously but need to regularly compare notes so that they can recognize uncommon exposures mentioned by multiple persons. This latter process forms the basis of the dynamic cluster investigation model described below.

5.1.2.6. Privacy of individuals, patients, and their families.

All outbreak investigations involve collection of private information, such as names and symptoms that must be protected from public disclosure to the extent allowed by law. All members of the investigation team, including epidemiologists, laboratorians, environmental health specialists, and food-safety personnel, need to be familiar with and follow relevant state and federal laws and practices.

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

5.2.1. Conduct a Preliminary Investigation

5.2.1.1. For complaints of illness attributed to a particular event or establishment

The following questions should be answered:

- Are the incubation period and symptoms (or specific agent, if one or more cases have been diagnosed) consistent with an illness resulting from the reported exposure?
- Are multiple cases being attributed to the same exposure?
- Are all of the illnesses similar (suggesting that all are the same disease)?
- Could these illnesses be reasonably explained by other common exposures?

If multiple cases of illness have the same incubation period and if multiple persons have symptoms consistent with an illness resulting from the reported exposure, the complaints might represent an outbreak and need to be investigated.

5.2.1.2. For case clusters identified through pathogen-specific surveillance

The following questions should be answered:

- Do the number of cases with the cluster characteristics exceed the number expected during this time frame and season?
- Does the demographic distribution (e.g., age, sex, and ethnicity) or geography suggest a common source of exposure?
- Do cases share any unusual exposures?
- Do new cases continue to be detected, suggesting the potential for ongoing transmission and the need for abatement procedures?

If the number of cases in a cluster or the demographic features or known exposures of cases suggest a common source, or if new cases continue to be detected, the cluster might represent an outbreak and needs to be investigated. (See model practices for cluster investigation, below).

5.2.2. Assemble the Outbreak Investigation and Control Team

(See also Chapter 3)

5.2.2.1. Alert outbreak investigation and control team

Alert outbreak investigation and control team leaders as soon as the possible outbreak is identified. Review descriptive features of the outbreak setting and relevant background information about the etiologic agent, establishment, or event.

5.2.2.2. Assess the priority of the outbreak investigation

On the basis of the outbreak setting and descriptive epidemiology, **outbreak investigation and control team leaders should assess the priority of the outbreak investigation.** Give highest priority for investigation to outbreaks that:

- Have a high public health impact:
  - Cause severe or life-threatening illness, such as infection with Shiga toxin–producing *E. coli* O157:H7, hemolytic uremic syndrome, or botulism;
  - Affect populations at high risk for complications of the illness (e.g., infants or elderly or immune-compromised persons); and
  - Affect a large number of persons.
- Appear to be ongoing:
  - Outbreak might be associated with food-service establishment in which ill food workers provide a continuing source of infection.
  - Outbreak might be associated with an adulterated food product in commercial distribution that is still being consumed.

5.2.2.3. Assemble and brief the outbreak investigation and control team

On the basis of the priority given the outbreak and the nature of the outbreak, investigation

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

and control team leaders should assess the availability of staff to conduct the investigation. **In particular, the team leader should ensure the presence of adequate staffing to interview cases within 24–48 hours and solicit controls as needed.** If sufficient staff are not available, external assistance should be requested to conduct interviews.

Outbreak investigation staff should be briefed on the outbreak, the members of the outbreak investigation and control team, and their individual roles in the investigation.

For outbreaks involving multiple jurisdictions, the outbreak investigation and control team should include members from all agencies participating in the investigation (see also Chapter 7).

If an agency does not believe it can manage an outbreak (i.e., the scale or complexity is likely to overwhelm agency resources, or the nature of the outbreak is beyond the expertise of agency staff), help should be requested as soon as possible (see also Chapter 3 section 3.9).

5.2.3. Establish Goals and Objectives for the Investigation

5.2.3.1. Goals

- Obtain sufficient information to implement specific interventions that will stop the outbreak.
- Obtain sufficient information to prevent a similar outbreak in the future.
- Increase knowledge of the epidemiology and control of foodborne diseases. Unanswered questions about the etiologic agent, mode of transmission, or contributing factors should be identified and included in the investigation to add to the public health knowledge base.

5.2.3.2. Objectives

For outbreaks associated with events or establishments (Table 5.1):

- Identify the etiologic agent.
- Identify persons at risk and size and scope of outbreak.
- Identify mode of transmission and vehicle.
- Identify source of contamination.
- Identify contributing factors (specific ways that food became contaminated or capable of causing illness) and environmental antecedents.
- Determine potential for ongoing transmission and need for abatement procedures.

For outbreaks identified by pathogen-specific surveillance (Table 5.2):

- Identify mode of transmission and vehicle.
- Identify persons at risk and size and scope of outbreak.
- Identify source of contamination.
- Identify contributing factors (specific ways that food became contaminated or capable of causing illness) and environmental antecedents.
- Identify size and scope of outbreak.
- Determine potential for ongoing transmission and need for abatement procedures.

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

CIFOR Keys to Success: Focus Area 6—Initial steps in investigation of clusters and outbreaks

Initial steps

- Agency/jurisdiction has processes for responding to a possible outbreak, including who is to be notified and/or involved in the investigation and specific actions. Processes are written and easily accessible by staff.
- Agency/jurisdiction has established criteria for determining the scale of the response to a possible foodborne disease outbreak on the basis of the likely pathogen, number of cases, distribution of cases, hypothesized source, and agencies likely to be involved.
- Staff can prioritize the response to a possible outbreak on the basis of agency/jurisdiction criteria and know what outbreak circumstances require an immediate response, a more moderate response, or no response at all.
- Staff have access to historical trends or other data to determine whether case counts exceed the expected number for a particular period and population.
- Staff develop one or more hypotheses about the source of an outbreak early in the investigation to guide investigation steps.

Requests for assistance

- Local agencies notify state agencies as soon as an outbreak is suspected.
- Agency/jurisdiction asks for help as soon as it recognizes the need.

Making Changes

- Agency/jurisdiction debriefs investigators after each outbreak response and refines outbreak response protocols on the basis of lessons learned.
- Agency/jurisdiction has performance indicators related to the initial steps of an outbreak investigation and routinely evaluates its performance in this Focus Area.

5.2.4. Select and Assign investigation Activities

Tables 5.1 and 5.2 outline objectives and investigation activities that can be conducted during epidemiologic, environmental health, and public health laboratory investigations of foodborne disease outbreaks. The table format highlights the major objectives of the investigation to help ensure coordination among epidemiologists, environmental health specialists, and laboratorians in meeting each objective. The assignment of investigation responsibilities to a particular discipline within each table is not intended to be prescriptive, nor do responsibilities always occur linearly. In addition, considerable overlap can exist between roles, especially in local health departments. The actual responsibilities for a staff member will vary in accordance with the practices of the jurisdiction responsible for the investigation, roles defined in the outbreak investigation and control team, and resources.

Table 5.1. Investigation activities for outbreaks associated with events or establishments reported through foodborne illness complaint systems*

OBJECTIVE	EPIDEMIOLOGY	ENVIRONMENTAL HEALTH	PUBLIC HEALTH AND/OR FOOD TESTING REGULATORY LABORATORY
Identify etiologic agent.	• Contact health-care providers of cases who have sought medical attention. • Interview cases to characterize symptoms, incubation period, and duration of illness. • Obtain stool specimens from cases. • Determine whether symptoms, incubation period, or duration of illness suggest a likely pathogen. • Establish case definition based on confirmed diagnosis or clinical profile of cases.	• Interview management to determine whether it has noticed any ill employees or any circumstances that could cause a foodborne illness. • Interview food workers to determine illness. This activity also could be conducted by nursing/health-care staff. • Obtain stool specimens from ill or all food workers. This activity could also be conducted by nursing/health-care staff. • Obtain and store samples of implicated and suspected food items and ingredients. • Determine whether setting or food item suggests a likely pathogen.	• Contact clinical laboratories that might have performed primary cultures on cases, and obtain specimens. • Test stool samples to identify agent. • Test samples of implicated food items to identify agent. • Subtype all isolates as soon as possible after receipt.
Identify persons at risk and determine size and scope of outbreak.	• Obtain from event organizer a list of persons attending event, or, if possible, list of persons patronizing the establishment during the outbreak period. • Interview persons who attended event or patronized establishment to determine attack rates, by time. • Contact health-care providers to identify additional persons seeking medical care whose illnesses meet the case definition. • If identified agent is reportable, review recently reported cases to identify possible exposures to event or establishment.	• Obtain list of reservations for establishment, credit card receipts, receipts for take-out orders, inventory of foods ordered at establishment, or guest lists for events. Where possible, obtain information electronically.	• Contact clinical laboratories to identify additional stool specimens being cultured.

Table 5.1. Investigation activities for outbreaks associated with events or establishments reported through foodborne illness complaint systems* *Continued*

OBJECTIVE	EPIDEMIOLOGY	ENVIRONMENTAL HEALTH	PUBLIC HEALTH AND/OR FOOD TESTING REGULATORY LABORATORY
Identify mode of transmission and vehicle.	• Interview identified cases and controls or well meal companions about all common exposure sources. Calculate odds ratios for specific exposures. • Interview persons with identified exposures to determine attack rates and relative risks for specific exposures.	• Obtain menu from establishment or event. • Interview food workers to determine food-preparation responsibilities. • Reconstruct food flow for implicated meal or food item. • Identify contributing factors and environmental antecedents. • Obtain samples of implicated food. • Obtain environmental samples from food contact surfaces or possible environmental reservoirs.	• Test implicated food and environmental samples to confirm presence of agent. • Subtype all isolates as soon as possible after receipt. • Conduct applied food-safety research to determine ability of agent to survive or multiply in implicated vehicle and how vehicle might have become contaminated.
Identify source of contamination.	• Combine descriptive and analytical epidemiology results to develop a model for the outbreak.	• Interview food workers to determine food-preparation responsibilities. • Reconstruct food flow for implicated meal or food item. • Evaluate food flow for implicated meal or food item to identify contamination event at point of preparation or service. • If no contamination event identified, trace source of ingredients of implicated food item back through distribution to point where a contamination event can be identified or, if no contamination events can be identified during distribution, to source of production.	• Evaluate results of all outbreak-associated cultures to highlight possible relations among isolates from clinical, food, and environmental samples. • Conduct applied food-safety research to determine how vehicle might have become contaminated.

Identify contributing factors.and antecedents	• Summarize information to identify confirmed or suspected agent. • Summarize information to identify confirmed or suspected food vehicle.	• Evaluate results of environmental assessment, given identification of agent and results of epidemiologic investigation, to identify factors most likely to have contributed to outbreak and their environmental antecedents.	• Summarize information about culture results from clinical, food, and environmental samples.
Determine potential for ongoing transmission and need for abatement procedures.	• On the basis of agent, incubation period, and likelihood of secondary spread, create epidemic curve, and evaluate the course of the epidemic to determine whether additional cases may still be occurring. • If outbreak appears to be ongoing, review possible control measures in collaboration with environmental health specialists.	• Implement control measures to prevent further exposures: o Verify that all food workers who pose a risk for transmission have been excluded or restricted, as needed; o Verify that potentially contaminated foods have been properly disposed; o Verify that food contact surfaces and potential environmental reservoirs have been adequately cleaned and sanitized; o Train staff in safe food-preparation practices; o Modify food-production and food-preparation processes with appropriate preventive controls; and o Modify menu. • If any of these measures cannot be verified, review additional control measures, or if further exposure appears likely, alert public or close premises.	• Assess status of completed and pending cultures to identify gaps that suggest a potential for ongoing transmission.

* These are general categories of roles to demonstrate typical investigation activities. The roles can overlap considerably, especially in local health departments. The persons who actually conduct each of these activities will vary by agency and investigation.

Table 5.2. Investigation activities for outbreaks identified by pathogen-specific surveillance

OBJECTIVE	EPIDEMIOLOGY	ENVIRONMENTAL HEALTH	PUBLIC HEALTH AND/OR FOOD TESTING REGULATORY LABORATORY
Identify mode of transmission and vehicle.	• Interview cases as soon as possible with standardized detailed exposure history questionnaire to identify possible common exposures (described in detail below). In some situations, cases are interviewed as soon as they are reported and before an outbreak has been recognized. • Establish case definition on the basis of characteristics of agent that led to detection of outbreak. • Characterize cases by person, place, and time, and evaluate this descriptive epidemiology to identify pattern possibly associated with particular food items or diets. • Compare detailed exposure history questionnaire frequencies against known or estimated background exposure rates, such as those in FoodNet Atlas of Exposures, to identify suspected food item. • Interview non-ill community controls or non–outbreak-associated ill persons to obtain detailed exposure information to be used in a case-comparison analysis of exposures. • Obtain shopper card information to identify and verify grocery purchases and possibly determine background rates of purchase of item. • Document brand names and product code information for prepackaged food items. • Analyze exposure information comparing cases to relevant comparison group (e.g., non-ill controls or cases not associated with outbreak) to implicate food item or nonfood-exposure source.	• Contact restaurants, grocery stores, or other locations identified by multiple cases to verify menu choices, identify ingredients, and identify distributors and/or source(s) for ingredients and/or food items of interest. • Obtain samples of suspected food items. Work with appropriate regulatory authority to ensure that food samples are collected and maintained with appropriate chain of custody (for example, USDA-FSIS Directive 10,000.1). This will help the regulatory authority to take appropriate regulatory action. • Conduct an investigational traceback to determine whether a suspected food vehicle from multiple cases has a distribution or other point in common. • If specific food item or ingredient is implicated, conduct formal regulatory traceback.	• Store collected food samples, pending results of epidemiologic analyses. • Culture implicated food samples to confirm presence of agent. • Conduct serotype/genotype tests, and further characterize pathogen as necessary for investigation. • Conduct applied food-safety research to determine ability of agent to survive or multiply in implicated vehicle and how vehicle might have become contaminated.

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

Identify persons at risk and determine size and scope of outbreak.	• Alert health-care providers of possible outbreak to identify additional persons seeking medical care, and review laboratory reports and medical charts at hospitals or physicians' offices to identify possible cases. • Ask cases if they know of others who are similarly ill. • Depending on nature of outbreak, take additional steps as warranted. Examples include reviewing employee or school absences, reviewing death certificates, surveying population affected, or directly asking members of the public to contact the health department if they have the illness under investigation.	• Review foodborne illness complaints to identify undiagnosed cases that could be linked to outbreak. • Contact restaurants, grocery stores, or other points of final service visited by multiple cases to identify employee illnesses or foodborne illness complaints from patrons.	• Contact clinical laboratories to identify additional stool specimens being cultured. • Speed up referral and subtyping of outbreak pathogen.
Identify source of contamination.	• Combine descriptive and analytical epidemiology results to develop a model for outbreak.	• Trace source of implicated food item or ingredients through distribution to point where a contamination event can be identified or to source of production if no contamination events can be identified during distribution. • Conduct environmental assessment of likely source of contamination, including o Reconstruct food flow for implicated food item. o Interview food workers to determine food-preparation responsibilities and practices before exposure. o Obtain samples of implicated food or ingredients. o Obtain environmental samples from food contact surfaces or potential environmental reservoirs.	• Evaluate results of all outbreak-associated cultures to highlight possible relations among isolates from clinical, food, and environmental samples. • Conduct applied food-safety research to examine likely sources of contamination. • Work with appropriate regulatory authority to ensure that food samples are collected and maintained with appropriate chain of custody (for example, USDA-FSIS Directive 10,000.1). This will help the regulatory authority to take appropriate regulatory action.

Table 5.2. Investigation activities for outbreaks identified by pathogen-specific surveillance
Continued

OBJECTIVE	EPIDEMIOLOGY	ENVIRONMENTAL HEALTH	PUBLIC HEALTH AND/OR FOOD TESTING REGULATORY LABORATORY
Identify contributing factors and antecedents.	• Summarize information to identify confirmed or suspected food vehicle.	• Evaluate results of environmental assessment, given identification of agent and results of epidemiologic investigation, to identify contributing factors and antecedents.	• Summarize information about culture results from clinical, food, and environmental samples. • Provide background statistics on pathogen prevalence.
Determine potential for ongoing transmission and need for abatement procedures.	• Create and evaluate epidemic curve to determine whether additional cases might still be occurring. • If outbreak appears to be ongoing, continue surveillance, and review potential abatement procedures.	• Verify that food workers who might have been infected during outbreak and who pose a risk for transmission have been excluded or restricted, as needed. • Verify that potentially contaminated foods have been removed from distribution. • Train staff on safe food-preparation practices. • Modify food-production and food-preparation processes by implementing appropriate preventive controls. • Modify menu.	• Assess status of completed and pending cultures to identify gaps that may suggest a potential for ongoing transmission.

* These are general categories of roles to demonstrate typical investigation activities. The roles can overlap considerably, especially in local health departments. The individuals that actually conduct each of these activities will vary by agency and investigation.

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

CIFOR Keys to Success: Focus Area 7—Epidemiologic investigation

Staff skills and expertise

- Staff have good interviewing skills and can collect complete and accurate exposure information from cases and controls, where appropriate, or have access to staff in other agencies who have this expertise.
- Staff have expertise in epidemiologic study design or have access to staff in other agencies who have this expertise.

Investigation

- Agency/jurisdiction has a written protocol outlining the steps in the epidemiologic investigation of a foodborne disease outbreak. Staff have easy access to the protocol and have been trained in its implementation.
- Staff interview cases about exposures as soon as possible after the illness is reported.
- Staff have access to standard epidemiologic questionnaires used by other investigators in similar outbreaks.

Communication

- Staff communicate in a timely fashion and coordinate activities with environmental health and laboratory staff during the investigation.

Making changes

- Agency/jurisdiction debriefs investigators after each outbreak response and refines outbreak response protocols on the basis of lessons learned.
- Agency/jurisdiction has performance indicators related to the epidemiologic investigation and routinely evaluates its performance in this Focus Area.

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

CIFOR Keys to Success: Focus Area 8—Environmental health investigation

Staff skills and expertise

- Staff have expertise in food production processes, Hazard Analysis and Critical Control Points (HACCP), and environmental health assessments.
- Staff have expertise in trace-back and traceforward investigations (or have access to staff in other agencies who have this expertise).
- Staff have good interviewing skills to solicit information from facility managers and food workers or have access to staff in other agencies who have this expertise.

Investigation

- Agency/jurisdiction has a written protocol outlining the steps in the environmental assessment of a foodborne disease outbreak. Staff have easy access to the protocol and have been trained in its implementation.
- Staff undertake environmental assessments at facilities or production sites implicated during a foodborne disease outbreak (not routine food-establishment inspections), and identify appropriate contributing factors and environmental antecedents.
- Staff undertake trace-back and traceforward investigations (or have access to staff in other agencies who undertake these investigations).

Communication

- Staff communicate in a timely fashion and coordinate activities with epidemiology and laboratory staff during the investigation.

Making changes

- Agency/jurisdiction debriefs investigators after each outbreak response and refines outbreak response protocols on the basis of lessons learned.
- Agency/jurisdiction has performance indicators related to the environmental assessment and routinely evaluates its performance in this Focus Area.

CIFOR Keys to Success: Focus Area 9—Laboratory investigation

Staff skills and expertise

- Staff have expertise in appropriate laboratory testing methods and access to necessary equipment and reagents to perform testing.

Specimen collection and testing

- Epidemiology and environmental health staff collect appropriate clinical and environmental specimens and store and transport them properly.
- Staff link patient and specimen information.
- Staff characterize isolates (e.g., by subtyping) in a timely fashion.
- Staff use standardized (currently approved) methods to subtype isolates.

Communication

- Staff communicate in a timely fashion and coordinate activities with epidemiology and environmental health staff during the investigation.
- Staff report subtyping information to appropriate national databases in a timely fashion.

Making changes

- Agency/jurisdiction debriefs investigators after each outbreak response and refines outbreak response protocols on the basis of lessons learned.
- Agency/jurisdiction has performance indicators related to the laboratory investigation and routinely evaluates its performance in this Focus Area.

5.2. Complaint, Cluster, and Outbreak Investigation Procedures

5.2.4.1. Cluster investigations—model practices

This section lists model practices for cluster investigations. Actual practices used in a particular situation will depend on the circumstances specific to the outbreak (e.g., the pathogen and number and distribution of cases), staff expertise, structure of the investigating agency, and agency resources. Although a systematic evaluation under different circumstances has not been performed on these practices, experiences from successful investigations support their value. Investigators are encouraged to use these practices as appropriate to the specific outbreak.

5.2.4.1.1. Use interview techniques to improve food recall

In general, to help improve food recall when collecting exposure information for a cluster investigation:

- Use trained interviewers who have demonstrated proficiency in conducting exposure interviews.
- Question subjects as soon as possible after illness is reported.
- Do not share information about suspected food items or working hypotheses with interviewees. However, do ask specifically about suspected item(s), as described in the dynamic cluster investigation model.
- Encourage interviewees to remember information by asking them to elaborate on where they ate, with whom they ate, and events associated with the meals. Ask interviewees to look at a calendar from the appropriate time periods to jog their memory.
- Use a structured list of venues, including restaurants, grocery stores, food pantries, farmers' markets, social events, business meetings, and other places where people might buy or eat food.
- Enlist the help of persons who prepared meals during the period of interest.
- Ask whether the interviewee keeps cash register or credit card receipts that might indicate when, where, or what he or she ate.
- If the subject uses a grocery store shopper card, ask permission to obtain purchase records for a specified time period. Some grocery chains readily cooperate with these requests.

5.2.4.1.2. Use a dynamic cluster investigation process to generate hypotheses

In the dynamic cluster investigation model, initial cases within a recognized cluster are interviewed with a detailed exposure history questionnaire. As new exposures are suggested during interviews, the initial cases are systematically re-interviewed to uniformly assess their exposure to the new exposures suggested by subsequent interviews. Newly reported cases also will be asked specifically about these exposures. See Figure 5.1 for a visual representation of this process.

Ideally, interviews of the first five to ten cases will produce a relatively short list of suspicious exposures—suspicious because they involve commodities that are not commonly eaten or involve specific brands of a commonly eaten food item. Because these exposures might not have been uniformly assessed on the original questionnaire, specific questions about the newly suspected exposures should be added to the questionnaire for future use. Re-interviews of initial cases, combined with interviews of new cases in the cluster, can result in rapid definition of a unique exposure shared among multiple cases. Occasionally, this evidence is so specific and so obviously unlikely to have occurred by chance alone that it can lead to direct public health intervention. More frequently, the various hypotheses will need to be tested with a case–control study, food testing, or investigational tracebacks in the ensuing investigation.

As the number of cases and jurisdictions increases, strict application of this approach

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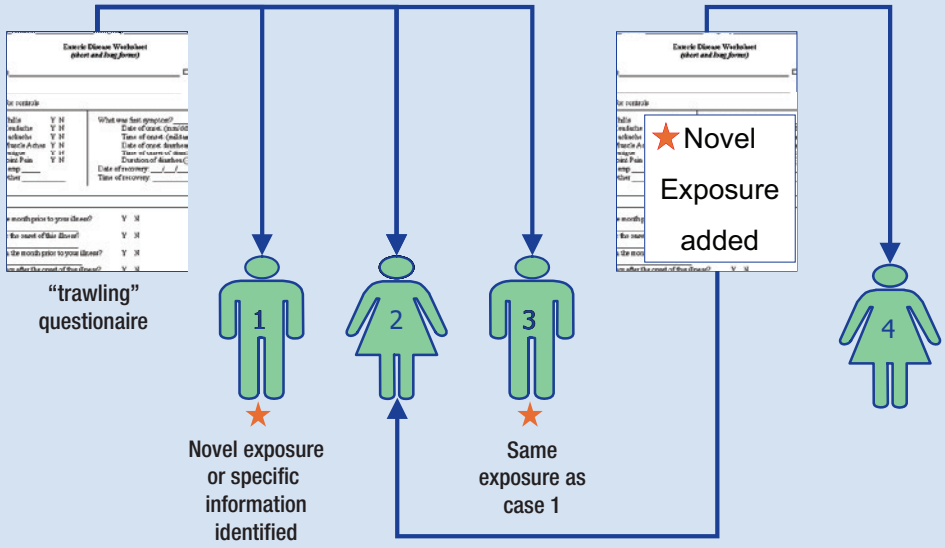
Figure 5.1. Dynamic cluster investigation.



In this model, cases are interviewed with a detailed exposure history questionnaire. Specific exposures shared by multiple cases might surface that are suspicious because they involve commodities not commonly eaten or involve specific brands of a commonly eaten food item. Because the original questionnaire might not have captured these exposures, specific questions should be added to the questionnaire for future use and to systematically re-interview cases to assess the suspicious sources discovered during the investigation process. "Novel exposure" refers to exposure that was not specifically listed on the original detailed exposure history questionnaire.

may become infeasible. In addition, some cases might not be amenable to multiple interviews. In any event, clear and timely communications with other investigators are critical to adequately evaluate suspicious new exposures reported elsewhere.

5.2.4.1.2.1. Dynamic cluster investigation with routine interview of cases

For agencies with resources sufficient to routinely interview cases with a detailed exposure history questionnaire as illness is reported, dynamic cluster investigation can be initiated with recognition of the first cases. This increases the sensitivity and speed of outbreak identification and resolution in several ways.

- Faster interviews:
  This process increases recall and the likelihood of meaningful intervention because more interviews are conducted sooner after the onset of illness.
- Increased recall:
  Recall is also amplified by what is essentially a group dynamic. People are less likely to recall exposures when asked in general about their exposure history and more likely to remember when questioned about specific exposures that other persons have identified. For example, in the 2007 multistate outbreak of *Salmonella* Wandsworth infections associated with a vegetable powder–coated snack, cases were less likely to report its consumption when asked to list all foods eaten during the period of interest but were highly likely to remember when asked specifically whether they had eaten the particular snack. This

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same principle underlies an advantage of questionnaires with longer lists of specific exposure questions.

- Potential to conduct case–case analytical studies:
  In jurisdictions that routinely conduct interviews using detailed exposure history questionnaires, case-to-case comparison studies offer an efficient tool to evaluate exposures as part of cluster investigations. **Cases with microbial agents other than the agent under investigation or of a different subtype, ideally from the same time period, are used as "controls" to identify risk factor differences.** This requires that the persons in the cluster and persons used for comparison have been interviewed using the same form. However, because some microbial agents have common food vehicles, case-to-case comparisons might cause investigators to overlook the source of an outbreak.

5.2.4.1.2.2. Dynamic cluster investigation without routine interview of cases

Because most public health agencies do not have sufficient resources to conduct detailed exposure history interviews for every case, a two-step interviewing process might be the best alternative approach. All cases should be interviewed with a standardized questionnaire to collect exposure information about limited high-risk exposures specific to the pathogen. When, on the basis of the novelty of the subtype pattern, geographic distribution of cases, or ongoing accumulation of new cases, the cluster appears to be an outbreak associated with a commercially distributed food product, all cases in the cluster should be interviewed using a detailed exposure history questionnaire as part of a dynamic cluster investigation, as described above.

5.2.4.1.3. Interpretation of results of hypothesis-generating interviews

As noted above, detailed exposure history questionnaires are frequently used in interviews to shorten the list of exposures evaluated in a hypothesis-testing study. Good judgment is required in the interpretation of hypothesis-generating interviews. This has followed a general approach outlined below, assuming that a sufficient number of cases have been interviewed (e.g., at least eight):

- If none of the persons interviewed report a specific exposure, the hypothesis is no longer viable and most likely can be dropped from subsequent study.
- If more than 50% of persons interviewed report an exposure, that exposure should be studied further.
- If fewer than 50% of persons report an exposure, that exposure still might be of interest, particularly if it is difficult to recognize or unusual.

This approach embodies the principle that implicated food items should have been eaten by most of the cases. However, previously identified risk factors (such as sprouts for Shiga toxin–producing *E. coli*) should not be ruled out just because fewer than half of cases reported the exposure, particularly if the exposure is unusual or difficult to recognize. The practice of focusing on foods reported by more than half of cases for use in a hypothesis-testing study delayed the identification of sprouts as the actual food vehicle in the outbreak of *E. coli* O104:H4 infections in Germany in 2011.[1,2]

For testing hypotheses, the specificity of exposure source information is critical. In addition to obtaining details of brand and product identity, purchase dates and locations, and distribution information from retailers and distributors for commodity products is essential to implicate a food item. For food items that are frequently co-mingled (e.g., lettuce and tomatoes, tomatoes and hot peppers), source tracing of commodities can help disentangle

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the exposures. In addition, rapid and thorough assessment of distribution sources can identify the source with sufficient precision so that the traceback becomes the hypothesis-testing step of the investigation.[3, 4]

5.2.4.1.4. Cross-reference case interviews with foodborne illness complaints

Regardless of whether a common restaurant or event is identified in interviews of cases in a cluster, it is a good practice to review foodborne illness complaints to identify undiagnosed cases that could be linked to an outbreak. Common exposures reported in case interviews and foodborne illness complaints could be key to identifying the source of the outbreak. In Minnesota, 10% of E. coli O157:H7 outbreaks reported during 2000–2008 and 11% of *Salmonella* outbreaks reported during 2001–2007 were solved because of links between case interviews and foodborne illness complaints.[5, 6]

5.2.4.1.5. Use the FoodNet Atlas of Exposures

The observed consumption rate of a food item among case can be tested against known or estimated background consumption rates by using a binomial distribution probability model (e.g., http://public.health.oregon.gov/DiseasesConditions/CommunicableDisease/Outbreaks/Gastroenteritis/Pages/Outbreak-Investigation-Tools.aspx). For food items with a relatively low expected frequency of consumption (e.g., oysters), even a small number of interviews can yield highly suggestive data. For common food items (e.g., eggs or chicken), additional and more specific product data (e.g., brand and place of purchase or consumption) are necessary.

The FoodNet Atlas of Exposures is one source of food consumption estimates, although it covers only a few dozen food items, represents only the population of FoodNet sites, and does not account for potential changes in consumption patterns since the last time the survey was performed.[7]

For example, bagged spinach was first identified as the source of a 2006 *E. coli* O157:H7 outbreak on the basis of only six structured interviews (with five persons reporting having eaten bagged, prewashed spinach). FoodNet survey data suggested that only about 17% of the U.S. population recalled eating any kind of fresh spinach within a given week. Combined with similar findings from other states conducting case investigations, these collective observations led to prompt action and further investigations, which rapidly identified the location, date, and even shift of contaminated spinach production.

The outbreak of *Salmonella* Tennessee infections associated with peanut butter highlights many of the issues discussed above. In November 2006, a widespread outbreak was detected. By December 1, 52 isolates from 25 states were linked by pulsed field gel electrophoresis pattern. Routine interviews by local officials did not identify a common food exposure. In January 2007, 31 patients were interviewed by using a standard hypothesis-generating questionnaire with over 200 items. Two food commodities (turkey and peanut butter) were identified with greater frequency of consumption than expected according to the Atlas of Exposures. However, the lack of brand information meant that cases had to be re-interviewed. Of six cases re-interviewed to assess peanut butter exposures, five reported a common brand. Had this information been systematically collected at the beginning of the investigation, a month or more may have been saved in identifying the source.[8] Thus, the practice of collecting detailed exposure information during hypothesis-generating interviews has sufficient evidence to be promoted as a standard practice. Because the Atlas of Exposures is based on surveys at selected sites at certain times, the findings must be extrapolated carefully to other populations

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and seasons. Results from the most recent FoodNet population survey are available at www.cdc.gov/foodnet/studies/population-surveys.html.

Even in the absence of survey data, common-sense estimates of the prevalence of a given exposure can be used to identify exposures of interest more quickly. For example, although not included in the FoodNet surveys, the significance of finding five of five *Salmonella* Enteritidis cases reporting consumption of shelled almonds of one brand in a 2003-2004 outbreak was readily apparent not only to epidemiologists but also to regulators and retailers, particularly because the *Salmonella* Enteritidis subtype had previously been implicated as the etiology of a large international outbreak traced to shelled almonds. If investigators have no idea of the background frequency of consumption of a food item, they can use an estimate that is very likely to be an overestimate (e.g., "I don't know how many people eat arugula each week, but I am sure it is less than 20%") for comparison with rates among cases. These what-if analyses can lead to source tracing, which can help confirm the hypothesis.

5.2.4.1.6. Conduct an environmental health assessment

When investigating a food-production, food-processing or food-service establishment implicated in an outbreak, conduct an environmental health assessment. An environmental health assessment is a systematic, detailed, science-based evaluation of environmental factors that contributed to transmission of a particular disease in an outbreak. It differs from a general inspection of operating procedures or sanitary conditions used for the licensing or routine inspection of a restaurant, food processor, or food-production facility. An environmental health assessment focuses on the problem at hand and considers how the causative agent, host factors, and environmental conditions interacted to result in the problem.

The goals of an environmental health assessment are to identify:

- Possible points of contamination of the implicated food with the disease agent;
- Whether the causative agent could have survived (or, in the case of a toxin, not been inactivated);
- Whether conditions were conducive for subsequent growth or toxin production by the disease agent; and
- Environmental antecedents that resulted in the conditions enabling the outbreak to occur.

Although a primary goal of an environmental health assessment is to identify possible points of contamination, survival, or growth of the disease agent, to be most valuable, investigators also need to identify environmental antecedents that resulted in these conditions. Environmental antecedents are the circumstances behind the problem and include inadequate worker education, behavioral risk factors, management decisions, and social and cultural beliefs. Only by identifying the problem behind the problem can investigators develop effective interventions and preventive controls.

The timing of the environmental health assessment depends largely on the specifics of the outbreak and available information but should be initiated as early as possible. Early investigation and collection of food and environmental specimens will best reflect the conditions at the time of the outbreak. In addition, possible food vehicles can be discarded or grow old, and persons involved in the production, processing, storage, transportation, or preparation of the item can change their practices and procedures. If investigators have identified a common location and a profile of symptoms among ill persons that indicates whether the disease agent is likely to be viral, bacterial, toxin, or chemical, they often can begin an environmental health assessment based on

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possible factors more likely to be associated with that disease agent.

5.2.4.1.6.1. Sources of information and activities included in an environmental health assessment

Epidemiologic information is necessary to initiate an environmental health assessment and guides the assessment as it progresses. Once an investigation begins, sources of information for an environmental health assessment include product information (e.g., chemical and physical characteristics and source); written policies or procedures; direct observations and measurements; interviews with employees and managers; and lab testing of suspected foods, ingredients, or environmental surfaces.

The specific activities in an environmental health assessment differ by causative agent, suspected vehicle, and setting but usually include the following:

- Describing the implicated food;
- Observing procedures to make the implicated food;
- Talking with food workers and managers;
- Taking measurements (e.g., temperatures);
- Developing a flow chart or food flow diagram for the implicated food item or ingredient to capture detailed information about each step in the food-handling process, including storage, preparation, cooking, cooling, reheating, and service and identifying opportunities for contamination, survival, and growth (proliferation) at each step;
- Collecting food specimens and occasionally clinical specimens from people in contact with the suspected food vehicle or the environment in which it was produced or used; and
- Collecting and reviewing documents on source of food.

These activities provide information needed to develop the most likely environmental picture of the facility before the exposures that led to the outbreak. Once a complete picture has been developed, contributing factors and environmental antecedents and preventive controls can be determined.

5.2.4.1.5.2. Qualifications to conduct an environmental health assessment

To accurately relate the opportunities for contamination, survival, and growth of a disease agent in a food to a specific outbreak, the investigator needs a good understanding of:

- Agent (e.g., likely sources, optimum growth conditions, inhibitory substances, means of inactivation);
- Factors necessary to cause illness (e.g., infectious dose, portal of entry);
- Implicated vehicle (e.g., physical and chemical characteristics of the vehicle that might facilitate or inhibit growth, methods of production, processing, preparation); and
- Possible risk factors in the environment or operation that can contribute to the transmission of the disease agent.

Critical thinking skills also are needed to analyze information that evolves from an environmental health assessment, identify the likely source of the problem, and determine how the disease agent, host factors, and environmental conditions interacted to support a specific outbreak. This level of knowledge and skill requires someone with special training in this field of investigation, such as a sanitarian or environmental health specialist.

5.2.4.1.7. Conduct tracebacks/traceforwards of food items under investigation

Tracing the source of food items or ingredients from point of purchase/consumption through distribution to source of production can be critical to identifying epidemiologic links among cases or ruling them out. This

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is known as an investigational traceback, although sometimes the terms "informational traceback" or "epidemiologic traceback" also are used. When some or all of a number of conditions occur, an investigational traceback/traceforward might be warranted:

- Linked cases occur in multiple locations or jurisdictions (particularly if they occur in multiple states);
- A vehicle cannot be clearly implicated with traditional epidemiologic, laboratory, and environmental assessment methods alone; and
- More information is needed to determine whether similar food items from different establishments, stores, or firms can be linked to a distributor or processor.

The decision to conduct an investigational traceback should be based on input from public health and regulatory agencies. Because tracebacks can be intensive and complex, it is very important that the suspected food exposures are prioritized to make the best use of available resources to identify the most likely source of the problem.

For nonbranded commodities, such as produce items, the convergence of multiple cases along a distribution pathway can identify the source of contamination. In an outbreak of *E. coli* O157:H7 infections associated with hazelnuts, identification of a common supplier confirmed the hypothesis generated by case interviews.[9] Conversely, failure to identify common suppliers might indicate that the food item in question is not a likely vehicle. In the large multistate outbreak of *Salmonella* Saintpaul infections, the failure of tomato tracebacks to converge on common suppliers helped indicate that tomatoes might have been a surrogate for the actual vehicle (hot peppers) with which they were co-mingled in multiple food items. Investigational tracebacks of this type need to be conducted quickly to be incorporated into epidemiologic studies. Rather than being an outcome of epidemiologic analyses, investigational tracebacks are an integral part of the exposure assessment needed to conduct the epidemiologic analysis and should be closely coordinated with partner agencies. Subsequent formal regulatory tracebacks might be needed to confirm the distribution of implicated products.

5.2.5. Coordinate Investigation Activities

Whether the outbreak is restricted to one jurisdiction or involves multiple jurisdictions, notification and updates should be provided to other interested agencies following the Guidelines for Multijurisdictional Investigations (Chapter 7).

Update the outbreak control team daily. In particular, if the outbreak has gained public attention, the public information officer needs to prepare a daily update for the media.

During investigation of outbreaks involving events or establishments, maintaining close collaboration between epidemiology and environmental health is particularly important. Interview results from persons who attended the event or patronized the establishment will help environmental health specialists focus their environmental assessments by identifying likely agents and food vehicles. Similarly, results of interviews of food workers and reviews of food preparation can identify important differences in exposure potential that should be distinguished in interviews of persons attending the event or patronizing the establishment. For example, environmental health investigators might determine that food items prepared only on certain days or by certain food workers are likely to be risky. These refinements also can help establish the need for or advisability of collecting stool samples from food workers or food and environmental samples from the establishment.

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During the earliest stages of the investigation, patrons need to be interviewed rapidly. However, the focus of outbreak activities is likely to shift to interviews of food workers, environmental health assessments of the establishment, and review of food-preparation procedures as the investigation progresses.

During investigation of outbreaks detected by pathogen-specific surveillance, the public health laboratory needs to immediately forward case information to epidemiologists for every new potentially outbreak-associated case they receive. This will ensure rapid enrollment of new cases in outbreak investigation studies. Similarly, as investigators acquire information from cases about exposures in restaurants and other licensed facilities, they should rapidly forward that information to environmental health specialists to ensure rapid identification of commodity ingredients and their distribution sources.

During the early stages of an investigation, efforts to identify mode of transmission and food vehicle require close coordination of the outbreak investigation team under the leadership of epidemiology. After identification of a likely food vehicle, efforts to identify the source of contamination and contributing factors require engagement of local, state, or federal food-regulatory programs. As the investigation proceeds, the outbreak investigation and control team should always consider whether any information indicates the outbreak might be multijurisdictional. See Chapter 7 for information about identifying and responding to multijurisdictional outbreaks.

5.2.6. Compile Results and Reevaluate Goals for Investigation (see also Chapter 6)

Compile results of outbreak investigations in a manner that enables comparisons with the original goals for the investigation. State the original goals of the investigation, and demonstrate how each goal was achieved; if the goal was not achieved, explain why. For example, in an investigation of an outbreak of vomiting and diarrhea associated with a restaurant, document the steps taken to identify the agent. These could include identifying the number of stool specimens collected, determining the intervals between onset of symptoms and collection of stool and between collection of stool and processing by the public health laboratory, identifying the methods used to culture or test the specimens, and determining the results of the tests.

Novel questions or opportunities to address fundamental questions about foodborne disease transmission can develop during the outbreak investigation. The opportunity to address these issues might require reevaluation of the investigation's goals.

Prepare epidemic curves, and update them daily to depict the beginning and end of the outbreak. Continued motion of successive epidemic curves, day by day over time, clearly indicates continuation of the outbreak (Box 5.1). Select time scales for the epidemic curve to highlight the agent, mode of transmission, and duration of the outbreak. Notable events, such as changes in food-processing methods or personnel or implementation of control measures, can be noted on the curve. Generating an accompanying timeline of the investigation's events as they happen often can be helpful.

5.2.7. Interpret Results

The outbreak investigator's job is to use all available information to construct a coherent narrative of what happened and why. This begins with the initial detection of the outbreak and formation of hypotheses on the basis of the agent's ecology, microbiology, and mechanisms of transmission in addition to the descriptive epidemiology of reported cases and interviews to identify unusual exposures or commonalities among cases. Results of subsequent analytic studies (e.g., cohort or case–control study) must

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Box 5.1. Interpretation of epidemic curves during an active outbreak

The epidemic curve (epi curve) shows progression of an outbreak over time. The horizontal axis (x-axis) is the date a person became ill (date of onset). The vertical axis (y-axis) is the number of persons who became ill on each date. These numbers are updated as new data come in and thus are subject to change. The epi curve is complex and incomplete. Several issues are important in understanding it:

- An inherent delay exists between the date of illness onset and the date the case is reported to public health authorities. This delay typically is 2–3 weeks for Salmonella infections. Therefore, a person who got sick last week is unlikely to have been reported yet, and a person who got sick 3 weeks ago might just now be reported. See Salmonella Outbreak Investigations: Timeline for Reporting Cases (Chapter 4, Figure 4.1)
- Some cases are background cases of illness that likely would have occurred even without an outbreak; therefore, determining exactly which case is the first in an outbreak is difficult. Epidemiologists typically focus on the first recognized cluster or group of cases rather than on the first case. Because of the inherent reporting delay, a cluster sometimes is not detected until several weeks after people became ill.
- For some cases, date of illness onset is not known because of the delay between reporting and case interview. Sometimes an interview never occurs. If the date an ill person brought his or her specimen to the laboratory for testing is known, date of illness onset can be estimated as 3 days before that.
- Determining when cases start to decline can be difficult because of the reporting delay but becomes clearer as time passes.
- Determining the end of an outbreak can be difficult because of the reporting delay. The curve for the most recent 3 weeks always makes the outbreak appear to be ending, even when it's ongoing. The full shape of the curve is clear only after the outbreak is over.

be integrated with results of investigational product tracebacks, interviews of food workers, environmental health assessments, and food-product and environmental testing. When all of these data elements support and explain the primary hypothesis, very strong conclusions can be drawn.

Identifying and exploiting less-obvious data sources might require some imagination. Interview questionnaires are a critical starting point but often do not provide all the answers. For example, when cases are associated with institutional settings or restaurants, it might be necessary to use the institution rather than the case as the unit of observation. Cross-referenced lists of suppliers and food items at different institutions can be more difficult to assess statistically because of their small numbers, but they can help focus commercial product-type investigations. Similarly, relevant restaurant records include much more than menu lists.

Investigators should consider their data critically and question the strength of the association, timing, dose-response, plausibility, and consistency of findings when implicating a food item (Box 5.2). Case interview data are often faulty: collected long after the fact, perhaps by proxy, and sometimes tainted by biases known and unknown. Investigators can create or compound errors during transcription, keypunching, or analysis. Records are often incomplete or unavailable. Without a systematic bias, larger data sets tend to be more robust; and minor errors may be cancelled out (or ignored), but the size of the data set is often beyond one's control. Statistical association between exposure and illness might reflect a causal link—but also might reflect confounding, bias, chance, and other factors. For example, a p value <0.05 for three food items on a questionnaire does not mean that all three (or, indeed, any of the three) are "implicated" as a vehicle, only that chance is an unlikely explanation for the observed association. Conversely, failure to achieve a p value <0.05 cannot rule out a causal role for a particular food item. As noted

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Box 5.2. Questions to consider when associating an exposure with an outbreak

Strength of association

- How strong was the association between illness and implicated item? (The strength of the association increases with the size of the odds ratio or relative risk: 1 = no association; <5 = relatively weak association; 5–10 = relatively strong association; >10 = very strong association.)
- Was the finding statistically significant? (<0.05 is a traditional cutoff p value, but in small studies, even relatively strong associations might not reach this level of significance. Conversely, in large studies examining many exposures, relatively weak associations might reach this level of significance by chance or as an effect of confounding.)
- Were most of ill persons exposed to the implicated item? (This is desirable but might not always be apparent if the implicated item is an ingredient in multiple food items.)

Timing

- Did the exposure to the implicated item precede illness by enough time to allow for a reasonable incubation period?
- Do the time windows obtained during trace-back and trace-forward investigations correlate with reported dates of production, distribution, and purchase of the implicated item?

Dose-response effects

If assessed, were persons with greater exposure to the implicated item more likely to become ill or have more severe clinical manifestations?

Plausibility

- Is the association consistent with historical experience with this or similar pathogens? Can investigators develop a rational explanation for opportunities for contamination, survival, and proliferation of the pathogen in the implicated item? (If otherwise strong and consistent results cannot be readily explained, the outbreak might herald emergence of a new hazard, which will require additional studies to confirm.)
- Is the geographic location of ill persons consistent with the distribution of the implicated item? (Discrepancies might be explained by gaps in surveillance, product distribution data or by involvement of additional food products).

Consistency with other studies

Studies associated with current investigation

- Do the results of trace-back and trace-forward investigations suggest a common source?
- Have environmental health assessments identified problems in the production, transport, storage, or preparation of the implicated item that would enable contamination, survival, and proliferation of the pathogen in that item?
- If the pathogen was isolated both from ill persons and the implicated item, do subtyping results (e.g., PFGE analysis) confirm the association?

Studies not associated with current investigation

Is the association between the pathogen and the implicated item consistent with other investigations of this pathogen?

above, observed associations have to be placed in the context of the other investigation results.

Although investigators should be open to new developments and new twists to old problems, they should be wary of explanations that depend on implausible scenarios. For example, truly localized outbreaks are unlikely to result from manufacturing defects in nationally distributed products. Outbreaks that differentially affect young children are unlikely to be caused by salad items. Persons with salmonellosis are unlikely to become symptomatic within 12 hours after exposure. Minor inconsistencies are common and can be ignored, but large numbers of inconsistencies

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might indicate that alternate hypotheses need to be considered.

General principles underlie successful investigations; however, no one specific method works best in all situations. Investigators need to be flexible and innovative as circumstances demand. On one point we can agree: investigations that are never begun or that are haphazardly conducted are unlikely to yield satisfactory results. "Eighty percent of success is showing up," said Woody Allen—and that applies to outbreak investigations too. Jurisdictions that cannot commit resources to outbreak investigations themselves should do whatever they can to facilitate follow-up of their cases by other agencies (e.g., counties to states; states to other states or CDC).

Experience reminds us—again and again, unfortunately—that even seemingly well-executed investigations can be inconclusive. Small sample sizes, multivehicle situations, "cryptic" food items, and foods with high background rates of consumption are only some of the factors that can reduce the effectiveness of standard epidemiologic methods and make investigations extremely difficult. The decision to stop an investigation depends on the gravity and scope of the outbreak and on the likelihood that it reflects an ongoing public health threat.

5.2.8. Conduct a Debriefing at End of Investigation

Encourage a post-outbreak meeting among investigators to assess lessons learned and compare notes on ultimate findings. Debriefing should include a review of coordination and communication during the investigations, where breakdowns may have occurred, and how prior experience and training facilitated or hindered investigation efforts. The post-outbreak meeting should take place as soon as possible after the investigation ends to capture this information while it is still fresh in people's memories. This is particularly important for multiagency investigations but also is important for single-agency investigations. Another practice to consider is including industry representatives to share lessons learned, when appropriate.

5.2.9. Summarize Investigation Findings, Conclusions, and Recommendations

At a minimum, document every outbreak investigation by using a standardized form to facilitate inclusion in state and national outbreak databases (e.g., CDC's form 52.13 or its equivalent).

Summary data should be reported nationally to CDC's National Outbreak Reporting System (NORS) database. The usefulness of the reports depends on the quality and quantity of information submitted. Make every effort to complete both **Part 1: Basic Information, and Part 2: Additional Information,** and submit the information as soon as possible.

In addition, investigators are encouraged to submit preliminary reports of outbreaks while the investigation is ongoing. If submission is timely, these reports can help identify possibly related outbreaks occurring simultaneously in multiple places and facilitate further investigation of the outbreaks.

Routinely review and summarize data from these reports (e.g., in annual outbreak summaries) at state and national levels.

Larger or more complex investigations or investigations with significance for public health and food-safety practice demand a more complete narrative report and, possibly, publication in a peer-reviewed journal. Written reports should include the following:

- Background, including information about the outbreak setting, timing, and manner of detection and an explicit statement of the goals of the investigation.

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- Methods, including other agencies involved in the investigation; investigation methods; case definition; number of people exposed, interviewed, and ill; number of stool and food samples collected; pathogens tested for in stools or foods; and a high-level summary of laboratory methods used.
- Results, including percentages of cases with fever, diarrhea, vomiting, and bloody diarrhea; median and range of incubation period and duration of illness; results of stool and food testing; food items or events associated with illness and odds ratio(s) or relative risk(s) and confidence interval(s) for implicated food(s); all relevant findings from environmental investigations of establishments and food-preparation reviews; results of food-worker interviews; and food-worker stool culture results, omitting confidential or personal health information protected under the Health Insurance Portability and Accountability Act.
- Conclusions, including etiologic agent, discussion of transmission route, contributing factors, justifications for conclusions, and limitations of the study.
- Recommendations, including all specific recommendations for abatement of this outbreak and prevention of similar outbreaks.
- Epi-curve with outbreak investigation timeline that highlighted key outbreak response events.

5.2.10. Distribute Report

Make copies of the report available to all persons involved with the investigation, including:

- Investigation team members and their supervisors;
- Health department officials and press officers;
- Food-safety and regulatory agency officials and press officers;
- Health-care providers who reported cases; and
- Laboratorians who performed tests.

Also distribute copies of the report to persons responsible for implementing control measures, including:

- Owners and managers of establishments identified as the source of the outbreak;
- Program staff who might oversee implementation of control measures or provide technical assistance; and
- Organizations or regulatory agencies that might develop or implement policies and regulations for which the investigation might have implications.

The report is a public record and should be made available to members of the public who request it.

5.3. Multijurisdictional Considerations for Outbreak Investigations

Increased reliance of the United States on large-scale food-distribution systems and international food sources has increased the likelihood of outbreaks in multiple jurisdictions. Local and state health agencies always need to be sensitive to the potential for rapid escalation of any outbreak to a regional or national event (see Chapter 7).

5.4. Indicators/Measures

Key indicators and measures to assist in assessing investigation processes and the overall success of outbreak investigations can be found in Chapter 8.

5.5. References

1 Askar M, Faber MS, Frank C, et al. Update on the ongoing outbreak of haemolytic uraemic syndrome due to Shiga toxin–producing *Escherichia coli* (STEC) serotype O104, Germany, May 2011. Euro Surveill 2011;16:pii: 19883.

2 Struelens MJ, Palm D, Takkinen J. Enteroaggregative, Shiga toxin–producing *Escherichia coli* O104:H4 outbreak: new microbiological findings boost coordinated investigations by European public health laboratories. Euro Surveill 2011;16:pii: 19890.

3 Cavallaro E, Date K, Medus C, et al. *Salmonella Typhimurium* infections associated with peanut products. N Engl J Med 2011;365:601–10.

4 Miller BD, Rigdon CE, Robinson TJ, Hedberg C, Smith KE. Use of global trade item numbers in the investigation of a *Salmonella* Newport outbreak associated with blueberries in Minnesota, 2010. J Food Prot 2013; 76:744–9.

5 Rounds JM, Hedberg CW, Meyer S, Boxrud DJ, Smith KE. *Salmonella enterica* pulsed-field gel electrophoresis clusters, Minnesota, USA, 2001–2007. Emerg Infect Dis 2010;16;1678–85.

6 Rounds JM, Boxrud DJ, Jawahir SL, Smith KE. Dynamics of *Escherichia coli* O0157:H7 outbreak detection and investigation, Minnesota 2000–2008. Epidemiol Infect 2012;140:1430–8.

7 CDC. Foodborne Diseases Active Surveillance Network. Available at www.cdc.gov/foodnet/about.html (accessed October 8, 2013).

8 Sheth AN, Hoekstra M, Patel N, et al. A national outbreak of *Salmonella* serotype Tennessee infections from contaminated peanut butter: a new food vehicle for salmonellosis in the United States. Clin Infect Dis 2011; 53:356–62.

9 Miller BD, Rigdon CE, Ball J, et al. Use of traceback methods to confirm the source of a multistate *Escherichia coli* O157:H7 outbreak due to in-shell hazelnuts. J. Food Prot 2012;75:320–7.