ERS Estimates U.S. Foodborne Disease Costs

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Microbial pathogens in food cause between 6.5 million and 33 million cases of human illness and up to 9,000 deaths each year in the United States. Over 40 different foodborne pathogens are believed to cause human illness. The annual cost of human illness caused by seven foodborne pathogens for which we have estimates ranges between $5.6 billion and $9.4 billion. Meat and poultry are the primary sources.

Microorganisms are commonly found in soil, water, plants, and animals. Most do not cause human illness. In fact, we rely on some microorganisms in the making of bread, alcohol, cheese, vitamins, and antibiotics.

Some, however, do cause human illness. Pathogens—microorganisms that cause disease—include viruses, bacteria, parasites, and fungi. The bacterium *Staphylococcus aureus* lives harmlessly on human skin and in the nasal cavities of less than half the people in the United States, but in food it can produce toxins that cause human illness. Another bacterium *Escherichia coli* O157:H7 usually lives harmlessly in the intestinal tracts of some cattle, but in people it can cause serious illness, including bloody diarrhea and kidney failure, as well as premature death. People can acquire the bacteria by eating mishandled or insufficiently cooked meat from infected animals. Half of all foodborne illnesses have no identified cause. Yet of those foodborne illnesses that are confirmed and reported to the Centers for Disease Control and Prevention (CDC), over 90 percent are attributed to bacteria.

Increasing Government scrutiny over food safety is improving efforts to restrict microbial pathogens in the food supply—as well as to improve data on the numbers of cases and costs associated with these pathogens. This article is the first in a new Economic Research Service series that will track the estimated costs and incidence of seven foodborne diseases over time (see box on key foodborne pathogens). These diseases were chosen for this series because they are commonly found in meat and poultry.

Public-health officials can compare the cost-of-illness (COI) estimates to identify the most expensive foodborne pathogens and illnesses. COI estimates can also be compared with the costs of pathogen-control programs to determine what level and direction of intervention may be needed.

Foods Contain Pathogens

Foods are the major source for some pathogens, such as *Listeria monocytogenes*, *E. coli* O157:H7, *Salmonella*, and *Campylobacter jejuni* (table 1). People also can be exposed to pathogens through inhalation, by drinking contaminated water, and by contact with infected pets, farm animals, and people.

Foods most likely to carry pathogens are high-protein, nonacid foods, such as meat, poultry, seafood, dairy products, and eggs (see box on sources of pathogens). Farm livestock and poultry infected with microbial pathogens may expose other animals in a herd or flock by excreting pathogens, pathogen cysts, or larvae.

However, for most pathogens commonly found on meat and poultry flesh, contamination does not usually occur until slaughter. Slaughtering, defeathering, chilling, and processing stages all provide opportunities for contamination. Accidental puncturing of the intestinal tract during slaughter can lead to widespread contamination of a packing line. Proper sanitation on the farm, in fishing vessels, and in processing plants can reduce the pathogen level on food that goes to retail. Animal products, such as milk and eggs, also require proper handling.

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Consumers can reduce their risks from foodborne illness by: cooking foods thoroughly; practicing sanitary kitchen techniques, such as washing utensils and cutting boards that came in contact with raw meat; immediately refrigerating and properly packaging leftover foods; and not consuming unpasteurized milk, and raw or rare meat, poultry, eggs, or seafood. However, consumers cannot protect themselves from all microbial hazards. Some pathogens are not easily killed by cooking or by refrigeration. For instance, if meat and poultry are contaminated with *Staphylococcus aureus* and are held at unsafe temperatures, *S. aureus* can produce heat-stable toxins that are able to withstand temperatures as high as 250°F. *Listeria* can survive and multiply during refrigeration.

Severity of Foodborne Illness Varies

Microbial pathogens in food can cause infections when the pathogens are eaten and are then established in the body, usually multiplying inside human intestinal tracts, and irritating the lining of the intestines. Two pathogens that cause infections are *Listeria* and *Campylobacter*. Sometimes these pathogens invade other

Seven Key Foodborne Pathogens Causing Human Illnesses in the United States

•Symptoms from *Campylobacter jejuni* infections range from a mild illness with diarrhea lasting a day, to severe abdominal pain, severe diarrhea (sometimes bloody), sometimes accompanied by fever, occasionally lasting for several weeks. The incubation period for most cases is 2-5 days and the illness usually lasts from 2 to 10 days, depending on its severity. Although the illness is generally regarded as a relatively mild disease, death can occur in some cases, especially for the very young, very old, or immunocompromised.

•Illness from *Clostridium perfringens* intoxications typically occurs 6 to 24 hours after ingestion of food bearing large counts of this bacteria. The illness in humans is frequently a mild gastrointestinal distress, lasting only around a day. Deaths are uncommon.

•*Escherichia coli* O157:H7 disease is usually a mild gastrointestinal illness that occurs 3 to 5 days after eating contaminated food. However, *E. coli* O157:H7 disease can result in illness requiring hospitalization: hemorrhagic colitis and hemolytic uremic syndrome (HUS). Hemorrhagic colitis is distinguished by the sudden onset of severe abdominal cramps, little or no fever, and diarrhea that may become grossly bloody. Although less than 5 percent of *E. coli* O157:H7 disease cases develop HUS, it is a severe, life-threatening illness. HUS is a disease characterized by red blood cell destruction, kidney failure, and neurological complications, such as seizures and strokes. Most of these HUS cases are children under 5 years old, although the feeble elderly may also be at risk.

•Illness caused by the bacterium *Listeria monocytogenes* may be either mild or severe. Milder cases are characterized by a sudden onset of fever, severe headache, vomiting, and other influenza-type symptoms. Severe cases can result in chronic illness and death. Listeriosis may appear mild in healthy adults and more severe in fetuses, the elderly, and the immunocompromised. Outbreak data show that the incubation period ranges from 3 to 70 days.

•Illness from the bacterium *Salmonella* usually appears 6 to 74 hours after eating contaminated food and lasts for a day or two. Common symptoms are nausea, diarrhea, stomach pain, and sometimes vomiting. In rare cases *Salmonella*, like many other bacterial and parasitic infections, can cause chronic disease syndromes such as arthritis and meningitis. Although the illness is generally regarded as a relatively mild disease, death can occur in some cases—especially for the very young, very old, or immunocompromised.

• *Staphylococcus aureus* intoxications occur usually within 1 to 6 hours following consumption of the toxins produced by the bacteria. In fact, onset of symptoms may occur within 30 minutes of consumption. Illness caused by *S. aureus* enterotoxin is characterized by severe nausea, vomiting, cramps, and diarrhea. Although the illness generally does not last longer than 1 or 2 days, the severity of the illness may indicate the need for hospitalization and possibly for surgical exploration.

•*Toxoplasma gondii* is a parasite that can cause acute or chronic human illness when people eat undercooked pork, mutton, and some other meats. The acute illness has mild flu-like symptoms. People can also be exposed to *T. gondii* through contact with cats or cat excrement. Most people infected with the parasite do not have any symptoms, and some people are at higher risk of getting sick from this parasite. Women infected with *T. gondii* during pregnancy may transmit the infection to their fetus, possibly leading to stillbirths or babies born with birth defects ranging from hearing or visual impairments to mental retardation. People with suppressed immune systems, such as AIDS and cancer patients, are also at higher risk than others from this parasite. One outbreak associated with undercooked meat indicates that the incubation period ranges from 10 to 23 days.

tissues, causing additional infections.

Other microbial pathogens when eaten in food may produce harmful or deadly toxins while growing in the human intestinal tract. These toxic byproducts—not the pathogens themselves—cause human illness. Two pathogens that cause this kind of foodborne illness are *Clostridium perfringens* and *E. coli* O157:H7.

Human illness from microbial pathogens can also occur when someone consumes food tainted with either toxins released during the growth stages of specific bacteria (such as *Staphylococcus aureus*) or mycotoxins produced by molds. Illnesses from these sources tend to occur quickly after consumption, because they do not involve any establishment or growth stage in the human body.

Four main categories of factors increase the risk and severity of a foodborne illness:

- **Microbial factors,** such as the type, strain, and quantity of pathogens or toxins ingested;
- **Host factors,** such as an individual's age, stress level, and strength of immune system;
- **Diet-related factors,** such as nutritional deficiencies; and
- **Other factors,** such as the geographical distribution of pathogens in soil and water.

Researchers are gaining greater knowledge of how these factors place people at greater risk for some pathogens. For example, high levels of iron in a person's blood can increase the risk of illness from ingesting *Vibrio vulnificus*, a deadly seafood pathogen. Some pathogens require ingestion of only very small amounts of a pathogen, or its cysts or larvae, to result in infectious illness. Ingestion of only one cyst, for example, can result in toxoplasmosis.

Most cases of foodborne illness are classified as "acute." These are usually self-limiting and of short duration, although they can range from mild to severe. Gastrointestinal problems and vomiting are common acute symptoms of many foodborne illnesses. Deaths from acute foodborne illnesses are uncommon and more typically occur in the very young, elderly, or patients with compromised immune systems (such as those suffering from AIDS and cancer). However, the U.S. Food and Drug Administration (FDA) estimates that 2 to 3 percent of all acute cases develop secondary long-term illnesses, called "chronic sequelae," such as arthritis.

Chronic sequelae of foodborne illness can occur in any part of the body and subsequently affect the joints, nervous system, kidneys, or heart. These chronic illnesses may afflict the patients for the remainder of their lives or result in premature death. For example, *Campylobacter* infections are estimated to be responsible for 20 to 40 percent of Guillain-Barré syndrome cases (a major cause of paralysis unrelated to

Table 1
Not All Illnesses and Deaths From These Pathogens Are From Food Sources

Pathogen	Estimated total cases	Estimated total deaths	Percent foodborne
	———-*Number*———		*Percent*
Selected bacteria:	12,221,795-15,431,860	8,865-12,960	N/A
Campylobacter jejuni or *coli*	2,500,000	200-730	55-70
Clostridium perfringens	10,000	100	100
Escherichia coli O157:H7	10,000-20,000	200-500	80
Listeria monocytogenes	1,795-1,860	445-510	85-95
Salmonella (non-typhoid)	800,000-4,000,000	800-4,000	87-96
Staphylococcus aureus	8,900,000	7,120	17
Parasite:			
Toxoplasma gondii	4,111	82	50
Total	12,225,906-15,435,971	8,947-13,042	N/A

Note: N/A = Not applicable.

Animal Products Are Major Sources of Illness-Causing Pathogens[1]

Pathogen	Food sources
Campylobacter jejuni or *coli*	Major: poultry Minor: milk, mushrooms, clams, hamburger, water, cheese, pork, shellfish, eggs, cake icing
Clostridium perfringens	Major: meat, meat stews, meat pies, and beef, turkey and chicken gravies Minor: beans, seafood
Escherichia coli 0157:H7	Major: beef--particularly ground beef Minor: poultry, cross-contamination has implicated apple cider, raw milk, vegetables, cantaloupe, hot dogs, mayonnaise, salad bar items
Listeria monocytogenes	Major: soft cheese, pâté, ground meat Minor: poultry, dairy products, hot dogs, potato salad, chicken, seafood, vegetables
Salmonella (non-typhoid)	Major: poultry, meat, eggs, milk, and their products Minor: vegetables, fruits, chocolate, peanuts, shellfish
Staphylococcus aureus[2]	Major: meat (especially sliced meat) poultry, fish, canned mushrooms Minor: dairy products, prepared salad dressing, ham, salami, bakery items, custards, cheese
Toxoplasma gondii	Major: pork, mutton Minor: lamb, insufficiently cooked hamburger, raw goat milk

Notes: [1]All the above are bacteria, except for *Toxoplasma gondii* which is a parasite. [2]Most human illness from this pathogen is caused by handling and contaminating food in manufacturing/processing facilities. Source: Adapted from CAST 1994, Benenson 1990, and Bean and others, 1990.

trauma) in the United States. About 5 percent of *E. coli* O157:H7 disease patients develop hemolytic uremic syndrome, which usually involves red blood cell destruction, kidney failure, and neurological complications, such as seizures and strokes.

National surveillance systems and laboratory-based reporting discover only a small percentage of foodborne disease cases. Surveillance systems rely on voluntary reporting by State Health Departments and primarily cover outbreaks. Lab-based systems only cover a handful of pathogens. Even if the disease is required to be reported to CDC, many foodborne illness cases never get associated with a particular pathogen, let alone with a particular food source. People who experience only mild foodborne illness usually do not seek medical treatment.

Only acute cases of some foodborne diseases are routinely documented. Reported cases are sometimes extrapolated to produce national "best estimates" of incidence and deaths. We compare CDC's estimates when possible with data from the medical literature and databases maintained by the National Center for Health Statistics.

Cost-of-Illness Estimates Understate True Social Costs

The costs of seven foodborne illnesses from all food sources range between $5.6 billion and $9.4 billion each year (table 2). For most of the illnesses, we used ranges to reflect uncertainty in the estimates of annual number of cases and/or deaths.

Estimated costs of foodborne illnesses vary because the incidence and severity of the illness are both factors. Salmonellosis and toxoplasmosis cases are the two most costly of the seven foodborne illnesses—largely because of the high number of annual *Salmonella* cases and because of the severity of chronic illness caused by *Toxoplasma gondii.*

Salmonella is a major cause of foodborne illness in most developed countries—including the United States and Canada. In the United States alone, estimated salmonellosis infections numbered as high as 3.8 million cases in 1993, and were responsible for an estimated $0.6 bil-

Table 2
Toxoplasma gondii and _Salmonella_ Ranked as the Most Costly Foodborne Pathogens in 1993

Pathogen	Estimated cases	Estimated foodborne— Deaths	Costs
	———————Number———————		Billion dollars
Selected bacteria:	3,603,526 - 7,130,767	2,654-6,546	2.9-6.7
Campylobacter jejuni or *coli*	1,375,000 - 1,750,000	110-511	0.6-1.0
Clostridium perfringens	10,000	100	0.1
Escherichia coli O157:H7	8,000 - 16,000	160-400	0.2-0.6
Listeria monocytogenes	1,526-1,767	378-485	0.2-0.3
Salmonella	696,000 - 3,840,000	696-3,840	0.6-3.5
Staphylococcus aureus	1,513,000	1,210	1.2
Parasite:			
Toxoplasma gondii	2,056	41	2.7
Total	3,605,582 - 7,132,823	2,695-6,587	5.6-9.4

lion to $3.5 billion in medical costs and lost productivity.

Although *Toxoplasma gondii* causes far fewer incidents of foodborne illness than do the other six pathogens (table 2), the estimated total annual costs are relatively high because of its disease severity. The estimated $2.7 billion annual cost of toxoplasmosis reflects three types of costs: productivity losses because of death or impairment, medical costs incurred from birth through adulthood, and residential care or special education required because of physical or mental disabilities caused by the disease.

COI estimates are calculated from the number of acute and chronic foodborne illness cases and deaths caused by each pathogen each year, the corresponding medical costs, costs of lost productivity, and other illness-specific costs, such as special education and residential care costs.

For each severity group, medical costs are estimated for physician and hospital services, supplies, medications, and special procedures unique to treating the particular foodborne illnesses. Such costs reflect the number of days/treatments of a medical service, the average cost per service/treatment, and the number of patients receiving such service/treatment.

Most people with foodborne illnesses only miss a day or two of work. However, some patients die or contract such physical complications that they never return to work, regain only a portion of their pre-illness productivity, or switch to less demanding and lower paying jobs. Lost productivity due to a foodborne illness is the present value (in today's dollars) of the lifetime stream of income the person would have earned if she or he had not had the foodborne illness. The total cost of lost productivity is the sum for all individuals affected, including the patients and their parents or paid caretakers in the case of ill children.

The COI method of computing the costs of foodborne illnesses underestimates costs to society, because the data cannot account for some costs that are difficult to measure (such as pain and suffering). Future analysis will explore methods to make more comprehensive estimates.

Our estimates of the annual costs to society of foodborne illness would increase considerably if:

- All foodborne pathogens were included in the analysis,
- All chronic illnesses that are triggered by foodborne disease were considered, and
- Less conservative estimates were used to value premature death.

Estimates Might Be Larger in the Next Decade

The number of cases of people affected by foodborne illness each year might increase with improved statistical reporting and estimation procedures. The proportion of the population that is highly susceptible to microbial foodborne illness is growing, largely due to the aging of the U.S. population and to the spread of chronic diseases (such as AIDS) that suppress the immune system. The pressure will be on reg-

ulators, processors, marketers, and consumers to become more vigilant in preventing and controlling foodborne illness.

New pathogen tests and improved epidemiological methods will allow us to recognize more human illnesses that have foodborne sources. Future advances in science can be expected to lead to the discovery of new links between microbial pathogens and chronic human illnesses. For example, *E. coli* O157:H7 was newly identified in 1985 as a foodborne pathogen causing chronic kidney failure in children.

Continuing technological and informational advances in the food marketing system (such as in refrigerating, pasteurizing, and labeling) have led to improved control techniques. For example, CDC researchers estimate that listeriosis cases have fallen by 44 percent in the last decade due to educational, industry, and regulatory efforts to reduce *Listeria* contamination of foods and subsequent illnesses.

Just as researchers find new control and treatment techniques, pathogens mutate. The short lifespan of the pathogens encourages improved virulence through quick adaptation to changes in their environment. Under favorable conditions, some bacteria replicate every 15-30 minutes. Researchers are concerned about a new strain of *E. coli* O157:H7 associated with a recent outbreak from dry salami. This strain appears to be more acid-tolerant, can survive at higher temperatures, and may more easily survive storage and cooking than some other *E. coli* strains—potentially resulting in more human illnesses.

The recent trend toward increased consumption of convenience foods and meals and snacks outside the home can pose greater food-safety risks, especially for the immunocompromised. For example, microwave heating of foods can be uneven—potentially creating an atmosphere for some parasites and bacteria to survive. Eating away from home (at places such as restaurants, fast-food outlets, nursing homes, and schools) means that consumers have less control over how their food is stored, handled, and cooked.

Public-health officials recognize these food-safety problems all along the food chain and are taking action. FDA continues to update the Model Food Code to help ensure safer food in restaurants, institutions, and supermarkets. USDA regulations now require labels describing safe-handling practices on all packages of raw meat and poultry sold at retail. Three States—Florida, California, and Louisiana—require restaurants serving raw shellfish to display warnings to customers about potential risks of consuming raw shellfish.

FDA, CDC, and USDA's Food Safety and Inspection Service (FSIS) are collaborating on a 6-month pilot project to improve estimates of which pathogens are responsible for diarrheal disease and to identify risk factors that increase or decrease the chances of becoming ill. Better information can be used to improve the design of control programs. *Salmonella* and *E. coli* 0157:H7 will be targeted first, followed by additional pathogens as the study gets underway.

In early 1995, FSIS published a proposal on the Hazard Analysis Critical Control Point (HACCP) approach to improving inspection practices for meat and poultry. HACCP is a science-based strategy to identify critical points in the manufacturing process that require special attention for pathogen control. FDA has promulgated a similar HACCP plan for seafood.

Successful implementation of HACCP by FSIS, as well as improved consumer awareness of food-safety risks, would be important components to reducing the number of foodborne illness cases from eating meat and poultry since the slaughter/processing facility and the home are two key control points.

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