CHAPTER 2

Fundamental Concepts of Public Health Surveillance and Foodborne Disease

During the past century, the American diet transformed significantly in what food we eat, how we grow or raise that food, and how that food arrives to our tables. Factors contributing to these changes included industry consolidation and globalization, health concerns and dietary recommendations, and culinary trends and dining habits. What we eat; how our food is cultivated or raised, processed, and distributed; and how and by whom our food is prepared relate directly to the foodborne diseases we experience.

Preventing foodborne disease relies on our ability to translate knowledge of the principles of food safety to the practices of food production and preparation at each level of the food system and in home kitchens. Foodborne disease outbreaks represent important sentinel events that signal a failure of this process. Determining whether this failure resulted from the emergence of a new hazard or failure to control a known hazard is critical to developing strategies to prevent future outbreaks and evaluating the success of those strategies.

2.0. Introduction

A variety of surveillance programs are required to accomplish this complex task. Some focus on specific enteric pathogens likely to be transmitted through food and have been used extensively for decades. More recently, new surveillance methods have emerged that shed light on food vehicles, settings, pathogens, contributing factors, and environmental antecedents.

This chapter provides an overview of fundamental concepts in public health surveillance and foodborne disease in the United States and outlines some factors responsible for recent trends and challenges.

2.1. Trends in Diet, the Food Industry, and Foodborne Disease Outbreaks

2.1.1. Dietary Changes

That we no longer are a nation of meat and potato eaters is evidenced by the most recent dietary recommendations of the U.S. Department of Health and Human Services and the U.S. Department of Agriculture (USDA), which emphasize the importance of eating a variety of fruit, vegetables, and protein.[1] From 1985 through 2005, the annual per capita consumption of fruit and vegetables rose from 89 to 101 pounds and from 123 to 174 pounds, respectively.[2] In 2011, the annual per capita consumption of seafood (fish and shellfish) was 15.0 pounds, compared with 12.4 in 1980.[3,4]

Changes in diets and food preferences have resulted in a greater demand for a broader variety of fruits, vegetables, and other foods. The food industry has accommodated this demand by moving from locally grown and raised products to routine importation of items once considered out of season or too exotic. According to a report by the USDA's Economic Research Service (ERS), U.S. food imports grew from $41 billion in 1999 to $103 billion in 2011.[5] Much of that growth occurred in fruit and vegetables, seafood, and processed food products. In 2011, an estimated 15%–20% of all food consumed in the United States originated from other countries, including over 70% of seafood and about 35% of fresh produce. In some seasons, as much as 60% of fresh produce consumed by Americans is imported.[6]

The safety of imported food products depends largely on the public health and food safety systems of other countries and is not always guaranteed. The existence of food safety problems in other countries is supported by recent analyses of foodborne disease outbreaks reported to the Centers for Disease Control and Prevention (CDC). During 2005–2010, 39 outbreaks (0.7% of outbreaks where the country of origin of the contaminated food item or ingredient was reported) were linked to imported items from 15 countries. Of those outbreaks, nearly half (17) occurred in 2009 and 2010. Overall, fish was the most commonly implicated food in these outbreaks, followed by spices (including fresh and dried peppers). Nearly 45% of the imported foods causing outbreaks came from Asia.[7]

Culinary preferences that use undercooked or raw foods—particularly dairy, fish, or shellfish—might also be contributing to more frequent infections and outbreaks caused by the microorganisms associated with these foods.[8, 9, 10, 11, 12, 13, 14] For example, among

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foodborne disease outbreaks reported to CDC during 1993–2006, unpasteurized dairy products caused a disproportionate number of outbreaks and outbreak-associated illnesses compared with pasteurized dairy products, on the basis of estimated units of product consumed. Outbreaks resulting from unpasteurized dairy products also disproportionately affected persons <20 years of age.[15] Similarly, among the 36 dairy-associated outbreaks reported to CDC during 2009–2010 for which pasteurization information was reported, 26 (81%) involved unpasteurized products.[16]

2.1.2. Changes in Food Production and Preparation

Changes in what we eat and drink are not the only contributors to trends in foodborne disease. How our food is cultivated or raised, processed, and distributed and where, how, and by whom our food is prepared also are factors. Food can be contaminated anywhere along the supply chain from farm to fork.

The demand for processed and ready-to-eat foods has led to the industrialization of food production, with concentrated animal feeding operations, increasingly intense agricultural practices, and broadening distribution of food products. Changes in agricultural, processing, or packaging methods might facilitate bacterial contamination or growth,[17, 18, 19, 20, 21, 22,23, 24, 25, 26.27, 28, 29] and use of antibiotics in livestock and poultry most likely has contributed to increased human infections caused by drug-resistant bacteria.[30, 31, 32, 33] In addition, the broadening distribution of food products has contributed to outbreaks of foodborne disease involving larger numbers of people, multiple states, and even multiple countries.[34]

In seeming contradiction to the growing industrialization of food production and mass distribution of foods nationally and internationally, interest in eating locally produced foods also has grown in many communities because of concerns about nutrition, the environment, and local economy. As a result of this increased interest in eating locally (sometimes termed the "locavore movement"), the number of small food producers and direct-to-consumer marketing avenues (e.g., farmers markets, farm stands, farm-to-school programs, and "pick-your-own operations") has also risen. According to census data, from 1997 to 2007, direct sales of agricultural products to the public increased by 105%, compared with an increase of 48% for all agricultural sales. Over the same period, the number of farms selling directly to consumers increased by 24%, compared with a 0.5% reduction in the total number of farms.[35]

The effect of increased consumption of locally produced foods is yet to be determined. It would seem that the consequences of consuming unsafe food differ marginally between small and large producers, although fewer people might be adversely affected by a limited distribution system, as is probably the case for smaller producers. On the other hand, implementation of improved food safety measures could be more challenging among an increased number of more widespread, smaller food producers. In addition, farm direct sales (i.e., farmers selling produce, eggs, and other foods that they produced directly to retail customers, such as through farmers' markets and farm stands) are not included among food facilities in the 2011 Food Modernization and Safety Act[36] and, in some states and local jurisdictions, have been exempted from food safety regulations that pertain to other food facilities.

By whom and where our food is prepared probably also plays a role in foodborne diseases occurrence and outbreaks. Increasingly more Americans eat their meals away from home. According to the National Restaurant

2.1. Trends in Diet, the Food Industry, and Foodborne Disease Outbreaks

Association's 2012 industry overview, 970,000 restaurant locations will have more than 70 billion meal and snack occasions.[37] Forty-nine percent of all food spending in 2011 was on food prepared away from home, up from 33% in 1970.[38]

The increased number of meals eaten away from home most likely has influenced the occurrence of foodborne disease. In an analysis of foodborne disease outbreaks reported to CDC during 2009–2010, 48% were associated with restaurants or delicatessens (including cafeterias and hotels).[38] In addition, studies of both sporadic and outbreak-associated foodborne illness, including infection with Shiga toxin–producing *Escherichia coli* (STEC) O157:H7, *Salmonella enterica* serotype Enteritidis, *S. enterica* serotype Typhimurium, and *Campylobacter jejuni*, suggest that commercial food-service establishments, such as restaurants, play an important role in foodborne disease in the United States.[40]

2.2. Trends in Food-Safety Problems

2.2.1. Food Product Recalls

Food recalls indicate both food safety problems and demonstrations of control measures in response to those problems. Distributors or manufacturers recall their food products for either of two reasons: (a) a regulatory authority or the food industry identifies a food-safety problem during production, processing or distribution or (b) suspicion or identification of the product as the cause of human disease. During 2012, the U.S. Food and Drug Administration (FDA) and the USDA Food Safety and Inspection Service (USDA-FSIS) reported more than 258 recalls of food associated with microbial contamination. Imported food products were also among the list of recalled foods. These recalls demonstrate the breadth of products and pathogens responsible for foodborne diseases in the United States.[41, 42]

During that period, manufacturers and distributors recalled shellfish and smoked, dried, frozen, and uneviscerated fish; fresh fruit, herbs, and vegetables; cheese, ice cream, and other dairy products; ready-to-eat prepared foods such as peanut butter and peanut butter products, vegetarian meatloaf, and salsa; pistachios, cashews, and other nuts; ready-to-eat meat and poultry products; raw ground beef and various types of raw beef; and food ingredients, such as flour, oat fiber, starter yeast, seasonings, and flavor concentrate. The products were distributed locally, nationally, or internationally and were sold not only by national chain retail stores and food services but also at farm stands and small health food stores carrying organic and "natural" products.[41,42]

Most of these recalls followed identification of bacterial contamination of a food or beverage, but in some instances, the contamination was associated with reported human illnesses.

The contaminating pathogens most commonly identified in food recalls were *Listeria monocytogenes*, STEC, and *Salmonella*; the latter two were associated most frequently with recalls resulting from the investigation of human illness. Additional products were recalled because of contamination (or potential contamination) with *Cronobacter sakazakii* and bacterial toxins (e.g., *Clostridium botulinum* neurotoxin, *Staphylococcus aureus* enterotoxin, and *Bacillus cereus* toxin).[41,42]

2.2. Trends in Food-Safety Problems

2.2.2 Foodborne Disease and Outbreaks

The occurrence of foodborne disease and outbreaks indicates both food-safety problems and surveillance efforts. In 2011, CDC estimated that foodborne diseases were responsible for 48 million illnesses each year, resulting in 128,000 hospitalizations and 3,000 deaths.[43] During 2009–2010, 1,527 foodborne disease outbreaks were reported to CDC, resulting in at least 29,444 individual illnesses and 23 deaths.[44] In recent years, the nature of foodborne disease outbreaks detected in the United States has shifted.

2.2.2.1. Localized "event" outbreaks

The traditional foodborne disease outbreak scenario involves an acute and highly local outbreak, resulting from an endpoint contamination event in a small kitchen that occurred shortly before consumption of the implicated food (i.e., terminal food-handling error). These localized outbreaks often follow a local event, such as a church supper, family picnic, wedding reception, or other social event. The inoculum dose and attack rate among exposed persons can be high, making the outbreak quickly apparent to those in the group that attended the social event. Affected persons commonly notify public health authorities through foodborne disease complaint systems (see below). The solution is typically local, necessitating education of food workers and changes in individual food-service establishment policies and operating procedures.

Localized event outbreaks, including those for which the exposure occurs at a single event but the population affected covers multiple counties or states, comprise more than 95% of outbreaks reported to CDC (CDC, unpublished data, 2006–2010).

2.2.2.2. Contaminated commercial product outbreaks

Another kind of outbreak involves food products that are contaminated upstream of the point of sale. Exposure typically occurs in multiple locations that reflect the distribution and subsequent handling of the product. Victims may be scattered across different counties, states, or even countries. The attack rate in these outbreaks may be very low, resulting in no readily apparent clustering of cases absent laboratory subtyping of ostensibly "sporadic" case isolates.

Investigation of commercial product outbreaks often requires the coordinated efforts of a multidisciplinary team to clarify the extent of the outbreak, implicate a specific food, and determine the source of contamination. Often, no obvious terminal food-handling error is found.[45, 46]

Although likely undercounted, commercial product outbreaks account for only a small proportion (2%) of all foodborne disease outbreaks reported to CDC. Such outbreaks, however, comprise a disproportionate number of reported outbreak-related illnesses (7%), hospitalizations (31%), and deaths (34%) (CDC, unpublished data, 2006–2010). The larger number and more serious illnesses associated with commercial product outbreaks most likely result in part from the efforts of PulseNet in helping to recognize these outbreaks. PulseNet, the national molecular subtyping network that analyzes bacterial isolates from human clinical specimens and food samples for their genetic relatedness, focuses on more serious foodborne pathogens, including *E. coli* O157:H7, *Salmonella*, and *Listeria*, and is better able than other means of detecting outbreaks by linking related cases, thus associating larger numbers of cases with each outbreak. Nonetheless, case counts in these outbreaks are likely to be severely undercounted.

Commercial product outbreaks involve a variety of investigators from local, state, and federal agencies and can highlight food safety problems in national (or multinational)

2.2. Trends in Food-Safety Problems

corporations with industrywide implications with regards to control measures. As a result, these outbreaks have been more publicly visible and most likely have received more investigation resources than the more prevalent localized outbreaks. Further studies are needed to better understand the occurrence of localized outbreaks and commercial product outbreaks and their impact on the health of the community.

2.2.2.3. Local investigator role in contaminated commercial product outbreaks

Because a seemingly localized outbreak might herald a more widespread and diffuse food-safety problem affecting multiple jurisdictions, local investigators need to watch for indicators of a commercial food safety problem (see Chapter 7) and alert others immediately when a multijurisdictional outbreak is suspected. Local investigators play an important role in the investigation of multijurisdictional outbreaks by searching for local cases, participating in hypothesis generation, and performing other agreed-upon tasks, such as case interviews, in an expedient manner.

Each and every case interview in a multijurisdictional outbreak is critical, as was illustrated in an outbreak of *E. coli* O157:H7 infection in 2003 that was associated with blade-tenderized frozen steaks. Information from three persons with culture-confirmed cases in Minnesota and from single confirmed cases in two other states enabled officials to identify the source of the steaks and recall 739,000 pounds of beef in a timely manner.[47]

2.3. Trends in Surveillance

Our ability to use public health surveillance to track cases of foodborne disease and outbreaks, as well as behaviors and conditions that contribute to foodborne disease, is critical to our understanding and control of these diseases.

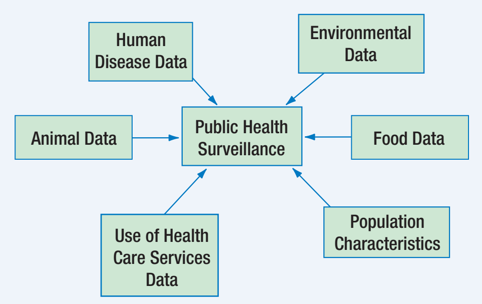
2.3.1. Overview

Public health surveillance is an active process of collecting, analyzing, interpreting, and disseminating data about selected diseases with the purpose of initiating action to improve the health of the community. It is the foundation of communicable disease epidemiology and an essential component of a food-safety program.[48] Surveillance data can reveal the burden of a particular disease in the community or the presence and scale of a possible outbreak. Surveillance data also can provide clues to the source of and contributing factors to disease outbreaks. Over time, surveillance data can identify disease and behavioral trends and enable investigators to learn more about the diseases being tracked and ways to prevent them (referred to as preventive controls in the Food Safety and Modernization Act).

Surveillance programs conducted by public health and other health-related agencies are much broader than those focused on detecting foodborne diseases. Surveillance also is conducted to identify waterborne diseases and diseases transmissible from person to person; breakdowns in infection control in health-care facilities; animal-based diseases that may affect humans; food contaminated by human pathogens; patterns of behavior that increase risk for poor health; and many other health-related events. Furthermore, surveillance programs typically use a variety of data sources to provide a complete understanding of a particular disease in the community and insight into its control (Figure 2.1).

2.3. Trends in Surveillance

Figure 2.1 Sources of information for public health surveillance



2.3.2. Selected Surveillance Systems of Relevance to Foodborne Diseases

Multiple types of surveillance systems related to foodborne disease are used in the United States. Some of them, including notifiable disease surveillance, complaints from consumers about potential illness, and reports of outbreaks, focus on the detection of specific enteric diseases likely to be transmitted by food and have been used extensively by health-related agencies for decades. More recently, new surveillance methods have emerged including hazard surveillance, sentinel surveillance systems, and national laboratory networks for comparing pathogen subtypes, which are particularly applicable to foodborne disease.[49]

Many surveillance systems play a critical role in detecting and preventing foodborne disease and possible outbreaks in the United States, helping to ensure food is safe as it moves through the food chain to the tables of consumers.

2.3.2.1. Notifiable disease surveillance

One of the oldest public health surveillance systems in the country is notifiable disease surveillance. Notifiable disease surveillance begins with an ill person who seeks medical attention. The health-care provider sends a specimen (for foodborne illness, this usually is a stool specimen) to the laboratory for the appropriate tests, and the laboratory identifies the agent responsible for the patient's illness so the patient can be treated. Next, the laboratory or health-care provider notifies local public health officials of the illness. Once the patient's information goes to a public health agency, the illness is compared with other similar reports. Combining the information in these separate reports allows investigators to detect illness clusters that might be outbreaks caused by contaminated food.

All states and territories have legal requirements for the reporting of certain diseases and conditions, including enteric diseases likely to be foodborne, by health-care providers and laboratories to the local or state public health agency. In most states and territories, the law usually requires local public health agencies to report these diseases to the state or territorial public health agency. What to report and with what urgency vary by state and by disease. In the past, disease reports usually arrived by mail, telephone, or fax, but many agencies now have developed electronic laboratory reporting systems.

States and territories (or sometimes local public health agencies) voluntarily share notifiable disease surveillance information with CDC through the National Notifiable Disease Surveillance System (NNDSS), which CDC oversees. No personal identifiers are forwarded, and only minimal information is available about cases (e.g., date of onset and patient age, sex, race/ethnicity, county of residence). National data are used to monitor disease trends and to target research, prevention, and control efforts.

State public health laboratories also participate in national notifiable disease surveillance through programs such as PulseNet (see below)[50] and the Laboratory-based Enteric Diseases Surveillance (LEDS) system, an electronic reporting system for laboratory-

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confirmed isolates, including *Salmonella*, *Shigella*, and STEC.[51,,52, 53]

2.3.2.2. Foodborne illness complaints

Receiving and responding to complaints of disease from the public is a basic function of many public health and other health-related agencies and can lead to the identification of foodborne illnesses in the community and clusters of persons with suspected foodborne disease.

With foodborne disease complaints, affected members of the community report illness they suspect to be foodborne to the health department. Sometimes the reports are made by a third party who recognizes a pattern of illness in the community (e.g., a physician who has seen multiple ill patients with a common exposure, a staff member from a nursing home reporting multiple diarrheal illnesses among residents, or a pharmacist who notes increased sales of antidiarrheal medications). Other agencies sometime receive these reports (e.g., agriculture food safety offices and poison control centers) and forward them to the health department.

The processing of foodborne illness complaints varies by agency on the basis of the suspected pathogen and agency resources. Some health departments are expected to investigate all commercial food establishments named by sick persons. Most health departments record complaints in a log book or on a standardized form. A growing number of health departments enter this information into an electronic database for easy review and analysis, a practice associated with the detection of more outbreaks per complaint reported.[54]

Some complaint systems are more well publicized and involve community members more heavily. A Web-based system in Michigan (RUsick2) piloted in the early 2000s enabled ill persons to share information about their illness and recent exposures and helped the health department identify clusters of persons with unsuspected foodborne disease. During the pilot test, the system resulted in an estimated fourfold increase in the reporting of foodborne illness complaints. Two foodborne disease outbreaks were identified that most likely would not have been identified through other means.[55]

Use of Web-based reporting systems has increased over time. In a 2010 survey of local health departments, 40% of responding agencies reported that they received illness complaints, at least in part, from Web-based reporting.[54]

The value of illness complaint systems was underscored in the 2010 survey of local health departments in which responding agencies reported that 69% of foodborne disease outbreaks in their jurisdiction were detected through complaint systems. Furthermore, agencies serving a population of one million or more reported that 85% of foodborne disease outbreaks were found through a consumer complaint surveillance system.[54]

FDA and USDA-FSIS also maintain complaint systems and interact with local, state, and federal public health agencies during complaint investigations.

More details on consumer complaint systems can be found in Chapter 4.

2.3.2.3. Contributing factor and environmental antecedent surveillance

Contributing factors are environmental factors that increase the risk for foodborne diseases and repeatedly contribute to foodborne disease outbreaks. The list includes factors that lead to contamination of food with microorganisms or toxins, allow survival and growth of microorganisms in food, or prevent inactivation of toxins present in food. Contributing factors are based on

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known microbiological characteristics of and symptoms produced by specific pathogens, toxins, or chemicals and historical associations between known etiologic agents, specific food vehicles, and the setting of production.

Environmental antecedents—root causes—are the underlying reasons for the contributing factors. Environmental antecedents must be identified and addressed for the contributing factors to be prevented.

Communicable disease control officials or foodborne disease outbreak surveillance officials from state and local health departments gather information about contributing factors and environmental antecedents in outbreaks from environmental health assessments conducted by food-control officials from their own environmental health assessments or through some combination of the two and report it to CDC. Factors contributing to an outbreak and their environmental antecedents usually cannot be identified through a regulatory inspection of a food-service or food-production establishment as conducted day to day by food-control authorities. The process of identifying contributing factors and environmental antecedents associated with an outbreak must be driven first by describing what and how events probably unfolded, focusing on the etiologic agent and the implicated food that was prepared or served during the outbreak, rather than on identification of regulation violations. Failures to implement regulatory requirements will come to light during the course of this process but are not the focus of the environmental health assessment. Unfortunately, many food-control authorities fail to adjust their day-to-day regulatory inspection process to adequately conduct an environmental health assessment during the investigation of an outbreak of foodborne illness; therefore, contributing factors and environmental antecedents often are not adequately assessed and reported.

In 2000, CDC established the Environmental Health Specialists Network (EHS-Net) to better provide information about environmental causes of foodborne disease. Current participants include environmental health specialists and epidemiologists from eight state and local health departments and from FDA, USDA-FSIS, USDA's Food and Nutrition Service, and CDC. Improving environmental health assessments in foodborne outbreak investigations and reporting contributing factors and antecedent data to CDC is one of EHS-Net's primary activities.

Through EHS-Net, CDC has developed the National Voluntary Environmental Assessment Information System (NVEAIS), a surveillance system that routinely and systematically monitors and evaluates environmental causes of foodborne disease outbreaks, including contributing factors and environmental antecedents. This system links with the existing surveillance system for reporting foodborne disease outbreaks to CDC (see below).[56]

The information collected through NVEAIS and similar surveillance systems can inform hypothesis generation regarding antecedents to foodborne disease outbreaks and strengthen the ability of food-control authorities to formulate and evaluate the effectiveness of food-safety actions. For example, Delea et al., in an analysis of contributing factors from 154 foodborne disease outbreaks during June 2006–September 2007, identified lack of paid sick leave, language barriers between management and workers, and inadequate hand sink availability as environmental antecedents for food workers working while ill and poor hand-washing practices.[57]

2.3.2.4. Hazard surveillance during routine inspections

Approximately 75 state and territorial agencies and approximately 3000 local agencies assume the primary responsibility for licensing and inspecting retail food-service establishments.[58] Many of these same agencies oversee other

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aspects of the domestic food supply chain. The retail food -service industry alone consists of more than one million establishments and 16 million employees.[56]

Contributing factors are used to develop prevention and control measures at food production and food-service establishments before a foodborne disease outbreak occurs. Inspections of these facilities, often referred to as Hazard Analysis Critical Control Point (HACCP) inspections, are targeted at the implementation of these prevention and control measures. Results of these inspections form the basis for hazard surveillance.

No national hazard surveillance system is available to food-control authorities, although work being conducted through the Conference for Food Protection may evolve into a national system.

2.3.2.5. Foodborne Diseases Active Surveillance Network

The Foodborne Diseases Active Surveillance Network (FoodNet) conducts active, population-based surveillance for laboratory-confirmed infections caused by nine pathogens and one syndrome commonly transmitted through food. FoodNet is a sentinel surveillance system, covering 15% of the U.S population (48 million in 2011) and is a collaboration of CDC, USDA-FSIS, FDA, and 10 state health departments. FoodNet site investigators regularly contact area laboratories to ascertain all infections with the pathogens under surveillance (i.e., active surveillance).

FoodNet sites also have conducted surveys of the frequency of enteric illness and food consumption in the population. The results of these surveys, distributed as the FoodNet Atlas of Exposures, provide crude estimates of the background rate of consumption of a variety of food items in the community and are useful in hypothesis generation during investigation of a foodborne disease outbreak.[59] FoodNet sites also have conducted surveys of practices for diagnosing enteric infections in clinical laboratories.[60]

Surveillance and special studies undertaken by FoodNet sites provide valuable insight into the national incidence of, and trends in, foodborne and diarrheal diseases [61, 62, 63, 64, 65, 66, 67, 68] and have identified previously unrecognized sources of foodborne infection, such as chicken as a risk factor for infection with *Salmonella* Enteritidis,[67, 69] hummus and melon as risk factors for infection with *Listeria monocytogenes,*[70] and riding in a shopping cart next to raw meat or poultry as a risk factor for infection with *Salmonella* and *Campylobacter* in infants.[71, 72] FoodNet also provides information for evaluating new strategies for conducting epidemiologic investigations, including investigations of outbreaks.[73]

2.3.2.6. Behavioral Risk Factor Surveillance System

The Behavioral Risk Factor Surveillance System (BRFSS) is a state-based system of surveys established by CDC in 1984 that provides information about the prevalence of health risk behaviors, preventive health practices, and health-care access. BRFSS data are collected by random-digit–dialed telephone interviews in all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam. A set of core questions is asked of all BRFSS respondents across the country; other questions can be selected for use by individual state and local health agencies, including questions related to food safety.

BRFSS is not appropriate for detecting foodborne illness, but it can be used to identify behaviors (e.g., food-preparation practices and eating meals away from home) that can inform foodborne illness prevention efforts. For example, in an analysis of 1995–1996 BRFSS food-safety questions from Colorado, Florida, Missouri, New York, Tennessee, Indiana, New Jersey, and South Dakota, several high-risk food-handling, preparation, and consumption

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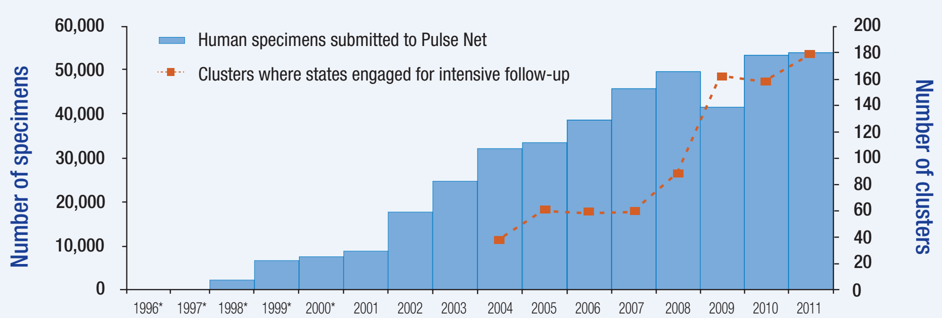
behaviors were common among respondents, and some were particular to specific population groups.[74]

2.3.2.7. National Molecular Subtyping Network for Foodborne Disease Surveillance

National Molecular Subtyping Network for Foodborne Disease Surveillance (PulseNet) is a national network of local, state or territorial, and federal laboratories coordinated by CDC that enables comparison of subtypes of pathogens isolated from humans, foods, animals, and environments across local, state, and national jurisdictions. The name derives from pulsed-field gel electrophoresis (PFGE), a laboratory method used to determine the molecular fingerprints of bacteria. This method, developed and refined during the 1980s and implemented for widespread use during the 1990s, revolutionized the investigation of foodborne disease outbreaks by identifying unique strains within a bacterial species. For example, each of the many strains of *Salmonella* has a unique PFGE pattern or fingerprint. Because foodborne disease outbreaks usually are caused by a single bacterial strain, investigators can identify illnesses in the subgroup of persons infected with the same strain of *Salmonella* as a cluster of possibly related cases, to be considered separately from persons infected with other strains of *Salmonella*. By focusing on the correct group of cases, investigators can more quickly determine whether a cluster of cases represents an outbreak and identify the source of the outbreak. PFGE also can be used to characterize bacterial strains in food or the environment to determine whether those strains match the pattern responsible for an outbreak.[75, 76, 77, 78, 79, 80]

PulseNet has standardized the PFGE methods used by participating laboratories to distinguish strains of STEC, *Salmonella*, *Shigella*, *Listeria*, and *Campylobacter*. In addition, PulseNet maintains a centralized electronic database of PFGE patterns at CDC. Participating laboratories can upload their pattern(s) into the national database and review their current and historical patterns. CDC compares uploaded PFGE patterns with patterns of bacterial strains circulating nationally. This capability has improved investigators' ability to rapidly detect even relatively small clusters of possibly related illnesses in a small geographic area or dispersed across the country. As the number of participating laboratories and popularity of PulseNet have grown, the number of patterns from human isolates uploaded to the system and clusters detected through the system have steadily increased over time (Figure 2.2).[81, 82]

Figure 2.2 Bacterial isolates from humans uploaded to PulseNet USA, and identified clusters, 1996–2011†



*For 1996–2000, data may not be complete. †For 2011, data are preliminary and subject to change.

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2.3.2.8. National Antimicrobial Resistance Monitoring System—Enteric Bacteria

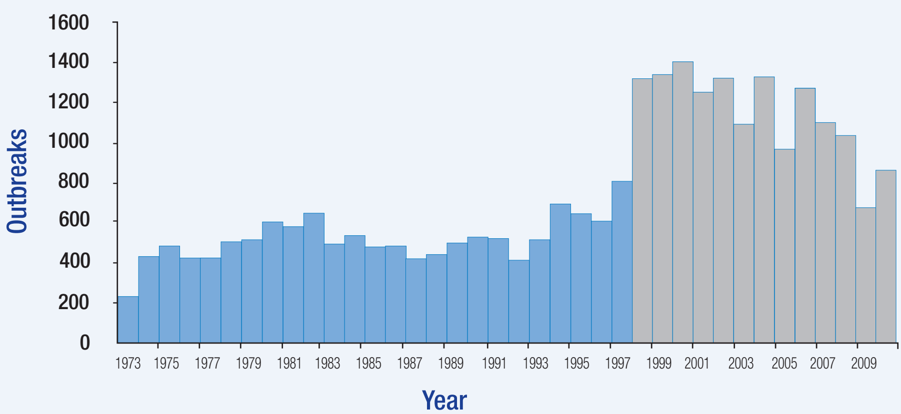
The National Antimicrobial Resistance Monitoring System—Enteric Bacteria (NARMS) was developed to monitor antibiotic resistance patterns in selected enteric bacteria found in humans, animals, and meat and poultry products. Bacterial isolates are forwarded to reference laboratories at CDC, USDA, or FDA and are tested against a panel of antimicrobial drugs important in human and animal medicine. Data collected by NARMS enable investigators to better understand the patterns of antibiotic resistance in microbes infecting animals and humans who ingest foods of animal origin. [83, 84, 85, 86, 87, 88, 89, 90]

2.3.2.9. Foodborne Disease Outbreak Reporting System

The Foodborne Outbreak Reporting System was initiated by CDC in the 1960s to collect voluntary reports from public health agencies summarizing the results of foodborne disease outbreak investigations. In 1973, the database for the system was computerized. In 1998, CDC increased communication with state, local, and territorial health departments about foodborne disease outbreaks and formalized procedures to finalize reports from each state each year. The system also became Web-based through the electronic Foodborne Disease Outbreak Reporting System (eFORS). These changes led to a substantial increase in the number of outbreaks reported, resulting in a discontinuity in trends during 1997–1998 (Figure 2.3).[91]

In 2009, the system was expanded to include reporting of waterborne outbreaks and enteric disease outbreaks caused by person-to-person contact, direct contact with animals, and contact with contaminated environments. The expanded system is called the National Outbreak Reporting System (NORS). CDC, USDA-FSIS, FDA, and other investigating agencies analyze these data to improve the understanding of the human health impact of foodborne disease outbreaks and the pathogens, foods, and settings involved in these outbreaks. Data are also available to the public online at http://wwwn.cdc.gov/foodborneoutbreaks/.

Figure 2.3 Number of reported foodborne disease outbreaks, United States, 1973–2010



Lighter gray bars starting in 1998 illustrate the change in number of outbreaks reported due to changes in the Foodborne Disease Outbreak Surveillance System.

Source: CDC Foodborne Disease Outbreak Surveillance System (2012).

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2.3.2.10. National Electronic Norovirus Outbreak Network

The National Electronic Norovirus Outbreak Network (CaliciNet) is a network of public health and food regulatory laboratories that submit norovirus sequences identified from outbreaks to a national database. CaliciNet participants perform molecular typing of norovirus strains by using standardized laboratory protocols. The information is used to link norovirus outbreaks that may be caused by common sources (such as food), monitor trends, and identify emerging norovirus strains. As of February 2012, public health laboratories in 25 states have been certified by CDC to participate in CaliciNet.[92]

2.3.2.11. Surveillance of the Food Supply

Testing of the food supply and associated environments is performed by local, state, and federal regulatory officials and the food industry. Food testing is a tool used to validate that an establishment's food safety system is functioning adequately to address hazards in food production and manufacturing and prevent foodborne illnesses. Food and environmental testing data, including PFGE subtyping data, can be used to inform hypothesis generation during outbreaks. Food testing data also can be used to estimate the fraction of selected foodborne illnesses that are caused by specific food sources, to assess changes in food contamination over time, and to assess the success of regulatory measures.

USDA-FSIS food laboratories maintain ISO 17025 accreditation, the international standard for laboratory quality systems. FDA is leading an effort to bring state manufactured food regulatory microbiological and chemical food-testing laboratories under ISO 17025 accreditation to enhance efforts to protect the food supply. Data generated by accredited laboratories will be made available for consideration during FDA enforcement actions as well as for surveillance purposes and during response to foodborne disease outbreaks through the Electronic Laboratory Exchange Network (eLEXNET). Laboratory accreditation will also assist state manufactured food regulatory programs in achieving conformance with the Manufactured Food Regulatory Program Standards (MFRPS).[93]

2.3.3. Quality and Usefulness of Surveillance Data

Surveillance plays a critical role in detecting and controlling foodborne diseases and outbreaks. Surveillance data can be used to examine long-term patterns of specific foodborne diseases, to characterize groups at greatest risk for these diseases, and to identify sudden changes in disease occurrence that suggest an outbreak or environmental hazard that needs investigation. Surveillance data can provide the basis for an understanding of foodborne illness in the community and how best to use limited resources to address problems associated with foodborne illness. Surveillance data can help generate hypotheses about specific foodborne diseases and provide clues about the problem for exploration through in-depth studies. Surveillance data can identify contributing factors and environmental antecedents to foodborne disease outbreaks, which in turn can be used to develop preventive controls and thereby reduce the burden of foodborne disease. Surveillance data also can be used to evaluate the effectiveness of interventions by the food industry and public health and regulatory agencies. Although surveillance data are of great utility, they are far short of perfect, and their shortcomings often compromise their utility.

2.3.3.1. Completeness of detection and reporting of foodborne diseases

Although national capacity for detection and surveillance of foodborne disease has improved considerably in the past 20 years,[94] for a number of reasons, surveillance statistics reflect only a fraction of cases: (a) some people do not seek medical attention for vomiting or diarrhea of limited duration or do not seek care because

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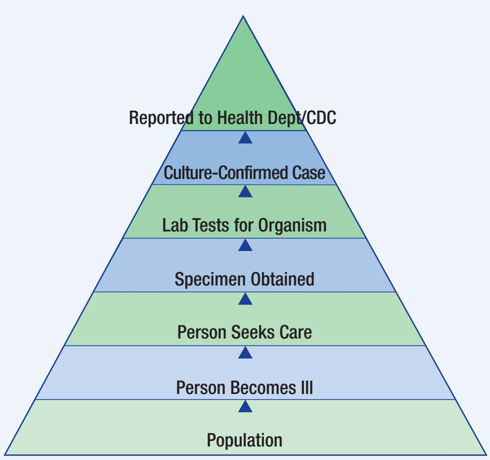
they lack health-care coverage; (b) health-care providers frequently do not obtain diagnostic tests for illnesses likely to be self-limited; (c) not all types of infections can be diagnosed with routine laboratory testing; and (d) laboratories and health-care providers may fail to report the illness to a public health agency.[95, 96, 97, 98] For example, according to a population-based survey undertaken in 1996–97 in selected states, only 12% of persons who had a diarrheal illness (14.6% of those with bloody diarrhea and 11.6% of those with nonbloody diarrhea) sought medical care. Among those who sought medical care, 21% were asked by their physician to provide a stool specimen for culture, and 89% of these complied with this request.[99]

As a result, cases of foodborne illness are lost at each step in the diagnosis and reporting process and thus are not included in national statistics. As little as 5% of bacterial foodborne illness might be reported to CDC through notifiable disease surveillance.[100] Some investigators portray this disparity between the occurrence of foodborne illness and the reporting of cases to the health department by using a burden of illness pyramid (Figure 2.4).[100]

Figure 2.4 Burden of illness pyramid reflecting the proportion of foodborne illnesses that make it through each step of the diagnosis and reporting process.[100]



With dozens—or even hundreds—of possible etiologies for foodborne disease, and most of them with similar or at least overlapping clinical manifestations, laboratory-confirmation of the agent is often essential for public health action. However, because most diarrheal illnesses are self-limited and laboratory test results often are not used to guide the initial course of treatment for a patient, health-care providers often do not request stool cultures. Physicians are more likely to request a culture for persons with acquired immunodeficiency syndrome, history of travel to a developing country, bloody stools, diarrhea of >3 days' duration, or fever, or who require intravenous rehydration.[101]

Lack of laboratory confirmation can hinder appropriate management and treatment of an individual patient with acute diarrhea and inhibit surveillance and other public health actions.[101, 102] For the individual patient, identification of the specific agent can:

- Help with the appropriate selection of antimicrobial therapy, shortening the patient's illness and reducing morbidity;
- Support the decision not to treat, if the patient would not benefit from antimicrobial therapy or would even be harmed by the use of antibiotics (e.g., prolongation of the carrier state with salmonellosis); and
- Guide the use of invasive diagnostic techniques (e.g., avoid colonoscopy if an infectious etiology is identified).

From a public health perspective, a pathogen-specific diagnosis with subtyping and prompt notification of public health authorities can:[100,101]

- Enhance actions to prevent the spread of infection to others through patient education and exclusion of ill persons from food preparation or care of individuals at increased risk for poor outcomes from foodborne diseases;

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- Allow tracking of trends in foodborne diseases through surveillance;
- Enhance the detection and control of outbreaks, particularly outbreaks caused by low-level contamination of food or exposures over a wide geographic area;
- Provide antimicrobial sensitivity data for the community;
- Prevent the emergence of drug resistance through the more judicious use of antibiotics and avoidance of broad-spectrum antibiotics; and
- Support studies of sporadic, non-outbreak–associated illnesses to describe changing epidemiology and identification of new risk factors.

Improved disease detection and completeness of reporting would facilitate the above patient care and public health goals. Nonetheless, it should still be appreciated that even with the capture of only a fraction of foodborne illnesses through surveillance, these intensely investigated events shed light on food vehicles, settings, pathogens, contributing factors, and environmental antecedents, and provide extremely valuable information.

2.3.3.2. Culture-independent diagnostic tests

Culture-independent diagnostic tests are also threatening surveillance and outbreak detection efforts. These tests, largely based on enzyme immunoassays and similar procedures, are becoming available for some foodborne illnesses. These methods allow for a quick identification of a pathogen and rapid initiation of treatment. However, they usually do not result in a culture that can be forwarded to the public health laboratory for further characterization (e.g., subtyping and antimicrobial susceptibility testing), limiting the identification of clusters, and tracking of antimicrobial resistance. Furthermore, the accuracy of culture-independent diagnostic tests differs from that of cultures, making it difficult to include the results of such tests in the definitions used in notifiable disease surveillance.[103, 104]

To address the impact of culture-independent diagnostic tests on foodborne disease surveillance and outbreak detection in the short term, steps need to be taken to maintain pathogen isolates for characterization at public health laboratories. This includes working with the medical device industry and the FDA to ensure that specimens collected for culture-independent diagnostic tests are adequate for subsequent culture and building capacity at public health laboratories that will be increasingly charged with isolating foodborne pathogens from patient samples. In the long term, new tests for determining pathogen subtype, virulence, and antimicrobial susceptibility need to be developed that are themselves culture-independent.

2.3.3.3. Quality and usefulness of information collected

Many factors influence decisions about which surveillance data to collect and how to collect them, both of which affect the quality and usefulness of the data. The contributing factor category of data reported to CDC through the Foodborne Disease Outbreak Surveillance System is a good example of how these decisions are made and how surveillance systems evolve over time to balance user needs, identification of data to collect, willingness of officials to report, and accuracy of officials' reports.

Before October 1999, contributing factor data were reported and summarized into five broad categories: improper storage or holding temperature; inadequate cooking; contaminated equipment or working surfaces; food acquisition from unsafe source; poor personal hygiene of food handler; and other. Food-control authorities used the information, but the broad categories were not detailed enough and did not fully meet their needs. Articles by Bryan et

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al., Guzewich et al., and Todd et al. [105, 106, 107, 108] framed information gleaned from foodborne disease surveillance systems in terms of the key end user of the data—those charged with foodborne disease prevention. Specifically, Bryan et al. described the value and limitations of existing food vehicle and contributing factor data and recommended a list of specific contributing factors to be reported.[108]

To meet the needs of data users, CDC incorporated the contributing factors suggested by Bryan et al. into the new foodborne outbreak reporting form in October 1999. Another factor, glove-handed contact by handler/worker/preparer, was also added.

The change, however, is not without controversy among those who report and use this information. Some question whether food-control authorities have the expertise to accurately identify the most likely contributing factors from among the now complicated list of factors. Consistent identification of these factors is also an issue. Some believe the contributing factor list is too complex for a surveillance system and should be removed entirely or returned to the pre-1999 abbreviated list. Still others believe without a context for the factors reported—even the pre-1999 abbreviated list of factors has limited, if any, value.

As new information becomes available about the value of specific data elements, the contributing factor surveillance system, like all surveillance systems, will continue to evolve. CDC's EHS-Net program has been addressing these problems through the National Voluntary Environmental Assessment Information System (NEVAIS) and related training programs (see above).

2.4. Etiologic Agents Associated with Foodborne Diseases

2.4.1. Overview

Foodborne illnesses have myriad causes, including microorganisms (e.g., bacteria, viruses, parasites, and marine algae) and their toxisns, mushroom toxins, fish toxins, heavy metals, pesticides, and other chemical contaminants (Table 2.1). These agents cause human disease through a number of mechanisms and are often categorized into those caused by toxins present in food before it is ingested (preformed toxins) and those caused by multiplication of the pathogen in the host and damage resulting from toxins produced within the host (enterotoxins) or adherence to or invasion of host cells (infection).

Details about the most common foodborne disease–causing agents, including signs and symptoms, incubation periods, modes of transmission, common food vehicles, and control measures, can be found in:

- American Public Health Association. *Control of Communicable Diseases Manual* (latest edition) Washington, DC: APHA;
- CDC. CDC A–Z Index. www.cdc.gov/az/a.html;
- U.S. Food and Drug Administration. The Bad Bug Book, 2nd edition. www.fda.gov/downloads/Food/FoodSafety/FoodborneIllness/FoodborneIllnessFoodbornePathogensNaturalToxins/BadBugBook/UCM297627.pdf;
- International Association of Milk, Food and Environmental Sanitarians. *Procedures to Investigate Foodborne Illness*. 6th edition. Des Moines, Iowa: IAMFES (reprinted 2007); and
- CDC. Diagnosis and management of foodborne illnesses: a primer for physicians and other health-care professionals. MMWR Recomm Rep 2004:53(RR-4). (www.cdc.gov/mmwr/pdf/rr/rr5304.pdf)

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Table 2.1. Examples of agents that commonly cause foodborne illness, by agent type and mechanism of action

TYPE OF AGENT	GENERAL MECHANISM OF ACTION	EXAMPLE
Bacteria	Preformed toxin	*Bacillus cereus* *Clostridium botulinum* *Staphylococcus aureus*
	Infection and production of enterotoxins	*Bacillus cereus* *Clostridium botulinum* *Clostridium perfringens* *Enterohemorrhagic Escherichia coli* Enterotoxigenic *E. coli (STEC)* *Vibrio cholerae*
	Infection	*Bacillus anthracis* *Brucella spp. (B. melitensis, B. abortus, B. suis)* *Campylobacter jejuni* Enteroinvasive *E. coli* *Listeria monocytogenes* *Plesiomonas shigelloides* *Salmonella spp.* *Shigella spp.* *Streptococcus pyogenes* *Vibrio parahaemolyticus* *V. vulnificus* *Yersinia enterocolytica and Y. pseudotuberculosis*
Virus	Infection	Hepatitis A virus Norovirus (and other caliciviruses) Rotavirus Astroviruses, adenoviruses, parvoviruses
Parasite	Infection	*Cryptosporidium* *Cyclospora cayetanensis* *Diphyllobothrium latum* *Entamoeba histolytica* *Giardia intestinalis* *Taenia saginata* *Taenia solium* *Toxoplasma gondii* *Trichinella spiralis*
Marine algae toxins	Preformed toxin	Brevetoxin (neurotoxic shellfish poisoning) Ciguatoxin (ciguatera) Domoic acid (amnestic shellfish poisoning) Saxitoxin (paralytic shellfish poisoning)
Fungal toxins	Preformed toxin	Aflatoxin Mushroom toxins (amanitin, ibotenic acid, museinol, muscarine, and psilocybin)

2.4. Etiologic Agents Associated with Foodborne Diseases

Table 2.1. *Continued* Examples of agents that commonly cause foodborne illness, by agent type and mechanism of action

TYPE OF AGENT	GENERAL MECHANISM OF ACTION	EXAMPLE
Fish toxins	Preformed toxin	Gempylotoxin (escolar) Scombrotoxin (histamine fish poisoning) Tetrodotoxin (puffer fish)
Chemicals	Preformed toxin (hazardous at certain levels)	Antimony Arsenic Cadmium Copper Fluoride Lead Mercury Nitrites Pesticides (e.g., organophosphates, carbamate) Thallium Tin Zinc

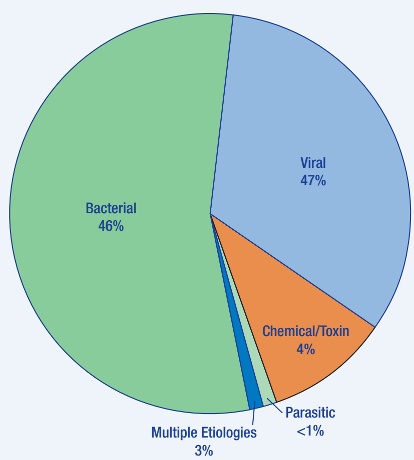
2.4.2. Patterns in Etiologic Agents Associated with Foodborne Disease Outbreaks

Patterns in the agents causing foodborne disease outbreaks have been identified through the voluntary reporting of outbreaks to CDC through the Foodborne Disease Outbreak Surveillance System.

In the most recent CDC surveillance summary of U.S. foodborne disease outbreaks (covering 2009–2010), bacteria (including their toxins) accounted for 46% of reported outbreaks that had an identified cause (Figure 2.5). The most common bacteria implicated in outbreaks were *Salmonella*, STEC, *Clostridium perfringens, Campylobacter, Bacillus cereus, Staphylococcus aureus, Shigella, Listeria monocytogenes,* and *Vibrio* spp. (Figure 2.6). Clostridium botulinum also was reported but was a less common bacterial cause of foodborne disease.[109]

During the same surveillance period, viruses constituted 47% of identified causes of foodborne disease outbreaks, increasing from 16% in 1998. The increase in proportion of outbreaks from viral pathogens over time reflects the increased availability of methods to diagnose viral agents in recent years.[109] During 2009–2010, noroviruses accounted for 99% of

Figure 2.5 Foodborne disease outbreaks by confirmed etiology, United States, 2009-2010*



* Includes only outbreaks for which an etiology was determined. For 31% of outbreaks, no etiologic agent was identified.

Source: CDC Foodborne Disease Outbreak Surveillance System (2012)

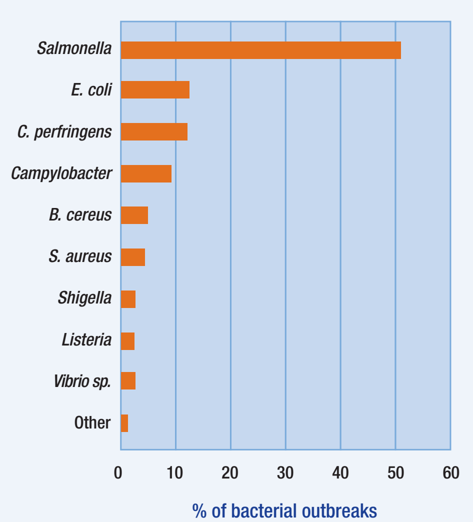
2.4. Etiologic Agents Associated with Foodborne Diseases

viral outbreaks. Hepatitis A virus and rotaviruses played a minor role in foodborne disease outbreaks during these years.

During 2009–2010, parasites accounted for <1% of outbreaks with identified etiologies. Marine algae and fish toxins, mushroom toxins, and chemicals accounted for 4% of outbreaks with an identified cause. The most commonly reported chemical/toxin causes were scombrotoxin (42%) and ciguatoxin (35%).[109]

For a large proportion (31%) of outbreaks reported during 2009–2010, no etiologic agent was identified. Reasons include inadequate collection of stool specimens, delay in outbreak detection and specimen collection, and inappropriate testing of specimens.[110,111] Because laboratory methods for confirming viral diseases are less available than tests for bacterial diseases, many outbreaks of foodborne illness from viruses probably fall into the "unknown etiologic agent" category.[110]

Figure 2.6 Distribution of bacterial foodborne disease outbreaks by etiologic agent, United States, 2009-2010



Source: CDC Foodborne Disease Outbreak Surveillance System (2012)

In addition, not all outbreaks are detected, investigated, and reported to CDC. Outbreaks most likely to be brought to the attention of public health authorities are those that can cause serious illness, hospitalization, or death.[109] Furthermore, outbreaks of diseases characterized by short incubation periods, such as those caused by chemical agents or staphylococcal enterotoxin, might be more likely to be recognized than diseases with longer incubation periods, such as hepatitis A.[110]

2.4.3. Determining the Etiologic Agent in an Outbreak

2.4.3.1. Laboratory confirmation of etiologic agent

Laboratory testing of clinical specimens from ill persons is critical in determining the etiology of a suspected foodborne disease outbreak and implementing appropriate control measures. For most foodborne diseases, stool is the specimen of choice; however, samples of blood, vomitus, or other tissues or body fluids are occasionally indicated. Specimens are collected as soon as possible after onset of illness from persons who manifest illness typical of the outbreak and who have not undergone antibiotic treatment. The number of specimens collected depends on the suspected agent and capacity of the testing laboratory; ideally, specimens from 5–10 persons are collected and tested. Methods for collection, storage, and transport vary depending on the suspected agent (e.g., bacterium, virus, or parasite).[109, 112, 113]

Isolation of the causative agent from a suspected food item can provide some of the most convincing evidence of the source of a foodborne disease outbreak and can obviate the need for more time-consuming analytic epidemiologic approaches. Food testing, however, has inherent limitations. Specific contaminants or foods might require special collection and testing techniques, and demonstration of an agent in food is not always possible. Because contaminants

2.4. Etiologic Agents Associated with Foodborne Diseases

in food change with time, samples collected during an investigation might not represent those ingested when the outbreak occurred. Subsequent handling or processing of food might result in the death of microorganisms, multiplication of microorganisms originally present at low levels, or introduction of new contaminants. If contamination of the food is not uniform, the sample collected or portion analyzed might miss the contaminated portion. Finally, because food is usually not sterile, microorganisms can be isolated from samples but not be responsible for the illness under investigation. False-negative results are more likely than false-positive results and are of little significance. In other words, a negative result does not rule out a food item as the source of an outbreak.

Food testing can be an important adjunct to many investigations of commercial products, but testing without a specific focus can be prohibitively expensive. As a result, food testing should not be undertaken routinely but should be based on meaningful associations, such as reports of ill persons eating the same food product or an environmental health investigation that identifies specific food safety problems.

2.4.3.2. Other clues to the etiologic agent

During the wait for laboratory confirmation, the following information can help shorten the list of likely agents causing an outbreak:

- Predominant signs and symptoms among ill persons;
- Incubation period, if known;
- Duration of illness; and
- Food history leading to suspected food, if known.

An example of how predominant signs and symptoms and incubation period can be used to help determine the etiologic agent in an outbreak is provided in Appendix 2.

In determining the clinical characteristics of ill persons in an outbreak, most investigators question ill persons specifically about the occurrence of a standard set of signs and symptoms often associated with foodborne diseases. A commonly used set of signs and symptoms includes headache, nausea, vomiting, myalgia (muscle aches), abdominal (stomach, belly) cramps, unusual fatigue (feeling tired), fever (and whether temperature was measured), chills, any diarrhea or loose stools, three or more loose stools within a 24-hour period, and any blood in the stool. Negative findings can be as pertinent as positive findings and should be recorded.

The incubation period is the time from exposure to the etiologic agent to development of symptoms. Determining the incubation period for an illness is influenced by whether the calculation is based on onset of the prodromal symptoms (e.g., general feeling of being unwell) or specific signs and symptoms of enteric disease (e.g., vomiting or diarrhea) that may occur later. Because ill persons typically recall onset of the latter more clearly, some investigators consistently use onset of these "hard" symptoms to calculate the incubation period. Many investigators, however, collect information from both times (where applicable), generally using onset of hard symptoms as the default. For most etiologies it is important to collect both the date and the specific time of symptom onset.

2.4.3.2.1. Signs, symptoms, incubation period, and duration of illness

In identifying the likely etiologic agent in an outbreak on the basis of signs, symptoms, incubation period, and duration of illness, it is often helpful to first categorize a suspected foodborne illness as resulting from a preformed toxin, enterotoxin, or infection.

Illnesses from preformed toxins are caused by ingestion of food already contaminated by toxins. Sources of preformed toxin include

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certain bacteria, poisonous chemicals, heavy metals, and toxins found naturally in animals, plants, or fungi. Preformed toxins most often result from bacteria, such as *Staphylococcus aureus*, *Bacillus cereus*, and *Clostridium botulinum*, that release toxins into food during growth in the food. The preformed toxin is ingested; thus live bacteria do not need to be consumed to cause illness.

Illness from a preformed toxin manifests more rapidly than does illness from an enterotoxin or infection because time for growth and invasion of the intestinal lining or production of enterotoxin is not required. The incubation period for illnesses from a preformed toxin is often minutes or hours.

Signs and symptoms depend on the toxin ingested but commonly include vomiting. Other symptoms can range from nausea and diarrhea to interference with sensory and motor functions, such as double vision, weakness, respiratory failure, numbness, tingling of the face, and disorientation. Fever is rarely present.

Infections result from growth of a microorganism in the body. Illness results from two mechanisms:

- Viruses, bacteria, or parasites invade the intestinal mucosa and/or other tissues, multiply, and directly damage surrounding tissues; or
- Bacteria and certain viruses invade and multiply in the intestinal tract and then release toxins that damage surrounding tissues or interfere with normal organ or tissue function (enterotoxins).

The necessary growth of the microorganism, damage of tissues, and production and release of toxins takes time. Thus, the incubation periods for infections are relatively long, often days, compared with minutes or hours as with preformed toxins.

Symptoms of infection usually include diarrhea, nausea, vomiting, and abdominal cramps. Fever and an elevated white blood cell count can also occur. If an infectious agent spreads from the gut to the bloodstream, other organs (e.g., liver, spleen, gallbladder, bones, and meninges) can be affected, resulting in an illness of longer duration, increased severity, and signs and symptoms associated with the particular organ affected.

2.4.3.2.2. Suspected food

Certain microorganisms are associated with certain food items because the food derives from an animal reservoir of the microorganism or the food provides conditions necessary for the survival and growth of the organism. As a result, the food item suspected in an outbreak, if known, can occasionally provide insight into the etiologic agent (Table 2.2). However, most foods can be associated with a variety

Table 2.2. Examples of food items and commonly associated microorganisms *(based on Chamberlain 2008)*[116]

ITEM	COMMONLY ASSOCIATED MICROORGANISM
Raw seafood	*Vibrio* spp., hepatitis A virus, noroviruses
Raw eggs	*Salmonella* (particurlarly serotype Enteritidis)
Undercooked meat or poultry	*Salmonella* and *Campylobacter* spp., Shiga toxin-producing *Escherichia coli* (STEC), *Clostridium perfringens*
Unpasteurized milk or juice	*Salmonella*, *Campylobacter*, and *Yersinia* spp., STEC
Unpasteurized soft cheeses	*Salmonella*, *Campylobacter*, *Yersinia Listeria monocytogenes*, STEC
Home-made canned goods	*Clostridium botulinum*
Raw hot dogs, deli meat	*Listeria* monocytogenes.

2.4. Etiologic Agents Associated with Foodborne Diseases

of etiologic agents, and new vehicles for transmission emerge each year. Therefore, care must be taken in inferring the etiologic agent from the suspected food item.

2.4.4. Mode of Transmission

Many agents responsible for foodborne illness also can be transmitted by other routes, such as drinking water, recreational water, and person-to-person and animal-to-person transmission. For example, only an estimated 31% of shigellosis cases, 8% of cryptosporidiosis cases, and 26% of norovirus infections result from foodborne transmission.[114] Consequently, early in the investigation of a possible foodborne disease outbreak, investigators should consider all possible sources of transmission and collect information from ill persons about sources of drinking water, exposure to other ill persons and child care settings, exposure to recreational water, and contact with animals and their environments, as well as about food and other environmental exposures.

Although in-depth interviews of persons with suspected cases and epidemiologic, environmental health, and laboratory studies are necessary to confirm suspicions about the mode of transmission in an outbreak, characteristics among cases or timing of illness onset might provide clues that suggest one mode of transmission over others and enable investigators to focus on investigating that source.

2.4.4.1. Transmission by food

Illness among persons with the following characteristics might suggest transmission of an agent by food:

- Persons who have shared a common meal or food, and onset of illness is consistent with when the shared meal or food was consumed;
- Persons with distinctive demographic characteristics (i.e., age group, sex, and ethnicity) and possibly unique food preferences; or
- Persons with a geographic distribution similar to the geographic distribution of food products.

2.4.4.2. Transmission by water

The following clues might suggest transmission of an agent by drinking water:

- Widespread illness affecting persons of both sexes and all age groups;
- Geographic distribution of cases consistent with public water distribution but not food distribution patterns (e.g., limited to persons residing within city limits or a clustering of cases adjacent to cattle ranches or farms served by well water);
- Absence of cases among breast-fed babies or persons who drink only bottled water or beverages from boiled water;
- Dose-response with increasing attack rates among persons drinking more water;
- Concurrent complaints about water quality in the affected community; or
- Involvement of multiple pathogens.

A clustering of cases among children, particularly children who have shared a common recreational water exposure, such as a water park, community pool, or lake, might suggest transmission by recreational water.

2.4.4.3. Transmission from person-to-person

Person-to-person transmission should be suspected when

- Cases are clustered in social units such as families, schools (and classes within schools), nursing homes, dorms or dorm rooms, and sororities/fraternities; and
- Cases occur in waves separated by approximately one incubation period of the etiologic agent.

2.4.4.4. Transmission from fomites

The importance of nonfood environmental sources in transmission is poorly understood,

2.4. Etiologic Agents Associated with Foodborne Diseases

but outbreaks that initially appear to be foodborne are occasionally linked to other sources. For example, a norovirus outbreak after a business luncheon was eventually linked to environmental contamination from a child with diarrhea.[115] In another instance, a protracted outbreak of salmonellosis was originally linked to consumption of pasteurized milk, but the vehicle was ultimately shown to be externally contaminated milk cartons (i.e., not the milk itself). [*Salmonella* Braenderup in Oregon, B. Keene, unpublished data, 2013].

2.5. References

1 U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary guidelines for Americans, 2010. 7th ed, Washington, DC: U.S. Department of Agriculture/U.S. Department of Health and Human Services, December 2010. Available at www.health.gov/dietaryguidelines/dga2010/dietaryguidelines2010.pdf (accessed April 6, 2013).

2 Huang S, Huang K. Increased U.S. import of fresh fruit and vegetables—a report from the Economic Research Service, U.S. Department of Agriculture. FTS-328-01. September 2007. Available at www.ers.usda.gov/publications/fts-fruit-and-tree-nuts-outlook/fts-32801.aspx#.UmK6VSQYLR0 (accessed February 21, 2008).

3 U.S Census. Per capita consumption of major food commodities: 1980 to 2009. Available at www.census.gov/compendia/statab/2012/tables/12s0217.pdf (accessed October 30, 2012).

4 National Oceanographic and Atmospheric Administration.Per capita consumption. Available at www.st.nmfs.noaa.gov/st1/fus/fus11/08_percapita2011.pdf (accessed October 30, 2012).

5 U.S. Department of Agriculture. U.S. food imports: summary data on food import values for 14 food categories, annual data since 1999. Available at www.ers.usda.gov/data-products/us-food-imports.aspx (accessed October 30, 2012).

6 Hamburg M, Import safety: status of FDA's screening efforts at the border. Testimony before Subcommittee on Oversight and Investigations Committee on Energy and Commerce U.S. House of Representatives on April 13, 2011. Available at www.fda.gov/NewsEvents/Testimony/ucm250710.htm (accessed October 30, 2012).

7 Gould LH, Morse D, Tauxe RV. Foodborne disease outbreaks associated with food imported into the United States, 2005–2010 [abstract]. International Conference on Emerging Infectious Diseases 2012: poster and oral presentation abstracts. Emerg Infect Dis 2012 Mar. Available at http://wwwnc.cdc.gov/eid/pdfs/ICEID2012.pdf (accessed November 18, 2013).

8 Mazurek J, Salehi E, Propes D, et al. A multistate outbreak of *Salmonella* enterica serotype Typhimurium infection linked to raw milk consumption—Ohio, 2003. J Food Prot 2004;67:2165–70.

9 Yeung PS, Boor KJ. Epidemiology, pathogenesis, and prevention of foodborne *Vibrio parahaemolyticus* infections. Foodborne Pathog Dis 2004;1:74–88.

10 Nawa Y, Hatz C, Blum J. Sushi delights and parasites: the risk for fishborne and foodborne parasitic zoonoses in Asia. Clin Infect Dis 2005;41:1297–303.

11 Leedom JM. Milk of nonhuman origin and infectious diseases in humans. Clin Infect Dis 2006;43:610–5.

12 Braden CR. *Salmonella enterica* serotype Enteritidis and eggs: a national epidemic in the United States. Clin Infect Dis 2006;43:512–7.

13 CDC. *Salmonella* Typhimurium infection associated with raw milk and cheese consumption—Pennsylvania, 2007. MMWR Morb Mortal Wkly Rep 2007;56:1161–4.

14 CDC. Preliminary FoodNet data on the incidence of infection with pathogens transmitted commonly through food—10 states, 2006. MMWR Morb Mortal Wkly Rep 2007;56:336–9.

15 Langer AJ, Ayers T, Grass J, Lynch M, Angulo FJ, Mahon BE. Nonpasteurized dairy products, disease outbreaks, and state laws—United States, 1993–2006. Emerg Infect Dis 2012;18:385–91.

16 CDC. Surveillance for foodborne disease outbreaks—United States, 2009–2010. MMWR Morb Mortal Wkly Rep 2013;62:41–7.

17 Winthrop KL, Palumbo MS, Farrar JA, et al. Alfalfa sprouts and *Salmonella* Kottbus infection: a multistate outbreak following inadequate seed disinfection with heat and chlorine. J Food Prot 2003;66:13–7.

2.5. References

18 Sivapalasingam S, Friedman CR, Cohen L, Tauxe RV. Fresh produce: a growing cause of outbreaks of foodborne illness in the United States, 1973 through 1997. J Food Prot 2004;67:2342–53.

19 CDC. Multistate outbreak of *Salmonella* serotype Tennessee infections associated with peanut butter—United States, 2006–2007. Morb MMWR Mortal Wkly Rep 2007;56:521–4.

20 Braden CR. *Salmonella enterica* serotype Enteritidis and eggs: a national epidemic in the United States. Clin Infect Dis 2006;43:512–7.

21 Steele M, Odumeru J. Irrigation water as source of foodborne pathogens on fruit and vegetables. J Food Prot 2004;67:2839–49.

22 Collignon P, Angulo FJ. Fluoroquinolone-resistant *Escherichia coli:* food for thought. J Infect Dis 2006;194:8–10.

23 Blackburn BG, Mazurek JM, Hlavsa M, et al. Cryptosporidiosis associated with ozonated apple cider. Emerg Infect Dis 2006;12:684–6.

24 Uesugi AR, Danyluk MD, Mandrell RE, Harris LJ. Isolation of *Salmonella* Enteritidis phage type 30 from a single almond orchard over a 5-year period. J Food Prot 2007;70:1784–9.

25 Erickson MC, Doyle MP. Food as a vehicle for transmission of Shiga toxin–producing *Escherichia coli.* J Food Prot 2007;70:2426–49.

26 Doane CA, Pangloli P, Richards HA, Mount JR, Golden DA, Draughon FA. Occurrence of *Escherichia coli* O157:H7 in diverse farm environments. J Food Prot 2007;70:6–10.

27 Delaquis P, Bach S, Dinu LD. Behavior of *Escherichia coli* O157:H7 in leafy vegetables. J Food Prot 2007;70:1966–74.

28 Arthur TM, Bosilevac JM, Brichta-Harhay DM, et al. Transportation and lairage environment effects on prevalence, numbers, and diversity of *Escherichia coli* O157:H7 on hides and carcasses of beef cattle at processing. J Food Prot 2007;70:280–6.

29 Doyle M, Erickson M. Summer meeting 2007—the problems with fresh produce: an overview. J Appl Micro 2008;105:317–30.

30 Varma JK, Marcus R, Stenzel SA, et al. Highly resistant *Salmonella* Newport-MDRAmpC transmitted through the domestic US food supply: a FoodNet case–control study of sporadic *Salmonella* Newport infections, 2002–2003. J Infect Dis 2006;194:222–30.

31 Zhao S, McDermott PF, Friedman S, et al. Antimicrobial resistance and genetic relatedness among *Salmonella* from retail foods of animal origin: NARMS retail meat surveillance. Foodborne Pathog Dis 2006;3:106–17.

32 Donabedian SM, Perri MB, Vager D, et al. Quinupristin-dalfopristin resistance in *Enterococcus faecium* isolates from humans, farm animals, and grocery store meat in the United States. J Clin Microbiol 2006;44:3361–5.

33 Nelson JM, Chiller TM, Powers JH, Angulo FJ. Fluoroquinolone-resistant *Campylobacter* species and the withdrawal of fluoroquinolones from use in poultry: a public health success story. Clin Infect Dis 2007;44:977–80.

34 CDC. List of multistate foodborne outbreak investigations, 2006–2013. Available at http://www.cdc.gov/foodsafety/outbreaks/multistate-outbreaks/outbreaks-list.html (accessed November 18, 2013).

35 Martinez S, Hand MS, Da Pra M, et al. Local food systems: concepts, impacts, and issues, ERR 97, U.S. Department of Agriculture, Economic Research Service, May 2010. Available at www.ers.usda.gov/Publications/ERR97/ERR97.pdf (accessed October 30, 2012).

36 FDA Food Safety Modernization Act. Public Law 111–353. Available at http://www.fda.gov/food/guidanceregulation/fsma/ucm247548.htm (accessed November 18, 2013).

37 National Restaurant Association. 2012 Restaurant industry overview. Available at www.restaurant.org/research/facts/ (accessed October 30, 2012).

38 USDA Economic Research Service. Available at www.ers.usda.gov/data-products/food-expenditures.aspx (accessed October 30, 2012).

39 CDC. Surveillance for foodborne disease outbreaks—United States, 2009–2010. MMWR Morb Mortal Wkly Rep 2013;62:41–7.

40 Jones TF, Angulo FJ. Eating in restaurants: a risk factor for foodborne disease? Clin Infect Dis 2006;43:1324–8.

41 USDA. USDA Food Safety and Inspection Service recall case archives. Available at www.fsis.usda.gov/wps/portal/fsis/topics/recalls-and-public-health-alerts/recall-case-archive/recall-case-archive-2012 (accessed November 18, 2013).

42 FDA. 2012 Recalls, market withdrawals & safety alerts. Available at www.fda.gov/Safety/Recalls/ArchiveRecalls/2012/default.htm (accessed November 18, 2013).

43 Scallan E, Griffin PM, Angulo FJ, Tauxe RV, Hoekstra RM. Foodborne illness acquired in the

2.5. References

United States—unspecified agents. Emerg Infect Dis 2011;17:16–22.

44 CDC. Surveillance for foodborne disease outbreaks—United States, 2009–2010. MMWR Morb Mortal Wkly Rep 2013;62:41-7.

45 Tauxe RV. Emerging foodborne diseases: an evolving public health challenge. Emerg Infect Dis 1997;3:425-34.

46 Sobel J, Griffin PM, Slutsker L, Swerdlow DL, Tauxe RV. Investigation of multistate foodborne disease outbreaks. Public Health Rep 2002;117:8–19.

47 Laine ES, Scheftel JM, Boxrud DJ, et al. Outbreak of *Escherichia coli* O157:H7 infections associated with nonintact blade-tenderized frozen steaks sold by door-to-door vendors. J Food Prot 2005;68:1198–202.

48 Todd ECD, Guzewich JJ, Bryan FL. Surveillance of foodborne disease. Part IV. Dissemination and uses of surveillance data. J. Food Prot 1997;60:715–23.

49 Guzewich JJ, Bryan FL, Todd ECD. Surveillance of foodborne disease I. Purposes and types of surveillance systems and networks. J.Food Prot 1997;60:555–66.

50 Tauxe RV. Molecular subtyping and the transformation of public health. Foodborne Pathog Dis 2006;3:4–8.

51 CDC. National Enteric Disease Surveillance: *Salmonella* surveillance overview. Available at www.cdc.gov/nationalsurveillance/PDFs/NationalSalmSurveillOverview_508.pdf (accessed May 1, 2013).

52 CDC.National Enteric Disease Surveillance: Shigella surveillance overview. Available at www.cdc.gov/ncezid/dfwed/PDFs/Shigella-Overview-508.pdf (accessed May 1, 2013).

53 CDC. National Enteric Disease Surveillance: Shiga toxin–producing Escherichia coli (STEC) surveillance overview.. Available at www.cdc.gov/ncezid/dfwed/PDFs/national-stec-surveillance-overiew-508c.pdf (accessed May 1, 2013).

54 Li J, Shah GH, Hedberg C. Complaint-based surveillance for foodborne Illness in the United States: a survey of local health departments. J Food Prot 2011;74: 432–7.

55 Wethington H, Bartlett P. The RUsick2 foodborne disease forum for syndromic surveillance. Emerg Infect Dis 2004;10:401–5.

56 CDC. National Voluntary Environmental Assessment Information System (NVEAIS). Available at www.cdc.gov/nceh/ehs/EHSNet/Foodborne_Illness_Outbreaks.htm#Foodborne_Illness_Outbreak_Study (accessed October 25, 2012).

57 Delea KC, Selman CA, EHS-Net. Understanding foodborne disease outbreaks using environmental assessment. Presented at the Conference on Emerging Infectious Diseases Biannual Meeting; 2008 March 16–19, Atlanta, GA. Available at www.cdc.gov/nceh/ehs/EHSNet/Foodborne_Illness_Outbreaks.htm#Foodborne_Illness_Outbreak_Study (accessed October 25, 2012).

58 FDA. Food Code 2009. Available at www.fda.gov/downloads/Food/GuidanceRegulation/UCM189448.pdf (accessed November 18, 2013).

59 CDC. Foodborne Diseases Active Surveillance Network (FoodNet): population survey atlas of exposures, 2002. Available at www.cdc.gov/foodnet/surveys/pop/2002/2002Atlas.pdf (accessed November 18, 2013).

60 Voetsch AC, Angulo FJ, Rabatsky-Ehr TR, Shallow S, Cassidy M, Thomas SM, Swanson E, Zansky SM, Hawkins MA, Jones TF, Shillam PJ, Van Gilder TJ, Wells JG, Griffin PM. Laboratory practices for stool-specimen culture for bacterial pathogens, including *Escherichia coli* O157:H7, in the FoodNet sites, 1995-2000. Clin Infect Dis 2004;38(Suppl 3):S190-197.

61 CDC. Preliminary FoodNet data on the incidence of infection with pathogens transmitted commonly through food—10 states, 2006. MMWR Morb Mortal Wkly Rep 2007;56:336–9.

62 Varma JK, Marcus R, Stenzel SA, et al. Highly resistant *Salmonella* Newport-MDRAmpC transmitted through the domestic US food supply: a FoodNet case-control study of sporadic *Salmonella* Newport infections, 2002–2003. J Infect Dis 2006;194:222–30.

63 Zhao S, McDermott PF, Friedman S, et al. Antimicrobial resistance and genetic relatedness among *Salmonella* from retail foods of animal origin: NARMS retail meat surveillance. Foodborne Pathog Dis 2006;3:106–17.

64 Scallan E. Activities, achievements, and lessons learned during the first 10 years of the Foodborne Diseases Active Surveillance Network: 1996–2005. Clin Infect Dis 2007;44:718–25.

65 Imhoff B, Morse D, Shiferaw B, et al. Burden of self-reported acute diarrheal illness in FoodNet surveillance areas, 1998–1999. Clin Infect Dis 2004;38(Suppl 3):S219–26.

66 Jones TF, McMillian MB, Scallan E, et al. A population-based estimate of the substantial burden of diarrhoeal disease in the United States; FoodNet, 1996–2003. Epidemiol Infect 2007;135:293–301.

2.5. References

67 Marcus R, Varma JK, Medus C, et al. Re-assessment of risk factors for sporadic *Salmonella* serotype Enteritidis infections: a case–control study in 5 FoodNet sites, 2002–2003. Epidemiol Infect 2007;135:84–92.

68 Voetsch AC, Kennedy MH, Keene WE, et al. Risk factors for sporadic Shiga toxin–producing Escherichia coli O157 infections in FoodNet sites, 1999–2000. Epidemiol Infect 2007;135:993–1000.

69 Kimura AC, Reddy V, Marcus R, et al. Chicken consumption is a newly identified risk factor for sporadic *Salmonella* enterica serotype Enteritidis infections in the United States: a case–control study in FoodNet sites. Clin Infect Dis 2004;38(Suppl 3):S244–52.

70 Varma JK, Samuel MC, Marcus, R, et al. *Listeria monocytogenes* infection from foods prepared in a commercial establishment: a case–control study of potential sources for sporadic illness in the United States. Clin Infect Dis 2007;44:521–8.

71 Jones TF, Ingram LA, Fullerton KE, et al. A case control study of the epidemiology of sporadic *Salmonella* infection in infants. Pediatrics 2006;118:2380–7.

72 Fullerton KE, Ingram LA, Jones TF, et al. Sporadic *Campylobacter* infection in infants: a population-based surveillance case–control study in eight FoodNet sites. Pediatr Infect Dis J 2006;118:2380–7.

73 Murphree R, Garman K, Phan Q, Everstine K, Gould LH, Jones TF. Characteristics of foodborne disease outbreak investigations conducted by FoodNet sites, 2003–2008. Clin Infect Dis 2012;54(Suppl 5):S498–503.

74 Yang S, Leff MG, McTague D, Horvath KA, Jackson-Thompson J, Murayi T. Multistate surveillance for food-handling, preparation, and consumption behaviors associated with foodborne diseases: 1995 and 1996 BRFSS food-safety questions. MMWR CDC Surveill Summ 1998;47(SS-4):33–41.

75 CDC. Ongoing multistate outbreak of *Escherichia coli* serotype O157:H7 infections associated with consumption of fresh spinach—United States, September 2006. MMWR Morb Mortal Wkly Rep 2006;55:1045–6.

76 Uesugi AR, Danyluk MD, Mandrell RE, Harris LJ. Isolation of *Salmonella* Enteritidis phage type 30 from a single almond orchard over a 5-year period. J Food Prot 2007;70:1784–9.

77 Zhao S, McDermott PF, Friedman S, et al. Antimicrobial resistance and genetic relatedness among *Salmonella* from retail foods of animal origin: NARMS retail meat surveillance. Foodborne Pathog Dis 2006;3:106–17.

78 Honish L, Predy G, Hislop N, et al. An outbreak of *E. coli* O157:H7 hemorrhagic colitis associated with unpasteurized gouda cheese. Can J Public Health 2005;96:82–4.

79 Barrett TJ, Gerner-Smidt P, Swaminathan B. Interpretation of pulsed-field gel electrophoresis patterns in foodborne disease investigations and surveillance. Foodborne Pathog Dis 2006;3:20–31.

80 CDC. PulseNet. Available at www.cdc.gov/PULSENET/ (accessed February 28, 2008).

81 Tauxe RV. Molecular subtyping and the transformation of public health. Foodborne Pathog Dis 2006;3:4–8.

82 Besser J. Culture-independent diagnostics: impact on public health. Presented at Clinical Laboratory Improvement Advisory Committee meeting, August 29–30, 2012, Atlanta, GA. Available at http://ftp.cdc.gov/pub/CLIAC_meeting_presentations/pdf/Addenda/cliac0812/11_BESSER_CIDT_for_CLIAC_2012_FINAL_for_live_presentation.pdf (accessed August 3, 2013).

83 Aarestrup FM, Hendriksen RS, Lockett J, et al. International spread of multidrug-resistant *Salmonella* Schwarzengrund in food products. Emerg Infect Dis 2007;13:726–31.

84 Varma JK, Marcus R, Stenzel SA, et al. Highly resistant *Salmonella* Newport-MDRAmpC transmitted through the domestic US food supply: a FoodNet case–control study of sporadic *Salmonella* Newport infections, 2002–2003. J Infect Dis 2006;194:222–30.

85 Zhao S, McDermott PF, Friedman S, et al. Antimicrobial resistance and genetic relatedness among *Salmonella* from retail foods of animal origin: NARMS retail meat surveillance. Foodborne Pathog Dis 2006;3:106–17.

86 Sivapalasingam S, Nelson JM, Joyce K, Hoekstra M, Angulo FJ, Mintz ED. High prevalence of antimicrobial resistance among Shigella isolates in the United States tested by the National Antimicrobial Resistance Monitoring System from 1999 to 2002. Antimicrob Agents Chemother 2006;50:49–54.

87 CDC. National Antimicrobial Resistance Monitoring System for Enteric Diseases (NARMS). Available at www.cdc.gov/narms/. Accessed February 28, 2008.

88 CDC. NARMS: National Antimicrobial Resistance Monitoring System—Enteric Bacteria, 2011. Human isolates final report. Available at www.cdc.gov/narms/pdf/2011-annual-report-narms-508c.pdf (accessed November 18, 2013).

2.5. References

89 Crump JA, Kretsinger K, Gay K, et al. Clinical response and outcome of infection with *Salmonella* Typhi with decreased susceptibility to fluoroquinolones: a United States FoodNet multi-center retrospective cohort study. Antimicrob Agents Chemother 2008;52:1278–84.

90 Varma JK, Greene KD, Ovitt J, Barrett TJ, Medalla F, Angulo FJ. Hospitalization and antimicrobial resistance in *Salmonella* outbreaks, 1984–2002. Emerg Infect Dis 2005;11:943–6.

91 CDC. Surveillance for foodborne disease outbreaks—United States, 2009–2010. MMWR Morb Mortal Wkly Rep 2013;62:41–7.

92 Vega E, Barclay L, Gregoricus N, Williams K, Lee D, Vinjé J. Novel surveillance network for norovirus gastroenteritis outbreaks, United States. Emerg Infect Dis 2011;17:1389–95.

93 ISO/IEC 17025:2005 Accreditation for state food testing laboratories (U18) Available at www.grants.nih.gov/grants/guide/rfa-files/RFA-FD-12-008.html (access May 1, 2013).

94 Scallan E. Activities, achievements, and lessons learned during the first 10 years of the Foodborne Diseases Active Surveillance Network: 1996–2005. Clin Infect Dis 2007;44:718–25.

95 Jones TF, Imhoff B, Samuel M, et al. Limitations to successful investigation and reporting of foodborne outbreaks: an analysis of foodborne disease outbreaks in FoodNet catchment areas, 1998–1999. Clin Infect Dis 2004;38(Suppl 3):S297–302.

96 Scallan E, Jones TF, Cronquist A, et al. Factors associated with seeking medical care and submitting a stool sample in estimating the burden of foodborne illness. Foodborne Pathog Dis 2006;3:432–8.

97 Scallan E, Majowicz SE, Hall G, et al. Prevalence of diarrhoea in the community in Australia, Canada, Ireland, and the United States. Int J Epidemiol 2005;34:454–60.

98 Hennessy TW, Marcus R, Deneen V, et al. Survey of physician diagnostic practices for patients with acute diarrhea: clinical and public health implications. Clin Infect Dis 2004;38(Suppl 3):S203–11.

99 Voetsch AC, Van Gilder T, Angulo FJ. FoodNet estimate of the burden of illness caused by nontyphoidal *Salmonella* infections in the United States. Clin Infect Dis 2004;38(Suppl 3):S127–34.

100 Angulo F, Voetsch A, Vugia D, et al. Determing the burden of human illness from foodborne diseases: CDC's Emerging Infectious Disease Program Foodborne Disease Active Surveillance Network (FoodNet). Vet Clin North Am Food Anim Pract 1998;14:165–72.

101 Hennessy TW, Marcus R, Deneen V, et al. Survey of physician diagnostic practices for patients with acute diarrhea: clinical and public health implications. Clin Infect Dis 2004;38(Suppl 3):S203–11.

102 Guerrant RL, Van Gilder T, Steiner TS, et al. Practice guidelines for the management of infectious diarrhea. Clin Infect Dis 2001;32:331–50.

103 Jones TF, Gerner-Smidt P. Nonculture diagnostic tests for enteric diseases. Emerg Infect Dis 2012;18:513–14.

104 Cronquist AB, Mody RK, Atkinson R, et al. Impacts of culture-independent diagnostic practices on public health surveillance for bacterial enteric pathogens. Clin Infect Dis 2012;54(Suppl 5):S432–9.

105 Guzewich JJ, Bryan FL, Todd ECD. Surveillance of foodborne disease I. Purposes and types of surveillance systems and networks. J.Food Protect 1997;60:555–66.

106 Todd ECD, Guzewich JJ, Bryan FL. Surveillance of foodborne disease. Part IV. Dissemination and uses of surveillance data. J. Food Protect. 1997;60:715–23.

107 Bryan FL, Guzewich JJ, Todd ECD. Surveillance of foodborne disease II. Summary and presentation of descriptive data and epidemiology patterns; their value and limitations. J.Food Protect 1997;60:567–78.

108 Bryan FL, Guzewich JJ, Todd ECD. Surveillance of foodborne disease III. Summary and presentation of data on vehicles and contributory factors; their value and limitations. J.Food Protect 1997;60:701–14.

109 CDC. Surveillance for foodborne disease outbreaks—United States, 2009–2010. MMWR Morb Mortal Wkly Rep 2013;62:41–7.

110 MacDonald KL, Griffin PM . Foodborne disease outbreaks, Annual summary, 1982. MMWR CDC Surveill Summ 1986;35:7SS–16SS.

111 Snider CJ, Vugia DJ, Cronquist A, et al. Epidemiology of foodborne outbreaks of undetermined etiology, FoodNet Sites, 2001–2004 [abstract]. Presented at the Infectious Diseases Society of America 43rd annual meeting, October 6–9, 2005, San Francisco, CA.

112 CDC. Recommendations for collection of laboratory specimens associated with outbreaks of gastroenteritis. MMWR Recomm Rep 1990;39(RR-14):1–13

113 CDC. "Norwalk-like viruses:" public health consequences and outbreak management. MMWR Recomm Rep 2001;50(RR-9) [erratum in MMWR Morb Mortal Wkly Rep 2001;50:496].

114 Scallan E, Griffin PM, Angulo FJ, Tauxe RV, Hoekstra RM. Foodborne illness acquired in the United States—unspecified agents. Emerg Infect Dis 2011;17:16–22.

115 Repp KK, Hostetler TP, Keene WE. A norovirus outbreak related to contaminated environmental surfaces. J Infect Dis 2013;208:295–8.

116 Chamberlain N. Infections and intoxications of the intestines. Available at http://www.atsu.edu/faculty/chamberlain/website/lectures/lecture/gi4.htm (accessed November 18, 2013).