Foodborne Disease

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- Complete the questions at the end of the course.
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Faculty

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Faculty Disclosure

Contributing faculty, Lori L. Alexander, MTPW, ELS, MWC, has disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

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The division planners and director have disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

Audience

This course is designed for physicians, physician assistants, nurse practitioners, and nurses seeking to enhance their knowledge of foodborne disease. The course is of particular importance for clinicians in the primary care and emergency settings.

Accreditations & Approvals

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NetCE designates this continuing education activity for 10 ANCC contact hours.

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Special Approvals

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Course Objective

Physicians and other healthcare practitioners are integral to the prevention, identification, and treatment of foodborne diseases, and also play an important role in the control of foodborne disease outbreaks. The purpose of this course is to provide healthcare professionals with the information necessary to rapidly and effectively diagnose, manage, report, and prevent foodborne diseases, in the interest of individual patient care and protection of the public at large.

Learning Objectives

Upon completion of this course, you should be able to:

1. List the bacterial and viral pathogens most often responsible for food-related illness in the United States.
2. Identify the subset of the populations most at risk for a foodborne disease.
3. Discuss the food sources of infectious and non-infectious pathogens.
4. Outline key steps in the diagnosis of foodborne disease, including patient history, differential diagnosis, microbiologic testing, and considerations for non-English-proficient patients.
5. Describe the general management principles and reporting requirements for cases of foodborne disease.
6. Discuss the epidemiology, presentation, diagnosis, and treatment of foodborne bacterial infection.
7. Identify viral foodborne pathogens, including associated diagnosis and treatment.
8. Compare and contrast foodborne parasitic disease found in the United States.
9. Describe marine toxins by source and the respective syndromes associated with food-related illness.
10. List the symptoms and disease course of mushroom poisonings.
11. Describe strategies to help individuals prevent foodborne disease.

EVIDENCE-BASED PRACTICE RECOMMENDATION

Sections marked with this symbol include evidence-based practice recommendations. The level of evidence and/or strength of recommendation, as provided by the evidence-based source, are also included so you may determine the validity or relevance of the information. These sections may be used in conjunction with the course material for better application to your daily practice.

INTRODUCTION

Foodborne diseases are common, costly, and preventable. Based on public health surveillance data from multiple sources, it is estimated that 48 million food-related illnesses occur in the United States each year [1]. Of this total, about 9.4 million cases are caused by food contaminated with 31 known pathogens, resulting in 56,000 hospitalizations and 1,350 deaths [1]. The incidence of foodborne disease is greatest among children younger than 5 years of age, while severe illness, hospitalization, and death occur predominantly among persons older than 65 years of age.

The Foodborne Diseases Active Surveillance Network (FoodNet) was established in 1996 to monitor the incidence and trends of foodborne disease in the United States. FoodNet is a collaborative effort between the Centers for Disease Control and Prevention (CDC), the U.S. Food and Drug Administration (FDA), the U.S. Department of Agriculture (USDA), and state health departments. Designed as a sentinel program, FoodNet conducts active, population-based surveillance across 10 geographic areas covering 15% of the U.S. population (48 million persons) [2]. The system monitors incidence of laboratory-confirmed infections caused by nine pathogens commonly transmitted in food. In 2019, preliminary data from FoodNet identified 25,866 cases, 6,164 hospitalizations, and 122 deaths attributable to foodborne diseases [2]. The overall incidence per 100,000 population was highest for *Campylobacter* (19.5), followed by *Salmonella* (17.1), Shiga toxin-producing *Escherichia coli* (STEC) (6.3), and *Shigella* (4.8).

Preliminary data show that compared with the previous three years (2017–2019), incidences of infections monitored by FoodNet decreased 26% in 2020 [237]. Public health interventions (e.g., restaurant closures, travel restrictions) to slow the spread of COVID-19 likely influenced exposures to enteric pathogens. Other factors may also have reduced laboratory detection and reporting of foodborne infection. Incidence of *Campylobacter, Salmonella*, STEC, and *Vibrio* infections, which had increased in recent years, decreased during 2020 [237].

Although most food-related illnesses are sporadic, regularly occurring foodborne disease outbreaks represent an ongoing, serious public health problem. Each year, approximately 800 – 900 linked clusters of cases (outbreaks) are reported through the CDC Foodborne Outbreak Reporting System. In 2017, 841 foodborne outbreaks were reported, resulting in 14,481 illnesses, 827 hospitalizations, and 20 deaths [3]. Norovirus accounted for the majority of confirmed, single-etiology outbreaks, followed by *Salmonella*, STEC, and *Clostridium perfringens* [3]. As in previous years, restaurants were the most commonly reported locations of food preparation associated with outbreaks.

Over the past decade, several national outbreaks of foodborne disease linked to a common source in the commercial food chain have heightened public awareness and illustrate the importance of a well-designed surveillance system. In 2008, two separate outbreaks of salmonellosis (serotypes Saintpaul and Typhimurium), affecting more than 1,400 persons in 44 states and Canada, were eventually traced to jalapeño and serrano peppers grown on farms in Mexico [4; 5]. In 2008–2009, another outbreak of salmonellosis (serotype Typhimurium) affecting 600 people in 44 states and Canada was traced to a peanut butter producer in Georgia [6]. In 2011–2012, cantaloupes contaminated with *Listeria* caused the deadliest outbreak of a foodborne illness since 1973. During that time period, 147 illnesses, 33 deaths, and 1 miscarriage were reported in 28 states [7]. Another outbreak in 2012 was traced to *Salmonella*-infected yellowfin tuna, leading to more than 400 illnesses and 55 hospitalizations in 28 states and the District of Columbia [8].

In 2018, outbreaks of *Salmonella* infections were linked to: kosher chicken (17 cases in 4 states, 8 hospitalizations and 1 death); ground beef (246 cases across 25 states, 59 hospitalizations, and a recall of 6.9 million pounds of beef products); raw turkey products (164 cases in 35 states, 63 hospitalizations and 1 death); and tahini (5 cases in 3 states, no deaths or hospitalizations) [9; 10; 11; 12]. Also in 2018, two *Listeria* outbreaks occurred (one was linked to pork products and one to deli ham, with small numbers of affected individuals) and one outbreak of *E. coli* infection was linked to romaine lettuce. This outbreak resulted in 62 cases in 16 states, 25 hospitalizations, and no deaths [13; 14; 15]. In November 2018, the manufacturer of four varieties of cake mix recalled the mixes after officials in Oregon identified *Salmonella* Agbeni. Seven cases were reported in five states [16]. One may conclude that despite advances in technology and food safety, foodborne disease remains a potentially serious public health threat. Physicians and other healthcare practitioners, by careful evaluation and prompt reporting of individual cases, play an important role in the early identification, control, and prevention of foodborne disease outbreaks.

Many factors account for the sustained threat of foodborne diseases. The global food supply, ease of travel and trade, changes in food preferences, increased consumption of fresh vegetables and fruits, changes in food production and distribution systems, a growing propensity to rely on food prepared in public places, and adaptation by microbial pathogens all contribute to the risk of contracting and spreading a foodborne disease [17; 18; 19; 20]. These factors ensure continued infection with traditional foodborne pathogens as well as the emergence of novel pathogens [21].

Infectious agents (i.e., bacteria, viruses, parasites) are the cause of most confirmed cases of foodborne disease. The pathogens most commonly identified in reported foodborne outbreaks are norovirus (35%), *Salmonella* (29%), and STEC (5%) [3]. Parasitic causes of foodborne disease are rare in the United States but occur more frequently in developing countries. Also contributing to the incidence of foodborne disease are noninfectious agents such as heavy metals and natural toxins. Of the two, natural toxins, especially marine toxins, are responsible for the majority of foodborne toxin-mediated gastrointestinal illness.

For a variety of reasons, a large percentage of foodborne disease goes undiagnosed and unreported [21; 22]. Under-reporting is a primary issue because many individuals with food-related gastrointestinal symptoms do not seek medical attention. Furthermore, healthcare providers may not pursue a specific diagnosis, take a careful travel and food exposure history, or recognize the potential link to additional cases in the community.

Trends in food consumption have had an impact on the particular source of foodborne disease. For example, the increased attention to the importance of a healthy diet has led to a greater consumption of fresh produce, and the proportion of outbreaks attributed to produce trended up from 1973 to 1997 [23]. Leafy greens, cut tomatoes, and cut melons have been responsible for 80% of outbreaks caused by fresh produce in recent years [24]. Of the outbreaks reported in 2017, mollusks (42 outbreaks), fish (37 outbreaks), and chicken (23 outbreaks) were the most common [3]. The most outbreak-associated illnesses were from turkey (609 illnesses), fruits (521), and chicken (487) [3]. Knowledge of changing trends helps practitioners to better recognize the possibility of a foodborne infection.

Foodborne disease usually presents as an acute illness with clinical manifestations that are common and nonspecific. Gastrointestinal symptoms predominate (e.g., nausea, vomiting, diarrhea, abdominal discomfort). Varying degrees of fever may be seen depending on the pathogen, and neurologic symptoms are common with certain toxins. Because of potential public health implications, practitioners should consider a foodborne etiology when evaluating a patient who presents with such symptoms. A careful, directed history is key to the identification of a foodborne disease, and practitioners should be prepared with an approach designed to elicit pertinent information. Studies have identified

gaps in healthcare practitioner knowledge of the epidemiology, etiology, diagnosis, and prevention of foodborne illnesses. A survey of practitioners in North Carolina showed that approximately one-third of respondents were not comfortable about their knowledge of foodborne disease or its diagnosis and treatment [25]. In addition, many practitioners did not adequately counsel patients about the prevention of foodborne illness.

This course provides an overview of infectious and noninfectious foodborne diseases in the United States. Topics to be covered include public health considerations and surveillance, common pathogens and toxins, clinical manifestations and evaluation, microbiologic testing, and management of infectious diarrhea. Emphasis is given to those foodborne pathogens and toxins that are encountered most frequently and that have the potential to cause widespread and severe disease. Pathogens and toxins are discussed in terms of their sources, the signs and symptoms they produce, the potential complications associated with infection, and the individuals who are at greatest risk. Toxins that can be deliberately introduced into a food or water supply as an act of terrorism are beyond the scope of this course.

The high incidence of foodborne disease also calls for increased education of the public at large, and healthcare professionals can play an integral role by discussing foodborne illness with their patients and providing educational resources. Media attention tends to focus on outbreaks stemming from food served in restaurants, but epidemiologic data demonstrate that a substantial proportion of food-related illness can be attributed to improper practices in food preparation in the home [26]. According to food safety experts, the importance of primary control factors in preventing foodborne infection varies according to the specific pathogen; the incidence of illness and the financial costs also vary according to pathogen [27; 28]. The course concludes with a brief discussion of how healthcare professionals can help their patients better understand the need to change behaviors that put them at risk for foodborne diseases.

OVERVIEW OF FOODBORNE DISEASE

According to the World Health Organization, a foodborne disease is "usually infectious or toxic in nature, caused by bacteria, viruses, parasites, or chemical substances entering the body through contaminated food or water" [29]. More than 250 specific pathogens or toxins have been identified as causes of human foodborne disease worldwide. An estimated 600 million people—almost 1 in 10 people in the world—fall ill after eating contaminated food and 420,000 die every year [29]. Children younger than 5 years of age account for 40% of the foodborne disease burden, with 125,000 deaths every year. In 2018, the World Bank estimated that the total productivity loss associated with foodborne disease in low-and-middle income countries cost $95.2 billion per year, and the annual cost of treating foodborne illnesses cost $15 billion [238]. In the United States, after combining the estimates for known pathogens and unspecified agents, the annual burden of foodborne diseases is estimated to be 48 million illnesses, 128,000 hospitalizations and 3,000 deaths [30]. The estimated annual economic burden is $77.7 billion, mainly due to healthcare costs and lost productivity [31]. Despite increased surveillance, intensified awareness/education campaigns, and improved food safety, the incidence of foodborne disease has not changed significantly since the late 1990s, and it may increase further as a result of the expanding global food economy and the increased threat of bioterrorism [32].

The landscape of food-related illness is continuously in flux as diseases emerge and re-emerge. For example, *Campylobacter jejuni* and STEC O157 were unknown pathogens in the 1970s [33]. By 2012, they were the first and third leading causes of foodborne infection, respectively, with *Campylobacter* accounting for more than 845,000 cases of laboratory-confirmed foodborne infections annually [34]. The CDC estimates that *Campylobacter* infection affects more than 1.5 million people every year in the United States [35].

As noted, causative agents of foodborne disease may be infectious (i.e., bacteria, viruses, parasites) or noninfectious (e.g., heavy metals, natural toxins) [36]. Prions or transmissible spongiform encephalopathies—normal animal proteins that can become infectious through misfolding—also cause foodborne illness, but prion-related disease is extremely rare in the United States [37].

SURVEILLANCE

The incidence of foodborne diseases and trends over time are identified through passive and active surveillance programs of the CDC [38]. The National Notifiable Diseases Surveillance System, a passive system, relies on voluntary state reporting of diseases listed by the CDC as nationally notifiable [38]. As discussed, FoodNet, a component of the CDC's Emerging Infections Program, was established to help public health officials better understand the epidemiology of foodborne illnesses in the United States. FoodNet conducts population-based surveillance for laboratory-confirmed cases of infection with one of eight bacteria and two parasites [38]. In total, FoodNet monitors 48 million people, which represents approximately 15% of the U.S. population [39]. FoodNet also monitors the incidence of post-diarrheal hemolytic uremic syndrome (HUS), a potentially fatal complication of bacterial infection in children, through a network of pediatric nephrologists and infection-control practitioners housed in nine sites.

Many other foodborne surveillance programs contribute to the effort to enhance the detection, evaluation, and management of foodborne disease outbreaks. Among these programs are the Environmental Health Specialists Network (EHS-Net), a group of environmental health specialists and epidemiologists who partner with the CDC's National Center for Environmental Health, FoodNet, and the FDA to facilitate information exchanges about the environmental causes of foodborne illnesses, and PulseNet, a national network that conducts molecular surveillance using standardized pulse-field gel electrophoresis DNA fingerprinting, allowing for serotyping and subtyping of foodborne pathogens, which has been critical to the early detection and termination of outbreaks.

Despite improvements in health information technology and laboratory testing, foodborne disease surveillance is still limited by several factors [36; 40; 41]:

- Under-reporting/delayed reporting of mild disease
- Ill individuals not seeking treatment for acute gastroenteritis
- Difficulties identifying causative factors
- Confounding routes of foodborne transmission
- Emerging/unrecognized food-related pathogens
- Misdiagnosis of illness caused by noninfectious agents
- Deaths caused by unknown foodborne agents attributed to other causes
- Limited ability to identify virally contaminated food

Overcoming these barriers in the future will increase the capacity of surveillance programs to prevent the transmission of foodborne infections. Healthcare practitioners play a vital role in enhancing foodborne disease surveillance by accurately diagnosing food-related illness and reporting cases in a timely manner.

OUTBREAKS

The CDC defines an outbreak of foodborne disease as "an incident in which two or more persons experience a similar illness resulting from the ingestion of a common food" [42]. After a healthcare practitioner has diagnosed a foodborne disease, he or she should notify the state health department about an outbreak (or potential outbreak). Epidemiologists then begin an investigation facilitated by the Foodborne Disease Surveillance and Outbreak

Investigation Toolkit. This kit provides a guide to confirming a diagnosis of a foodborne disease, public health training network, standard questionnaires, and guidelines for specimen collection to investigate outbreaks [21]. Serotyping and genetic sequencing of pathogens enable investigators to link cases of an infection, sometimes across states, and a common source is then sought. State reports are published in *Morbidity and Mortality Weekly Report*, and the incidences are summarized at the end of the reporting year.

The FDA, USDA, Environmental Protection Agency (EPA), and CDC support the efforts of state health departments as needed. In outbreak situations, state health departments commonly perform tasks such as antimicrobial susceptibility testing of submitted isolates, patient counseling, contact notification, and follow-up testing [17]. With the help of the CDC and other government agencies, state health departments may also attempt to identify the source of the illness, which could exist anywhere along the so-called farm-to-table continuum [21]. With outbreaks of bacterial and parasitic foodborne illnesses, a food source is the focal point. Because viral foodborne illnesses are usually transmitted through infected food handlers, a specific setting (e.g., restaurant, banquet) is usually the common denominator.

Identifying the source of an outbreak is associated with a variety of challenges. In 2008, the House Energy and Commerce Subcommittee on Oversight and Investigation were critical of the CDC and the FDA for not identifying rapidly and accurately that contaminated Mexico-grown jalapeño and serrano peppers were the cause of more than 1,000 cases of salmonellosis [43]. Because CDC epidemiologists determined that 84% of ill individuals ate tomatoes, tomatoes were initially targeted as the probable source [43; 44]. During the search for contaminated tomatoes, the FDA found contaminated jalapeños in Texas, and investigators subsequently traced contaminated peppers back to two farms in Mexico [44].

As another example, between November 25, 2008, and January 28, 2009, 529 persons from 43 states and one person from Canada were reported to be infected with *Salmonella* (serotype Typhimurium) [6]. The source of the outbreak did not become apparent until after several weeks of detailed case interviews, investigations of local clusters of illness, and joint epidemiologic efforts across states. The source was a factory that made peanut butter and peanut paste for peanut butter-containing products (e.g., crackers, cookies, cereal, candy). The CDC refers to this type of outbreak as ingredient-driven, an outbreak in which a contaminated ingredient affected a variety of products that were distributed through different channels and consumed in various settings [6]. Tracing the first implicated product to its point of manufacture was crucial in defining the outbreak. The number of products and brands and the large quantities of some products recalled makes this one of the largest recalls in the United States [6].

On September 14, 2011, a farm in Colorado conducted a voluntary recall on cantaloupes that were potentially contaminated with *Listeria*. In its final update, the CDC reported that infected cantaloupes caused 147 illnesses, 33 deaths, 143 hospitalizations, and 1 miscarriage in 28 states [7]. In 2012, the common link for an outbreak of *Salmonella* Bareilly and *Salmonella* Nchanga among 425 people in 28 states was found in frozen and raw fresh yellowfin tuna products [8]. Even after the manufacturer recalled the product, infections developed in a substantial number of people, suggesting that food establishments were still serving the tuna during the recall [8].

The CDC coordinates investigation of between 17 and 36 possible multistate foodborne outbreaks each week [239]. As of mid-January 2022, there were nine active investigations of *Listeria* (associated with packaged salads), five of *Salmonella* (onions), and three of STEC (packaged salads). Information on selected multistate foodborne outbreak investigations of these and other pathogens are published on the CDC's website [239]. Each year, the CDC

SELECT FOODBORNE-ILLNESS OUTBREAKS IN THE UNITED STATES			
Pathogen/Toxin	**Source**	**Number of Cases**	**Action**
2021			
Salmonella (serotype Oranienburg)	Fresh whole onions imported from Mexico	892 cases in 35 states, 183 hospitalizations	Voluntary recall of products
2018			
Shiga toxin-producing *Escherichia coli* O157:H7	Romaine lettuce	210 cases in 36 states, 96 hospitalizations, 5 deaths	Voluntary recall of products
Cyclospora cayetanensis	Fresh vegetable trays	250 cases in 4 states, 8 hospitalizations	Voluntary recall of products
2017			
Shiga toxin-producing *Escherichia coli* O157:H7	Soy nut butter	32 cases in 12 states, 12 hospitalizations	Voluntary recall of products
Listeria monocytogenes	Soft raw milk cheese	8 cases in 4 states, 8 hospitalizations, 2 deaths	Voluntary recall of products
2016			
Shiga toxin-producing *Escherichia coli* O121	Wheat flour	42 cases in 21 states, 11 hospitalizations	Voluntary recall of products
2015			
Salmonella (serotype Poona)	Cucumbers imported from Mexico	907 cases in 40 states, 204 hospitalizations, 6 deaths	Voluntary recall of product
Multidrug-resistant *Salmonella* I 4,[5],12:i:- and *Salmonella* (serotype Infantis)	Pork	192 cases in 5 states, 30 hospitalizations	Voluntary recall of product
2014			
Cyclospora	Cilantro imported from Mexico	207 cases in 19 states (mainly Texas)	—
Salmonella (serotype Newport)	Cucumbers imported from Mexico	275 cases in 29 states	Voluntary recall of product
2013			
Cyclospora	Prepackaged salad mix served at restaurant chains	511 cases in 16 states, 24 hospitalizations	—
Salmonella (serotype Saintpaul)	Cucumbers imported from Mexico	84 cases in 18 states, 17 hospitalizations	—
2012			
Salmonella (serotype Bredeney)	Peanut butter and other products containing nuts and seeds	30 illnesses in 19 states, 4 hospitalizations, no deaths	Voluntary recall of product
Salmonella (serotypes Bareilly and Nchanga)	Yellowfin tuna	425 illnesses in 28 states, 55 hospitalizations, no deaths	Voluntary recall of product
2011–2012			
Listeria monocytogenes	Cantaloupes	147 illnesses in 28 states, 33 deaths, 1 miscarriage	Voluntary recall of produce
2010			
Salmonella (serotype Enteritidis)	Eggs	1,939 illnesses in 14 states	Voluntary recall of more than 500,000 eggs
Source: [6; 7; 8; 45; 46; 47; 48; 49; 50; 51; 52; 53; 54; 55; 56; 57; 58; 59; 60; 61; 62; 63; 64; 65]			*Table 1*

provides a comprehensive list of outbreaks that have been reported through the Foodborne Disease Outbreak Surveillance System [38]. A review of select outbreaks since the mid-2000s demonstrates a range in causative pathogens, sources, and number of individuals affected (***Table 1***).

Outbreak data should be kept in perspective, because they represent only a portion of all food-related illness occurring over time. For example, the proportion of all food-related illnesses associated with outbreaks is low, and some small outbreaks may not be recognized or may not be reported [66]. Also, the specific etiology of an outbreak is not always confirmed. However, outbreak data serve three important functions [67]. First, the investigation of foodborne disease outbreaks leads to changes that help prevent contamination at all levels of food production. Second, outbreak data provide information on the impact of specific pathogens and help investigators recognize emerging pathogens and ongoing problems. Third, analysis of data over time enables public health authorities to monitor trends, providing a basis for regulatory and other changes to improve food safety.

INFECTIOUS FOODBORNE DISEASE

The hallmark characteristics of an infectious food-related illness are gastrointestinal symptoms, most notably diarrhea, abdominal cramps, and vomiting. However, some individuals may be asymptomatic or only mildly ill. Approximately 36% of all cases of acute gastroenteritis are attributable to foodborne disease [36].

Foodborne diseases caused by bacteria and parasites are most often acquired by ingestion of food or water that has become colonized or contaminated. Viral pathogens capable of causing food-related illness do not replicate on foods; instead, their stable structure allows them to survive for prolonged periods in the environment and they are transmitted through the fecal-oral route. Such viruses replicate in the human intestinal tract, are shed through stool, and are transmitted to other humans through foods as a result of direct or indirect contamination with human feces [68]. Most infectious foodborne agents can also be spread through secondary and tertiary transmission [69]. These modes of transmission include droplet transmission (e.g., vomitus, respiratory secretions), vertical transmission (parent to child/fetus), and fomite contamination of objects.

INFECTIOUS AGENTS

Bacteria

Bacterial contamination of food can occur at any of a number of stages along the farm-to-table continuum: during growing, harvesting, processing, storing, shipping, or final preparation (in a restaurant or home). Most available information on the incidence of bacterial foodborne disease is derived from FoodNet surveillance of disease caused by the eight common foodborne bacterial pathogens [39]:

- *Salmonella*
- *Campylobacter*
- *Shigella*
- STEC O157
- STEC non-O157
- *Yersinia*
- *Listeria*
- *Vibrio*

Preliminary data indicate that in 2019, these bacteria were the cause of 25,111 cases of foodborne infections reported in FoodNet's 10 states (***Table 2***) [2]. One of the food safety objectives in Healthy People 2030 is to reduce the incidences of four bacterial infections—*Salmonella, Campylobacter*, STEC O157, and *Listeria* [2; 70]. In 2019, compared with the previous three years, the incidence of infections either increased for some pathogens (e.g., *Campylobacter, Cyclospora*, STEC, *Vibrio, Yersinia*)

LABORATORY-DIAGNOSED BACTERIAL AND PARASITIC FOODBORNE INFECTIONS IN 2019[a]		
Pathogen	**No. of Cases**	**Incidence per 100,000**
Campylobacter	9,731	19.5
Salmonella	8,556	17.1
Shigella	2,416	4,8
STEC O157	3,127	6.3
Cyclospora	755	1.5
Yersinia	681	1.4
Vibrio	466	0.9
Listeria	134	0.3
[a]According to preliminary FoodNet data. STEC = Shiga toxin-producing *Escherichia coli*.		
Source: [2]		*Table 2*

or remained unchanged (e.g., *Listeria, Salmonella, Shigella*) [2]. Infections caused by *Salmonella* serotypes Typhimurium and Heidelberg have decreased considerably over the past 10 years, in part due to the widespread practice of vaccinating chickens against *Typhimurium*. Despite these decreases, the overall incidence of *Salmonella* has not substantially declined in the past 15 years, as infections with other *Salmonella* serotypes (i.e., Javiana, Newport, Infantis) have increased [2].

Viruses

As discussed, while bacterial contamination of food can occur at several points, viral contamination usually occurs during food handling. Viruses may also be transmitted to humans through mollusks from contaminated waters [44; 68]. Produce can be a vehicle if exposed to contaminated water. The pathogenicity of viruses is enhanced by their capacity to withstand dehydration, low pH, and other adverse, environmental conditions [68]. They endure on human hands, in fresh and dried fecal matter, in water, and on nonbiologic surfaces (fomites) such as kitchen counters and carpets [71].

More than 100 types of enteric viruses cause food-related illness, but in the United States, three types of viruses are most common [71]:

- Noroviruses (and other caliciviruses)
- Hepatitis A virus
- Rotaviruses

Noroviruses and hepatitis A virus are the viruses most often transmitted through food [68]. Noroviruses are the most common cause of outbreaks of nonbacterial gastroenteritis; they accounted for 36% of outbreaks in 2016 [3].

Parasites

Parasitic infection can be spread through food or water but is more commonly transmitted through contaminated water [72]. Parasitic protozoa do not multiply in foods, but they are able to survive in or on moist foods for months in a cool, damp environment [72]. Four parasites present the greatest risk of foodborne illness: *Cryptosporidium, Cyclospora, Giardia*, and *Toxoplasma gondii* [72]. Infections caused by *Cryptosporidium* and *Cyclospora* are monitored through FoodNet.

RISK FACTORS FOR FOODBORNE INFECTIONS

Crowding and poor hygiene are risk factors for food-related infectious illness. This accounts for the high rates found among closed populations, such as childcare centers and healthcare facilities [38]. A review of 75 enteric outbreaks in long-term care facilities found that 52% of bacterial infections were transmitted through food [73]. Other common risk factors for exposure to foodborne pathogens include [17; 69]:

- Eating raw/undercooked meats or fish
- Ingesting raw/unpasteurized milk or dairy products
- Working with animals or animal products
- Traveling to developing countries
- Abusing drugs
- Having children in daycare or school

INDIVIDUAL SUSCEPTIBILITY TO INFECTION

The complexity of the host-pathogen relationship creates a spectrum of individual responses to foodborne agents; some people remain asymptomatic whereas others develop severe illness [74]. In addition, the incubation period (time from acquisition to onset of symptoms) varies in relation to pathogen and certain host factors, such as age and comorbidities. Several characteristics of a foodborne agent have major roles in susceptibility, including pathogenicity, antigenicity, infective dose, mechanisms of disease production, and exposure route [75]. However, host-associated variables predominantly dictate the occurrence and severity of disease [75]. Determinants of individual susceptibility to a foodborne illness include [69; 75]:

- Extremes of age (especially children younger than 4 years of age)
- Status of immune system at the time of exposure
- Underlying medical conditions (e.g., diabetes, human immunodeficiency virus/acquired immunodeficiency syndrome [HIV/AIDS], cancer, organ transplantation)
- Medications that alter normal flora (e.g., antimicrobial agents, corticosteroids, immunosuppressant drugs)
- Pregnancy
- Surgical procedures and radiation therapy
- Low gastric acidity

OUTBREAKS, INCIDENCE, AND MORTALITY

The incidences of specific foodborne pathogens vary according to the age of the patient, geographic location, the severity of illness caused, and susceptibility of common food sources to contamination by a given pathogen.

Bacterial Foodborne Outbreaks

The number of confirmed bacterial foodborne outbreaks fluctuates from year to year, showing an increase in the early 2000s followed by a decrease according to the most recent full report for 2017 [3]. In 2005, 188 outbreaks (4,348 illnesses) were reported. The number increased to 257 (6,410 illnesses) in 2007, then decreased to 841 outbreaks (14,481 illnesses) in 2017 (***Table 3***) [44; 3]. Bacteria were the confirmed cause of 20 deaths in 2017 [3].

FoodNet surveillance data show that the highest incidence of bacterial foodborne disease is found among children younger than 5 years of age, followed by children 5 to 9 years of age (***Table 4***) [76]. The most common causative pathogens in these two age groups are *Salmonella*, *Campylobacter*, and *Shigella* [76; 77]. Only *Vibrio* and *Listeria* infections occur more frequently in older individuals than in children. Among individuals 60 years of age or older, *Salmonella* and *Campylobacter* are the leading causes of bacterial foodborne infection [76].

FOODBORNE DISEASE OUTBREAKS FOR 2007 AND 2017		
Etiology	**2007**	**2017**
Bacterial		
Confirmed	257	198
Suspected	61	73
Viral		
Confirmed	199	148
Suspected	127	177
Parasitic		
Confirmed	5	11
Suspected	1	2
Chemical and Toxin[a]		
Confirmed	34	38
Suspected	15	2
Single Etiology		
Confirmed	495	395
Suspected	204	254
Multiple Etiologies		
Confirmed	12	6
Suspected	22	19
Unknown Etiology		
Total	362	0
All Known Outbreaks		
Total	1,097	841
[a]Agents causing outbreaks in the chemical category consisted primarily of marine toxins.		
Source: [3]		*Table 3*

Few studies have been conducted to evaluate differences in food-related illness according to race or ethnicity, but the available reports suggest that the rates of some bacterial infections are higher among black, Hispanic, and Asian populations than among the white population [79; 80; 81]. The infections occurring at higher rates are associated with food consumption habits specific to certain populations. For example, outbreaks of *Yersinia* have been associated with chitterlings (chitlins), a common food item in the black community, particularly in the South, and outbreaks of *Listeria* and *Salmonella* have been linked to Mexican-style cheeses and *carnitas*, respectively, in the Hispanic population [46; 80; 82]. These disparities call attention to the need for education on foodborne illnesses that is targeted to distinctive needs of specific populations.

The incidence of foodborne disease caused by bacterial pathogens also varies substantially according to geographic location. For example, the incidence of *Campylobacter* is more than three times higher in California (29.37 per 100,000) than in Maryland (8.34 per 100,000), while the incidence of *Shigella* ranges from 0.77 (per 100,000) in New York to 6.71 (per 100,000) in Georgia [76]. A survey of testing practices among laboratories in the FoodNet areas indicated that the regional differences in these incidences are not attributable to variations in stool culture practices [83].

Viral Foodborne Outbreaks

Viral pathogens, principally norovirus, are a leading cause of foodborne gastroenteritis outbreaks investigated since 2000. In 2016, a viral etiology was identified for 326 reported foodborne outbreaks affecting 6,406 persons [3]. In all but four of these outbreaks, the causative agent was a norovirus; hepatitis A accounted for 3 of the outbreaks [3]. More than two-thirds of outbreaks of norovirus are linked to restaurants [3].

Viral gastroenteritis is the leading cause of food-related illness in the United States [34]. The illness may be caused by a number of viruses, but noroviruses are the leading cause of illness from contaminated food or water [34]. More than 5 million cases of foodborne noroviruses are reported each year [34; 84].

Approximately 1,566 cases of hepatitis A infection each year are attributed to a food source [71]. Most individuals 18 years of age or older have lifelong protection against reinfection through immunity [34]. The percentage of adults with hepatitis A immunity increases with age, from 10% for individuals who are 18 to 19 years of age to 65% for individuals older than 50 years of age [34]. In 2016, the incidence of hepatitis A virus was highest in Hawaii (285 cases) and California (229 cases) and lowest in Wyoming (0 cases) [85].

INCIDENCE OF LABORATORY-CONFIRMED BACTERIAL AND PARASITIC FOODBORNE DISEASE ACCORDING TO AGE					
Pathogen	**Incidence (per 100,000)**				
	<5 years of age	**5 to 9 years of age**	**10 to 19 years of age**	**20 to 64 years of age**	**>65 years of age**
Bacteria					
Salmonella	63.5	19.3	11.3	12.2	17.2
Campylobacter	24.1	10.5	9.4	14.5	15.3
Shigella	16.9	14.8	2.9	3.1	1.4
STEC O157	4.7	2.3	1.7	0.6	0.7
STEC non-O157	4.8	1.3	1.7	0.7	0.9
Yersinia	1.3	0.3	0.2	0.2	0.5
Listeria	0.2	—	0.03	0.2	1.1
Vibrio	0.1	0.3	0.1	0.4	0.8
Parasites					
Cryptosporidium	3.7	3.1	1.7	2.5	3.0
Cyclospora	—	—	—	0.04	0.03
Source: [78]					*Table 4*

Rotavirus infection is the leading cause of severe acute diarrhea among infants and young children worldwide, but foodborne transmission represents only approximately 1% of cases [71; 86]. Prior to the introduction of a rotavirus vaccine in 2006, almost all U.S. children were infected with the virus before 5 years of age [86]. Rotavirus occurs primarily in the winter and spring [86]. In 2017 in California, the CDC examined three rotavirus outbreaks that resulted in mostly mild-to-moderate illness among vaccinated and unvaccinated children and adults. One unvaccinated child died [87].

Parasitic Foodborne Outbreaks

In the United States, parasites cause far fewer outbreaks or isolated incidences of foodborne infection than either bacteria or viruses. In 2017, a parasite was confirmed as the cause of 11 outbreaks (122 illnesses) [3]. *Cryptosporidium* is the leading cause of waterborne illness in the United States, and some years has been among the leading foodborne pathogens identified by the FoodNet program [2; 186]. The incidence of *Cryptosporidium* is highest among children younger than 5 years of age and children 5 to 9 years of age and is lowest among individuals 10 to 19 years of age [78]. Although the overall incidence of *Cyclospora* has been low, preliminary FoodNet data from 2019 reports an increased incidence of 1,209%. This is in part attributed to the increased use of culture-independent diagnostic tests [2]. The highest incidence is among individuals 60 years of age or older [78].

As with bacterial pathogens, the incidence of foodborne infection caused by *Cryptosporidium* and *Cyclospora* varies according to geographic location. In 2009, the incidence of *Cryptosporidium* ranged from 7.36 per 100,000 in New Mexico to 1.26 per 100,000 in Tennessee [76]. The incidence of *Cyclospora* was highest in Connecticut (0.51 per 100,000), and no cases were reported in California, Colorado, or Oregon [76].

The incidence of infection with *Giardia* attributable to a food or water source is not clear, but giardiasis is most frequently associated with consumption of contaminated water [34]. In general, the infection is more prevalent among children than adults, which may be related to the potential for immunity after infection [34]. The parasite is believed to affect approximately 22.5% of the U.S. population [34]. From 2005 to 2007, there were approximately 65 cases of foodborne outbreaks associated with *Giardia*-infected food [34]. *Toxoplasma gondii* has been found in nearly one-third of the worldwide population [88]. In the United States, the seroprevalence of toxoplasmosis has decreased among U.S.-born individuals (12 to 49 years of age) from 14.1% in 1988–1994 to 9% in 1999–2004 [89; 90]. The seroprevalence is higher in women of childbearing age (15 to 44 years of age), with a rate of 11% in 1999–2004 [89]. According to the CDC, *Toxoplasma gondii* is the second leading cause of foodborne illness-related deaths and hospitalizations in the United States, causing more than 300 deaths and 4,400 hospitalizations each year [34; 91]. *Toxoplasma gondii* also can lead to acute ocular disease, with an estimated 4,800 cases occurring each year [34].

Severity of Illness

Most foodborne infections result in self-limited illness that resolves within a few days to a week. Severity of illness caused by bacterial foodborne disease varies by etiology, as evidenced by hospitalization rates reported by FoodNet for 2016 (***Table 5***) [92]. The case-fatality rate also varies by pathogen; mortality rates in 2015 were 12.9% for *Listeria*, 2.6% for *Vibrio*, 0.4% for *Salmonella,* and 0.2% for *Campylobacter* [93]. Hospitalization and mortality rates are somewhat higher among persons older than 65 years of age, and the hospitalization rate for children younger than 5 years of age ranges from 11.3% for *Shigella* to 100% for *Listeria* foodborne infections [93].

According to statistics published in 1999, bacteria accounted for 72% of the deaths associated with foodborne disease; parasites accounted for 21%, and viruses for 7% [36]. In 2016, bacteria accounted for 81% of deaths associated with foodborne disease; parasites accounted for three deaths, and viruses accounted for none [92]. Since 1999, *Listeria* has been the pathogen most likely to cause death from food-related illness, with 20% to 30% of infections in high-risk individuals being fatal [94; 95].

HOSPITALIZATION RATES FOR INDIVIDUALS 50 YEARS OF AGE OR OLDER

Pathogen	Hospitalization Rate
Listeria	97%
Vibrio	28%
Yersinia	27%
STEC (all serogroups)	23%
Shigella	23%
Campylobacter	19%

Source: [92] *Table 5*

FOOD SOURCES

Pathogen-specific surveillance data define the scope of foodborne disease as a public health problem. However, effective prevention also requires up-to-date information on types of foods contributing to the problem, and the Interagency Food Safety Analytics Collaboration (IFSAC) is a tri-agency group created for this purpose. The IFSAC uses outbreak data from 1998 through the most recent year to derive an estimate of foodborne illness attributed to certain sources for four priority pathogens: *Salmonella*, *Escherichia coli* 0157, *Listeria*, and *Cambylobacter* [240]. According to the 2019 IFSAC report, more than 75% of *Salmonella* illnesses were attributed to seven food categories: chicken, fruits, pork, seeded vegetables (e.g., tomatoes), other produce, turkey, and eggs. *E. coli* 0157 illnesses were most often linked to leafy green vegetables and beef, and *Listeria* illnesses were linked to dairy products and fruits. More than 80% of *Campylobacter* illnesses were attributed to either dairy products (principally unpasteurized milk) or chicken (principally chicken liver products) [240].

PATHOGENS MOST COMMONLY ASSOCIATED WITH SPECIFIC FOOD SOURCES	
Food Source	**Pathogens**
Beef	*Escherichia coli* *Salmonella*
Poultry	*Salmonella* *Campylobacter jejuni*
Pork	*Yersinia* *Toxoplasma gondii*
Meat products, gravies	*Clostridium perfringens* *Bacillus cereus* (diarrheal type)
Raw (unpasteurized) milk and dairy products (soft cheeses)	*Listeria* *Salmonella* *Shigella* *Campylobacter jejuni* *Yersinia* *Bacillus cereus* (diarrheal type) *Brucella*
Raw and undercooked eggs	*Salmonella*
Improperly canned goods; smoked or salted fish	*Clostridium botulinum*
Fresh or minimally processed produce (vegetables, fruit)	*Escherichia coli* *Listeria* *Salmonella* *Shigella* *Yersinia* *Bacillus cereus* (diarrheal) Hepatitis A virus *Cryptosporidium* *Cyclospora* *Giardia*
Shellfish (raw or undercooked)	*Vibrio* *Yersinia* Norovirus Hepatitis A virus
Processed meats	*Salmonella* *Staphylococcus aureus* *Escherichia coli* (dry-cured salami) Hepatitis A virus
Rice products and other starchy foods, including potato, pasta, and cheese products	*Bacillus cereus* (emetic type)
Prepared salads (potato, tuna, macaroni, chicken) and sandwiches	*Shigella* Norovirus Hepatitis A virus *Giardia*
Puddings, custards, pastries	*Staphylococcus aureus* *Bacillus cereus* (emetic type)
Fruit juices (unpasteurized)	*Salmonella* *Escherichia coli* Hepatitis A virus
Source: [34; 96; 97]	*Table 6*

The pathogens associated most commonly with specific food sources are outlined in ***Table 6***. Food sources become contaminated with pathogens in a variety of ways. Raw foods and beverages pose the greatest risk because they have not been processed, cooked, or refrigerated/frozen, all of which reduce or destroy most pathogens. Produce (fruits and vegetables) may become contaminated in the field if soil or water is contaminated, leading to the growth of a variety of pathogens, such as *Salmonella*, STEC O157, *Cyclospora*, and hepatitis A [34]. If not pasteurized, milk or fruit juices may become the source for a variety of bacteria, most notably *Listeria* and *Salmonella*. Some pathogens, such as *Campylobacter*, *E. coli*, *Toxoplasma gondii*, and *Yersinia*, live in the intestinal tracts of animals, contaminating raw meat and poultry; this contamination can spread to other animals during slaughter. Eggs may become contaminated with *Salmonella* through infection of hens' ovaries.

Freezing meat and poultry impedes bacterial replication, and cooking at an appropriate temperature serves to destroy remaining pathogens. Bacteria and parasites will not be destroyed unless the food is thoroughly cooked (at an appropriate cooking temperature and for an appropriate duration). Food may become contaminated again if left at room temperature for more than two hours [96]. Contamination may also occur during food preparation in a restaurant or a home kitchen through handling by an infected person or through exposure to contaminated surfaces or equipment. Norovirus is the pathogen most commonly transmitted through an intermediary food handler. *Staphylococcus aureus* and *Cryptosporidium* are also transmitted more often through an infected food handler than through direct contamination of a food product [34; 96]. Rotavirus has not been isolated from any food associated with an outbreak [34].

The source of a food-related illness cannot always be identified; approximately 56% of cases have no known cause [66; 67]. In 2015, an identifiable food source accounted for approximately 46% of outbreaks of known etiology [44]. The number of outbreaks and infected individuals associated with

a food source varies over time. In 2008, poultry was the most common source, associated with 32 outbreaks; in 2015, fish was the leading source, associated with 222 outbreaks [44; 66; 67]. The highest number of foodborne infections was associated with exposure to vegetables (1,596) in 2002, to poultry (1,355) in 2006, to fruits and nuts (1,755) in 2008, and to chicken (3,114) in 2009–2015 [66; 67]. Analysis of data from 2016 demonstrated that the top six pathogen-food source pairs representing the most outbreaks/illnesses were [92]:

- Scombroid or ciguatoxin in fish (23 outbreaks, 68 illnesses)
- *Salmonella* in chicken (8 outbreaks, 307illnesses)
- *Campylobacter* in dairy (7 outbreaks, 57 illnesses)
- Norovirus in mollusks (6 outbreaks, 209 illnesses)
- *Salmonella* in pork (6 outbreaks, 96 illnesses)
- *Vibrio parahaemolyticus* in mollusks (6 outbreaks, 19 illnesses)

NONINFECTIOUS FOODBORNE DISEASE

Heavy metals and natural toxins are the primary causes of noninfectious food-related illness [47; 98]. Heavy metals, such as iron, lead, copper, and zinc, are primarily ingested through water contaminated by pipes or containers [98; 99; 100]. Food vessels, utensils, or containers are potential sources for ingestion of antimony, copper, and tin [21; 98; 100]. Water, soil, or food (including shellfish and finfish) may also be contaminated with arsenic, and fish and other seafood may be contaminated with methyl mercury [98; 101]. Foodborne illness caused by heavy metals is extremely rare. One outbreak was reported in 2007, two outbreaks were reported in 2008, and none were reported in 2013 [44; 66].

SOURCES OF MARINE TOXINS

Toxin	Fish
Ciguatoxin	Grouper, snapper, amberjack, mackerel, triggerfish, barracuda
Tetrodotoxin	Pufferfish
Scombroid	Tuna, mahi mahi, bluefish, sardines, mackerel, amberjack, abalone
Shellfish Toxins	
Paralytic	Mussels, clams, cockles, scallops
Diarrhetic	Mussels, oysters, scallops, clams
Neurotoxic	Shellfish harvested along the Florida coast and the Gulf of Mexico
Amnesic	Bivalve mollusks, crabs, lobsters

Source: [34] *Table 7*

Naturally occurring toxic agents, principally marine and mushroom toxins, account for the great majority of noninfectious foodborne disease. Marine toxins include ciguatoxin, pufferfish toxin (tetrodotoxin), scombroid, and shellfish toxins. The sources of these toxins differ (***Table 7***) [34]. The CDC estimates that 34 cases of poisoning with marine toxins are reported each year in the United States and that four people die from such poisoning every year [102]. The frequency of illness caused by marine toxins is not well defined for several reasons: underreporting (related primarily to the lack of a reporting requirement), the generally mild nature and short duration of the disease, and the paucity of medical information on the toxins [34]. However, illness caused by marine toxins can be severe and carries an annual healthcare cost burden in the United States of approximately $350 million [103].

Mushroom toxins are found in several species of wild mushrooms, and poisoning occurs when the toxic mushrooms are misidentified as edible. Poisonous species of mushrooms grow in a range of habitats, from deep woods to suburban yards [34]. The frequency of mushroom poisoning is difficult to determine, but the number of reported cases is low, cases are sporadic, and large outbreaks are rare [34].

FOUR DIAGNOSTIC CLUES TO DETERMINE THE ETIOLOGY OF A FOODBORNE ILLNESS	
Diagnostic Clue	**Likely Etiology**
Incubation Period (Time to Onset of Symptoms)	
Very short (hours)	Toxin
Approximately one day	Virus
Several days	Bacteria
Duration of Illness	
Short	Virus or toxin
Long	Bacteria
Predominant Clinical Symptoms	
Diarrhea	Virus or bacteria
Vomiting	Toxin
Severe illness	Bacteria
Population Involved in the Outbreak	
Closed population (school, healthcare facility)	Virus
Large catered event	Toxin or virus
Source: [21]	*Table 8*

DIAGNOSIS AND MANAGEMENT OF FOODBORNE DISEASE

Accurate and efficient diagnosis and management is essential for minimizing the spread of a foodborne disease. In addition, rapid identification of a causative agent can help to control an outbreak. Diagnosis requires a comprehensive approach that includes a detailed clinical evaluation with attention to any history of suspect food exposures and appropriate cultures to identify the etiologic agent. Four clues can help in determining the etiology of a foodborne illness: period of incubation, duration of illness, predominant clinical symptoms, and the location of the individual or the ingested food (***Table 8***) [21].

The diagnosis and management of a food-related illness is challenged by several factors [17; 69; 104]:

- Many symptoms are common among foodborne illnesses that require disparate treatments.
- The cost of ordering multiple diagnostic laboratory tests is high.
- Empirical treatments can lead to serious complications, secondary transmission, and emergence of drug-resistant pathogens.

Diarrhea is the symptom that prompts many individuals to seek medical attention. It is important to distinguish between inflammatory and noninflammatory diarrhea, as the pathogens for these two types differ. With inflammatory diarrhea, mucosal invasion, usually of the large intestine, causes stools to be bloody and often to contain many fecal leukocytes [21]. Inflammatory diarrhea is usually associated with fever, abdominal pain and tenderness, headache, nausea, vomiting, malaise, and myalgia. In contrast, noninflammatory diarrhea involves watery stool, which is sometimes severe, and fever and systemic symptoms are often absent. Such diarrhea is caused by mucosal hypersecretion or decreased absorption without mucosal destruction and usually involves the small intestine. Mild dehydration is typical, although severe dehydration may be present in children or individuals older than 65 years of age [21].

Evidence-based recommendations for the diagnosis and management of food-related illness have been established in a primer developed collaboratively by the American Medical Association (AMA), the CDC, the American Nurses Association (ANA), the FDA, and the USDA [21]. In addition, recognizing the increasing number of enteric pathogens associated with foodborne disease (and other gastrointestinal illnesses), the Infectious Diseases Society of America established practice guidelines for the management of infectious diarrhea [17]. These guidelines include five evidence-based recommendations [17]:

- Carry out clinical, demographic, and epidemiologic evaluation
- Order microbiologic testing, as appropriate
- Begin rehydration therapy
- Treat severe disease empirically, when appropriate
- Educate the patient about preventing secondary transmission

QUESTIONS TO ASK PATIENTS TO HELP DETERMINE WHETHER ILLNESS IS OF FOODBORNE ETIOLOGY	
Domain	**Suggested Questions**
Travel	Have you traveled recently? If so, where (foreign country, coastal area, mountains, cruise)?
Work/activities	Where do you work? Have you spent time recently at a childcare center? Dormitory? Farm? Petting zoo? Have you had contact with animals recently? If so, what kind? Have you recently spent time as an inpatient in a hospital, rehabilitation facility, or long-term care institution?
Eating habits	Have you recently eaten raw/undercooked food? Eggs? Soft cheeses? Shellfish or finfish? Fresh produce? Wild mushrooms? Have you consumed raw/unpasteurized milk? Did you drink water from an unknown source? Have you eaten home-canned foods? Have you eaten food that had a bitter or metallic taste, abnormal smell, unusual appearance? Have you eaten at a buffet? At a banquet? At a picnic? Do you know how the food you've eaten recently was prepared?
Symptom characteristics	When did your symptoms first occur, especially in relation to foods you've eaten? What was your first symptom? Did symptoms begin abruptly or develop gradually? How long have you had your symptoms? What are your stools like in terms of frequency, quantity, and characteristics (bloody, watery, febrile, mucoid, purulent)?
Other	Do any family members, friends, coworkers, or classmates have similar symptoms? Do you have a history of drug use? If so, what prescription and/or illicit drugs have you taken recently? What do you think caused the illness?
Source: Compiled by Author	*Table 9*

In addition to clinical evaluation, diagnosis, and treatment of the patient, suspected or confirmed cases of foodborne disease should be reported to local health departments so that a possible association with similar cases may be identified.

Most food-related illnesses are self-limited and require supportive care only (i.e., rest, rehydration). The routine use of antidiarrheal agents is not recommended, especially in infants and young children, as many agents have the potential for causing serious adverse effects [21]. Healthcare practitioners should ensure that patients understand the importance of checking with the practitioner before using an antidiarrheal.

CLINICAL/EPIDEMIOLOGIC EVALUATION

The clinical presentation of a foodborne disease is often nonspecific and similar to that of viral syndromes unrelated to food exposure. Common clinical manifestations of foodborne infection are diarrhea, nausea, vomiting, and abdominal discomfort in some combination. Fever, if present, is usually low-grade, and other signs of systemic infection are absent. Non-gastrointestinal symptoms may predominate in less common foodborne diseases, such as ciguatera fish poisoning, scombroid, and botulism. The presence of muscle aches or joint pain makes a viral syndrome more likely, but care should be taken to distinguish such symptoms from neurologic symptoms (e.g., weakness, paresthesias) that may be signs of food-related illnesses that target the neurologic system [21].

DIFFERENTIAL DIAGNOSIS OF FOODBORNE ILLNESSES ACCORDING TO SYMPTOMS ON CLINICAL PRESENTATION	
Symptom	**Possible Diagnosis**
Gastroenteritis, with vomiting as primary symptom (fever and/or diarrhea may also be present)	Viral gastroenteritis (rotavirus in infants and calicivirus in older children and adults) Food poisoning with *Bacillus cereus* or *Staphylococcus aureus* Ingestion of heavy metal
Noninflammatory diarrhea (acute watery diarrhea, usually without fever)	Can be caused by virtually all enteric pathogens (bacterial, viral, parasitic) but is a classic symptom of: Enterotoxigenic *Escherichia coli* (traveler's diarrhea) *Giardia* *Vibrio cholerae* Enteric virus *Cryptosporidium* *Cyclospora cayetanensis*
Inflammatory diarrhea (grossly bloody stool, fever, invasive gastroenteritis)	*Shigella* *Campylobacter* *Salmonella* Enteroinvasive *Escherichia coli* STECs (O157 and non-O157) *Vibrio parahaemolyticus* *Yersinia enterocolitica*
Persistent diarrhea (14 days or more)	*Cyclospora cayetanensis* *Cryptosporidium* *Giardia*
Neurologic symptoms (paresthesias, respiratory depression, bronchospasm, cranial nerve palsies)	*Clostridium botulinum* (botulism) Marine toxins Mushroom toxin Guillain-Barré syndrome (associated with infectious diarrhea due to *Campylobacter jejuni*)
Systemic illness (fever, weakness, arthritis, jaundice)	*Listeria monocytogenes* *Brucella* *Toxoplasma gondii* *Vibrio vulnificus* Hepatitis A virus
Source: [21]	*Table 10*

A clinical/epidemiologic evaluation of the patient is essential, and a directed history regarding travel, recent food exposures, and other illness among family and associates can help healthcare practitioners identify an illness as having a foodborne pathogen etiology (***Table 9***). A complete description of the patient's symptoms is an important key to diagnosis, and the healthcare practitioner should ask the patient to describe predominant symptoms as well as mild ones. The type of symptoms can help narrow the list of potential pathogens (***Table 10***) [21]. Noninfectious causative agents should be suspected for patients with nondescript gastrointestinal symptoms who became ill less than 12 hours after ingestion, especially if the onset of symptoms is within minutes after ingestion [21; 32; 105].

In addition, the patient's medical history or health record should be reviewed for underlying medical conditions and prescription medication use. Gastrointestinal symptoms may be related to a host of other conditions, such as irritable bowel syndrome, inflammatory bowel diseases, gastrointestinal surgery, malabsorption syndromes, and malignant disease, or as a side effect of antibiotics or other medications [21]. Particular attention should be paid to medical conditions that may increase the risk or severity of a foodborne illness.

EVIDENCE-BASED PRACTICE RECOMMENDATION

When determining a differential diagnosis of foodborne illnesses, the Centers for Disease Control and Prevention (CDC), the American Medical Association (AMA), the American Nurses Association (ANA), and others recommend that, in addition to underlying medical conditions, consideration also should be given to exogenous factors such as the association of the illness with travel, occupation, emotional stress, sexual practices, exposure to other ill persons, recent hospitalization, child care center attendance, and nursing home residence.

(https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm. Last accessed January 26, 2022.)

Level of Evidence: Expert Opinion/Consensus Statement

Careful clinical evaluation of the patient is necessary, and the patient should be examined for signs of fever and abdominal tenderness and for indications of volume depletion, such as decreased skin turgor, thirst, reduced urination, tachycardia, orthostatic pulse, and dry mucous membranes.

Because specific details about the patient's history are crucial to diagnosing a foodborne illness, effective communication is required. Communicating effectively is more challenging when the patient's primary language differs from that of the practitioner. According to the U.S. Census Bureau, more than 64 million Americans speak a language other than English at home, and more than 25 million (8.5% of the total population) have limited English proficiency; that is, they speak English less than "very well" [106]. It has been suggested that when patients are first evaluated, they should be asked what language is spoken at home and if they speak English "very well" [107]. In addition, patients should also be asked what language they prefer for their medical care information, as some patients prefer their native language even though they have said they can understand and discuss symptoms in English [107]. Many studies have demonstrated that the lack of an interpreter for patients with limited English proficiency compromises the quality of care and that the use of professional interpreters improves communication (errors and comprehension), utilization, clinical outcomes, and patient satisfaction with care [108; 109].

"Ad hoc" interpreters (untrained staff members, family members, friends) are often used instead of professional interpreters for a variety of reasons, including convenience and cost. However, the reliability and specificity of information obtained through ad hoc interpreters is less than with professional interpreters [110]. In addition, individuals with limited English language skills have indicated a preference for professional interpreters rather than family members [111]. A systematic review of the literature has shown that the use of professional interpreters facilitates a broader understanding and leads to better clinical care than the use of ad hoc interpreters [109].

MICROBIOLOGIC TESTING

The results of physician surveys have indicated a wide variation in practice with respect to requesting a stool culture from patients with acute diarrhea. The percentage of respondents who say they request this culture ranges from 38% to 71% [25; 112; 113]. Microbiologic studies should be done on the basis of the results of the clinical evaluation. In particular, testing of stool samples should be done if diarrhea has lasted more than 1 day or if any of the following signs and symptoms occur [21]:

- Bloody diarrhea
- Weight loss
- Diarrhea leading to dehydration
- Fever
- Prolonged diarrhea (three or more unformed stools per day for several days)
- Neurologic involvement (paresthesias, motor weakness, cranial nerve palsies)
- Sudden onset of nausea, vomiting, and/or diarrhea
- Severe abdominal pain

To better prevent and manage potential outbreaks, fecal studies are also recommended when the patient is a food handler, has contact with a childcare facility or other closed populations, has a compromised immune system, has traveled to a developing country, was recently hospitalized, or has recently taken antibiotics [21]. The appropriate fecal studies depend on the clinical presentation.

Routine stool culture examinations vary according to the particular suspected pathogens, and practitioners should be aware of pathogens that must be specifically requested. Many physicians surveyed have said they do not know whether stool culture examination includes testing for some specific species (e.g., *Yersinia*, *Vibrio*, STEC O157) [112]. A routine stool culture usually includes screening for *Salmonella* and *Shigella* species and *Campylobacter jejuni* or *coli* [21]. As such, if *Vibrio*, *Yersinia*, STEC O157, or *Campylobacter* species other than *jejuni/coli* is suspected, the practitioner should communicate this to, and consult with, the receiving clinical microbiology laboratory.

Testing for norovirus and rotavirus is not typically done, but the viruses can be detected in stool specimens, if necessary. Hepatitis A virus is confirmed through serologic testing.

Stool specimens should be examined for parasites if a patient has a travel history that suggests parasitic infection, when diarrhea has been chronic or persistent, when diarrhea has not responded to appropriate antimicrobial therapy, and when the incubation period for the diarrhea/illness has been long [21]. Usually, a request for an ova and parasite examination of a stool specimen allows for the identification of *Giardia lamblia*, whereas examination for *Cryptosporidium*, *Cyclospora cayetanensis*, and *Toxoplasma gondii* must be requested specifically. Because routine procedures for parasite detection vary among laboratories, it is helpful to contact the testing laboratory to confirm the appropriate procedures according to the parasites suspected.

Some bacteria, viruses, and parasites can be identified rapidly with direct antigen detection tests and molecular biology techniques. In some cases, vomitus or food samples should be submitted to the laboratory for testing [21]. Other diagnostic evaluations, such as serum chemistry analysis, urinalysis, complete blood cell count, blood culture, abdominal radiograph, and flexible endoscopy may also be considered when appropriate [17; 21]. Consultation with an infectious disease specialist, a clinical microbiologist, or a state public health official can be beneficial in some cases.

If microbiologic testing identifies the causative pathogen as a nationally notifiable disease, the healthcare practitioner should report the illness promptly [114]. Reporting requirements for each state or territory are available on the Council of State and Territorial Epidemiologists website. Practitioners should also report suspected outbreaks to the local or state health department.

All public health laboratories have resources to serotype *Salmonella* and *Shigella* and subtype *Listeria* and STEC isolates using pulsed-field gel electrophoresis, which helps to determine antimicrobial susceptibility [17]. The use of specialized laboratories for diagnostic needs is arranged through the state health department [69].

CLINICAL MANAGEMENT ISSUES

Rehydration Therapy

Diarrhea and vomiting can lead to intravascular volume depletion, dehydration, and electrolyte imbalance. Oral rehydration should be started for patients who have mild or moderate fluid losses. An oral rehydration solution should be used rather than a sports drink, which does not replace fluid and sodium losses correctly. Intravenous therapy should be used for severe dehydration and for debilitated patients. Studies have indicated that for children with mild-to-moderate volume depletion caused by gastroenteritis, oral rehydration is as effective as intravenous therapy [115]. For young children (i.e., 5 to 33 months of age), rice-based oral fluid therapy plus recombinant human lactoferrin and

lysozyme has been shown to reduce the duration of diarrhea better than reduced-osmolarity oral hydration therapy [116].

Empirical Antimicrobial Therapy

The use of antimicrobial therapy should be limited, as antibiotic resistance has increased for many enteric pathogens [21]. Empirical antimicrobial therapy is usually reserved for patients with severe illness. Antibiotics should not be administered to reduce secondary transmission risk.

The decision to treat and selection of antimicrobial therapy should be based on clinical considerations and epidemiologic clues or positive identification of the causative pathogen, such as [21]:

- Clinical signs and symptoms
- Organism detected in clinical specimens
- Antimicrobial susceptibility tests

The antimicrobial selection for specific foodborne infections will be discussed in detail later in the course.

Education about Secondary Transmission

Healthcare practitioners should educate the patient or parents about what actions he or she should take to prevent secondary transmission, emphasizing the importance of appropriate hand hygiene, the use of disinfectant cleaner to wash surfaces, and the need to remain out of work, school, or daycare until symptoms have resolved. Many educational resources are available, and efforts should be made to provide resources that are language and culture appropriate.

REPORTING OF FOODBORNE DISEASE

Because healthcare professionals are often the first to identify foodborne illnesses, they are the frontline protection for the public against many foodborne disease outbreaks [21]. Prompt and accurate disease reporting to the local or state health department is necessary for the prevention and control of outbreaks as well as for accurate surveillance [17; 21]. Healthcare practitioners should be familiar with the list of nationally notifiable diseases and check with the CDC for the most recent list, as it is updated annually [114].

The CDC recommends that suspected foodborne-illness outbreaks or sporadic illnesses that may be caused by a nationally notifiable disease should be reported as soon as possible [21]. Because early intervention is crucial, definitive diagnoses are unnecessary [17; 21]. Links to state health department websites, which include contact information for local health departments, are available on the CDC website. When reporting, the practitioner should provide the following information to the local or state health department [117; 118]:

- Date of illness(es)
- Age, sex, and full residence address and phone number for patient(s)
- Symptom complexes (especially unusual symptoms)
- Disease patterns

Local or state health departments may communicate additional requests or requirements to practitioners under their jurisdiction.

Many practitioners leave the reporting responsibilities up to the clinical laboratory [117; 118]. However, the practitioner should report the illness because he or she is the one who is uniquely able to describe symptomatic clusters and communicate other specific information [117]. Practitioner failure to report foodborne illnesses has led to missed opportunities for the implementation of early prevention measures and postexposure prophylaxis [117].

BACTERIAL FOODBORNE PATHOGENS

Misdiagnosing a foodborne illness or beginning empirical treatment to which the responsible pathogen is resistant may prolong illness and lead to complications. Thus, it is important for healthcare practitioners to be familiar with key characteristics of the most common foodborne pathogens and toxins.

TOP 10 *SALMONELLA* SEROTYPES IN THE UNITED STATES IN 2016		
Serotype	**No. of Cases**	**Percent of Reported Infections**
Enteritidis	7,830	16.8%
Newport	4,728	10.1%
Typhimurium	4,581	9.8%
Javiana	2,719	5.8%
I 4,[5],12:i:-	2,179	4.7%
Infantis	1,281	2.7%
Muenchen	1,216	2.6%
Montevideo	1,018	2.2%
Braenderup	1,001	2.1%
Thompson	792	1.7%
Saintpaul	778	1.7%
Source: [120]		*Table 11*

The bacterial foodborne pathogens discussed in this section include the 10 agents tracked by FoodNet as well as other bacteria that are significant because of either the incidence or severity of disease they cause.

SALMONELLA

Salmonella are rod-shaped, non-spore-forming, gram-negative enterobacteria that have become the most common bacterial cause of foodborne illness in the United States [2; 39; 44; 76]. One serotype, *Salmonella typhi*, causes systemic infections and typhoid fever; many other serotypes cause gastroenteritis and are referred to as nontyphoid *Salmonella* [119]. Typhoid (or enteric) fever is rare in the United States. Of the more than 6,371 isolate serotypes of *Salmonella*, 10 are responsible for most cases (87%) of *Salmonella* infection in the United States (***Table 11***) [120]. As few as 200 cells may cause infection [119].

National *Salmonella* surveillance systems from France, England and Wales, Denmark, and the United States have identified the emergence of multidrug-resistant isolates of *Salmonella enterica* (serotype Kentucky) with a demonstrated high-level resistance to ciprofloxacin [121]. Between 2000 and 2008, 679 *S. enterica* serotype Kentucky isolates were reported to the CDC. Poultry flocks have been identified as the primary vector. Samples of spices imported from North Africa are also being investigated [122].

Epidemiology

Salmonella infection, or salmonellosis, is the leading cause of bacterial foodborne disease. According to preliminary FoodNet data for 2019, the incidence was 17.1 per 100,000 [2]. Compared with 2016–2018, the 2019 incidence was significantly lower for *Salmonella* serotype Typhimurium. While overall the rate of foodborne salmonellosis has not declined in recent years, a decline in the incidence of serotypes Typhimurium and Heidelberg have been observed [2]. *Salmonella* remains the second most common cause of outbreak-related foodborne illness, accounting for 113 outbreaks (29% of single-pathogen outbreaks) in 2017 [3].

The highest incidence of salmonellosis occurs among children, with a rate of approximately 110.0 cases per 100,000 in children younger than 1 year of age [76]. However, the population affected can vary according to the food source of infection; the 2008 *Salmonella* (Saintpaul) outbreak caused by contaminated Mexican peppers primarily affected adults 20 to 29 years of age [44]. The incidence of *Salmonella* infection is highest in the summer and fall [76; 123].

Contamination and Transmission

Transmission of *Salmonella* is generally animal-to-human, caused by human ingestion of food that has been exposed to the gastrointestinal systems or fecal matter of animals (e.g., birds, reptiles, mammals) or contact with pet reptiles (especially turtles), baby chicks, and ducklings [69]. Contaminated foods are typically eggs and raw/processed meats [69]. Although modern disinfection practices render eggshell contamination rare, egg yolks may harbor *Salmonella* from the ovaries of infected hens [124]. In the northeastern United States, one in 10,000 eggs is contaminated [124]. Raw fruits and vegetables (e.g., cantaloupe, tomatoes, alfalfa sprouts) are usually externally contaminated, although *Salmonella* can infect the inside of a growing fruit or vegetable [69].

Clinical Presentation and Disease Course

The onset of symptoms is usually 1 to 3 days after ingestion of contaminated food [21]. Salmonellosis is characterized by diarrhea, abdominal cramps, vomiting, and nausea that typically lasts 4 to 7 days [21; 69]. Some individuals with infection may be asymptomatic, and others may present with colitis, bacteremia (sustained or intermittent), and/or focal infections (e.g., meningitis, osteomyelitis) [69].

Diagnostic Testing and Treatment

Salmonella infection is diagnosed with a routine stool culture and is a nationally notifiable disease [21]. Antimicrobial treatment is avoided in the usual case of gastrointestinal salmonellosis, as this often leads to antimicrobial resistance and prolongs the carrier state. If the patient is at increased risk for the invasive form of the disease (i.e., not isolated to the gastrointestinal tract), antimicrobial agents such as fluoroquinolones or expanded-spectrum cephalosporins are suggested [17]. In addition, ampicillin, gentamicin, and trimethoprim-sulfamethoxazole (TMP-SMX) have been effective [21; 69].

The use of fluoroquinolones is not recommended for children if safe and effective alternatives are available; physicians should weigh the benefits of therapy against potential adverse musculoskeletal events, such as tendinitis and tendon rupture [17; 69]. In July 2008, the FDA requested the addition of a boxed warning to fluoroquinolone prescribing information emphasizing these risks [125].

CAMPYLOBACTER JEJUNI

Campylobacter jejuni is a spiraled, motile, thermophilic, gram-negative rod considered unique among other foodborne pathogens because of its microaerophilic growth needs (i.e., 5% O_2, 10% CO_2) [69; 74]. *Campylobacter jejuni* are more sensitive to low pH, heat, and arid conditions than other common foodborne pathogens [126]. The infective dose is 400 cells [34].

Epidemiology

Campylobacter infection, campylobacteriosis, is the leading cause of infectious foodborne illness in the United States, with an incidence of 19.5 cases per 100,000 each year [2]. Compared with 2016–2018, the incidence of reported *Campylobacter* foodborne infections increased 13% in 2018 [2]. Most cases of campylobacteriosis are sporadic and not associated with an outbreak. However, in 2017, 23 outbreaks were reported (17 confirmed and 6 suspected), affecting 147 individuals [3]. In 2012, a multistate outbreak of *Campylobacter* infections resulting in 147 illnesses was associated with ingestion of unpasteurized milk. The common source traced to a single dairy holding a permit to produce unpasteurized milk [127]. In 2016, 7 outbreaks of *Campylobacter* infection from dairy products resulted in 57 illnesses and 5 hospitalizations [3].

Contamination and Transmission

Campylobacter is associated with poultry, livestock, flies on farms, wild and caged animals, and pets [35; 128]. Most cases of foodborne *Campylobacter* infection are caused by the consumption of undercooked poultry or from cross-contamination of other foods by these items. Outbreaks are most often associated with unpasteurized dairy products, poultry, and produce irrigated with contaminated water [35; 127].

Clinical Presentation and Disease Course

Symptoms usually occur 2 to 5 days after consumption of contaminated food [21]. The classic symptoms of campylobacteriosis are similar to those associated with acute appendicitis. Symptoms include so-called sticky diarrhea with blood/fecal leukocytes, abdominal pain, fever, nausea, and muscular pain; vomiting is rare [21; 69]. Symptoms generally last for 2 to 10 days [21].

Acute *Campylobacter* infection may cause intestinal hemorrhage, toxic colitis, meningitis, bacteremia, and HUS [69]. HUS is characterized by renal impairment, microangiopathic hemolytic anemia, and thrombocytopenia and most frequently affects children with campylobacteriosis [34; 69]. Other potential long-term complications of campylo-

bacteriosis include reactive arthritis (1% to 7%), irritable bowel syndrome (25%), and Guillain-Barré syndrome (0.1%) [69; 129; 130]. The mortality rate associated with campylobacteriosis is 0.1% [34].

Diagnostic Testing and Treatment

Most clinical laboratories can isolate *Campylobacter* spp. on request. Treatment is recommended only for severe cases of *Campylobacter* infection or for individuals who have a compromised immune system. When antimicrobial therapy is warranted, macrolides, such as erythromycin, or fluoroquinolones are the preferred drugs; however, resistance to these agents has increased with the use of antibiotics in chickens (as therapeutic agents or growth promoters) [17; 131]. In general, *Campylobacter* is susceptible to chloramphenicol and clindamycin [131].

SHIGELLA SPP.

Shigella spp. are highly infectious, gram-negative, non-spore-forming, facultative anaerobes [34]. Unlike pathogenic *Salmonella* and *Campylobacter*, *Shigella* is nonmotile [34]. Four species (with more than 40 serotypes) have been identified: *Shigella dysenteriae*, *Shigella flexneri*, *Shigella boydii*, and *Shigella sonnei* [69]. These species are also known as groups A, B, C, and D, respectively [74]. Because *Shigella* is enteroinvasive in the large intestine, it is commonly mistaken for an enteroinvasive *E. coli* [74]. As few as 10 organisms has caused disease in 10%, and fewer than 500 organisms have routinely been associated with outbreaks [132].

Epidemiology

According to preliminary data from 2019, *Shigella* is the fourth leading cause of foodborne illness in the United States, with an incidence of 4.8 per 100,000 [2]. The most prevalent pathogenic species is *Shigella sonnei*, which has been isolated in 75% to 80% of *Shigella* infections [133; 134; 135]. Outbreaks may continue for months in closed populations [136]. The other *Shigella* spp. isolated in association with outbreaks are *Shigella flexneri* (18%), *Shigella boydii* (1%), and *Shigella dysenteriae* (<1%) [134]. In 2017, *Shigella* accounted for 4 reported outbreaks, 54 illnesses, and 10 hospitalizations [3].

Contamination and Transmission

Typically, only primates harbor *Shigella* [34; 69]. The pathogen is transmitted via the fecal-oral route through person-to-person contact, ingestion of contaminated food/water, and fomite contamination [34; 69]. Because incidence rates peak in the late summer, the most common routes of *Shigella* exposure may differ from *Salmonella* and *Campylobacter* [123].

Clinical Presentation and Disease Course

Shigellosis manifests as diarrhea (usually mucoid, possibly bloody), which may be accompanied by abdominal cramps/pain, fever, and tenesmus; symptoms usually occur within 8 to 48 hours after ingestion of the contaminated food and last 4 to 7 days [21; 34]. Symptoms vary by *Shigella* species. For example, *Shigella flexneri*, *Shigella boydii*, and *Shigella dysenteriae* typically present with bloody diarrhea and severe systemic symptoms, whereas *Shigella sonnei* typically causes watery stools [69].

As with STECs, *Shigella dysenteriae* type I produces Shiga toxins, which cause HUS [34; 69]. However, the development of HUS is delayed with *Shigella dysenteriae*, with a median of 7 days from the onset of *Shigella*-induced diarrhea to the development of HUS, compared with the typical 4 days for HUS caused by STEC infections [34; 137].

Reactive arthritis will develop in approximately 2% to 7% of individuals with shigellosis, and Reiter syndrome will develop in 3% [74; 138]. The mortality rate associated with the infection is less than 1% in the United States [76; 139].

Diagnostic Testing

Stool samples or rectal swabs should be obtained during the acute phase of the disease and cultured for *Shigella* [69]. Blood samples should be examined for signs of bacteremia in patients who are severely ill, are malnourished, or have a compromised immune system [69]. *Shigella* infection is a nationally notifiable disease.

Shigella dysenteriae type I Shiga toxins are often identified with use of enzyme-linked immunosorbent assays [69]. *Shigella*-induced neutrophilia is typically greater than that caused by STECs; the degree of neutrophilia at the onset of disease may be used to predict the development and potential severity of HUS [139].

Treatment

Antimicrobial therapy is not advised for most cases of infection with *Shigella* spp. because of high rates of resistance [34; 69]. These resistance rates have been reported to be approximately 78% for ampicillin, 56% for streptomycin, 47% for sulfisoxazole, and 46% for TMP-SMX [134]. In addition, resistance to both ampicillin and TMP-SMX has been found in 38% of cases [134]. In 2023, the CDC issued a health advisory regarding an increase in extensively drug-resistant shigellosis in the United States [244]. Extensively drug-resistant *Shigella* bacteria as strains that are resistant to all commonly recommended empiric and alternative antibiotics, including azithromycin, ciprofloxacin, ceftriaxone, TMP-SMX, and ampicillin. In 2022, about 5% of *Shigella* infections reported to CDC were caused by extensively drug-resistant strains, compared with 0% in 2015. Currently, there are no data from clinical studies of treatment of extensively drug-resistant *Shigella* to inform recommendations for the optimal antimicrobial treatment of these infections. As such, CDC does not have recommendations for optimal antimicrobial treatment of these *Shigella* infections [244].

For patients with severe disease, most resistant *Shigella* strains can be treated with azithromycin (oral) or ceftriaxone (intramuscular) [69]. Fluoroquinolones may be effective for adults with suspected shigellosis who have fever, tenesmus, and inflammation [17]. Early and appropriate antimicrobial treatment of *Shigella dysenteriae* type I infections may prevent HUS [69; 74].

ESCHERICHIA COLI

E. coli is a motile gram-negative rod common to the human gastrointestinal tract. Although most *E. coli* are nonpathogenic and beneficial, some are diarrheagenic [74]. Six diarrheagenic virotypes have been identified, of which the primary ones are STEC (Shiga toxin-producing or enterohemorrhagic *E. coli*) and enterotoxigenic *E. coli* (traveler's diarrhea). Enteropathogenic *E. coli* (infantile diarrhea) occurs primarily in developing countries. The remaining three virotypes—enteroaggregative, enteroinvasive, and diffusely adherent *E. coli*—are not as well-established as the others [133; 140]. The incubation period is usually 3 to 4 days after exposure but may be as short as 1 day or as long as 10 days [140].

STECs (STEC O157:H7 AND OTHERS)

STECs adhere to and efface the wall of the large intestine [74]. The infective dose of STEC O157:H7 has been reported to be as low as 10 organisms, ranging to 700 organisms [132].

Epidemiology

STEC O157 is the most virulent as well as the most commonly identified STEC [77; 140]. Preliminary data from 2019 indicate that STEC O157 was the third leading bacterial cause of foodborne illness in the United States [2]. In 2019, the reported incidence of STEC was 6.3 cases per 100,000, a 34% increase over that reported for 2016–2018 [2]. Infection with STEC non-O157 is increasingly reported in the United States, primarily due to improvements in diagnostic tests [141]. During 2000–2010, FoodNet sites reported 2,006 cases of non-O157 STEC infection, an increased incidence from 0.12 per 100,000 population in 2000 to 0.95 per 100,000 in 2010 [142]. Non-O157 serogroups in the United States include O26 (26%), O103 (22%), O111 (19%), O121 (6%), O45 (5%), and O145 (4%) [142]. In 2017, 19 confirmed outbreaks of STEC O157 were reported, affecting 513 individuals [3].

Contamination and Transmission

Human STEC infection typically follows consumption of fecally contaminated food/water or person-to-person contact with infected (usually symptomatic) individuals [69; 140]. Undercooked ground beef or cattle contact causes most STEC O157 outbreaks; however, contaminated raw milk, dry-cured salami, unpasteurized fruit juice, vegetables, and petting zoos have also been associated with STEC O157 outbreaks [77; 140].

Clinical Presentation and Disease Course

Symptoms typically begin 1 to 8 days after consumption of contaminated food [19]. Initially, individuals experience severe abdominal cramping/pain, watery diarrhea, vomiting, and/or low-grade fever [74; 140]. Medical attention is usually sought during the second stage, when diarrhea becomes visibly bloody [69]. In most cases, the disease is self-limiting, with symptoms resolving within 5 to 10 days [21; 140].

Diagnostic Testing

Stool samples for culture should be obtained as close to the onset of symptoms as possible, and testing for STEC O157 must be specifically requested [21; 69]. In some clinical laboratories, immunoassays are used to detect Shiga toxins [77; 69]. Physicians should request that STEC strains be identified for patients and their contacts who have bloody diarrhea, HUS, and/or thrombotic thrombocytopenia purpura (TTP) [69].

Treatment

Nonspecific supportive treatment approaches, including hydration, are used for patients with STEC infections. Antimicrobial therapy is not recommended [140]. It was once thought that antimicrobial agents promoted the development of HUS, but a meta-analysis has shown that this is not the case [143]. Nevertheless, STECs cause approximately 90% of all cases of HUS, and the syndrome will develop in 8% of children infected with STEC [139]. Patients should be monitored for potential HUS development with measurements of complete blood cell count with differential and blood urea nitrogen and creatinine levels [69]. HUS is unlikely to develop in patients with no indication of hemolysis, nephropathy, and thrombocytopenia 3 days after infection [69]. TTP, which is characterized by HUS, neurologic abnormalities, and fever, typically affects adults, especially individuals older than 65 years of age [69].

Enterotoxigenic *Escherichia coli*

In contrast to STECs, enterotoxigenic *E. coli* adheres to and effaces the small intestine [74]. The infective dose is 10^8 cells [74].

Epidemiology

Enterotoxigenic *E. coli* is a major cause of bacteria-related diarrhea in individuals who travel outside the United States, especially to developing countries [133; 144]. The infection has become more frequently identified as a cause of foodborne illness in the United States [145].

Contamination and Transmission

Enterotoxigenic *E. coli* is spread through fecally contaminated food or water. Infected food handlers may also be a source of contamination [74; 144].

Clinical Presentation and Disease Course

Symptoms usually occur 1 to 3 days after ingestion of contaminated food or water [21; 144]. Symptoms include watery diarrhea for 3 to 7 days, abdominal cramps, nausea, and malaise; low-grade fever is an infrequent symptom [21; 69; 144]. Manifestation of the infection ranges from minor discomfort to a severe cholera-like syndrome [74].

Diagnostic Testing

Distinguishing enterotoxigenic *E. coli* from nonpathogenic *E. coli* is difficult for most clinical laboratories, but enterotoxigenic *E. coli* can be identified in research laboratories accessed through the state health department [69; 144]. Testing for the organism must be specifically requested [21; 144].

Treatment

Treatment with antibiotics is not routinely needed for enterotoxigenic *E. coli* infection [21]. For severe illness, recommended antimicrobial agents are TMP-SMX, ciprofloxacin, and azithromycin [69]. Fluoroquinolones may also decrease the duration of illness caused by enterotoxigenic *E. coli* and other travel-related bacterial pathogens from 3 to 5 days to 1 to 2 days [17; 144].

LISTERIA MONOCYTOGENES

Listeria monocytogenes is an aerobic, gram-positive, usually pathogenic bacillus [34; 69]. Although non-spore-forming, *Listeria* is resistant to freezing, drying, and heat, and it multiplies in refrigerated foods [34; 69]. The organism attacks the gastrointestinal epithelium and then enters the bloodstream to replicate; it can enter the brain and placenta by infecting circulating phagocytes [34; 74]. The infective dose is fewer than 1,000 cells [34].

Epidemiology

Since 2000, the incidence of listeriosis has decreased considerably, by 34% between 1989 and 1993, by 36% from 1996 to 2006, and by 26% from 2014 to 2016 [2; 133]. In 2008, 33 individuals were affected by three confirmed outbreaks [66]. In 2017, 8 confirmed foodborne listeriosis outbreaks resulted in 32 illnesses, and 31 hospitalizations [3]. In 2011, health officials in Colorado notified the CDC of seven cases of listeriosis associated with consumption of cantaloupe from the same farm [146].

Pregnant women are at high risk for the disease, but symptoms are nonspecific and diagnosis is difficult [147]. Maternal infection leads to premature birth or spontaneous abortion in many cases [34; 148; 149]. The mortality rate associated with *Listeria* infection is approximately 20% to 30% [94; 95].

Contamination and Transmission

Ubiquitous in the environment, *Listeria* is found in many species of mammals (particularly herd animals), birds, and marine life [34; 69]. Contaminated soil or water can cause contamination of fruits and vegetables or farm animals. Raw (unpasteurized) milk is a primary source. As many as 10% of humans are carriers of the pathogen [34].

Clinical Presentation and Disease Course

Foodborne listeriosis often begins with fever, muscle aches, nausea, and possibly diarrhea; gastrointestinal symptoms usually begin within 9 to 48 hours after ingestion [21]. In pregnant women, infection usually manifests as mild flu-like symptoms [21]. Potential complications include bacteremia and meningitis [21]. Listeriosis-related meningitis is associated with a mortality rate of approximately 70% [34]. Invasive disease typically manifests 2 to 6 weeks after ingestion [21].

Diagnostic Testing and Treatment

Samples of blood, cerebrospinal fluid, gastric washings, meconium, placental tissue, and other infected tissue are appropriate for culture and gram stain [34; 69]. Infection with *Listeria* is a nationally notifiable disease. Since 2004, the CDC has requested that patients with listeriosis be interviewed with use of a standardized *Listeria* Initiative questionnaire. Use of this tool provides timely exposure information for case-control analyses [149].

Intravenous ampicillin, penicillin, or TMP-SMX is recommended for invasive disease; cephalosporins are ineffective [21; 69]. Patients with meningitis should be treated with antibiotics for 14 to 21 days [69].

VIBRIO SPP.

Vibrio are gram-negative, motile, comma-shaped rods [82; 89]. Commonly found in aquatic environments, they are salt-tolerant, facultative anaerobes [89]. Pathogens in this species/class include *Vibrio cholerae* and noncholera *Vibrio* spp.

Vibrio cholerae

Vibrio cholerae is classified into two serotypes: O1 and non-O1 [150]. O1 is further subdivided into two biotypes: classical and El Tor. El Tor is the major cholera-causing biotype [69; 151; 152]. Of the non-O1 serotypes, O139 and O141 cause clinical cholera [69; 152; 153]. The infective dose is 10^7 cells [34].

Epidemiology

Cholera is rare in the United States as well as in other industrialized nations [3; 154]. However, it is still common in some parts of the world. In 2016, a total of 38 countries reported a cumulative total of 132,121 cases, including 2,420 deaths, to the World Health Organization. However, because cholera is under-reported, as many as 2.9 million cases and 95,000 deaths are suspected to actually occur each year. There has been an ongoing global pandemic in Asia, Africa, and Latin America for the last five decades [152].

EVIDENCE-BASED PRACTICE RECOMMENDATION

The AMA, the ANA, and the CDC have identified street-vended foods from Latin America or Asia as potential carriers of *Vibrio cholerae*.

(https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm. Last accessed January 26, 2022.)

Level of Evidence: Expert Opinion/Consensus Statement

Contamination and Transmission

The ingestion of fecally contaminated water or food is the most common mode of transmission [74; 133; 152]. Person-to-person transmission is rare.

Clinical Presentation and Disease Course

Symptom onset is 1 to 3 days after ingestion [21]. Most patients with cholera will experience minimal or no symptoms [133]. However, the disease can be associated with profuse, watery diarrhea that lasts 3 to 7 days; there is usually no abdominal pain or fever [69; 152]. Stool is colorless with flecks of mucus—sometimes referred to as "rice water"—and the initial stool may exceed one liter [69; 152]. In approximately 5% to 10% of cases, the individual becomes severely dehydrated and metabolic acidosis and hypokalemia may develop within hours [21; 69; 152]. *Vibrio cholerae* infection can progress to hypovolemic shock, seizures, coma, and death, particularly in children [69].

Diagnostic Testing

Vibrio cholerae can be detected in culture of stool or vomitus, but the test must be specifically requested [21; 152]. Isolates should be forwarded to the state health department for serogrouping [69]. Cholera is a nationally notifiable disease.

Treatment

Rehydration should begin as soon as cholera is suspected and should be aggressive [21; 69; 152]. If possible, antimicrobial susceptibility testing is recommended because many *Vibrio cholerae* type O139 strains are resistant to TMP-SMX [69]. Oral doxycycline (single dose) or tetracycline (3-day regimen) is recommended, especially for adults [21]. Although tetracycline stains developing teeth in children younger than 8 years of age, the American Association of Pediatrics has noted that the benefit of tetracycline therapy outweighs the risks for children with severe cholera [69]. Tetracycline-resistant strains may be effectively treated with ciprofloxacin, ofloxacin, or TMP-SMX [21; 69].

Noncholera *Vibrio* spp.

Noncholera *Vibrio* is commonly found in all seawater [34; 69]. The species of noncholera *Vibrio* that cause gastroenteritis include *Vibrio parahaemolyticus* and *Vibrio vulnificus* [21]. *Vibrio parahaemolyticus* naturally inhabits coastal waters in the United States and Canada and is present in higher concentrations during the summer [133]. *Vibrio vulnificus* normally inhabits warmer seawater [133; 152]. The infective dose is 10^7 cells [34].

Epidemiology

According to preliminary data from 2019, the incidence of *Vibrio* infection is 0.9 per 100,000, and the incidence is highest among individuals 60 years of age and older [2]. The risk for infection is greatest for individuals who consume raw/undercooked seafood (especially oysters, shrimp, and crabs) and individuals who have liver disease [69]. In 2017, 2 suspected outbreaks of *Vibrio* were reported, affecting 19 individuals [3].

Contamination and Transmission

Ingestion of raw or undercooked seafood (e.g., mollusks, crustaceans) is the primary mode of transmission [21; 34; 152].

Clinical Presentation and Disease Course

The time from ingestion to onset of symptoms can be as short as 2 to 48 hours (*Vibrio parahaemolyticus*) or 1 to 7 days (*Vibrio vulnificus*) [21]. Unlike cholera, noncholera *Vibrio* infection, or vibriosis, causes abdominal cramps along with watery diarrhea [34; 69]. More than half of patients have a fever, chills, and headache, and at least 25% experience vomiting [69]. Bacteremia may develop in individuals with a compromised immune system [69].

Diagnostic Testing

Vibriosis can be diagnosed by culture of stool or vomitus samples, and the test must be specifically requested [21; 34; 69; 152]. *Vibrio* infection became a nationally notifiable disease in January 2007 [133].

Treatment

Treatment is recommended only for severe disease. Recommended antimicrobial agents include tetracycline and doxycycline, as well as gentamicin and cefotaxime (*Vibrio parahaemolyticus*) and ceftazidime (*Vibrio vulnificus*) [21].

YERSINIA

Yersinia are pleomorphic, gram-negative rods [69]. Only *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* are associated with gastroenteritis [34]. The infective dose is unknown but is estimated to be between 10^4 to 10^6 organisms [34].

Epidemiology

In 2019, the incidence of yersiniosis was 1.4 per 100,000, an increase of 153% compared with that reported for 2016–2018 [2]. The incidence is highest among children younger than 5 years of age. *Yersinia enterocolitica* O:3 is the most frequently identified serotype [34; 69].

Contamination and Transmission

Pigs are the primary reservoirs for *Yersinia* [155]. However, humans may be carriers for several months after infection [69; 155]. Commonly associated foods are raw/undercooked pork, oysters, fish, unpasteurized milk, and ice cream [34; 69]. The organism can grow at 4°C, which means that refrigerated meats can be sources of infection [34; 132]. Waterborne infections are rare [69].

Clinical Presentation and Disease Course

Symptoms associated with *Yersinia* infection usually occur within 24 to 48 hours after ingestion of contaminated food [21]. The clinical presentation of yersiniosis is age-specific. In infants and young children, mucoid diarrhea with blood and leukocytes, as well as fever, is common, whereas in adolescents and adults, an appendicitis-like syndrome (i.e., diarrhea, vomiting, fever, abdominal pain) usually occurs [34; 69]. *Yersinia enterocolitica* may lead to reactive arthritis in 2% to 3% of individuals with infection, even in the absence of obvious symptoms [34; 69]. Bacteremia is a potential complication among children with excessive iron storage or who have compromised immune systems [69].

Diagnostic Testing and Treatment

Yersinia can be detected in a stool, vomitus, or blood culture, if specifically requested [21; 34]. Serology testing is available in some research and reference laboratories.

Antimicrobial therapy is recommended if septicemia or invasive disease develops [21]. Options for antimicrobial agents include gentamicin, cefotaxime, doxycycline, and ciprofloxacin [21].

CLOSTRIDIUM PERFRINGENS

Clostridium perfringens are anaerobic, gram-positive spore-forming rods that are widely distributed in the environment. Spores exist in soil, sediments, and areas subject to human or animal fecal pollution [34]. The infective dose is more than 108 vegetative cells [34]. Related disease is caused by toxins excreted by the bacteria rather than infection.

Epidemiology

The CDC has attributed nearly 1 million domestically acquired foodborne illnesses to *Clostridium perfringens* [156]. In 2017, *Clostridium perfringens* accounted for the second greatest number of illnesses (843) in 41 reported outbreaks (19 confirmed and 22 suspected) of foodborne disease [3].

Contamination and Transmission

Small numbers of *Clostridium perfringens* are present in some foods after cooking and multiply to the level of an infective dose if cooked foods are cooled or stored at inappropriate temperatures [34; 156]. Common source outbreaks are associated with inadequately cooked or improperly stored and reheated meat products and gravy [43; 156].

Clinical Presentation and Disease Course

Symptoms of *Clostridium perfringens* poisoning include watery diarrhea, abdominal cramps, and nausea; fever is rare [21; 34]. The onset of symptoms is usually 8 to 22 hours after ingestion of contaminated food. Illness is usually relatively mild and rarely leads to hospitalization. Symptoms usually resolve within 24 to 48 hours, although less severe symptoms may last for 1 to 2 weeks in some patients (i.e., older individuals, individuals with compromised immune systems) [21; 34; 156].

Diagnostic Testing and Treatment

Perfringens poisoning is diagnosed primarily by the clinical presentation, but the toxin can be detected in stool samples. A stool culture can also be done to detect *Clostridium perfringens*, but because these bacteria are normally found in stool, a quantitative analysis should be done [21; 156]. Food can also be cultured, and an exceptionally high number of the bacteria indicates contamination [34]. Antimicrobial therapy is not indicated for perfringens poisoning, as it is ineffective against the toxin [21; 156].

CLOSTRIDIUM BOTULINUM

Clostridium botulinum is ubiquitous in soil, and under anaerobic conditions, the rod-shaped bacteria form spores that allow them to survive in a dormant state until they are exposed to conditions that support their growth [133]. The bacteria produce neurotoxins; human disease is typically caused by neurotoxins A, B, and E; F rarely causes disease in humans [34; 69]. The infective dose is an extremely small amount (i.e., several nanograms) [34].

Epidemiology

Foodborne botulism is relatively rare, primarily due to the improvements in commercial canning processes, which have reduced the incidence of botulism. However, outbreaks do occur. A small outbreak (eight cases) in 2007 involved a commercial brand of canned chili sauce [49]. During 2008 and 2009, the CDC and state and local health departments in Ohio and Washington investigated three outbreaks of botulism caused by unsafe home canning of vegetables [157]. In 2011, consumption of commercially produced (and then improperly stored) potato soup was associated with toxin type A botulism in two individuals in separate states [158]. In 2017, there were 3 confirmed and 1 suspected foodborne outbreaks of *Clostridium botulinum* resulting in 17 illnesses, 16 hospitalizations, and 1 death [3].

The incidence of foodborne botulism in Alaska remains more than 800 times the overall U.S. rate [159]. Approximately 27% of all foodborne botulism cases in the United States have occurred in that state [160]. Between 1950 and 2016, 200 outbreaks (366 cases; 303 confirmed, 63 suspected) of foodborne botulism were recorded in Alaska and involved Alaska Natives [160; 161]. In 2016, 205 confirmed cases of botulism were reported to the CDC, with foodborne botulism accounting for 29 of the cases (14%) [162]. Infant botulism was more common than foodborne botulism, with 150 cases (73%) reported in 2016 [162]. Most cases of infant botulism have occurred in breastfed babies when

nonhuman-milk foods were introduced [69; 119]. The rate of mortality associated with the disease is approximately 5% [133].

Contamination and Transmission

Botulism is caused by ingestion of *Clostridium botulinum* toxin produced in food [133]. The most common source is home-canned foods that have been prepared in an unsafe manner. Infant botulism occurs when *Clostridium botulinum* spores germinate and produce toxin in the gastrointestinal tract of infants. The risk of infant botulism is high among infants who eat honey before the age of 1 year, as honey is a source of the spores that produce *Clostridium botulinum* [69].

Clinical Presentation and Disease Course

Symptoms of foodborne botulism typically occur within 12 to 72 hours after ingestion of contaminated food but may occur as late as 10 days following ingestion [21; 163]. Characteristic symptoms include weakness with disproportionate involvement of cranial nerves (diplopia, dysarthria, dysphagia) and symmetric descending flaccid paralysis in the absence of sensory changes that usually accompany other disorders with similar symptoms, such as stroke or Guillain-Barré syndrome [34; 69]. If symptoms of muscle paralysis are left untreated, they may progress to cause permanent paralysis of the arms, legs, trunk, and respiratory muscles.

Infant botulism is characterized by constipation, lethargy, lack of appetite, drooling, and weakness, which begin 1 to 30 days after ingestion of contaminated food [21]. Subsequent symptoms include descending symmetrical paralysis manifested as bulbar palsies (e.g., poor head and muscle control, flat affect, ptosis, impaired swallow reflexes, sluggish pupillary reaction) [21]. Intubation and ventilatory support are necessary in the vast majority of cases [69].

Diagnostic Testing

Serum, stool, gastric fluid, vomitus, or food samples can be used to detect botulism neurotoxins [133]. Because its clinical presentation is similar to neurologic conditions, diagnostic testing should be done to rule out these conditions [133; 163]. For example, the incremental increase of evoked muscle potentials at high frequency 20–50 Hz nerve stimulation may distinguish botulism from Guillain-Barré syndrome or myasthenia gravis [69]. *Clostridium botulinum* is a category A bioterrorism agent, and infection is a nationally notifiable disease [133].

Treatment

Treatment should begin when botulism is suspected on the basis of symptoms and should not be delayed while waiting for confirmation from laboratory results [69; 163]. If diagnosed early, foodborne botulism can be treated with an equine antitoxin that will prevent worsening of the disease. Antitoxins can be obtained from the CDC Drug Service [163]. Induced vomiting, gastric lavage, rapid purgation, or high enema can remove contaminated food in the gut [21; 69]. A respirator is often needed, and complete recovery can take many weeks to months.

Infant botulism can be treated with botulism immune globulin, which can be obtained from the Infant Botulism Prevention Program, California Department of Public Health [163; 164].

BACILLUS CEREUS

Bacillus cereus are gram-positive, aerobic spore-forming rods [34]. A large-molecular-weight protein is the cause of the diarrheal type illness, and a low-molecular-weight, heat-stable peptide is the cause of the emetic type illness [34]. The infective dose is thought to be greater than 10^6 organisms per gram of food [34].

Epidemiology

Infection with *Bacillus cereus* is infrequent, but sporadic outbreaks occur from year to year. In 2008, 15 outbreaks of the illness were reported (three confirmed and 12 suspected), affecting a total of 73 individuals [66]. In 2017, there were 11 reported foodborne outbreaks (3 confirmed and 8 suspected) and 341 illnesses [3].

Contamination and Transmission

Bacillus cereus food poisoning is transmitted through ingestion of contaminated food, and there is a broad range of potential food sources, including meats, milk, vegetables, and fish (diarrheal-type illness) and rice products and other starchy foods, such as potato, pasta, and cheese products (emetic-type illness) [34]. *Bacillus cereus* occurring in grains and beans was the pathogen-food category pair responsible for the most illnesses in outbreaks [3]. Outbreaks also have often involved food mixtures, such as sauces, puddings, soups, casseroles, and pastries. *Bacillus cereus* is heat resistant and can survive cooking (even at recommended temperatures). In addition to contaminated food, transmission of infection can also occur with improper food handling or storage; person-to-person transmission is rare [34].

Clinical Presentation and Disease Course

The symptoms caused by the diarrheal type of *Bacillus cereus* food poisoning are similar to those of *Clostridium perfringens* infection. Symptoms include watery diarrhea and abdominal cramps that may be accompanied by nausea but usually not vomiting. The onset of symptoms is typically 6 to 16 hours after ingestion of contaminated food [21; 34]. Symptoms usually resolve within 24 to 48 hours [21].

The enteric type of *Bacillus cereus* food poisoning causes symptoms similar to those associated with foodborne *Staphylococcus aureus* infection. The onset of nausea and vomiting occurs within one to six hours after ingestion of contaminated food and may be accompanied by diarrhea and/or abdominal cramps [21; 34]. Symptoms usually resolve within 24 hours.

Diagnostic Testing and Treatment

The diagnosis of either type of *Bacillus cereus* food poisoning is based primarily on the clinical presentation. Laboratories do not routinely identify the enteric type of *Bacillus cereus*; testing for the toxin in food and stool samples should be considered if an outbreak is suspected [21]. Antimicrobial therapy is not indicated for *Bacillus cereus* food poisoning [21].

BRUCELLA

Brucella spp. are gram-negative, nonmotile coccobacilli [69]. *Brucella melitensis* and *Brucella ovis* are found in sheep and goats, *Brucella abortus* is found in cattle, and *Brucella suis* is found in pigs [133]. The infective dose for aerosolized infection is 10–100 organisms [165].

Epidemiology

Brucellosis is rare in the United States, with an incidence of less than 0.5 per 100,000 [44]. Most cases are caused by *Brucella melitensis*, the majority of which are reported from California, Florida, Texas, and Arizona [166]. There were no foodborne outbreaks of *Brucella* reported in 2017 [3].

Contamination and Transmission

In the United States, milk or dairy products from contaminated animals are the most common sources of infection with *Brucella* [133; 166]. Transmission through person-to-person contact is extremely rare.

Clinical Presentation and Disease Course

Symptoms typically occur 7 to 21 days after ingestion of contaminated food [21]. The clinical presentation of brucellosis is nonspecific and includes fever with chills, sweating, malaise, headache, and myalgia as well as diarrhea, which may be bloody during the acute stage of disease [21]. Symptoms may last for weeks. Meninges, bone, and/or the heart may be involved, which can lead to such complications as meningitis, osteomyelitis, and endocarditis [69; 166]. Disease is usually more severe in adults than in children [69].

Diagnostic Testing and Treatment

Samples of blood, bone marrow, or other tissues are tested for the bacteria and must be incubated for 4 weeks before testing [69; 166]. The CDC has designated *Brucella* as a category B bioterrorism agent, and infections are nationally notifiable [133].

Recommended therapy for brucellosis is doxycycline and rifampin for at least 6 weeks [166]. Individuals who have complications should be treated with the combination of rifampin, tetracycline, and an aminoglycoside [21].

STAPHYLOCOCCUS AUREUS

Staphylococcus aureus is a gram-positive, catalase-positive coccus that grows in grape-like clusters or chains when cultured [34]. Pathogenicity is caused by eight heat-stable enterotoxins (A, B, C1, C2, C3, D, E, and F) [34; 69]. Of these, staphylococcal enterotoxin A is usually responsible for foodborne-illness outbreaks [69]. The infective dose is 1.0 mcg of toxin [34].

Epidemiology

In 2017, *Staphylococcus aureus* enterotoxin was implicated in 12 reported outbreaks involving 128 illnesses, and no hospitalizations [3].

Contamination and Transmission

Staphylococcus aureus is transmitted through person-to-person contact, usually as a result of a food handler who is infected with the bacteria [133]. The bacteria will multiply on improperly stored foods, especially pastries, custards, salad dressings, cheeses, meat products, and expressed human milk [69; 133]. Staphylococcal toxins are resistant to heat and cannot be destroyed by cooking [133].

Clinical Presentation and Disease Course

Staphylococcal food poisoning is characterized by the rapid onset of nausea and vomiting, which may occur within 30 minutes of ingestion (range: 1 to 6 hours) [21; 133; 167]. Other symptoms include abdominal pain, diarrhea, and fever [21; 167]. The disease is usually mild, with recovery within 1 to 3 days [21; 133].

Diagnostic Testing and Treatment

Staphylococcus aureus toxins can be identified from stool, vomitus, and food, but microbiologic testing is not usually done [21; 167]. Staphylococcal enterotoxin B is classified as a category B bioterrorism agent and is nationally notifiable [133].

Antimicrobial agents should not be used to treat foodborne *Staphylococcus aureus* infection, as they are not effective against the toxins [167].

VIRAL FOODBORNE PATHOGENS

As noted previously, the three viruses associated with foodborne illness are caliciviruses (e.g., norovirus), hepatitis A virus, and rotavirus. Astroviruses and enteric adenoviruses have been implicated in isolated cases and outbreaks of viral gastroenteritis but are much less common. Treatment of viral foodborne illnesses consists primarily of rehydration and supportive therapy.

CALICIVIRUSES

Caliciviruses are nonenveloped ribonucleic acid (RNA) viruses. The two caliciviruses most likely to cause foodborne illness are norovirus and sapovirus. There are six recognized norovirus genogroups divided into 33 different genotypes. Three of the genogroups (GI, GII, and GIV) affect humans [168]. Variants of the GII.4 genotype have been the most common cause of norovirus illnesses worldwide. Recently, previously rare genotypes (GII.17 and GII.2) have emerged worldwide [168].

Sapovirus also consists of five genogroups (GI–GV), and all except GIII cause infection in humans [169; 170]. The infective dose for both types of viruses is 10–100 viral particles [171].

Epidemiology

Norovirus is the leading cause of gastroenteritis and foodborne disease outbreaks in the United States. According to estimates derived from surveillance data, norovirus causes 2 million illnesses, 56,000 to 71,000 hospitalizations, and 570 to 800 deaths annually [172]. In 2017, norovirus was the most common cause of confirmed single-etiology foodborne outbreaks, accounting for 140 (35%) outbreaks and 4,092 (46%) illnesses; moreover, it was the suspect etiologic agent for an additional 177 outbreaks and 2,140 food-related illnesses [3]. The incidence of norovirus infection increases during the winter months, and periodic outbreaks tend to occur in association with the emergence of new GII strains that evade population immunity [171].

In 2009, the CDC launched CaliciNet, an outbreak surveillance network for noroviruses in the United States [173; 174]. The CDC uses the information to link norovirus outbreaks, monitor trends, and identify emerging strains. As of 2018, 34 laboratories in 29 states and the District of Columbia have been certified by the CDC to participate in CaliciNet [175].

Between 2009 and 2012, norovirus was the etiologic pathogen identified in 1,008 foodborne outbreaks, accounting for 48% of all reported outbreaks with a single known cause [176]. Eating in restaurants was the most common setting (65%), and food handlers were implicated as the source in 70% of outbreaks in which factors contributing to contamination could be identified. Other factors included contamination of food during preparation (92%) and consumption of raw food (75%) [176]. Specific food categories were implicated in only 67 outbreaks, the most frequent being leafy vegetables (30%), fruits (21%), and mollusks (19%) [176].

Contamination and Transmission

Foodborne infection with either norovirus or sapovirus is transmitted via the fecal-oral route through infected food handlers, exposure to contaminated surfaces, consumption of contaminated food, or rarely, ingestion of contaminated water [171; 176; 177]. Aerosolized norovirus particles in vomitus can also contribute to spread of the disease, and these particles can travel a distance of up to 3 feet [177; 178; 179]. The most common sources are prepared foods (e.g., sandwiches, salads) and raw produce [84].

Clinical Presentation and Disease Course

The symptoms associated with infection with either norovirus or sapovirus are nausea, vomiting, abdominal cramps, diarrhea (usually watery), fever, myalgia, and headache [21; 177]. Diarrhea is more common among adults, and vomiting is more common among children [21; 177]. The onset of disease is 24 to 48 hours but may be as few as 12 hours [21; 177]. Symptoms usually resolve within 24 to 72 hours [177]. Viral shedding lasts 2 weeks in otherwise healthy individuals and longer in individuals with compromised immune systems [171].

Diagnostic Testing

The diagnosis of norovirus or sapovirus is usually made on the basis of the clinical presentation and the lack of positive results on stool cultures for bacteria [21]. The absence of white blood cells in the stool is also an indicator of the virus [21]. Reference/research laboratories can identify norovirus or sapovirus in stool with reverse transcriptase polymerase chain reaction (RT-PCR), immunoassays, or electron microscopy [171; 177].

HEPATITIS A VIRUS

Hepatitis A is an RNA virus with only one serotype, and seven genotypes (I–VII); genotypes I, II, III, and VII cause disease in humans [69]. In North America, most hepatitis A infections are caused by subtype IA [180]. The infective dose is believed to be 10–100 viral particles [34]. The virus replicates in the liver and is shed (in high concentrations) in the stool [180]. Unlike other forms of hepatitis, hepatitis A infection is self-limited and does not cause chronic infection or chronic liver disease [180].

Epidemiology

The hepatitis A vaccine, which became available in 1995, led to a 95% decrease in the incidence of the disease [180]. However, the incidence of hepatitis A increased 1,325% between 2015 and 2019, primarily because of person-to-person outbreaks reported in 31 states among people who use injection drugs and people experiencing homelessness [85]. In 2019, there were 18,846 reported cases of acute hepatitis, an incidence of 5.7 per 100,000 [85]. Five confirmed outbreaks of foodborne hepatitis A (35 individuals) were reported in 2017 [3]. Outbreaks of hepatitis A have been caused by fruits (strawberries) and vegetables (green onions) that were contaminated during packing or shipping from farms outside the United States; one of these outbreaks involved 601 individuals who had consumed green onions at a single restaurant in Pennsylvania [50].

Contamination and Transmission

Foodborne hepatitis A is transmitted via person-to-person contact (fecal-oral); waterborne transmission is rare in the United States and other developed countries [180]. The virus is destroyed if heated to 185°F for 1 minute; however, the virus may be spread from cooked food if it is contaminated after cooking [69]. Because children with hepatitis A are often asymptomatic, they play a key role in transmission.

Clinical Presentation and Disease Course

The incubation period of hepatitis A is 2 to 5 weeks (average: 4 weeks) [181]. Jaundice occurs in most infected older children and adults [21]. In children younger than 6 years of age, jaundice is uncommon; only 30% of children are symptomatic at this age [21]. Other common symptoms among children and adults are dark urine, fever, malaise, and loss of appetite [21; 69].

Symptoms persist for several days to months [21; 69]. Communicability extends from 1 to 2 weeks before the onset of disease to about 1 week after the development of jaundice [180]. The risk for severe illness is higher for individuals with chronic liver disease or clotting-factor disorders [69; 180]. Hepatitis A-induced acute liver failure is uncommon (0.4%) and is most likely to manifest in people with chronic liver disease [69].

EVIDENCE-BASED PRACTICE RECOMMENDATION

According to the AMA, the ANA, and the CDC, treatment for foodborne rotavirus infection is generally limited to supportive care. Severe diarrhea may require fluid and electrolyte replacement.

(https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm. Last accessed January 26, 2022.)

Level of Evidence: Expert Opinion/Consensus Statement

Diagnostic Testing

The presence of anti-hepatitis A immunoglobulin (Ig) M in serum represents current or recent infection; anti-hepatitis IgG in the absence of IgM indicates past infection [69]. Increases in serum levels of bilirubin and alanine aminotransferase are also indicators of infection [21].

ROTAVIRUS (GROUP A)

"Rota" (Latin for wheel) describes the wheel-like structure of these viruses, which is made up of 11 double-stranded RNA segments surrounded by a distinctive two-layered protein capsid [34]. Six serologic groups have been identified, three of which (groups A, B, and C) infect humans [34]. The infective dose is believed to be 10–100 viral particles [21].

Epidemiology

In the United States, annual epidemics of rotavirus spread from the Southwest to the Northeast between fall and spring [69]. Prior to introduction of the rotavirus vaccine in 2006, almost all children in the United States had been infected by 5 years of age [182]. By extension, the virus affects approximately 20% of adults having close contact with an infant [69].

Contamination and Transmission

Rotavirus is transmitted via the fecal-oral route through person-to-person contact or fomites. Rotavirus is stable in the environment [182].

Clinical Presentation and Disease Course

The primary symptoms of rotavirus infection are vomiting, watery diarrhea, and low-grade fever, all of which occur 1 to 3 days after infection [21]. Temporary lactose intolerance may occur [34]. Symptoms typically last 4 to 8 days and are milder in adults than in children [21]. Infection can become persistent in individuals who have compromised immune systems [69].

Diagnostic Testing

Diagnosis of rotavirus infection is made primarily on the basis of the clinical presentation and the nondetection of bacteria in stool cultures. The virus can be detected in a stool sample with use of a radioimmunoassay [182].

ASTROVIRUSES AND ADENOVIRUSES

Astroviruses are nonenveloped single-stranded RNA viruses with a star-like morphology; eight antigenic types cause human disease [34; 69]. Adenoviruses, which contain double-stranded DNA, usually cause respiratory infection, but serotypes 40 and 41 are enteric [34]. Adenoviruses are unusually stable, allowing them to survive outside the body for prolonged periods [183]. The infective doses are not known but are thought to be low [34].

Epidemiology

Astroviruses and adenoviruses infect children more often than adults, and the incidence is highest among children younger than 4 years of age [69; 183]. According to the most recent data, no outbreaks of astrovirus have occurred in the United States [44].

Contamination and Transmission

Astroviruses and adenoviruses are transmitted via the fecal-oral route through an infected food handler or exposure to a contaminated surface [69]. Enteric adenovirus may also be transmitted via respiratory secretions [34].

Clinical Presentation and Disease Course

The incubation period for these viruses ranges from 10 to 70 hours [21]. Associated symptoms include diarrhea, nausea, vomiting, abdominal pain, fever, malaise, and headache [21; 69]. Symptoms typically resolve within 2 to 9 days, and the virus is shed for a median of 5 days after the onset of symptoms [21; 69]. In individuals with a compromised immune system, viral shedding is often persistent [69].

Diagnostic Testing

Commercial assays are available to detect astroviruses and adenoviruses in stool samples, although testing is uncommon [21].

FOODBORNE PARASITES

As with bacterial and viral infections, most parasitic infections are self-limiting. Treatment with only rehydration is often adequate.

CRYPTOSPORIDIUM

Cryptosporidium are obligate intracellular coccidia with an infective oocyst stage [34]. Oocysts are excreted by an infected host through feces and possibly other routes (e.g., respiratory secretions) [184]. Cryptosporidiosis is the human illness caused by *Cryptosporidium hominis* and *Cryptosporidium parvum* [184]. The infective dose for healthy adults is 10 to 100 oocysts; the dose is greater (100 – 1,000 oocysts) for reinfection after one year [34]. *Cryptosporidium* targets the jejunum and terminal ileum. *Cryptosporidium* is the leading cause of waterborne disease outbreaks in the United States and the third leading cause of zoonotic enteric illness in this country [186].

Epidemiology

Prevalence studies show 2% of the population of North America harbors *Cryptosporidium* in the gastrointestinal tract; serologic surveys indicate that 80% of the population has had a past infection [34]. Two confirmed outbreaks of foodborne infection with *Cryptosporidium* were reported in 2017, affecting 12 individuals [3]. The incidence of *Cryptosporidium* was 3.7 per 100,000 in 2017, ranking it fourth among the infectious foodborne pathogens monitored in the FoodNet program [2]. Rates of cryptosporidiosis peak strongly in the late summer [123].

Contamination and Transmission

Foodborne acquisition of cryptosporidiosis usually occurs by way of an infected food handler [21]. Animals raised for food may also serve as vehicles for transmission, and the parasite most commonly infects herd animals (e.g., cows, goats, sheep) [34]. Fresh produce may also become contaminated [34].

Clinical Presentation and Disease Course

Infection with *Cryptosporidium* causes noninflammatory, profuse watery diarrhea lasting up to two to three weeks, often accompanied by stomach cramps, nausea and vomiting, slight fever, anorexia, and weight loss [21; 185]. Some individuals may be asymptomatic [69; 185]. The onset of symptoms is usually within 2 to 10 days [21; 185]. Although infection is self-limiting in otherwise healthy individuals (10 to 14 days), it can become chronic in individuals with compromised immune systems [185].

Diagnostic Testing

A confirmed case requires evidence of *Cryptosporidium* organisms or DNA in stool, intestinal fluid, or tissue samples. Light microscopy of stained specimens is a common means of testing; other methods include direct florescent antibody (DFA) test, enzyme immunoassay (EIA), and polymerase chain reaction (PCR) [69; 186]. These tests must be ordered specifically [21]. Because shedding may be intermittent, three stool samples collected on different days should be tested before suspected cryptosporidiosis can be ruled out [69]. *Cryptosporidium* infection is a nationally notifiable disease.

Treatment

Treatment is usually reserved for severe disease, and paromomycin (7-day course) is the recommended drug [21]. Treatment with nitazoxanide (3-day course) is suggested for children 1 to 11 years of age [21].

CYCLOSPORA CAYETANENSIS

Cyclospora cayetanensis is an oocyst-forming, unicellular coccidium [69; 184; 187]. This species is the cause of all cyclosporiasis in humans [184; 187]. Unlike *Cryptosporidium*, the oocyst of *Cyclospora* shed in stools is not infective [184]. The infective dose is not known [34].

Epidemiology

Cyclosporiasis occurs most commonly in tropical and subtropical areas [97; 184]. The disease is not known to be endemic in the United States; however, since 1990, multiple foodborne outbreaks of cyclosporiasis, affecting thousands of individuals, have been documented in the United States and Canada [184; 187; 188]. During the period of 1997–2008, the CDC was notified of 1,110 laboratory-confirmed cases of sporadic cyclosporiasis, occurring in 37 states, including seven in which cyclosporiasis is not an explicitly reportable disease. More than one-third of the case-patients had a documented history of international travel [97]. In 2009, 141 cases of *Cyclospora* were reported to the CDC [187]. In 2019, FoodNet surveillance identified 755 cases of *Cyclospora* foodborne disease, an incidence rate of 1.5 per 100,000 persons [2]. In 2018, multiple outbreaks of cyclosporiasis (2,299 confirmed cases) linked to produce items were reported to the CDC from 33 states [188; 189]. Approximately one-third of the illnesses were associated with one of two large multistate outbreaks in the Midwest: one outbreak involved prepackaged vegetable trays (broccoli, cauliflower, carrots) sold at a convenience store chain; and one involved salads (carrots, romaine, spinach, kale, red leaf lettuce) sold at a fast food chain. Additional clusters were associated with basil and cilantro. Two basil-associated clusters of 8 confirmed cases were identified in two states in the West and Midwest. Multiple cilantro-associated clusters were identified, including three associated with unrelated Mexican-style restaurants in the Midwest. The CDC received reports of 53 confirmed cases associated with these three clusters. FDA traceback investigations are ongoing [189].

Contamination and Transmission

Individuals become infected with *Cyclospora* by ingesting oocysts that have become environmentally contaminated [187]. Direct person-to-person transmission of *Cyclospora* is unlikely because shed oocysts are noninfectious [184]. Washing of contaminated produce decreases, but does not eliminate, the risk of transmission [69]. A large outbreak of *Cyclospora* on imported raspberries demonstrates the potential risk for transmission from contaminated water or infected food handlers [51].

Clinical Presentation and Disease Course

The onset of symptoms of cyclosporiasis is typically at least 1 week after ingestion of contaminated food (range: 2 to 14 days) [21; 187]. Symptoms include profuse, usually watery diarrhea, loss of appetite with resultant weight loss, stomach cramps, nausea and vomiting, and fatigue [21; 187]. Illness may become persistent (10 to 12 weeks) and relapsing if left untreated [21; 187].

Diagnostic Testing and Treatment

Oocysts can be detected in stool samples, but testing must be specifically requested [21; 187]. Cyclosporiasis is a nationally notifiable infection. The recommended treatment is oral TMP-SMX for 7 to 10 days [21; 184; 187].

GIARDIA INTESTINALIS

Giardia infects the small intestine and biliary tract [190]. The parasite survives best in cool moist conditions, and the infective dose is one cyst [34].

Epidemiology

Giardiasis affects approximately 2% of the U.S. adult population [34; 190]. In 2015, three outbreaks of laboratory-confirmed giardiasis affected 12 individuals [190]. Similar to cryptosporidiosis, the incidence of giardiasis peaks in late summer [34; 123].

Contamination and Transmission

Transmission of giardiasis is most commonly waterborne. However, infection can be transmitted through ingestion of cysts in food or by the fecal-oral route [34; 190].

Clinical Presentation and Disease Course

The onset of symptoms is usually 1 week after ingestion of contaminated food [21; 190]. Symptoms of giardiasis include watery diarrhea, abdominal pain, bloating, nausea, and vomiting, which usually last for 1 to 3 weeks or longer [184]. However, many individuals with giardiasis are asymptomatic [69; 190]. Disaccharide intolerance develops in approximately 40% of individuals [34]. Lasting immunity after infection is common [34]. Chronic, debilitating giardiasis may occur and affects more adults than children [34; 69].

Diagnostic Testing

Diagnosis can be determined through the identification of cysts in stained fecal smears, of trophozoites in a smear of stool or duodenal fluid, or of antigens in stool samples [34; 69]. The sensitivity of diagnostic testing is higher when samples of diarrhea are tested and when testing is done on specimens obtained on alternating days [69]. At least three stool specimens may be needed for accurate results [21]. Giardiasis is a nationally notifiable disease.

Treatment

Metronidazole is the recommended agent for treatment, although it is not FDA-approved for this indication [21; 184]. Other options include tinidazole, nitazoxanide, paromomycin, furazolidone, or quinacrine [184].

TOXOPLASMA GONDII

Toxoplasma gondii is a protozoan parasite that infects most species of warm-blooded animals, including humans [184]. The parasite forms tissue cysts, most commonly in skeletal muscle, myocardium, and brain, and these cysts may remain throughout the life of the host [184]. The infective dose is not known [34].

Epidemiology

Toxoplasmosis is one of the most common human infections worldwide. An estimated 22.5% of the population 12 years of age and older has been infected with the parasite. More than 60 million people in the United States carry the *Toxoplasma* parasite. In some locations, up to 95% of the local human population either is or has been infected with *Toxoplasma gondii* [34; 191]. It is more common in warm climates and at lower altitudes [184].

Contamination and Transmission

Cats are the main reservoirs of *Toxoplasma gondii*, and they become infected through carnivorism [184; 191]. Although cats shed oocysts for only 1 to 2 weeks, large numbers may be shed, and they can survive in the environment for several months (even years under certain conditions), with considerable resistance to disinfectants, freezing, and drying [34; 184]. Humans become infected by ingesting raw or undercooked, cyst-contaminated meat, not only meats like pork and beef, but also seafoods, like clams and oysters, or by ingesting oocysts from fecally contaminated hands or food [34; 69; 184; 191; 192]. Congenital toxoplasmosis develops as a result of maternal infection during pregnancy and can lead to a range of serious morbidity and mortality [34; 184; 191].

Clinical Presentation and Disease Course

The incubation period for *Toxoplasma gondii* is 5 to 23 days [21]. Infected individuals are usually asymptomatic or have nonspecific symptoms [34; 191]. Lymphadenopathy, with or without flu-like symptoms, will develop in approximately 10% to 20% of affected individuals [184]. Symptoms usually resolve within a few months to a year. Fetuses (infected through maternal transmission) and individuals with AIDS are the most susceptible to complications [69; 191]. Although not evident at birth, mental retardation, visual impairment, and learning disabilities are likely to develop in children born with congenital toxoplasmosis [69; 191].

Diagnostic Testing

Serologic testing for *Toxoplasma gondii* antibodies is the most commonly used diagnostic test [34; 69; 191]. It is important to note that chronic *Toxoplasma gondii* is difficult to diagnose in patients with HIV, as serologic tests are considered unreliable in this population [69].

EVIDENCE-BASED PRACTICE RECOMMENDATION

The CDC indicates that congenital *Toxoplasma gondii* infection may be diagnosed by isolation of the organism from placenta, umbilical cord, or infant blood. Polymerase chain reaction of white blood cells, cerebrospinal fluid, or amniotic fluid, or IgM and IgA serology, performed by a reference laboratory are the definitive tests.

(https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm. Last accessed January 26, 2022.)

Level of Evidence: Expert Opinion/Consensus Statement

Treatment

Treatment is not necessary for individuals with healthy immune systems who are not pregnant. Pyrimethamine plus sulfadiazine has been used to treat central nervous system toxoplasmosis in individuals with HIV infection [184].

NATURAL TOXINS

The natural toxins most associated with foodborne illness are marine toxins and mushroom toxins.

MARINE TOXINS

Ocean and gulf algal blooms that occur along coastal areas are capable of producing many marine toxins that lead to foodborne "shellfish poisoning." These blooms were previously known as "red tides" because of the red discoloration they cause in the ocean. Contrary to common belief, however, there is poor correlation between red tides and reported outbreaks of shellfish poisoning. Red tide refers to the phenomenon caused by excessive reproduction of pigmented phytoplankton to such a degree that

HARMFUL ALGAL BLOOMS THAT PRODUCE MARINE TOXINS RESPONSIBLE FOR HUMAN ILLNESS			
Region of the United States	**Harmful Algal Bloom Organism**	**Toxin**	**Human Illness**
Gulf of Mexico (Florida, Texas), Hawaii, Pacific Islands, Puerto Rico, U.S. Virgin Islands	*Gambierdiscus* spp., *Prorocentrum* spp., *Ostreopsis* spp.	Ciguatoxin, gambiertoxin, maitotoxin	Ciguatera fish poisoning
Northeast, Pacific Coast, Alaska	*Alexandrium* spp.	Saxitoxins	Paralytic shellfish poisoning
New England, Gulf of Mexico, Pacific Coast	*Dinophysis* spp.	Okadaic acid	Diarrheic shellfish poisoning
Gulf of Mexico, South-Atlantic Coast	*Karenia* spp.	Brevetoxins	Neurotoxic shellfish poisoning
Pacific Coast, Alaska, Gulf of Mexico, Northeast, Mid-Atlantic Coast	*Pseudo-nitzschia* spp.	Domoic acid	Amnesic shellfish poisoning
South-Atlantic Coast (Florida)	*Pyrodinium bahamense*	Saxitoxins	Pufferfish poisoning
Source: [194]			*Table 12*

it turns the water red or dark brown. However, non-toxic algae can also cause red tides. With the hope of clarifying this, the scientific community has adopted the term harmful algae bloom (HAB) for toxic red tides. It should also be noted that in most cases, production of toxic algae is not accompanied by the red coloration of seawater [193]. Algal blooms in the United States have been increasing, augmented by warmer water temperatures and nutrients from industry and agricultural run-off. National surveillance data identified 321 emergency department visits related to harmful algal bloom exposure during 2017–2019 [241].

EVIDENCE-BASED PRACTICE RECOMMENDATION

The CDC notes that mercury poisoning may develop in people who consume fish exposed to organic mercury. Pregnant women and the developing fetus are especially vulnerable.

(https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm. Last accessed January 26, 2022.)

Level of Evidence: Expert Opinion/Consensus Statement

Different types of blooms occur in various geographic locations in the United States, and the toxins produced differ according to the bloom (***Table 12***) [194]. *Pyrodinium bahamense* from harmful algal blooms have caused toxic pufferfish exclusively in the waters off the coast of Florida. Another toxin, tetrodotoxin, is also found in pufferfish, but in species that inhabit the shallow waters of the temperate and tropical zones [195]. These fish (e.g., ocean sunfishes, porcupine fishes, pufferfish [fugu]) are considered to be a delicacy in some cultures but are the most poisonous of all marine life [196]. Tetrodotoxin is among the most potent poisons known [197; 198].

An additional toxin, scombroid, is caused by an elevated level of histamine in fish, most frequently tuna, albacore, and mackerel. The growth of certain bacteria and their decarboxylase enzyme activity causes this histamine formation [20]. The CDC has also identified non-scombroid fish (e.g., mahi-mahi) as a source of scombroid toxicity. Scombroid poisoning is the principal chemical agent type of foodborne disease found in the United States [199; 200].

Some mouse bioassays are available as diagnostic tools to identify marine toxins [198; 201]. However, testing with these assays is usually available only in specialized laboratories. Tetrodotoxin may be detected by fluorescent spectrometry [198]. Diagnosis of marine toxin poisoning is typically based on the clinical presentation and a history of recent ingestion of a particular type of seafood. If a portion of the type of seafood eaten is still available, it can be tested for the presence of the toxin. However, treatment does not depend on the type of toxin, so such testing is not essential.

Ciguatera

Epidemiology

Ciguatera fish poisoning is endemic in tropical and subtropical regions of the Pacific basin, Indian Ocean, and Caribbean [52; 202]. The illness occurs much less frequently in the United States, with 141 single exposures reported in 2016 [191; 203]. However, the CDC estimates that 2% to 10% of poisonings may not be reported [201]. Worldwide, an estimated 50,000 cases of ciguatera poisoning occur each year [52; 204].

Clinical Presentation and Disease Course

Gastrointestinal symptoms (e.g., diarrhea, vomiting, abdominal pain) occur in more than 50% of individuals within 2 to 6 hours after ingestion of the toxin and may last 1 to 2 days; neurologic symptoms, which include reversal of temperature sensations, distal and perioral numbness and/or tingling, and dizziness, usually occur within a few hours to 3 days and can be persistent, lasting weeks to several months [21; 201; 202]. Within 2 to 5 days, cardiovascular symptoms (less common but potentially severe), such as bradycardia, hypotension, and T wave abnormalities, may appear [21; 202].

Muscular weakness, paresthesias, and fatigue may last for weeks to months [201; 202]. Women of childbearing age may have increased pain during menses, and intercourse may be painful for both men and women [52; 205]. Among individuals with chronic symptoms, relapse may occur after stressful conditions or ingestion of fish (any type), alcohol, caffeine, or nuts, 3 to 6 months after the initial poisoning [201; 206].

Serious illness may involve severe hypotension with bradycardia, respiratory difficulties, and paralysis [202; 206]. Death as a result of respiratory and cardiovascular failure occurs in approximately 2% of infected individuals [207]. Children are most vulnerable to severe illness [208].

Treatment

Intravenous mannitol should be given within 24 to 48 hours to relieve neurologic symptoms [21; 201; 208]. Gut emptying and charcoal decontamination is recommended acutely; however, gastrointestinal symptoms may prohibit this measure [201]. Atropine may be necessary for bradycardia, and dopamine or calcium gluconate may be administered for shock [202]. Amitriptyline (and similar medications) may be effective in relieving chronic symptoms of fatigue and paresthesias [201]. Opiates and barbiturates should be avoided, as they may interact with the toxin and cause hypotension [201].

Shellfish Toxins

Epidemiology

Six outbreaks of foodborne disease attributed to shellfish poisoning (three amnesic, three paralytic) were reported in 2009–2015 [44]. In 2014, health officials in Alaska received reports of 177 cases of paralytic shellfish poisoning comprising 70 incidents from consumption of noncommercially harvested Alaskan shellfish [209]. Children are particularly sensitive to paralytic shellfish toxins, and the mortality rate is particularly high in children [210]. Individuals older than 65 years of age are predisposed to the severe neurologic effects of amnesic shellfish poisoning [21]. The incidence of shellfish poisoning has been declining as a result of careful monitoring, beach closures, and improved public awareness [193].

Clinical Presentation and Disease Course

The shellfish toxins differ according to the timing from ingestion of the toxin to the onset of symptoms, the symptoms caused, and the severity of illness [21; 201].

Paralytic shellfish poisoning is the most severe type of illness. It has a mortality rate of 6% worldwide (higher in developing countries) [193]. This toxin (e.g., saxitoxin) causes tingling, burning, numbness, drowsiness, incoherent speech, and respiratory paralysis within 15 minutes to 3 hours after ingestion [193; 201]. Other symptoms may include headache, dizziness, nausea, vomiting, rapid-onset pain, and anuria [201]. With severe illness, respiratory paralysis is common, occurring within 2 to 12 hours in severe poisoning, and persisting for as long as 72 hours to one week. Death may occur if respiratory support is not provided [193; 201]. Patients surviving 9 hours usually recover, and recovery begins 12 hours after the onset of symptoms and may take a few days to resolve completely [201].

With diarrheic shellfish poisoning, symptoms occur 30 minutes to 12 hours after ingestion of the toxin [193; 201]. Diarrhea occurs in almost all affected individuals (92%), and nausea and vomiting are also common (80% and 79%, respectively) [201]. Other symptoms may include abdominal pain, chills, headache, and fever [21]. Illness usually resolves within 2 to 3 days, and recovery is complete, with no aftereffects [21; 201]. No cases of death from diarrheic shellfish poisoning have been reported [193].

Symptoms of neurotoxic shellfish poisoning occur within a few minutes to 3 hours. The toxin (e.g., brevetoxin) causes both gastrointestinal and neurologic symptoms, generally mild and self-limited [193; 211]. Gastrointestinal symptoms may include diarrhea and vomiting. Neurologic symptoms may include tingling and/or numbness of the lips, tongue, and throat; muscle aches; dizziness; and reversal of temperature sensations [21; 193; 212]. Neurotoxic shellfish poisoning is the least common of the shellfish poisonings and is less severe than ciguatera poisoning. Recovery is complete within hours to 2 to 3 days [21; 201]. No fatalities have been reported [211].

Amnesic shellfish poisoning (e.g., domoic acid poisoning) causes symptoms of gastroenteritis (nausea, vomiting, abdominal cramps, diarrhea) within 24 hours after ingestion [201]. Although a potentially serious poisoning, only one human outbreak has been reported [213]. The primary symptom was vomiting, occurring in approximately 76% of infected individuals; abdominal cramps occurred in about half of those affected [201; 213]. In cases of severe poisoning, neurologic symptoms (i.e., dizziness, headache, seizures, disorientation, short-term memory loss, respiratory difficulty, coma) occur within 48 hours [201]. Cognitive dysfunction is most likely to be permanent in individuals who have neurologic symptoms within 48 hours after ingestion of the toxin, in men older than 60 years of age, and in individuals who have pre-existing conditions such as renal disease, diabetes, and hypertension with a history of transient ischemic attacks [201]. All reported fatalities associated with this toxin have involved individuals older than 65 years of age [201].

Treatment

Gut decontamination and administration of activated charcoal or dilute bicarbonate solution is recommended when shellfish poisoning is diagnosed during the early stage of illness [201]. Treatment should include oral rehydration therapy, as it may enhance renal excretion of the toxin [201]. Respiratory support is recommended for individuals with moderately severe cases [21]. Anticholinesterase agents are not advised and may be harmful [201; 214]. If seizures occur, intravenous diazepam or phenobarbital is recommended; the seizures may be resistant to phenytoin [201; 215].

Tetrodotoxin and Saxitoxin (Pufferfish Toxins)

Epidemiology

Although foodborne illness caused by ingestion of pufferfish (tetrodotoxin [TTX]) is rare in the United States, three outbreaks were reported in 2009–2015 [44; 193]. Most reports of pufferfish poisoning occur due to unskilled preparation by unlicensed cooks. The FDA allows importation into the United States through a single certified Japanese importer, but illegal importation continues and has resulted in multiple poisonings [216; 217]. The minimum lethal dose of TTX is estimated to be 2 mg but can vary depending on age and existing comorbidities. Reports of toxicity with consumption of 0.25–1.5 ounces of incorrectly prepared pufferfish have been reported by the CDC [193].

Clinical Presentation and Disease Course

Symptoms typically occur 5 to 45 minutes after ingestion of the toxin but may be observed as late as several hours later [21; 34; 193]. Higher toxin ingestion is associated with a more rapid onset of symptoms [193]. Pufferfish poisoning is characterized by slight numbness of the lips and tongue, followed by increasing paraesthesia in the face and extremities and sensations of lightness or floating [34; 212]. Gastrointestinal symptoms (vomiting, diarrhea, abdominal pain) and difficulty walking may occur. As paralysis increases, patients are unable to move and have respiratory distress. Decreased levels of consciousness, seizures, and death have occurred in as few as 17 minutes [193]. Without treatment, death occurs in 4 to 8 hours [21; 34]. Patients are conscious and often lucid until shortly before death [212]. The mortality rate has been reported to be nearly 60% [218]. If treatment is begun before poisoning becomes severe, life-threatening effects are highly unlikely after 24 hours [197].

Treatment

There is no known antidote for pufferfish poisoning [212]. Intravenous therapy, gastric lavage, and activated charcoal are recommended to reduce absorption of the toxin [196; 201]. Individuals who have moderate-to-severe reactions to tetrodotoxin should be admitted to an intensive care unit, and respiratory support may be needed for 24 to 72 hours [193; 197; 212]. Atropine can be used to treat bradycardia in severe cases [219].

Scombroid

Epidemiology

Scombroid toxin was the causative agent in 101 foodborne outbreaks reported in the United States in 2009–2015 (95 confirmed and 6 suspected), affecting a total of 299 individuals [44]. In 2019, an outbreak of scombroid toxin fish poisoning involving 51 cases (two hospitalizations) from 11 states was linked to imported tuna from two Vietnamese manufacturers [242].

Clinical Presentation and Disease Course

Symptoms are immediate, usually occurring within 1 minute to 3 hours [220]. Symptoms include flushing, rash on the upper body, dizziness, and burning sensation of the skin, mouth, and throat [220]. Other symptoms may include throbbing headache and an unusual taste in the mouth, frequently described as peppery or pungent, but in some cases bitter or metallic [220]. Symptoms usually last about 3 to 6 hours but may persist for several days [220]. Patients with comorbidities such as coronary artery disease may experience acute coronary syndrome caused by scombroid-associated tachycardia and hypotension [34]. Death is rare.

Treatment

Gut decontamination and administration of activated charcoal or dilute bicarbonate solution is recommended when poisoning is diagnosed within the first few hours [220]. Treatment with antihistamine medication is recommended, and rehydration therapy (oral or intravenous) may also be needed [220].

MUSHROOM TOXINS

Mushrooms can contain one or more of several toxins, including amanitin, gyromitrin, orellanine, muscarine, ibotenic acid/muscimol, and psilocybin, which are produced by the mushrooms themselves [34; 221]. Poisonous mushrooms are referred to as toadstools.

Mushroom poisoning is caused by the ingestion of raw or cooked toadstools. Most mushrooms that cause human poisoning cannot be made nontoxic by cooking, canning, freezing, or any other means of processing [34; 221]. The chemical composition of most mushroom toxins is unknown, and poisonings are therefore categorized according to their physiologic effects: protoplasmic poisons (amanitin, gyromitrin, orellanine), neurotoxins (muscarine, ibotenic acid/muscimol, psilocybin), gastrointestinal irritants, and disulfiram-like toxins.

As with marine toxins, the diagnosis of mushroom poisoning is based on the clinical presentation and a history of mushroom ingestion. A commercial radioimmunoassay is available to detect mushroom toxin in urine and plasma, but the time needed for incubation and testing may not be warranted. Identification of the mushroom species ingested is important; however, this it is not often possible. Other food sources should be ruled out before the mushroom is definitively determined to be the cause [34].

Epidemiology

From 1999 to 2016, 133,700 cases (average: 7,428 per year) of toxic mushroom exposure, mostly by ingestion, were reported to the National Poison Data System [203]. Cases were most frequently unintentional (83%) and caused no or only minor harm. Approximately 704 (about 39 per year) exposures resulted in major harm, including 52 (about 3 per year) fatalities. Cyclopeptide-producing mushrooms ingested by older adults accounted for the majority of fatalities. Mushroom poisonings usually result from misidentifying a wild mushroom, a non-native of the United States picking (and consuming) a mushroom that appears similar to one in his or her native country, or intentionally seeking to consume a mushroom with psychoactive compounds [34; 203]. Children, the elderly, and persons with disabilities are at highest risk for the development of serious complications from mushroom poisoning [221].

Clinical Presentation and Disease Course

A careful patient history is the most important component of the diagnostic process. The history should include: the quantity of mushrooms ingested; how they were prepared (or if they were eaten raw); the source of the mushroom; time of ingestion; and identification of other individuals who may have ingested the same mushrooms [221]. While failure to obtain history may be inconsequential for most mushroom ingestions, it is critical for patients who have ingested mushrooms containing amatoxin, orellanine, or gyromitrin, because their early removal from the GI tract may alter the outcome [221]. The clinical presentation and disease course vary according to the toxin. Diagnosis historically has relied on the timing between ingestion and onset of symptoms and the amount of mushrooms ingested (***Table 13***) [34; 221]. However, a growing consensus suggests that mushrooms are best classified by the physiologic and clinical effects of their poisons rather than by the timing of symptom onset [221].

Treatment

If definitive identification of the mushroom cannot be made, all ingestions should be considered serious and potentially lethal [221]. The treatment of most mushroom poisonings consists primarily of supportive care. For severe cases (as with ingestion of amanitin), life-support measures may be necessary [221].

DIAGNOSIS OF MUSHROOM POISONINGS ACCORDING TO SYMPTOMS AND THEIR ONSET			
Symptoms	**Onset**	**Cause**	**Disease Course**
Nausea, abdominal discomfort (sometimes with diarrhea and vomiting)	15 minutes to 2 hours	Unknown toxins (from numerous genera)	Rapid and complete recovery; severe illness may cause symptoms to last 2 to 3 days and require fluid replacement
Excessive sweating, lacrimation, salivation	15 to 30 minutes	Muscarine	Complete recovery within approximately 2 hours; death is rare but may result from cardiac or respiratory failure
Inebriation or hallucinations without drowsiness or sleep	15 minutes to 2 hours	Psilocybin	Complete and spontaneous recovery occurs within 5 to 10 hours; if large amount of toxin ingested, recovery may take up to 24 hours; more severe in children
Delirium with sleepiness or coma	1 to 2 hours	Ibotenic acid/ muscimol	Alternating periods of drowsiness and excitement occur for several hours, followed by total recovery
Feeling of abdominal fullness, severe headache, vomiting (no diarrhea)	6 to 10 hours	Gyromitrin	Complete recovery occurs within 2 to 6 days; correction of metabolic acidosis may be required; some deaths have occurred as a result of liver failure
Persistent and intense vomiting; abdominal pain; profuse, watery diarrhea	6 to 12 hours	Amanitin	Apparent recovery occurs a few hours after onset of symptoms, followed by a symptom-free period of 3 to 5 days, and subsequently by a period of jaundice, loss of strength, coma, and often death
Intense, burning thirst and frequent urination, followed by gastrointestinal disturbances, headache, pain in the limbs, spasms, and loss of consciousness	3 to 21 days	Orellanine	Recovery (including recovery of renal function) may require several months in cases of less severe poisoning; death from kidney failure may occur in cases of severe poisoning
Flushing; palpitations; rapid heartbeat; rapid, labored breathing within 30 minutes to 2 hours after consuming alcohol	Within 72 hours	Coprine	Recovery is spontaneous and complete within a few to several hours after onset of symptoms
Source: [34; 221]			*Table 13*

PREVENTION OF FOODBORNE DISEASE

The prevention of foodborne illness is essential to maintaining the health of individuals as well as protecting overall public health. Although infectious foodborne diseases usually produce mild symptoms and are self-limited in most people, the course of disease can be complicated in many, especially young children, older individuals, and people with a compromised immune system. The ease with which many foodborne pathogens can be transmitted heightens the need to prevent secondary transmission. Preventive measures are also important to avoid illness from natural toxins. The prevention of foodborne illness involves three main features: food safety, vaccination, and education.

FOOD SAFETY

Prevention of foodborne illness requires a focus on food safety at every point on the farm-to-table continuum. Several government agencies, including the USDA, the FDA, and the CDC, collaborate to ensure the safety of all foods for human consumption and to investigate and analyze foodborne-illness outbreaks.

Food safety depends on safeguards at several key points on the continuum, including:

- Pre-harvest
- Slaughter and processing
- Food distribution
- Food preparation/consumption

Both the USDA and the FDA regulate the safety of the food supply. These government agencies inspect food products, develop and enforce food safety regulations, test suspect foods, and work with industry to improve safety practices. The USDA oversees meat, poultry, and processed egg products, and the FDA is responsible for nonmeat products such as seafood, fruits, vegetables, and shell eggs. Initiatives and research efforts regarding food safety can be found at the Food Safety website (https://www.fda.gov/Food), which provides links to news and research reports from these agencies and the state and local regulatory departments with which they collaborate.

In mid-2009, the House Energy and Commerce Committee passed legislation to reform the U.S. food safety system, granting the FDA more authority and funding. The bill also calls for a new focus on prevention, with a shared responsibility between the FDA and food manufacturers. The FDA Food Safety Modernization Act (FSMA), which was enacted in January 2011, is intended to help reduce foodborne illness by means of a paradigm shift from responding to contamination of the U.S. food supply to preventing contamination. The law establishes new prevention measures for food regulated by the FDA [222; 223].

In 2021, the FDA announced the release of the Foodborne Outbreak Response Improvement Plan [243]. This plan is designed to help the FDA, the CDC, and other public health partners enhance the speed, effectiveness, and coordination of foodborne outbreak investigations. The plan targets four specific priority areas in which improvements are expected to have the most impact on outbreaks associated with food consumption [243]:

- Technology-enabled product traceback: Engaging smarter ways to digitize and receive information needed to streamline the traceback process used to pinpoint the source of food contamination
- Root-cause investigations (RCIs): Systematizing, expediting, and sharing FDA RCIs
- Strengthen analysis and dissemination of outbreak data: Working with the CDC and other partners to identify recurring, emerging, and persistent strains of pathogens
- Operational improvements: Building on performance measures across the FDA's foods program to better evaluate the timeliness and effectiveness of outbreak and regulatory investigation activities

State and local health departments collaborate with federal organizations to prevent the transmission of infectious and noninfectious foodborne illnesses. These departments have issued requirements about food handlers in a variety of settings (e.g., farm work, food distribution, food service), the primary source of viral foodborne illnesses. For example, many state and local health departments require that food handlers who have gastroenteritis refrain from working until 2 or 3 days after symptoms have resolved [176]. State and local health departments also issue policies and guidelines regarding such preventive measures as proper food storage and heating temperatures, appropriate hand hygiene, the cleaning and disinfection of food preparation surfaces, and the disposal of any food or nonfood items that may have been contaminated. Routine inspections are carried out to ensure compliance with these guidelines.

Prevention of infection with marine toxins is a major concern. To ensure that commercially available shellfish are safe for consumption, rigorous shellfish monitoring programs are established in all states. When harmful algal blooms (the source of shellfish poisoning) become high, state alerts are given to ban shellfish harvesting. Monitoring of blooms also helps to reduce the likelihood of ciguatera poisoning. In addition, the Ecology and Oceanography of Harmful Algal Blooms Program and the Monitoring and Event Response for Harmful Algal Blooms Program have funded approximately $100 million in marine research to gain a better understanding of harmful algae blooms [194].

The commercial and personal importation of pufferfish into the United States is heavily restricted to avoid tetrodotoxin poisoning, and the state of Florida bans commercial and recreational harvesting of pufferfish from the waters of most counties on the East Coast because of persistent saxitoxin toxicity [224]. The FDA advises that tetrodotoxin has not been found in northern pufferfish from the mid-Atlantic coastal waters (typically between Virginia and New York), but potential risk still exists without routine toxin screening [224].

VACCINES

Vaccines have been developed for two viruses that can be transmitted through food: rotavirus and hepatitis A. Two vaccines are now available for rotavirus: RV5 (RotaTeq) was approved for use in 2006, and RV1 (Rotarix) was approved in 2008. The American Academy of Pediatrics recommends routine vaccination with either vaccine, without noting a preference for either one [225]. RV5 is given orally in a three-dose series, at 2, 4, and 6 months of age. RV1 is given orally in a two-dose series, at 2 and 4 months of age [225]. Studies have shown that the vaccines provide 85% to 95% protection against severe rotavirus and 74% to 87% protection against any rotavirus illness [225; 226].

Vaccines are also available for hepatitis A virus. The CDC and the American Academy of Pediatrics recommend that vaccination against hepatitis A be included in the early childhood immunization schedule [227]. The vaccine is given (intramuscularly) in a two-dose series, with the first dose given at 12 months and the second dose given 6 to 18 months later, depending on the vaccine. The rate of hepatitis A in the United States was 88% lower in 2003 than the rate in 1996 before immunization was initiated [228].

Among individuals who were not vaccinated in childhood, those at increased risk of the virus should receive the vaccine. This includes individuals traveling to or living in areas with an intermediate or high endemicity for the infection, men who have sex with men, users of either injectable or noninjectable illicit drugs, individuals treated with clotting factors, and individuals who work with hepatitis A virus in the laboratory setting [228].

EDUCATION

Education about preventing foodborne illness requires a multifaceted approach that includes heightening awareness and enhancing knowledge about foodborne illnesses at the individual level and supporting broad public education campaigns. In addition, physicians and other healthcare professionals are encouraged to remain up-to-date on foodborne illnesses and their diagnosis and management.

Patient Education

Healthcare practitioners should take every available opportunity to provide their patients with information about the prevention of foodborne illnesses in the home and while traveling, focusing on the specific needs of certain populations. For example, pregnant women should be cautioned about the potential risks of infection with *Listeria* and *Toxoplasma gondii*. Parents should be advised of the need to avoid secondary transmission of viruses by keeping children with gastroenteritis out of daycare or school until symptoms have resolved. Individuals preparing for international travel (particularly to developing countries) should receive appropriate immunizations and will benefit from a description of ways to prevent traveler's diarrhea.

Educational resources for patients are available online, and some websites offer downloadable fact sheets and posters. The USDA Food Safety and Inspection Service website offers fact sheets on food safety for the general population as well as for a wide range of target populations, including ethnic minorities, older individuals, pregnant women, and individuals with cancer, diabetes, or HIV. Fact sheets are also available for preparing food for large groups, such as church suppers and other community meals. Consumer brochures and posters are commonly available in English and Spanish, and some are tailored to consumers' cultural food practices.

Individuals in high-risk groups are often confused about proper safe handling processes and are resistant to many food safety recommendations [229]. The findings of studies suggest that the primary barrier to accepting recommendations is the lack of understanding about the importance of the precautions [229; 230]. Cultural and economic factors as well as simple food hygiene habits have also been shown to be barriers [231; 232]. When discussing foodborne illnesses with high-risk individuals, healthcare professionals should emphasize why certain foods should be avoided or be prepared in a designated manner [229; 233]. Providing consistent information in a patient-friendly form is key to patient compliance [234].

It has been suggested that education on food safety is most effective when it is targeted to changing behaviors that most likely result in foodborne illness [28]. The following behaviors have been recommended as the primary focus of education on food safety [28; 235]:

- Handwashing
- Use of a thermometer to cook foods adequately
- Avoidance of cross-contamination

Also recommended (of secondary importance) are keeping foods at safe temperatures and avoidance of foods likely to be contaminated [28]. These behaviors were also emphasized by food experts who were asked to identify and rank food-handling and consumption behaviors as being of primary or secondary importance in preventing infection with 13 foodborne pathogens [27]. According to these experts, the following are of primary importance [27]:

- Keeping foods at safe temperatures (*Bacillus cereus* and *Clostridium perfringens*)
- Use of a thermometer to cook foods adequately (*Campylobacter jejuni*, *Salmonella*, STEC O157, *Toxoplasma gondii*, and *Yersinia*)
- Hand washing (*Shigella*)
- Avoidance of certain foods that are likely to be contaminated (*Listeria*, noroviruses, and *Vibrio*)

In addition, the experts indicated that keeping foods at safe temperatures were of secondary importance in preventing foodborne infection with *Staphylococcus aureus*, and avoidance of cross-contamination was of secondary importance in preventing infection with most pathogens [27].

Public Education Campaigns

The key messages identified as being of primary importance for education form the core of public health education campaigns on food safety. The most prominent campaigns have included "BAC Down!," "Be Safe," and "Ounce of Prevention."

"BAC Down!" is a collaborative initiative of the FDA and the Partnership for Food Safety Education. Its primary objective is to urge consumers to keep their refrigerators at 40°F or below to prevent foodborne illness such as listeriosis. "BAC Down!" uses the media, the Partnership's website, and eye-catching strategies for information dissemination at grocery stores. The Partnership also manages "Be Safe," which emphasizes four basic safe food-handling behaviors: Clean, Separate, Cook, and Chill. In addition, education on six steps to safer fresh fruits and vegetables and other topics are available in Spanish on the website.

The popular and successful "Ounce of Prevention" campaign is led by the National Center for Infectious Diseases, the CDC's coordinating center for infectious diseases, in partnership with Reckitt Benckiser, Inc. This campaign provides health educators and consumers with information and tips to prevent infectious diseases, including how to handle, store, and cook foods safely.

Education for Healthcare Professionals

Practitioners are urged to seek supplemental information regarding foodborne agents, particularly agents that are prevalent in their geographic location. There is a variety of print and Internet information available on infectious foodborne agents (***Resources***). Many cases of foodborne illness affect individuals in the community, but outbreaks, especially of viral etiology, often occur in hospitals and long-term care facilities. Nevertheless, no foodborne illness risk management guidelines exist specifically for U.S. hospitals [236]. Because of this, healthcare professionals should also be familiar with the evidence-based isolation and control guidelines for infectious diseases developed by the Healthcare Infection Control Practices Advisory Committee [75].

CONCLUSION

A variety of infectious and noninfectious foodborne diseases cause substantial morbidity and mortality in the United States each year. In addition to the high number of sporadic cases and cases related to outbreaks, researchers estimate that thousands of cases are unreported or undiagnosed annually. Although a steady decline in the incidence of several foodborne infections was observed between 1996 and 2007, the composite annual rate of foodborne disease has remained stable since that time [2]. Several foodborne-illness outbreaks in the last several decades are continued evidence of the threat to public health and the need for improved food safety. Bacteria (especially *Salmonella*) and viruses (especially norovirus) are the primary causes of most foodborne illness and outbreaks. Parasitic causes are rare in the United States. Noninfectious agents, especially natural toxins, are also important causes of foodborne disease. Among natural toxins, marine toxins and mushroom toxins are responsible for most cases and outbreaks of foodborne disease. Although uncommon, these toxin-related illnesses can be severe and life-threatening.

The diagnosis of foodborne disease can be challenging because the symptoms are often similar to those associated with other conditions. The patient history is key to the identification of an illness with a foodborne etiology, and practitioners should know the appropriate questions to elicit the information essential to making an accurate diagnosis. Physicians and other healthcare practitioners should also be familiar with the mechanisms of contamination and transmission of foodborne pathogens and toxins, the characteristic symptoms of food-related illnesses, and the appropriate reporting procedures. Healthcare professionals play a key role in preventing foodborne disease by providing education and resources on food safety and secondary transmission.

RESOURCES

Centers for Disease Control and Prevention: Epidemic Information Exchange (Epi-X)
https://emergency.cdc.gov/epix
Portal through which state and local health departments, poison control centers, and other public health professionals can access and share preliminary health surveillance information.

Centers for Disease Control and Prevention: Food Safety
https://www.cdc.gov/foodsafety
Information on food safety, prevention of illness for high-risk populations, and outbreaks.

Centers for Disease Control and Prevention: Foodborne Outbreak Response Team
https://www.cdc.gov/ncezid/dfwed/orpb/index.html
Collaborates with network of epidemiologists and other public health officials who investigate outbreaks of foodborne, waterborne, and other enteric illnesses in the United States.

Centers for Disease Control and Prevention: Traveler's Health
https://wwwnc.cdc.gov/travel
Current information regarding outbreaks in worldwide destinations.

Council of State and Territorial Epidemiologists
https://www.cste.org
Represents public health epidemiologists.

Fight BAC! Partnership for Food Safety Education
https://www.fightbac.org
Provides information about protecting health through safe food handling and hygiene.

FoodSafety.gov
https://www.foodsafety.gov
Consumer advice, information on foodborne pathogens, news on outbreaks and recalls.

American Academy of Pediatrics
Red Book: 2018 Report of the Committee on Infectious Diseases
https://publications.aap.org/redbook

U.S. Food and Drug Administration: Bad Bug Book (2nd Edition)
https://www.fda.gov/food/foodborne-pathogens/bad-bug-book-second-edition
Provides current information about the major known agents that cause foodborne illness.

U.S. Food and Drug Administration: Food
https://www.fda.gov/Food
Information on foodborne illness, news on outbreaks, alerts and recalls.

USDA Food Safety and Inspection Service (FSIS)
https://www.fsis.usda.gov
Variety of downloadable fact sheets on food safety, with some targeted to specific populations and others describing appropriate preparation of specific foods.

Implicit Bias in Health Care

The role of implicit biases on healthcare outcomes has become a concern, as there is some evidence that implicit biases contribute to health disparities, professionals' attitudes toward and interactions with patients, quality of care, diagnoses, and treatment decisions. This may produce differences in help-seeking, diagnoses, and ultimately treatments and interventions. Implicit biases may also unwittingly produce professional behaviors, attitudes, and interactions that reduce patients' trust and comfort with their provider, leading to earlier termination of visits and/or reduced adherence and follow-up. Disadvantaged groups are marginalized in the healthcare system and vulnerable on multiple levels; health professionals' implicit biases can further exacerbate these existing disadvantages.

Interventions or strategies designed to reduce implicit bias may be categorized as change-based or control-based. Change-based interventions focus on reducing or changing cognitive associations underlying implicit biases. These interventions might include challenging stereotypes. Conversely, control-based interventions involve reducing the effects of the implicit bias on the individual's behaviors. These strategies include increasing awareness of biased thoughts and responses. The two types of interventions are not mutually exclusive and may be used synergistically.

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