Bacterial Foodborne Disease: Medical Costs and Productivity Losses.
Food and Consumer Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 741.

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Abstract

Microbial pathogens in food cause an estimated 6.5-33 million cases of human illness and up to 9,000 deaths in the United States each year. Over 40 different foodborne microbial pathogens, including fungi, viruses, parasites, and bacteria, are believed to cause human illnesses. For six bacterial pathogens, the costs of human illness are estimated to be $9.3-$12.9 billion annually. Of these costs, $2.9-$6.7 billion are attributed to foodborne bacteria. These estimates were developed to provide analytical support for USDA's Hazard Analysis and Critical Control Point (HACCP) systems rule for meat and poultry. (Note that the parasite *Toxoplasma gondii* is not included in this report.) To estimate medical costs and productivity losses, ERS uses four severity categories for acute illnesses: those who did not visit a physician, visited a physician, were hospitalized, or died prematurely. The lifetime consequences of chronic disease are included in the cost estimates for *E. coli* O157:H7 and fetal listeriosis.

Keywords: cost-of-illness, foodborne pathogens, lost productivity, medical costs.

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Summary

Foodborne illnesses from six bacterial pathogens are estimated to account for $2.9-$6.7 billion in human illness costs in the United States each year. This report provides the first comprehensive, detailed cost-of-illness analyses for the six bacteria in one document, and it puts all cost figures in 1993 dollars. These estimates were developed to provide analytical support for USDA's Hazard Analysis Critical Control Point (HACCP) systems rule for meat and poultry. (The parasite *Toxoplasma gondii* is not included in this report.)

Microbial pathogens in food cause an estimated 6.5 million to 33 million cases of human illness and up to 9,000 deaths annually, according to the Council for Agricultural Science and Technology. Foods most likely to cause human illness are animal products such as red meat, poultry and eggs, seafood, and dairy products.

The six bacterial pathogens studied in this report—all found in animal products—are *Salmonella, Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes, Staphylococcus aureus,* and *Clostridium perfringens*. The U.S. Centers for Disease Control and Prevention (CDC) is the source of most epidemiological information on numbers of foodborne illnesses and deaths used in this report.

The cost of human illness caused by the six bacterial pathogens is between $9.3 billion and $12.9 billion annually in the United States. Between $2.9 billion and $6.7 billion of these costs are attributed to foodborne causes.

To estimate medical costs and productivity losses, ERS uses four severity categories for acute illnesses—those who: did not visit a physician, visited a physician, were hospitalized, or died prematurely. The lifetime consequences of chronic disease are included in the cost estimates for *E. coli* O157:H7 and fetal listeriosis. The cost estimates can be used to evaluate the economic impact of foodborne diseases, to target pathogen reduction efforts, and to compare benefits and costs of control efforts in order to determine the most cost-effective measures.

Bacteria are one type of microorganism that cause diseases. Others are fungi, parasites, and viruses. More than 40 different foodborne pathogens, including some bacteria, are believed to cause human illnesses. 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.

Some pathogens that cause human illness are carried by animals but do not cause disease in the animals. *E. coli* O157:H7 lives harmlessly in the intestinal tracts of some cattle, but humans who eat undercooked meat from infected animals can develop illness that in some cases leads to kidney failure.

Glossary

Abbreviations

AIDS	Acquired immunodeficiency syndrome
AV	Artificial ventilation
BLS	Bureau of Labor Statistics
CAPD	Continuous ambulatory peritoneal disease
CCPD	Continuous cyclic peritoneal disease
CDC	Centers for Disease Control and Prevention
CFR	Case fatality rate
COI	Cost-of-illness
CPI	Consumer Price Index
ERS	Economic Research Service
ESRD	End-stage renal disease
FSIS	Food Safety and Inspection Service
GAO	Government Accounting Office
GBS	Guillain-Barré syndrome
GPO	Government Printing Office
HC	Hemorrhagic colitis
HCFA	Health Care Finance Administration
HUS	Hemolytic Uremic Syndrome
ICD	International Classification of Diseases
ICU	Intensive care unit
IOM	Institute of Medicine
IVIG	Immunoglobulin treatments
LS	Landefeld and Seskin
NHDS	National Hospital Discharge Survey
PE	Plasma exchange
QUALY	Quality-adjusted life-year
USDA	United States Department of Agriculture
VOSL	Value of a statistical life
WTP	Willingness to pay
LOS	Length of stay

Medical and Economic Terms

The definitions below clarify terms used in this report.

Bacteria. One-celled microorganisms that are either free-living or parasitic, some of which may be pathogenic.

Bacteremia. Presence of viable bacteria in the bloodstream.

Case. An individual who is ill following ingestion of food. Outbreak cases reported by CDC are determined to be contaminated on the basis of laboratory analysis and/or epidemiological evidence. Not all outbreak cases need be confirmed by laboratory analysis if there is sufficient epidemiological evidence linking them to the outbreak.

Campylobacteriosis. An illness in humans caused by *Campylobacter jejuni* or *C. coli*. Symptoms range from general malaise and diarrhea lasting for a day, to severe abdominal pain and bloody diarrhea, which may last several weeks.

Cholecystitis. Inflammation of the gall bladder.

Colonization. "Implantation and growth of a microorganism on a host" (Dorland's Dictionary 1994).

Colony forming unit (CFU). Unit of measurement for viable bacteria numbers.

Consumer price index (CPI). A measure of the average change in prices over time in a fixed "market basket" of goods and services purchased either by urban wage earners and clerical workers or by all urban consumers.

Contingent valuation method. The use of surveys of individuals to elicit their preferences, measured in monetary terms (willingness to pay, WTP), for a specified improvement in their health outcomes. It circumvents the absence of markets for health outcomes by presenting survey respondents with hypothetical markets in which they are asked their WTP for the improvement in question.

Cost of illness (COI) method. An approach that is used to estimate the societal costs of a particular illness or injury in a given time frame (typically a 1-year period). The approach typically focuses on two main types of societal costs associated with the particular illness or injury: direct medical and non-medical costs and indirect costs of lost productivity due to morbidity or premature mortality.

Diarrhea. Three or more unusually frequent evacuations of loose stools within a 24-hour period. Diarrhea may be caused by microbial, parasitic, or viral infections, or other factors.

Direct costs. Costs associated with resources expended for healthcare (compare with **indirect costs**).* Does not include lost wages—see productivity loss and indirect costs.

Direct medical costs. The costs of resources for medical treatment (*e.g.*, the cost of a physician visit).*

Direct non-medical costs. Costs incurred in connection with a health intervention or illness, but which are not expended for medical care itself (*e.g.*, the transportation costs associated with a physician visit).*

Discounting. A method for adjusting the value of future costs and benefits to an equivalent value today to account for time preference and opportunity cost, *i.e.*, a dollar today is worth more than a dollar a year from now (even if inflation is not considered).*

Discount rate. A rate used in determining a present value equivalent of a future stream of dollars. The lower the discount rate, the higher the present value of a future stream of dollars.

Endocarditis. Infection of the heart.

Gastroenteritis. Inflammation of the intestine and stomach.

Guillain-Barré Syndrome (GBS). An autoimmune reaction of the body that affects the peripheral nerves and causes weakness, paralysis, and occasionally death.

Hedonic wage studies. Statistical analyses that estimate the effect of intrinsic job characteristics, such as health risks, fringe benefits, or autonomy, on pay.

Hemodialysis. Separation of large and small molecules of the blood by use of selective diffusion through a semipermeable membrane. A medical treatment used to treat kidney failure.

Hemolytic Uremic Syndrome (HUS). A disease characterized by kidney failure and neurological failure. HUS especially strikes children under 5 years of age and the immunocompromised elderly.

Hemorrhagic Colitis. A clinical syndrome manifested by bloody inflammation of the colon. This syndrome can be the result of several diseases including *E. coli* O157:H7 disease.

Hospital discharge. The completion of an inpatient's continuous period of stay in a hospital where the stay lasts one night or more.

Human capital approach. A method for estimating the impact of an individual's illness or premature death on society by measuring the discounted value of his/her productivity loss (labor earnings) due to morbidity or premature mortality.

Immunocompromised. Individuals with a weakened immune system, making them susceptible to additional infections.

Incidence. A measure of the magnitude of a disease, usually expressed as the number of new cases of a disease per 100,000 individuals in the U.S. population in a 1-year period.

Incidence-based costs. The total lifetime costs of new cases of a disease or injury that occur during a certain period of time.*

Indirect costs. The resources forgone either to participate in an intervention or as the result of a health condition (*e.g.*, earnings forgone because of loss of time from work).*

Infection. An illness or carrier state arising from colonization of foodborne microbial pathogens in the human gastrointestinal tract or other parts of the human body. Human antibodies that resist these pathogens may cause chronic complications.

Infectious Dose. The number of organisms that make individuals ill or carriers. In reality, there is a probability distribution associated with different pathogen exposure levels.

Isolation rate. In microbiology, the rate at which an organism is identified in a culture.

Labor force participation rate. The percentage of average civilian noninstitutional population in the civilian labor force in a year. The civilian labor force comprises all employed and unemployed civilians in the noninstitutional population 16 years and over.

Life expectancy. The average remaining lifetime in years for an individual of a particular age, given sex-specific and age-specific death rates.

Listeriosis. A gastrointestinal illness in humans caused by *Listeria*. 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 meningitis, chronic illness, and death. Listeriosis may appear mild in healthy adults and more severe in fetuses, the elderly, and the immunocompromised. Pregnant women with *Listeria* infections may have spontaneous abortions and offspring with visual, mental, or other problems. Outbreak data show that the incubation period ranges from 3 to 70 days.

Meningitis. Infection of the brain or spinal tissues.

Neonate. A newborn child.

Net present value (NPV). The sum that results when the discounted value of the costs of a prevention strategy is deducted from the discounted value of the benefits of the strategy.*

Opportunity costs. The monetary value of the resources used in providing a specific set of health-care services valued in terms of forgone alternative uses.*

Outbreak data. CDC data on foodborne disease outbreaks define an outbreak as an incident in which two or more persons experienced a similar illness after ingestion of a common food, and epidemiologic analysis implicated a food as

the source of the illness. There are two exceptions, botulism and chemical poisoning, in which one case constitutes an outbreak.

Pathogen. A disease-causing agent such as a certain bacterium, parasite, virus, or fungus.

Pneumonia. Acute or chronic disease characterized by inflammation of the lungs. The disease is typically caused by bacteria, viruses, or other agents.

Premature mortality. a) Any preventable death. b) Deaths that occur before a specified age, often age 65, or the average life expectancy of a certain population.*

Prevalence. The total number of cases of a given disease at a particular point in time, includes new (*i.e.*, incidence) as well as chronic cases.

Productivity loss. The monetary value of output that would have been produced in the absence of an illness, disability, injury, morbidity, or premature mortality.

Reiter syndrome. Inflammation of the joints and sometimes the eyes and urinary tract. Reiter syndrome (a form of reactive arthritis) typically lasts for 6 weeks and can go on to develop other rheumatoid syndromes, such as rheumatoid arthritis. Reactive arthritis is seen equally in females and males, and sometimes in children. Almost all sexually acquired Reiter syndrome cases are seen in males aged 20-40 years.

Recurrent. "1. Running back, or toward the source, 2. returning after remissions" (Dorland's Dictionary 1994).

Reservoir of infection. "1. Any person, animal, arthropod, plant, soil, or substance, or a combination of these, in which an infectious agent normally lives and multiplies, on which it depends primarily for survival, and where it reproduces itself in such a manner that it can be transmitted to a susceptible host. 2. The natural habitat of the infectious agent" (Dict. of Epid. 1995, p. 146).

Resistance. "The natural ability of an organism to resist microorganisms or toxins produced in disease" (Dorland's Dictionary 1994).

Risk premium. The increased wage needed to attract workers to riskier jobs.

Salmonellosis. An illness in humans caused by *Salmonella*. The disease induces fever, nausea, abdominal cramps, diarrhea, and sometimes vomiting. Severity ranges from mild diarrhea to bacteremia and death.

Sepsis. "Presence of disease-causing organisms or their toxins in the blood or tissues" (Webster's Dictionary 1984). Sepsis is a syndrome of decreased blood pressure and capillary leakage.

Septicemia. "Systemic disease caused by pathogenic organisms and their toxins in the bloodstream" (Webster's Dictionary 1984).

Sequelae. Abnormal conditions that arise following the acute phase of a disease. For example, kidney failure may follow acute *E. coli* O157:H7 disease.

Serotypes. "A group of related microorganisms distinguished by its composition of antigens" (Webster's Dictionary 1984). Serotype is sometimes called serovar.

Societal perspective. The perspective of society as a whole. Economic analyses typically take a societal perspective to include all benefits of a program regardless of who receives them and all costs regardless of who pays them.*

Surveillance data. Data on individual cases of foodborne illness that were cultured in a laboratory and reported to the CDC surveillance system.

Virulence. The pathogenic or poisonous potential of bacteria, fungi, or other agents.

Willingness-to-pay (WTP). A measure of the value an individual would place on reducing risk of death or illness. It is the maximum dollar amount the individual would be willing to give up in a given hypothetical risk-reducing situation.

* These terms are from Haddix, A. C., S. M. Teutsch, P. A. Shaffer, and D. O. Duñet (eds.). *Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation*. New York: Oxford University Press, 1996 (definitions may have been adapted for this report).

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Medical Costs and Productivity Losses

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Introduction

Foodborne diseases in the United States cost billions of dollars each year. The Council for Agriculture and Science Technology (CAST) concludes that microbial pathogens in food cause 6.5-33 million cases of human illnesses in the United States and up to 9,000 deaths each year (1994). Pathogens are microorganisms that cause diseases and include bacteria, fungi, parasites, and viruses. Researchers at the Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA) estimate that the annual cost of human illnesses for seven of these foodborne pathogens (six bacteria and one parasite) from all food sources is $5.6-$9.4 billion (*Federal Register* Feb. 3, 1995). Of these estimated costs, meat and poultry sources account for $4.5-$7.5 billion (*Federal Register* Feb. 3, 1995). These estimates undervalue the true costs of foodborne illnesses to society, because there are over 40 different foodborne pathogens believed to cause human illnesses (CAST 1994, pp. 11-15).

This report documents ERS analyses for the six bacteria mentioned above, providing a comprehensive, detailed accounting of how the cost-of-illness (COI) estimates were calculated and updated to 1993 dollars.[1] Previously, documentation for COI studies on these bacteria were spread out over diverse sources as each individual COI analysis was completed. This report is the first to comprehensively document the ERS COI analyses in terms of a given base year (in this case, 1993 dollars). The intended audience for this report is all researchers and policymakers interested in the societal costs of food safety.

Specifically, this report presents previously estimated costs of salmonellosis (Roberts 1988), listeriosis (Roberts and Pinner 1990), *E. coli* O157:H7 disease (Roberts and Marks 1995), campylobacteriosis (Lin *et al*. 1993), *Staphylococcus aureus* illness (Roberts 1989), and *Clostridium perfringens* illness (Roberts 1989), after updating to 1993 dollars and with more recent estimates of annual cases and deaths. These six bacteria from all food sources cost the United States an estimated $2.9-$6.7 billion annually (in 1993 U.S. dollars), with $1.8-$4.8 billion attributable to meat and poultry (*Federal Register* Feb. 3, 1995).

The COI estimates reported here can be used in three main ways. First, they can be used to evaluate the economic impact of foodborne diseases on the United States. Second, they can be used to target pathogen reduction efforts toward the most costly diseases. Third, they can be used to compare benefits and costs of control efforts to determine the most cost-effective interventions.

Bacteria

Of the four pathogen types (*i.e.*, bacteria, fungi, parasites, and viruses), Bean *et al.* (1990) found that over 90 percent of confirmed foodborne human illness cases and deaths reported to the Centers for Disease Control and Prevention (CDC) are attributed to bacteria.[2] Bacteria are commonly found in soil, water,

[1]The parasite, *Toxoplasma gondii,* was not included in this document because we wanted to focus on bacterial pathogens as a group and because the cost-of-illness analysis for *T. gondii* was well documented by Roberts and Frenkel (1990).

[2]Note that bacteria are more easily cultured than viruses and therefore the percentage attributed to bacteria may be biased upward. Also note that roughly half of the foodborne outbreaks cannot be attributed to a specific bacterial, viral, parasitic, or fungal pathogen.

plants, and animals (including humans). Most bacteria do not cause human illnesses and society relies on some bacteria to make bread, alcohol, vitamins, and antibiotics. Bacteria in the human body outnumber human cells (CAST 1994, p. 24). Over 400 species of bacteria live harmlessly in the gastrointestinal tracts of humans and some live on human skin (CAST 1994, p. 24). For example, *Staphylococcus aureus* lives harmlessly on human skin and in nasal cavities of up to 50 percent of all people in the United States; present in food, however, it can produce toxins that cause human illness (Labbe 1989, p. 498).

Food sources account for most human illness cases caused by the six bacteria discussed here except for *Staphylococcus aureus*. People can also be exposed to some bacteria through inhalation, contaminated drinking water, and contact with infected pets, farm animals, and humans. Here, "food sources" is broadly defined to include all sources of exposure to pathogens in the food chain, between exposure at the farm or production level to exposure at the food consumption level. Here, food sources also include secondary sources of exposure to foodborne illnesses, such as transmission of a foodborne illness from an ill person to other family members or other children in a day care center. Therefore, "foodborne illnesses" or "foodborne diseases" can originate at any of these stages.

Table 1 lists seven pathways through which people can be exposed to pathogens found in animals. Illnesses from exposure to pathogens through any of those seven pathways are included in estimates of foodborne diseases. Illnesses in farm families or slaughterhouse workers that arise from either direct or indirect contact with live animals are categorized here as illnesses from food sources, because these illnesses would not have occurred had these people not been exposed to this occupational hazard.

Although table 1 focuses on pathogens found in meat, an abbreviated list could be developed for pathways of human exposure to pathogens found in non-animal food sources, such as on fruits and vegetables. Also, the seven pathways in table 1 do not have an equal likelihood of causing human illnesses. Most foodborne illnesses occur from consumption of food contaminated with pathogens. Less common is the inclusion of kitchen/processing plant workers who become

Table 1—Potential pathways of human exposure to pathogens found in animals

I. Direct contact with live food animal.
- ° Food animal bite.
- ° Contact with the skin, fur, tail, etc., and microorganisms found there.

II. Indirect contact with the live food animal.
- ° Aerosol contamination of the barn and air system.
- ° Contamination of the walls, floor, gates, etc.
- ° Animal waste.
- ° Bites by flies or fleas that had become disease vectors from previous contact with infected animals.

III. Direct contamination by the carcass.
- ° Penetration of the skin of the personnel handling meat by microorganisms.
- ° Entry of organisms through cuts and nicks on the hand of slaughterhouse or processing plant workers.

IV. Indirect contamination by the carcass.
- ° Aerosol contamination through pathogens released when the carcass is cut up and/or slapped onto the counter.
- ° Contact with knives, wiping clothes, sinks, etc., where pathogens have been deposited.

V. Cross contamination of other edible products from the environment, other foods, or pests.
- ° In the slaughterhouse, spreading from one contaminated carcass to others.
- ° Meat products in the processing plant.
  - ° Other raw or cooked foods in the kitchen of a private home or commercial feeding establishment.

VI. Consumption of meat, poultry, and dairy products.

VII. Person-to-person transmission.

Source: Economic Research Service, USDA, adapted from Roberts, T. "A Retrospective Assessment of Human Health Protection Benefits from Removal of Tuberculous Beef," *Journal of Food Protection* 49,4(April 1986):293-8.

ill by handling contaminated food. For example, brucellosis, psittacosis, and tuberculosis are occupational hazards among slaughterhouse workers.

Some pathogens that cause human illnesses are carried by animals but do not cause animal diseases. *Escherichia coli* O157:H7 seems to live innocuously in the intestinal tracts of some cattle, though people who eat rare hamburgers from infected animals can develop bloody diarrhea and kidney failure.

Farm livestock and poultry infected with bacterial pathogens may spread infection among the herd or flock through their excrement. Nonetheless, contamination of meat and poultry flesh does not usually occur until slaughter. For example, Martz (1994-95) quotes Stephen Knabel, a food scientist at Pennsylvania State University, as stating that "only 5 percent of live poultry are contaminated with *Salmonella*, but after processing, nearly half of the carcasses contain *Salmonella*." Defeathering, slaughtering, chilling, and processing stages all provide opportunities for cross-contamination. Accidental puncturing of the intestinal tract during slaughter can lead to widespread contamination of the packing line.

Animal products such as milk and eggs also require proper handling. For example, if pasteurization of raw milk is not done properly, some *Listeria* may survive, though injured, and recover sufficiently to grow in refrigerated milk. Proper sanitation on the farm, in fishing vessels, and in slaughter and processing plants can reduce the pathogen level in food that goes to retail.

For each of the six bacterial pathogens discussed here, table 2 provides estimates of the number of annual U.S. cases and deaths from all sources and from foodborne sources. The estimates are subject to revision as new data become available or alternative databases are used.

Table 3 presents major and minor food sources for these pathogens. Foods most likely to cause outbreaks of human illness in the United States are animal foods and their products such as meat, poultry, seafood, dairy products, and eggs (CAST 1994, p. 32). Table 3 also lists acute symptoms and chronic complications associated with infections from each of these foodborne pathogens.

Human illnesses caused by microbial pathogens are generally classified in three categories: foodborne infections, foodborne toxicoinfections, and foodborne intoxications (CAST 1994, pp. 17-20). Figure 1 shows the classification of foodborne disease causes.

- *Foodborne infections* occur when pathogens are eaten and are then established in the body. The pathogens usually multiply inside human intestinal tracts, irritate the lining of the intestines, and cause human illnesses. Sometimes, the pathogens invade other tissues causing additional infections. Of the six pathogens investigated here, *Listeria*, *Salmonella*, and *Campylobacter* cause foodborne infections.

- *Foodborne toxicoinfections* occur when the pathogens produce harmful or deadly toxins while multiplying in human intestinal tracts. It is these toxic byproducts and not the pathogens themselves that cause human illnesses. In this report, two pathogens that cause foodborne intoxication are examined: *Clostridium perfringens* and *E. coli* O157:H7.

- *Foodborne intoxications* are caused by consuming food that contains either toxins released during the growth stages of specific bacteria (*e.g.*, enterotoxins produced by *Staphylococcus aureus*, a pathogen included here) or mycotoxins produced by molds. Illnesses from foodborne intoxications tend to occur quickly after consumption, because they do not involve any establishment or growth stage in the human body.

The CAST report (1994, p. 27) identifies four main categories of factors that increase the risk or severity of a foodborne illness: **microbial factors** such as the type, strain, and quantity of pathogens or toxins ingested; **host factors** such as age, stress, health of the individual's immune system, and personal hygiene; **diet-related factors** such as consumption of antacids and nutritional deficiencies; and **other factors** such as geographical location.

Most cases of foodborne illnesses are classified as acute, because they have a rapid onset and are self-limiting. Acute foodborne illnesses can be mild or severe and may result in premature death. Common acute symptoms of foodborne illnesses are gastrointestinal problems and vomiting.

Table 2—Estimated annual U.S. cases, deaths, and percentage foodborne for selected bacterial pathogens, 1993

Pathogen	Total cases	Total deaths	Percent foodborne	Foodborne cases	Foodborne deaths
	- - - - - - - -Number- - - - - - - -		*Percent*	- - - - - - - -Number- - - - - - - -	
Campylobacter jejuni or *coli*	2,500,000[f]	200-730[f]	55-70[h]	1,375,000 - 1,750,000	110-511
Clostridium perfringens	10,000[b]	100[b]	100[b]	10,000	100
Escherichia coli O157:H7	10,000-20,000[a]	200-500[a]	80[a]	8,000 - 16,000	160-400
Listeria monocytogenes	1,795-1,860[d]	445-510[d]	85-95[e]	1,526-1,767	378-485
Salmonella (non-typhoid)	800,000-4,000,000[bc]	800-4,000[bc]	87-96[bg]	696,000 - 3,840,000	696-3,840
Staphylococcus aureus	8,900,000[b]	7,120[b]	17[b]	1,513,000	1,210
Total	12,221,795-15,431,860	8,865-12,960	N/A	3,603,526 - 7,130,767	2,654-6,546

N/A = Not applicable.

Sources: USDA, Economic Research Service, based on:

[a] Personal communication with researchers at the U.S. Centers for Disease Control and Prevention, and from the article: American Gastroenterological Association, "Consensus Conference Statement on *E. coli* O157:H7 Infections, An Emerging National Health Crisis." July 11-13, 1994. *Gastroenterology* 108(1995):1923-1934.

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[g] Tauxe, R.V. and P.A. Blake. 1992. "Salmonellosis." Chapter 12 in Last, J.M., R.B. Wallace, and E. Barrett-Conner (eds.), *Public Health & Preventive Medicine*, 13th ed., Norwalk, Connecticut: Appleton & Lange, pp. 266-268.

[h] Tauxe, R.V., N. Hargrett-Bean, C.M. Patton, and I.K. Wachsmuth. "*Campylobacter* Isolates in the United States, 1982-1986," *Morbidity and Mortality Weekly Report*, 31,SS-2(1988):1-14.

Table 3—Pathogen food reservoirs/transmission and possible acute symptoms and chronic complications

Pathogen	Food sources	Acute symptoms and chronic complications[1]
Campylobacter jejuni or *coli*	Major: poultry Minor: milk, mushrooms, clams, hamburger, water, cheese, pork shellfish, eggs, cake icing.	Acute: abdominal pain, diarrhea (sometimes bloody), fever, malaise, vomiting. Chronic: appendicitis, arthritis, carditis, cholecystitis, colitis, endocarditis, erythema nodosum, Guillain-Barré syndrome, hemolytic-uremic syndrome, meningitis, pancreatitis, Reiter syndrome, septicemia, urinary tract infection.
Clostridium perfringens	Major: meat, meat stews, meat pies, and beef, turkey and chicken gravies. Minor: beans, seafood.	Acute: diarrhea, nausea Chronic: gas gangrene, necrotizing enteritis.
Escherichia coli O157:H7	Major: beef particularly ground beef. Minor: poultry, apple cider, raw milk, vegetables, cantaloupe, hot dogs, mayonnaise, salad bar items.	Acute: abdominal pain, diarrhea, fever, malaise. Chronic: erythema nodosum, hemolytic uremic syndrome, chronic kidney disease, thrombotic thrombocytopenic purpura, seronegative arthropathy.
Listeria monocytogenes	Major: soft cheese, pâté, ground meat. Minor: poultry, dairy products, hot dogs, potato salad, chicken, seafood, vegetables.	Acute: fever, severe headache, vomiting, sometimes delirium or coma. Chronic: chronic neurological complications, endocarditis, granulomatous lesions in organs, internal or external abscesses, meningitis, sepsis, septicemia.
Salmonella (non-typhoid)	Major: poultry, meat, eggs, milk, and their products. Minor: vegetables, fruits, chocolate, peanuts, shellfish.	Acute: abdominal pain, bloody stools, cold chills, dehydration, diarrhea, exhaustion, fever, headache, and sometimes vomiting. Chronic: abscesses, aortitis, arthritis, cholecystitis, colitis, endocarditis, epididymo-orchitis, meningitis, myocarditis, pericarditis, pneumonia, proderma or pyelonephritis, rheumatoid syndromes, septicemia, reactive arthritis, Reiter syndrome, splenic abscesses, thyroiditis.
Staphylococcus aureus	Major: workers handling foods: meat (especially sliced meat) poultry, fish, canned mushrooms. Minor: dairy products, prepared salad dressing, ham, salami, bakery items, custards, cheese.	Acute: severe nausea, cramps, vomiting, prostration, often with diarrhea. Chronic: none identified to date.

[1]USDA, Economic Research Service, adapted from:

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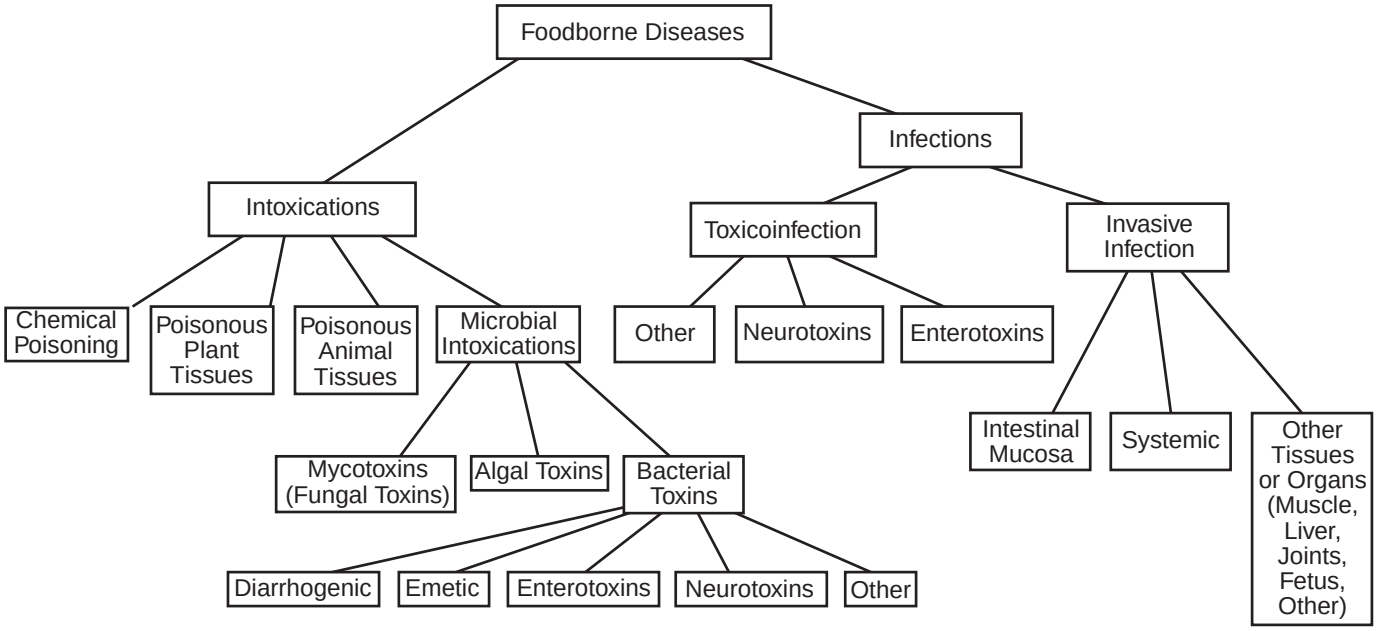
Figure 1
A Classification of foodborne disease causes



Source: CAST report, Figure 2.1, 1994 (adapted from Bryan, 1982).

Archer and Kvenberg (1985) estimate that 2-3 percent of these acute cases develop secondary long-term illnesses or chronic sequelae. Chronic sequelae of foodborne illnesses can occur in any part of the body and include rheumatoid, cardiac, and neurological syndromes (table 3). These chronic illnesses may afflict the patients for the remainder of their lives or cause premature death. For example, reactive arthritis and Guillain-Barré syndrome (a major cause of non-trauma neuromuscular paralysis in the United States) may follow *Campylobacter* infections.

Traditionally, only acute cases of some foodborne diseases have been recorded. Improved collection and documentation of data on foodborne illnesses may increase our understanding of the magnitude of chronic sequelae and show that the longrun effects of chronic illnesses are often greater than the initial acute illnesses.

Regulation

Food safety regulations reduce human illnesses through preventing and controlling the presence and amount of foodborne pathogens and other disease-causing elements (*e.g.*, pesticides) in food. In making food safety policy decisions, the Federal Government relies, in part, on economic information of foodborne illnesses and alternative regulatory programs that reduce foodborne health risks (*i.e.*, increase food safety). A comparison of societal benefits and costs among programs aimed at reducing different pathogens can facilitate setting priorities as to which pathogens should be targeted first. Estimates and comparisons of the benefits and costs of competing programs can also help the Federal Government efficiently allocate tax dollars.

A case in point is the Pathogen Reduction Program proposed in 1994 by the Food Safety and Inspection Service (FSIS) of the USDA. As part of this program, FSIS promulgated a Hazard Analysis Critical Control Point (HACCP) system to improve the current meat and poultry inspection. A portion of the COI estimates from this document plus the estimated annual costs of illness caused by *Toxoplasma gondii*, a parasite, provide the foundation of the estimated benefits of HACCP (*Federal Register* Feb. 3, 1995). Preliminary results indicate that the benefits of implementing HACCP outweigh the costs.

Table 4 outlines societal costs of foodborne illnesses. The three cost categories are costs incurred by individuals/households, industry, and the regulatory and public health sector. Note that traditional COI analyses often include only individual's/household's medical costs and cost of lost productivity. Other costs are usually omitted due to lack of suitable measures.

The costs of food safety regulation include expenditures associated with design and implementation of, and compliance with, such programs. In fiscal year 1994, the Federal Government budgeted $1.2 billion on food safety regulatory activities, such as inspection and laboratory testing (GAO March 1996). The food industry also incurs millions of dollars of expense to comply with food safety rules and regulations. If new regulations are added to the current system, industry compliance costs will be higher.

Societal benefits of food safety regulation arise from improvement of individuals' health status. From an economic perspective, these benefits include, at least, savings in disease prevention and mitigation expenditures, increases in worker productivity, reduction in pain and suffering, and reduction in anxiety about foodborne health risk.

ERS COI estimates represent the maximum benefits that could be obtained if the microbial infections or intoxications were eliminated or reduced. However, eradication of these illnesses is neither technically nor economically feasible at present. The information contained in this report can help Federal agencies identify the most cost-beneficial risk-reduction strategies for bacterial pathogens.

Overview of the Willingness-to-Pay and Cost-of-Illness Methods

Three principles guide economic analysis of regulations aimed at improving health and safety. The first is that benefits from the regulation need to be measured and compared with costs, because regulatory costs are opportunity costs. That is, the resources used could have been applied elsewhere, with potentially greater health benefits. For example, an expenditure of $100 million that is expected to prevent 4 deaths may not be very sensible if that $100 million could have prevented 50 deaths by being spent in another application.

The second principle asserts that health and safety regulations typically do not aim to save the lives of specific people who would otherwise die, but rather aim at reducing the level of risk of illness and death faced by large populations. That view intertwines with the third principle, that the benefits of a regulation do not represent the value of keeping a specific person alive, but rather the value of reducing those risks. To this end, the most theoretically appropriate way to value a risk reduction is to ask what affected individuals are willing to pay for it. However, as we shall see here, estimating the costs of an illness by summing estimated medical costs and costs of lost earnings is useful for studying specific policy questions.

Taken together, the principles recognize that regulators act on behalf of society to reduce societal risk by spending taxpayers' money and by setting and enforcing regulations. In other contexts, people spend their own money to reduce health risks (*e.g.*, through regular physician visits, or through diet control, or when choosing among different brands of durable goods like cars, household appliances, or power equipment). Once it is recognized that regulation delivers an outcome (small risk reductions) that people also purchase in other public and private venues, one can ask whether publicly delivered risk reductions appear to be worth it to the relevant populations, based on what they are willing to expend to achieve risk reductions in other contexts.

Economic theory provides a precise framework that associates the benefits of risk reduction with the amount that people are willing to pay to achieve the reduction, and suggests methods of measuring those benefits (Just *et al*. 1982). As is often the case, some key theoretical constructs cannot be observed; as a result, practical applications of the theory aim at approximations of the theoretically appropriate measures. The practical applications for human illnesses can be grouped into two primary methods of benefit estimation, the cost-of-illness (COI) method and the willingness-to-pay (WTP) method. The WTP method aims, as the name implies, to estimate the value that individuals place on reductions in risk to identify the value to society of publicly provided risk reduction.

Table 4—Societal costs of foodborne illness

Costs to individuals/households[1]
Human illness costs:
- Medical costs—
  - Physician visits
  - Laboratory costs
  - Hospitalization or nursing home
  - Drugs and other medications
  - Ambulance or other travel costs
- Income or productivity loss for—
  - Ill person or person dying
  - Caregiver for ill person
- Other illness costs—
  - Travel costs to visit ill person
  - Home modifications
  - Vocational/physical rehabilitation
  - Child care costs
  - Special educational programs
  - Institutional care
  - Lost leisure time
- Psychological (psychic) costs—
  - Pain and other psychological suffering
  - Risk aversion

Averting behavior costs—
- Extra cleaning/cooking time costs
- Extra cost of refrigerator, freezer, etc.
- Flavor changes from traditional recipes (especially meat, milk, egg dishes)
- Increased food cost when more expensive but safer foods are purchased

Altruism (willingness to pay for others to avoid illness)

Industry costs[2]
Costs of animal production:
- Morbidity and mortality of animals on farms
- Reduced growth rate/feed efficiency and increased time to market
- Costs of disposal of contaminated animals on farm and at slaughterhouse
- Increased trimming or reworking at slaughterhouse and processing plant
- Illness among workers because of handling contaminated animals or products
- Increased meat product spoilage due to pathogen contamination

Control costs for pathogens at all links in the food chain:
- New farm practices (age-segregated housing, sterilized feed, etc.)
- Altered animal transport and marketing patterns (animal identification, feeding/watering)
- New slaughterhouse procedures (hide wash, knife sterilization, carcass sterilizing)
- New processing procedures (pathogen tests, contract purchasing requirements)
- Altered product transport (increased use of time/temperature indicators)
- New wholesale/retail practices (pathogen tests, employee training, procedures)
- Risk assessment modeling by industry for all links in the food chain
- Price incentives for pathogen-reduced product at each link in the food chain

Outbreak costs:
- Herd slaughter/product recall
- Plant closings and cleanup
- Regulatory fines
- Product liability suits from consumers and other firms
- Reduced product demand because of outbreak:
  - Generic animal product - all firms affected
  - Reduction for specific firm at wholesale or retail level
- Increased advertising or consumer assurances following outbreak

See footnotes at end of table.

--Continued

Table 4—Societal costs of foodborne illness--Continued

Regulatory and public health sector costs for foodborne pathogens

Disease surveillance costs to:
- Monitor incidence/severity of human disease by foodborne pathogens
- Monitor pathogen incidence in the food chain
- Develop integrated database from farm to table for foodborne pathogens

Research to:
- Identify new foodborne pathogens for acute and chronic human illnesses
- Establish high-risk products and production and consumption practices
- Identify which consumers are at high-risk for which pathogens
- Develop cheaper and faster pathogen tests
- Risk assessment modeling for all links in the food chain

Outbreak costs:
- Costs of investigating outbreak
- Testing to contain an outbreak (for example, serum testing and administration of immunoglobulin in persons exposed to Hepatitis A)
- Costs of cleanup
- Legal suits to enforce regulations that may have been violated[3]

Other considerations:
- Distributional effects in different regions, industries, etc.
- Equity considerations, such as special concern for children

[1] Willingness-to-pay estimates for reducing risks of foodborne disease is a comprehensive estimate of all these categories (assuming that the individuals have included employer-funded sick leave and medical programs in their estimates). The estimate is comprehensive and covers reduced risks for everyone—those who will become ill as well as those who will not.

[2] Some industry costs may fall with better pathogen control, such as reduced product spoilage, possible increases in product shelf-life, and extended shelf-life permitting shipment to more distant markets or lowering shipment costs to nearby markets.

[3] In adding up costs, care must be taken to assure that product liability costs to firms are not already counted in the estimated pain and suffering cost to individuals. However, the legal and court expenses incurred by all parties are societal costs.

Source: USDA, Economic Research Service, based on Roberts, Tanya, and Ewen Todd. "Approaches to Estimating the Cost of Foodborne Disease," *WHO Consultation on the Economic Implications of Animal Production Food Safety.* Washington, DC, June 8-10, 1995.

The COI approach can be thought of as measuring the costs of an illness to the measured economy, via effects on current and future Gross Domestic Product. In brief, COI measures the sum of medical expenses, forgone earnings of affected individuals, and productivity losses to employers of affected individuals on paid sick leave. The important advantage of a COI measure is that it employs readily available and reliable data. Also, these relevant data are precise enough to allow for sensitivity analyses of the response of the measure to changes in medical costs, productivity losses, and disease severity categories of affected individuals. Because they are so tractable, COI measures have been widely used for several decades.

For some human illnesses, patients die prematurely or are unable ever to return to work. In a COI analysis, the lost productivity for these patients can be represented either by human capital estimates of forgone earnings or by WTP estimates of the value of a statistical life. Therefore, the COI method can partially incorporate the WTP measure for these categories of patients.

In general, COI methods aim at calculating the costs of illness to the measured economy. That is not the same thing as calculating the valuation that people place on reductions in risk, because forgone earnings are not necessarily a good indicator of that valuation. Some authors (Harrington and Portney 1987) argue that COI can serve as a lower bound estimate for willingness to pay.

Taken literally, human capital estimates of forgone earnings suggest that the method places little value on reducing risk of the elderly, because they have low future earnings to forgo. Similarly, the method typically attaches rather low values to risk reduction for children, because future earnings are discounted to present values. Depending on the discount rate

used, the present value of children's future earnings can be quite small. Common observation suggests that assigning low values for reducing risks to children and the elderly is not a good approach, since we can observe people spending substantial amounts on risk avoidance for those groups, especially children.

More generally, the COI approach seems to be crudely "economic" in the sense that it values lost income and the associated consumption expenditures; but in fact the approach does not conform with economic theory because it fails to recognize the value that individuals may place on (and pay for) feeling healthy, avoiding pain, or using their free time. Because the COI approach explicitly ignores these valuable aspects of health, the method is generally thought to understate the true societal benefits from risk reduction.

While there are several methods that attempt to isolate willingness to pay, recent attention in estimating the value of a statistical life has focused on one, hedonic wage estimation.[3] Hedonic wage studies derive the value of risk reduction by statistically estimating the effect of occupational mortality and injury risks on wages. Typically, employers must offer workers higher wages to induce them to take a job with some injury risks, as opposed to a similar job with no such risks. Conversely, workers accept jobs with lower wages, given that those jobs offer minimal risks. The "risk premium" is then the increased wage needed to attract workers to riskier jobs. Economists began to use statistical methods to estimate typical risk premiums in the 1970's, in analyses that could control for other factors that influenced wages, such as education, experience, and location.

Economists are partial to the hedonic wage method, because it uses actual choices made in response to differing risk environments. However, early applications of the method were controversial for reporting widely varying values for risk premiums. With the development of more precise risk measures, better understanding of the affected populations in the studies, and better control variables, analysts have been able to generate a narrower range of values, leading to greater acceptance of hedonic wage models in recent years.

The typical hedonic wage study uses a measure of mortality risk, and measures the effects of a change in mortality risk on wages; a typical study might find that an increase in mortality risk of 1 in 10,000 (one extra death in a year for every 10,000 workers in the relevant population) would be associated with a wage increase of $300. In an industry with 10,000 workers, then, we could expect one additional worker to die each year on average, and as a result total wage payments would be $3 million higher ($300 times 10,000 workers). In that case we would say that the value of a statistical life was estimated to be $3 million, because industry had to pay that amount to induce workers to take on a risk that would likely leave one dead (alternatively, one could in this analysis say that workers would in the aggregate be willing to pay $3 million, through wage reductions, to purchase a reduction in risk).

Note the emphasis above on our second principle, that what we purchase in these cases are small reductions in health risks. Analysts often carelessly refer to the "value of a life" derived from these studies, which is easily confused with the crude idea that economic analyses associate the value of a life with lifetime earnings. But that is not what economic theory describes as the appropriate measure, nor is it what willingness-to-pay studies seek to uncover. They seek to measure the value that individuals place on small reductions in risk, a value likely to be only loosely related to income.

Does method matter? Apparently so. Cost-of-illness studies, as shown in more detail below, estimate separate values of forgone earnings for illnesses and for deaths. COI aggregate estimates are usually dominated by the forgone earnings associated with premature deaths; typical values of forgone earnings vary between methods. The Landefeld and Seskin value of statistical life varies, depending on age, from $11,867 to $1,584,605 in 1993 dollars. However, hedonic wage studies suggest that employed people would be willing to pay between $3 million and $7 million (1990 dollars) to reduce the risks generating each additional death (Viscusi 1993). As a result, the COI method is likely to give extremely conservative benefit estimates for publicly provided risk reduction.

[3]Fisher *et al.* (1989, p. 89) divide the WTP approach into three categories of studies: (1) contingent market studies, (2) consumer market studies, and (3) wage-risk studies.

Our example shows how hedonic wage studies use the wage response to mortality risks to generate estimates for the value of a statistical life. The exercise points out one current weakness of hedonic wage studies; these studies have much better data, and more useable estimates, for mortality risks than they do for morbidity risks (*i.e.*, risk of temporary or chronic illness). Even where morbidity risks are incorporated, it is questionable how closely risk aversion to the job-related illnesses resembles risk aversion to illnesses associated with foodborne pathogens. If we base estimated values of risk reduction on hedonic wage studies only, we may make the error of understating the value of the risk reduction because these studies focus on mortality risks and often implicitly ignore morbidity risks.

Cost-of-Illness (COI) Method

This section outlines the basic framework behind the six COI analyses presented here. Due to differences in available data and differences in chronic sequelae examined for each bacterial pathogen, these six analyses vary in depth, though all basically look at both medical costs and the costs of lost productivity from the illnesses.

Incidence

The first step in any COI analysis is to determine the incidence of a specific illness. Incidence rates are often expressed as the number of new cases of a disease per 100,000 individuals in the U.S. population in a 1-year period.[4] The quantification of foodborne disease incidence is a matter of great controversy because of uncertainties over the true state of the world (CAST 1994; Roberts and Foegeding 1991). The enumeration of a case of a foodborne disease depends on whether: (1) the affected individual recognizes food as the cause of the illness, (2) a physician is consulted, (3) a hospital is sought for treatment, (4) the physician recognizes the illness as foodborne, (5) the laboratory identifies a foodborne pathogen, and (6) the case is reported to the CDC.

Because the nature and reporting of foodborne diseases result in vast under-counting of the actual incidence of illnesses, incidence rates are often estimated by expert opinion.

There are five main data sources for incidence of acute foodborne illnesses: (1) national surveys or databases such as those conducted and published by the National Center for Health Statistics (NCHS), (2) CDC data ranging from reports of foodborne disease to active surveillance studies, (3) risk models based on pathogens' prevalence in foods, and on infectious doses, (4) medical data on individual cases, often published in the literature as a case history, and (5) extrapolations by experts to obtain estimates of the total number of cases and the disease severity distributions (CAST 1994, p. 40).[5] Extrapolations are upward adjustments made to account for those cases that go undiagnosed or unreported. Estimates from these data sources form the basis for some of the COI studies of foodborne diseases. Where data were available to suggest a range of cases and/or deaths, ranges were used.

Costs

Given the incidence of an illness, we computed annual medical costs and costs of lost productivity. Where possible, we considered both acute and chronic illnesses.

In general, medical costs include physician and hospital services, supplies, medications, and special procedures required for a specific foodborne illness. Hospitalization accounts for a large proportion of these costs. Estimates of medical costs come from nationwide databases such as the published Medicare reimbursement rates and per capita expenditures on physician services from the Health Care Financing Administration (HCFA), the American Hospital Association's Hospital Statistics, and the National Center for Health Statistics' National Hospital Discharge Survey (NHDS) and National Mortality Follow-back Survey.

In general, productivity loss measures the decline in production (output) because workers were ill and either missed work, performed poorly at work, were unable ever to return to work, or died prematurely.

[4]To facilitate comparison of the relative occurrence of different pathogens, incidence rates are used rather than prevalence rates. The *incidence* of a disease signifies the number of new cases occurring during a year in the United States. *Prevalence* measures the number of people sick, regardless of when the disease began, at a given point of time or over a period of time which may vary by pathogen. For decisionmaking with respect to preventative programs (such as food safety regulations), incidence rates are the appropriate statistics (Hartunian *et al.* 1980, p. 1249).

[5]Bennett *et al.* (1987) estimated the proportion of infections, for known categories, acquired through food.

Productivity losses for those who died or were unable to return to work were calculated differently from those who missed some work but later resumed work.

For those cases in which work is interrupted temporarily, the productivity loss is the product of time lost from work multiplied by the corresponding wage rate. The daily wage of an individual is frequently used in economic studies as a proxy for the value of output produced in a day's work. When data are not available on time lost from work due to illness, this lost time is estimated by assuming a typical ratio of time spent in the hospital to time lost from work. Time spent by parents, as well as payments to paid caretakers, caring for sick children may also be included as forgone productivity.

In this report, estimated productivity losses for those who die or were unable to return to work were based on Landefeld and Seskin's (LS) (1982) human capital/WTP measure. We used the LS estimates directly in the first four COI analyses (salmonellosis, listeriosis, *E. coli* O157:H7 disease, campylobacteriosis). In the remaining two COI analyses (*Staphylococcus aureus* intoxications and *Clostridium perfringens* intoxications), we extrapolated COI estimates from other analyses that used LS estimates directly.[6]

The LS method combines elements of both the human capital and WTP methods to generate the present value of expected lifetime after-tax income and housekeeping services. The LS method generates the present value of expected lifetime after-tax income and housekeeping services at a 3-percent real rate of return, adjusted for an annual 1-percent increase in labor productivity and a risk aversion factor of 1.6. The risk aversion factor is based on the ratio of life insurance premium payments to life insurance loss payments. In most cases, life insurance premiums represent "household WTP for potential losses associated with the death of an income-earning household member" (Landefeld and Seskin 1982, p. 562). The LS value of a statistical life lost is:

$$VOSL = \left[\sum_{t=0}^{T} \frac{Y_t}{(1 + r)^t}\right]\alpha \qquad (1)$$

where T = remaining lifetime, t = a particular year, Y_t = after-tax income including labor and nonlabor income, r = household's opportunity cost of investing in risk-reducing activities, and α = risk aversion factor. Table 5 provides estimates of the value of statistical life using LS estimates, after averaging across gender, interpolating between the LS's 4-year age groups, and updating to 1993 dollars.

General Framework for the Six COI Analyses

The general framework for the first two COI analyses presented here (salmonellosis and campylobacteriosis) used the following classification system: all cases were first divided into four severity categories for acute illness, and costs were then applied to each of the categories. The four severity categories were those who: did not visit a physician, visited a physician, were hospitalized, or died prematurely. Costs were summed over the four categories to calculate total costs. Medical costs and costs of lost productivity were not calculated separately.[7] The COI analyses for salmonellosis and campylobacteriosis did not consider chronic complications.

The general framework for the third and fourth COI analyses presented here (*E. coli* O157:H7 disease and listeriosis) was more inclusive than the COI analyses for salmonellosis and campylobacteriosis, because some chronic complications were considered. In the *E. coli* O157:H7 disease and listeriosis COI analyses, we first calculated medical costs and then calculated lost productivity costs. For each of these cost categories, acute and chronic cases were considered separately. We used the four severity subcategories for acute illness from the previous two analyses (*i.e.*, those who: did not visit a physician, visited a physician, were hospitalized, or died). After costs in each subcategory were estimated, total costs were calculated. For chronic cases, the lifetime course of disease and associated costs were estimated.

The remaining two COI analyses (*Staphylococcus aureus* intoxications and *Clostridium perfringens* intoxications) were more simplistic in that estimates

[6]As previously mentioned, this study updates the annual COI of *Staphylococcus aureus* and *Clostridium perfringens* intoxications from Roberts (1989) to 1993 dollars and uses more recent estimates of the numbers of cases and deaths. Roberts (1989) used the LS estimates in this fashion and we continue the practice.

[7]These COI analyses rely heavily on data from Cohen *et al.* (1978). Their data for the four disease severity categories did not distinguish between medical costs and costs of lost productivity but instead made vague comments such as "could mainly be attributed to medical care." Rather than impose assumptions about what percentage of total costs were attributed to medical costs and costs of lost productivity, we did not separate these two types of costs.

Table 5 — Estimates of the value of a statistical life

Individual age	Annual interpolated value	Individual age	Annual interpolated value	Individual age	Annual interpolated value
0	$1,097,792	28	$1,506,486	58	$401,484
0.5	$1,112,617	29	$1,447,742	59	$365,960
1	$1,127,442	30	$1,448,998	60	$330,436
2	$1,157,093	31	$1,420,254	61	$294,911
2.5	$1,171,918	32	$1,391,510	62	$259,387
3	$1,184,108	33	$1,361,425	63	$237,002
4	$1,208,488	34	$1,331,340	64	$214,617
5	$1,232,869	35	$1,301,255	65	$192,232
6	$1,257,249	36	$1,271,170	66	$169,847
7	$1,281,630	37	$1,241,085	67	$147,462
8	$1,308,213	38	$1,205,340	68	$136,672
9	$1,334,796	39	$1,169,594	69	$125,881
10	$1,361,379	40	$1,133,849	70	$115,090
11	$1,387,962	41	$1,098,104	71	$104,300
12	$1,414,546	42	$1,062,358	72	$93,509
13	$1,438,530	43	$1,018,773	73	$86,870
14	$1,462,514	44	$975,188	74	$80,231
15	$1,486,497	45	$931,602	75	$73,592
16	$1,510,481	46	$888,017	76	$66,953
17	$1,534,465	47	$844,431	77	$60,314
18	$1,544,493	48	$803,427	78	$56,302
19	$1,554,521	49	$762,423	79	$52,290
20	$1,564,549	50	$721,418	80	$48,278
21	$1,574,577	51	$680,414	81	$44,265
22	$1,584,605	52	$639,410	82	$40,253
23	$1,574,730	53	$598,929	83	$34,576
24	$1,564,855	54	$558,449	84	$28,899
25	$1,554,980	55	$517,969	85	$23,221
26	$1,545,105	56	$447,489	86	$17,544
27	$1,535,229	57	$437,009	87	$11,867

Source: Compiled by USDA's Economic Research Service, based on Landefeld and Seskin (LS) estimates. LS are divided by gender and use four-year age groups. Here, these 1977 estimates are updated to 1993 dollars, averaged across gender, and interpolated within age groups.

of the annual number of cases were multiplied by estimates of the average annual costs provided by Roberts (1989) and updated to 1993 prices. Roberts (1989) did not report medical costs and costs of lost productivity separately (or acute and chronic cases separately), and therefore they are not reported separately here.

COI Estimates of Salmonellosis

Salmonella is the main cause of documented foodborne human illnesses in most developed countries (CAST 1994, pp. 16, 32). Although there are over 2,000 *Salmonella* serotypes,[8] only around 200 serotypes are detected in the United States annually (Benenson 1990, p. 382). Most strains of *Salmonella* are from the *S. enteritidis* species and these strains are traditionally classified by their serotype designation and not by their species name (Helmick et al. 1994, p. 104). For example, the serotype *typhimurium* is found among the *S. enteritidis* species, yet is referred to as *S. typhimurium* (Helmick et al. 1994, p. 104). The 10 most common serotypes are responsible for over 70 percent of the U.S. human illnesses (Helmick *et al.* 1994, p. 104). Human illness due to *Salmonella* infections is most commonly caused by *S. typhimurium*, *S. enteritidis*, or *S. heidelberg* serotypes in the United States (Merck 1992).[9]

Typically, *Salmonella*-caused human disease is limited to salmonellosis, an acute gastroenteritis. After eating contaminated food, salmonellosis generally appears in 6 to 74 hours with an average incubation period of 12 to 36 hours (Benenson 1990, p. 383). Salmonellosis may cause only mild abdominal discomfort, with diarrhea lasting less than a day. Most people who become ill in salmonellosis outbreaks believe they have the stomach flu, not salmonellosis (Tauxe, 1987, personal communication with Roberts). Other symptoms may include dehydration, fever, headache, nausea, stomachache, and sometimes vomiting (Benenson 1990). In rare cases, blood may be present in the stools.

Salmonella infections, like many other bacterial and parasitic infections, can cause secondary-disease syndromes, some of which may be chronic illnesses (Archer 1984 and 1985; Mossel 1988) (table 3). Most *Salmonella* serotypes can penetrate the intestinal lining in humans without advancing deep into other tissues (CAST 1994, p. 17). Infrequently, the organism may invade the bloodstream causing bacteremia or septicemia, with potentially deadly results. Some complications of septicemia include endocarditis (infection of the heart), meningitis (infection of the brain or spinal tissues), and pneumonia (Merck 1992). Deaths are uncommon.

Most human salmonellosis comes from eating contaminated food (Helmick *et al.* 1994, p. 107), especially food from animal origin (Tauxe 1991, p. 565). Tauxe and Blake (1992, p. 267) found that 87 percent of all salmonellosis cases were foodborne (100 percent minus 10 percent person-to-person and 3 percent pets). Bennett *et al*. (1987, p. 109) estimated that, due to improvements in sanitation, nearly all (96 percent) salmonellosis infections are foodborne (3 percent waterborne and 1 percent from day care). We assume that 87 to 96 percent of all salmonellosis cases are foodborne.

Salmonella contamination occurs in a wide range of animal and plant products (table 3). Poultry products and eggs are frequently contaminated with *S. enteritidis*, while beef products are commonly contaminated with *S. typhimurium* (Merck 1992).[10] Other food sources of *Salmonella* may include raw milk or other dairy products and pork. *Salmonella* outbreaks also have been traced to contaminated vegetables, fruits, and marijuana (Helmick *et al.* 1994, p. 107). Tauxe reports that *Salmonella*-associated bacteremia is common in AIDS patients, some of whom consume raw milk, raw eggs, or raw beef under the mistaken belief that these products will improve their health (Tauxe 1991, p. 566).

Individuals vary greatly in their susceptibility to salmonellosis, depending partly on the virulence of the

[8]Webster's dictionary (1988) defines serotypes as "a group of related microorganisms distinguished by its composition of antigens."

[9]S. typhi, the cause of typhoid fever in the United States between the late 1800's and 1949, used to be the chief serotype affecting humans in the United States (Tauxe 1991). Typhoid fever has been virtually eliminated in the United States through public health measures such as improved drinking water treatment and sewage disposal (Tauxe 1991). Therefore, this report covers non-typhoid Salmonella cases.

[10]S. enteritidis serotype enteritidis has emerged as a major food safety problem with shell eggs during the past decade because of genetic or other changes that permit the organism to get inside the egg. Infected hens transmit S. enteritidis to the egg as the egg is produced (Tauxe 1991, p. 567). This has resulted in an epidemic of S. enteritidis infections and a corresponding shift in the overall ranking of serotypes. Salmonella outbreak investigations have shown that the most common source of infections are grade A shell eggs (Helmick et al. 1994, p.104).

serotype and partly on the individual's immune system, along with other factors such as the quantity of *Salmonella* ingested. The infectious dose may be as low as one colony forming unit (CFU) for some *Salmonella* serotypes (CAST 1994, p. 13; Archer and Young 1988, p. 380). Usually, ingestion of at least 10^{2-3} organisms are required for infection (Benenson 1990, p. 382).

Those most vulnerable to *Salmonella* infection and secondary complications are infants, the elderly, and the immunocompromised (*e.g.*, those with cancer, sickle cell anemia, and AIDS) (Helmick *et al.* 1994, p. 104). People who take oral antibiotics may have decreased colonization resistance to *S. typhimurium* (CAST 1994, p. 25). Riley *et al.* (1984, p. 878) suggest that those *Salmonella* serotypes that are resistant to antimicrobial agents depend more heavily on the characteristics of the host to cause human illness than do those serotypes sensitive to antimicrobial agents. Arthritis complications provoked by *Salmonella* infection are more likely to be found among those who are genetically predisposed (Helmick *et al.* 1994, p. 107). Ryan *et al.* (1987, p. 3271) found that children under 10 years of age were more likely to contract salmonellosis than people 10 years old or older.[11] They also found that those most severely affected out of a sample of culture-confirmed salmonellosis cases were children 1 to 4 years old (Ryan *et al.* 1987, p. 3271). Salmonellosis patients who are immunocompromised, very old, or very young face a higher risk of death (Benenson 1990, p. 381). Figure 2 shows *Salmonella* isolation rates by age and sex.

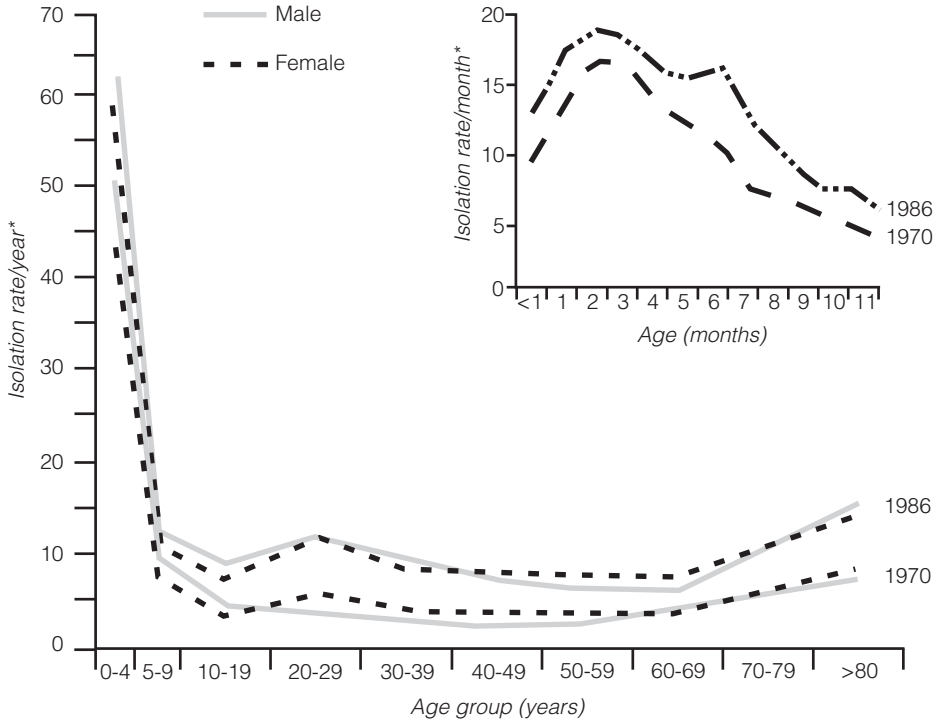
Estimates of Cases

Three basic sources of data can be used to estimate the number of annual salmonellosis cases: surveillance data, outbreak data, and extrapolations from sur-

[11]This result is based on a sample of persons with a salmonellosis-like illness after drinking contaminated milk. The data are from a survey of persons in two Illinois counties (April 14-25, 1985).

Figure 2

Salmonellosis rates, by age and sex of patient and year, United States, 1970 and 1986



* Per 100,000 population

Source: Hargrett-Bean N., A. T. Pavia, and R. V. Tauxe. "*Salmonella* Isolates from Humans in the United States, 1984-86" *Morbidity and Mortality Weekly Report,* 37, SS-2 (1988): 25-31.

veillance and outbreak data.[12] Since 1943, CDC's National Notifiable Diseases Surveillance System has recommended that States report salmonellosis cases (Helmick *et al.* 1994, p. 104). This means that, in participating States, physicians report salmonellosis cases to local health departments, local health departments report these cases to State health departments, and State health departments report total annual cases to CDC (Tauxe 1991, p. 564). Local health departments also investigate to determine if the cases are foodborne. This reporting results in a better estimate of the incidence of salmonellosis than for most other bacterial diseases. A second surveillance reporting system, introduced in 1963 where State public health laboratories report *Salmonella* isolates to CDC (Helmick *et al.* 1994, p. 104), has an even higher rate of salmonellosis positive tests.

Both surveillance data and outbreak are clearly underestimates. As previously mentioned, infection may not be suspected, cultured, diagnosed, or reported for a variety of reasons. Therefore, estimates of the "true" incidence of salmonellosis are generally extrapolated from these two types of data.

Chalker and Blaser (1988, p. 120) investigated various methods to calculate the annual number of *Salmonella* infections not reported. They estimated that each year, only 1-5 percent of all *Salmonella* infections are reported to CDC. Tauxe (1991, p. 564) found that in the late 1980's, the National *Salmonella* Surveillance System reported 40,000 to 45,000 *Salmonella* isolates each year. Using the low estimate of isolates (40,000) and Chalker and Blaser's multipliers,[13] the CDC's best estimate of human *Salmonella* infections annually in the United States is 800,000 to 4 million cases (Helmick *et al.* 1994, p. 104) (table 6).

This report uses a range of 800,000 to 4 million annual cases of salmonellosis to update Roberts' (1988) COI estimates for salmonellosis. As with each of the six foodborne illnesses discussed here, salmonellosis cases are divided into four severity categories, those who: do not seek medical attention, visit a physician, are hospitalized, and die prematurely. Both a low and a high cost estimate were calculated for each severity category. Table 6 presents the estimated U.S. salmonellosis cases by severity category. Figure 3 presents the distribution of estimated annual U.S. cases of salmonellosis and disease outcomes.

Table 6—Estimated U.S. salmonellosis cases, 1993

Severity of illness	Estimated cases	
	Low	High
	Number	
No physician visit[1]	746,880	3,734,400
Physician visit[2]	40,320	201,600
Hospitalized[3]	12,000	60,000
Deaths[4]	800	4,000
Total[5]	800,000	4,000,000

[1] Cases in this category were calculated as a residual.
[2] Assuming 5.04% of all cases visit a physician (Ryan 1987).
[3] This category is for those who were hospitalized and survived. Assuming 1.5% of all cases are hospitalized (Ryan *et al.* 1987).
[4] Deaths are calculated using a case fatality rate of 1/1,000. Those who die are assumed to be hospitalized prior to their deaths. Therefore, the total number of salmonellosis patients hospitalized each year is 12,800 in the low estimate and 64,000 in the high estimate.
[5] The low estimate of 800,000 cases was calculated by multiplying CDC's estimate of 40,000 *Salmonella* isolates (Tauxe 1991) by Chalker and Blaser's (1988) low estimate of the number (20) of unreported cases to each reported case. The high estimate of 4 million cases was calculated by multiplying CDC's estimate of 40,000 *Salmonella* isolates (Tauxe 1991) by Chalker and Blaser's (1988) high estimate of the number (100) of unreported cases to each reported case.

A 1984-85 survey found a 1.3-percent death rate for reported cases of salmonellosis (CDC memo from the Foodborne and Diarrheal Disease Branch, Oct. 31, 1994).[14] After adjusting for unreported cases, it is assumed that there is a 0.1 percent death rate for all salmonellosis cases. Applying this ratio to the estimated range of 800,000 to 4 million salmonellosis cases results in a range of 800 to 4,000 deaths occurring annually. This range of annual salmonellosis deaths was used in this report.

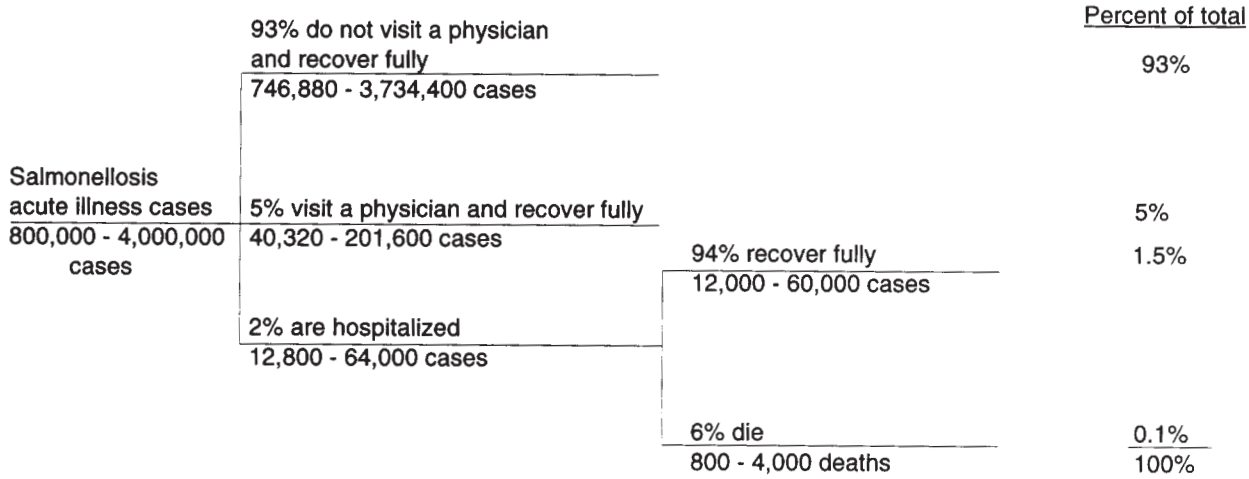
[12]In the United States, most *Salmonella* infections are believed to be sporadic cases as opposed to being associated with outbreaks (Feldman and Blaser 1980, p. 436).

[13]That is, the actual number of infections is 20 to 100 times larger than the 40,000 reported cases of salmonellosis.

[14]Death certificate data (Vital Statistics) reported to CDC show an average of 79 deaths per year due to salmonellosis between 1979 and 1984 (Public Health Service, U.S. Dept. of Health and Human Services, 1979-84). Death certificate information is very inaccurate for two reasons. First, death certificates are filled out within hours of death and are not updated with laboratory tests showing the causative organism. Second, autopsy data are not subsequently entered on the death certificate. However, these death data were useful here in providing an age distribution of deaths attributed to salmonellosis.

Figure 3

Distribution of estimated annual U.S. salmonellosis cases and disease outcomes[1]



[1]Percentages are rounded.
Prepared by Economic Research Service, USDA.

The largest U.S. outbreak of salmonellosis occurred in Chicago in 1985. It was linked to two antimicrobial-resistant strains of *S. typhimurium* in pasteurized milk from one dairy plant (Ryan *et al.* 1987).[15] Two surveys of randomly selected households in two Chicago area counties provided data on the extent of this outbreak. For each of these surveys, Ryan *et al.* (1987) estimated the average number of salmonellosis cases based on the amount of illness in the survey samples and the distribution of implicated milk. The average of these two incidence estimates is roughly 185,000 cases. A third survey found that at least 2,777 of the culture-confirmed cases were hospitalized (Ryan *et al.* 1987, pp. 3270 and 3272).[16] These figures were used to conservatively calculate that approximately 1.5 percent (2,777/185,000) were hospitalized and survived.

Applying this rate to the estimated 800,000 to 4 million annual cases of salmonellosis provides an estimate of the range of cases that were hospitalized for salmonellosis (12,000 to 60,000). To this range, the 800 to 4,000 estimated annual deaths were added because those who died were likely to incur medical costs associated with hospitalization prior to death. Therefore, including deaths, the estimated number of annual hospitalizations for salmonellosis ranges from 12,800 to 64,000.

Data from the 1985 Chicago milk outbreak were also used to obtain estimates of the annual number of U.S. salmonellosis patients who visited a physician. A sample of 600 cases was randomly drawn from the culture-confirmed cases. Of this sample, 63 percent of the respondents reported that they visited a physician either in the emergency room or in a private office (Ryan 1987, personal communication with Roberts). It was assumed that 63 percent of the roughly 16,000 culture confirmed cases saw a physician and that none of the remaining 200,000 cases (184,000) saw a physician.[17] The rate of doctor visits

[15]Ryan *et al.* (1987) suggest that the original source of the resistant strains was the use of antimicrobials on dairy cattle. A cross-connection between pasteurized and raw milk lines may have been responsible for the outbreak (D'Aoust 1989, p. 360).

[16]Questionnaires were given to 15,459 (93 percent) of the 16,659 culture-confirmed cases. Of the 12,624 respondents, 2,777 (or 22 percent) were hospitalized (Ryan *et al.* 1987, pp. 3270 and 3272).

[17]Note that these estimates are slightly different than those used for the calculations on hospitalizations. These estimates are from preliminary data and are used to calculate a conservative estimate of the percentage of salmonellosis cases who visited a physician. The assumptions used here were suggested by Ryan (1987), CDC, to offset the higher-than-average rate of people seeking medical attention because of the publicity and the possibility of class action suits against the dairy in this unusually well-publicized case.

then is 5.04 percent for the whole Chicago outbreak ((63%)(16,000)/200,000).[18] Multiplying 5.04 percent times the estimated range of 800,000 to 4 million annual salmonellosis cases results in an estimated 40,320 to 201,600 doctor visits for salmonellosis annually.

The estimated number of salmonellosis cases where no medical care was sought was computed as a residual (total cases minus all hospitalizations, including deaths and physician visits). Estimated cases for this category range between 746,880 and 3,734,400 cases annually.

Costs of Salmonellosis from All Sources

Cohen *et al.* (1978) surveyed 234 people who had culture-confirmed cases of salmonellosis during the 1976 outbreak caused by eating *S. heidelberg*-contaminated cheddar cheese in Colorado. For the current analysis, cost estimates for the different severity categories were taken from Cohen *et al.* and updated to 1993 using average weekly earnings or consumer price indexes (CPI), where appropriate. These costs are the only estimates available in the literature. Although Cohen *et al.* state that 26 percent of the total cost of this outbreak is for lost income or productivity, 68 percent is for medical costs, and 5 percent is for miscellaneous costs, they do not separate medical costs from lost productivity for each disease severity category.[19] Therefore, table 7 presents the costs summary for annual cases of salmonellosis, broken down by disease severity category but not by type of cost.

- No physician visit. For this category, Cohen *et al.* (1978) estimated that the costs per case were $125 in 1976 dollars.[20] Per case costs increased from $125 to $371 after adding 39 percent to account for fringe benefits (U.S. Dept. Comm., Bureau of the Census 1993, table 677) and updating to 1993 dollars. Costs were updated to 1993 dollars with Bureau of Labor Statistics' (BLS) average weekly earnings for all production or nonsupervisory workers in private nonagricultural industries in 1993 (GPO: *Economic Indicators*, July 1994). Estimated costs for the 746,880-3,734,400 cases each year who did not seek physician care for salmonellosis totaled $276.8 million to $1,384.1 million.

- Physician visit only. Cohen *et al.* (1978) estimated that salmonellosis patients who saw a physician but were not hospitalized incurred an average cost of $222 per case (1976 dollars) and stated that these costs "could mainly be attributed to medical care."[21] We updated Cohen *et al.'s* (1978) estimate of $222 per case to $794 using BLS's CPI for the physician services component (U.S. Dept. Comm., Bureau of the Census 1993, tables 151 and 163). This amount is all inclusive (*e.g.*, costs of doctors' fees, laboratory charges, and medication).[22] For the 40,320-201,600 cases in the category, we estimated total costs to run $32-$160 million annually.

- Hospitalized. Cohen *et al.* (1978) also estimated that salmonellosis patients who were hospitalized (and survived) incurred an average cost of $1,750 per case (1976 dollars) and stated that these costs "could mainly be attributed to medical care or hospitalization." We updated the $1,750 cost per case to 1993 dollars ($9,087) using BLS's CPI for hospital rooms (U.S. Dept. Comm., Bureau of the Census 1993, table 163). This estimate includes the costs of emergency plus regular room charges, hospital doctors' fees, medication, and operations. Estimated medical costs for the 12,000-60,000 hospitalized cases who survived total $109.0-$545.2 million annually.

- Deaths. Roberts (1988 and 1989) extended Cohen *et al.'s* estimates to include the value of lives lost annually to salmonellosis. This report updates Robert (1988 and 1989) COI estimates for salmonellosis to 1993 dollars.

[18]Note that this percentage is strikingly similar to that found in two studies of salmonellosis surveillance cases in 1979-80 and 1984-85 where 2,200 of the 40,000 cases involved a visit to a doctor (or 5.5 percent) (Cohen and Tauxe 1986).

[19]Over all disease severity levels, Cohen *et al.* (1978) estimated that those employed lost, on average, 12 days from work. Moreover, family members missed an average of 3 days from work to care for the sick relative (Cohen *et al.* 1978).

[20]Although Cohen *et al.* (1978) stated that these "costs were primarily accountable to loss of salary or output," they did not specify what proportion is for lost productivity and what proportion is for medical costs. Therefore, costs were not broken down between these two cost sub-categories.

[21]Note that whereas physician expenses and laboratory tests were the key costs cited by Cohen *et al.* (1978), productivity loss is also included in their estimate.

[22]Adults over 50 years of age and infants incurred higher than average costs due to more frequent or longer hospitalization (staying a median of 10 days versus 6 days for other age groups) (Cohen *et al.* 1978).

Table 7—Cost summary for U.S. salmonellosis cases, 1993[1]

Severity of illness	Cost per case: Cohen *et al.*	Cost per case: This analysis	Estimated cases and total costs: Low: Cases	Low: Costs	High: Cases	High: Costs
	1976$	*1993$*	*Number*	*Mil. Dollars*	*Number*	*Mil. Dollars*
No physician visit[2]	125	371	746,880	276.8	3,734,400	1,384.1
Physician visit[3]	222	794	40,320	32.0	201,600	160.0
Hospitalized[4]	1,750	9,087	12,000	109.0	60,000	545.2
Deaths[5]	N/A	385,355	800	308.3	4,000	1,541.4
Total[6]	N/A	N/A	800,000	726.1	4,000,000	3,630.8
If 87-96% are foodborne, foodborne costs are $0.6-3.5 billion annually.[7]						

[1]Some numbers have been rounded for this table.

[2]Cases in this category were calculated as a residual. We use Cohen *et al.'s* estimate that the costs per case are $125 (1976 dollars), after we increase this value by 39% to account for fringe benefits and update to 1993 dollars using average weekly earnings for non-agricultural workers from the U.S. Dept. of Comm., Bureau of Labor Statistics (BLS).

[3]Assuming 5.04% of all cases visit a physician (Ryan, personal communication, 1987). Cost per case is from Cohen *et al.'s* (1978) estimate of $222 (1976 dollars), updated to 1993 dollars using BLS's CPI for physician services (U.S. Dept. of Comm., Bur. of the Census).

[4]This category is for those who were hospitalized and survived. Assuming 1.5% of all cases are hospitalized (Ryan *et al.* 1987). Cost per case is from Cohen *et al.'s* (1978) estimate of $1,750 (1976 dollars), updated to 1993 dollars using BLS's CPI for hospital rooms (U.S. Bur. of the Census).

[5]Deaths are calculated using a case fatality rate of 1/1,000. Those who die are assumed to be hospitalized prior to their deaths and incur the same costs as those who are hospitalized and survive. Therefore, the total number of salmonellosis patients hospitalized each year is 12,800 for the low estimate and 64,000 for the high estimate. Costs for those who die are the sum of the cost per hospitalized case ($9,087) and Landefeld and Seskin's (1982) average value of a statistical life for the age distribution ($376,268 after averaging across gender and updating to 1993 values using the average weekly earnings.)

[6]The low estimate of 800,000 cases was calculated by multiplying CDC's estimate of 40,000 *Salmonella* isolates (Tauxe 1991) by Chalker and Blaser's (1988) low estimate of the number (20) of unreported cases to each reported case. The high estimate of 4 million cases was calculated by multiplying CDC's estimate of 40,000 *Salmonella* isolates (Tauxe 1991) by Chalker and Blaser's (1988) high estimate of the number (100) of unreported cases to each reported case.

[7]The 87% foodborne estimate is from Tauxe and Blake (1992) and the 96% foodborne estimate is from Bennett *et al.* (1987).

We assumed that each of the 800-4,000 salmonellosis cases who die prematurely because of their illness incurred the same amount of medical costs as a salmonellosis patient who was hospitalized and survived ($9,087). We estimated medical costs for those who die from salmonellosis to range between $7.3 million and $36.3 million annually.[23]

Assuming the reported age distribution is representative of all estimated salmonellosis deaths, it can be used with Landefeld and Seskin's (1982) value of a statistical life (VOSL) numbers to estimate the benefits of reducing premature death from salmonellosis. Updated to 1993 values using the Consumer Price Index for all goods (U.S. Dept. Comm, Bur. Lab. Stats. 1994), the average value for the stream of productivity lost for each premature salmonellosis death is $376,268.[24] Multiplied by the 800-4,000 estimated salmonellosis deaths, the productivity loss estimates range from $301.0-$1,505.1 million annually. Combining this estimated productivity loss with the estimated $7.3-$36.3 million in medical costs sums to an annual total of $308.3-$1,541.4 million for those who die from salmonellosis.

- Total. In summary, the annual human illness costs of salmonellosis are substantial. Our estimate of the total costs of non-typhoid salmonellosis from

[23]Total medical costs for all hospitalized cases (those who survive plus those who die) are estimated at $116.3 million to $581.6 million annually.

[24]Therefore, the total cost of a death is $385,355 (table 7), the sum of medical costs ($9,087) from Cohen *et al.* (1987) and productivity losses ($376,268) from Landefeld and Seskin.

all sources ranges from $726.1 million to $3,630.8 million annually. The difference between the low and the high costs estimates is completely due to the difference in the two estimates of the incidence of salmonellosis.

Costs of Foodborne Salmonellosis

Adjusting for foodborne causes (87-96 percent), an estimated 696,000 to 3,840,000 salmonellosis cases stem from food sources each year (see page 70 of text). Of these cases, 649,786 to 3,585,024 do not visit a physician for their illness and 35,078 to 193,536 visit a physician. When adjusted for foodborne causes, the range of all hospitalized cases becomes 11,136 to 61,440 which includes a range of 696 to 3,840 deaths annually.[25]

The total costs of non-typhoid foodborne salmonellosis were estimated in the same manner as above. Total costs range from $0.6 billion to $3.5 billion annually.

Remarks

Salmonellosis currently ranks as the most costly bacterial foodborne disease estimated to date, partly due to the large number of cases and partly due to its virulence among specific population subgroups: the elderly, infants, and, increasingly, the immunocompromised.

The per person costs for the three non-death severity categories rely exclusively on Cohen *et al.* (1978). Of particular concern is the cost estimate for those who did not seek medical care, because it is based on such a small sample. These cases are a large contributor to total costs because the vast majority of salmonellosis cases are of mild severity. Because Cohen *et al.* (1978) did not explicitly state the medical costs and productivity loss by severity level, estimates could be improved with this information. To the extent the outbreak investigated in Cohen *et al*. (1978) may differ from a "typical" salmonellosis outbreak, several sources of bias are possible; the disease severity may be higher or lower than average depending on the *Salmonella* serotype, the number of *Salmonella* ingested, and the age and sex composition of the group of people affected.

These COI estimates do not include the costs of chronic medical conditions, which may be significant. The likelihood of such occurrences and associated costs are unknown. Archer (1984, 1985) estimated that 2 percent of salmonellosis patients will end up with reactive arthritis, an inflammation of the joints that lasts from a few days to 6 months. A fraction of these cases develop rheumatoid arthritis, a life-long inflammation of the joints.[26] With better data on incidence and associated costs of chronic illnesses caused by salmonellosis, total costs of these chronic illnesses could be computed and added to estimated costs associated with acute salmonellosis.

Other costs to individuals are ignored. For example, a Canadian economist, Leo Curtin (1984) estimated that the loss of leisure time was greater than the loss of work time due to salmonellosis. Estimates using his methodology of valuing leisure time at the prevailing wage rate would more than double the cost of salmonellosis estimates presented here.

Since reporting of *Salmonella* began in 1943, the reported incidence in the United States has increased considerably (Tauxe 1991, p. 563). For the past 30 years, this increase has been progressive and significantly greater than the population increase (Chalker and Blaser 1988, p. 113). During the 1970's, roughly 30-40 outbreaks and 20,000-25,000 isolates of salmonellosis were reported to CDC versus 60-80 outbreaks and 40,000-45,000 isolates in the late 1980's (Helmick *et al.* 1994, p. 104).[27] Massive outbreaks of salmonellosis such as the Chicago milk outbreak have increased the annual average number of infections reported to CDC.

The proportion of *Salmonella* infections due to *S. enteritidis* has increased to the extent that this serotype is now the most common cause of salmonellosis in some regions of the country (Tauxe 1991, p. 566). As previously mentioned, *S. enteritidis* infections have been increasingly attributed to consumption of lightly cooked or raw shell eggs.

[25]Some of these deaths are AIDS patients.

[26]As an aside, one survey found that rheumatoid arthritis sufferers were willing to pay 22 percent of their household income to be rid of arthritis (Thompson 1986, p. 394).

[27]In contrast, *Shigella* infections have remained constant over the past 30 years, even though they are reported by identical mechanisms as *Salmonella* infections (Chalker and Blaser 1988).

Some evidence (*e.g.*, 1985 outbreak traced to milk) exists to support the theory that widespread use of antimicrobials (*i.e.*, tetracycline) for both human illnesses and animal husbandry has led to an increase in resistance and infection with specific strains of *Salmonella* (MacDonald *et al.* 1987). Tauxe *et al.* (1991, p. 566) state that "treatment with antimicrobial agents can actually promote *Salmonella* infections in both humans and animals, particularly if the infecting strain is resistant to the agents being used."

AIDS patients are among the sub-groups most at risk of salmonellosis. Jackson *et al.* (1991, p. 32) discuss AIDS patients with salmonellosis and cite Celum *et al.* (1987) as saying that AIDS patients are 19.2 times more likely to contract salmonellosis than people who do not have AIDS. Recurrent bacteremia caused by *Salmonella* was included as an indicator of AIDS in 1987 (Tauxe 1991, p. 566).

Ryan *et al.* (1987, p. 3274) caution that the trend in food production toward a relatively small number of large producers make catastrophic consequences from *Salmonella* contamination possible. A case in point is the 1994 Schwan *Salmonella* outbreak, associated with consumption of ice cream, which led to around 100,000 cases in 25 States, including 102 hospitalizations (Food Chemical News Feb. 13, 1995, p. 53). The Food and Drug Administration (FDA) has implicated milk tanker trucks that previously carried raw egg products as the source of this outbreak.

In addition, large and dispersed outbreaks have been shown to cross State and national boundaries. For example, in 1984, a large international airline served *Salmonella*-contaminated food on 29 flights from London to the United States over a 3-day period, affecting an estimated 2,737 passengers (Tauxe *et al.* 1987, p. 150).[28] Incidents such as this have the potential to spread infections among people of many countries, especially where the infection can be spread person-to-person. A *S. Chester* outbreak in 1990 in the United States was linked to cantaloupe from Central America and Mexico (Ries *et al.* 1990). These concerns suggest a need for a global strategy for handling food safety issues such as *Salmonella* infections in humans.

[28]Passengers to the United States were not the only ones affected. The airline potentially exposed 23,576 passengers of 125 overseas flights from London to non-European destinations.

COI Estimates of Campylobacteriosis

There are nine named or proposed *Campylobacter* species that are pathogenic or are believed to be potentially pathogenic to humans (Tauxe et al. 1988, p. 1).[29] Of these, *Campylobacter jejuni* and *C. coli* (two closely related species) organisms are the species most frequently associated with campylobacteriosis in humans.[30] In the United States, most *C. jejuni* infections are associated with consumption of poultry and most *C. coli* infections are associated with consumption of pork. Worldwide, *Campylobacter* is estimated to cause 5 to 14 percent of all human diarrheal illnesses (Benenson 1990, p. 69).

Campylobacteriosis symptoms can range from diarrhea and lethargy that lasts a day to severe diarrhea and abdominal pain (and occasionally fever) that lasts for several weeks (Park *et al.* 1991, p. 995). Diarrhea and abdominal pain are the most common symptoms and the vast majority of cases are mild. Skirrow and Blaser (1992, p. 3) report that abdominal pain from campylobacteriosis can be so strong that it has been misdiagnosed as originating from appendicitis and has led to unnecessary appendectomy. The incubation period is 1 to 10 days, with most cases occurring 3 to 5 days after exposure (Benenson 1990, p. 70).

Although most cases of campylobacteriosis are self-limiting, up to 20 percent have a prolonged illness (longer than 1 week) or a relapse (Blaser *et al.* 1979), and 2 to 10 percent may be followed by chronic sequelae (CAST 1994, p. 11). Complications that may follow *Campylobacter* infections include meningitis, cholecystitis (inflammation of the gall bladder), urinary tract infection, appendicitis, septicemia, and Reiter syndrome (urethritis, arthritis, and conjunctivitis) (Mossel 1988) (table 3). Mishu and Blaser (1993) estimate that 20-40 percent of all Guillain-Barré Syndrome (GBS) cases are caused by *Campylobacter* infections. GBS is the major cause of non-trauma-related paralysis in the United States. Although paralysis from GBS is generally reversible over time, some patients die prematurely because of the illness while others are bedridden for life.

[29]In 1913, *Campylobacter* was discovered as a pathogen and was called *Vibrio fetus* because it was associated with abortion and infertility in cattle and sheep (Stern and Kazmi 1989, p. 72). The link with human illness occurred in the 1950's when *Campylobacter* was isolated from human blood (Tauxe *et al.* 1988, p. 1).

[30]For the remainder of this report, *C. jejuni* will be used to refer to both *C. jejuni* and *C. coli*.

Poultry is the predominant source of sporadic cases of *Campylobacter* (Tauxe 1992, p. 12). In the United States, an epidemiological study by Harris *et al.* (1986a, p. 410) found that in approximately half of all *Campylobacter jejuni/coli* enteritis cases, ingestion of contaminated chicken was the primary source of infection. The intestine of birds and warm-blooded animals is a natural habitat for *Campylobacter* (Park *et al.* 1991, p. 101S) and studies have concluded that chicken slaughter and processing leads to heavy surface contamination (Park *et al.* 1991; Skirrow and Blaser 1992, p. 6; Sjögren and Kaiser 1988, p. 3). Up to 80 percent of poultry at retail are contaminated with *Campylobacter* (Skirrow and Blaser 1992, p. 4) and contamination appears to peak during the summer (July through October)(Tauxe *et al.* 1988; Harris *et al.* 1986b, p. 404).[31] This seasonal pattern of contamination in raw poultry is reflected in the reported number of *Campylobacter* isolates, by month and year, in the United States between 1982 and 1989 (fig. 4). To a lesser extent, turkey, raw milk, cake icing, raw clams, raw hamburger, water, and contact with pets have been epidemiologically linked with human diseases in the United States (Blaser *et al.* 1983a, p. 163; Stern 1992, p. 50; Tauxe *et al.* 1988; CAST 1994, p. 11).

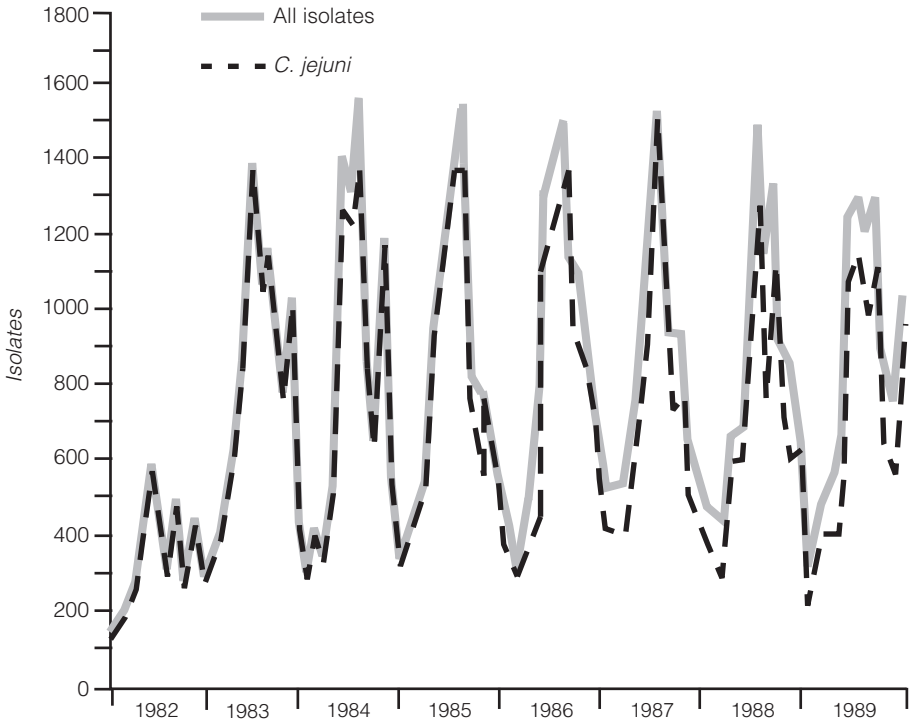
Campylobacteriosis outbreaks are relatively uncommon, perhaps because *Campylobacter jejuni* does not multiply in food; most outbreaks can be traced to drinking untreated stream or river water or to drinking raw milk (Helmick *et al.* 1994, p. 110).[32] *Campylobacter* in unchlorinated water is a major cause of travelers' diarrhea (Benenson 1990, p. 69).

[31]Note that reported isolates, which are primarily from sporadic cases, peak in the summer (July-Aug.) whereas the distribution of outbreaks is bimodal with peaks in May and October (Tauxe 1992, p. 13). This difference may be largely due to the difference in reservoirs, that is poultry for sporadic cases and raw milk and contaminated water for outbreak cases (Tauxe 1992, p. 12).

[32]Bean and Griffin (1990, p. 806) provide estimates of the number of foodborne disease outbreaks, by pathogen. Between 1973 and 1987, there were 53 *Campylobacter*, 190 *Clostridium perfringens*, 367 *Staphylococcus aureus*, and 790 *Salmonella* outbreaks. They did not mention *Listeria* outbreaks and estimated *E. coli* O157:H7 outbreaks are not relevant for this time period, because *E. coli* O157:H7 was not identified as a cause of human illness until 1982.

Figure 4

Reported number of U.S. *Campylobacter* isolates, by month and year, 1982-89



Source: Tauxe, R. V., "Epidemiology of *Campylobacter jejuni* Infection in the United States and Other Industrialized Nations." Chapter 2 in Nachamkin, Irving, Martin J. Blaser, and Lucy S. Tompkins, eds. *Campylobacter jejuni: Current Status and Future Trends.* Washington, DC: American Association of Microbiology, 1992, p. 10.

There is little evidence to suggest that significant person-to-person transmission of *Campylobacter* takes place (Tauxe 1992, p. 11). However, there have been a few documented cases of pregnant women with bacteremia that have been associated with severe fetal infections (Blaser *et al.* 1983a, p. 165).

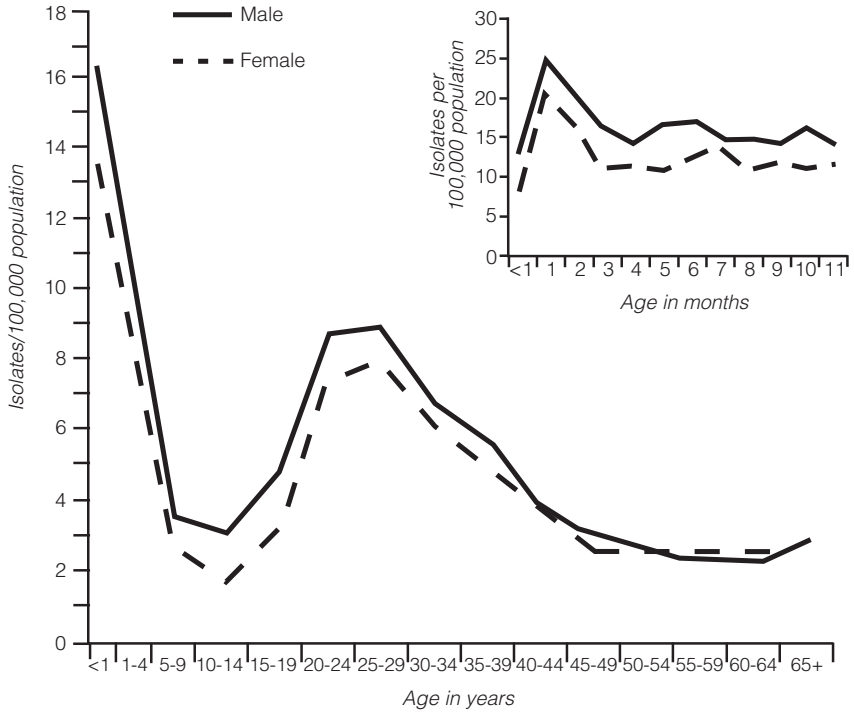
There is uncertainty as to the percentage of *Campylobacter* cases that are foodborne. In a Seattle-King County Department of Public Health surveillance study (1984, p. 153), roughly 55 percent of all *Campylobacter* cases were attributed to food origins: drinking raw milk (5.2 percent) and eating poultry (48.2 percent).[33] Deming *et al.* (1987) summarized in Tauxe [1992, p. 15] found that 70 percent of campylobacteriosis cases in students at a Georgia college were attributed to eating chicken (the remaining 30 percent were attributed to contact with cats). We assumed that 55-70 percent of all U.S. campylobacteriosis cases are foodborne.

The human infective dose is relatively small. Robinson (1981) describes his personal experience where 500 *Campylobacter* cells caused disease. Yet, there is great variation in individual susceptibility and illness severity. Benenson claims that in developing countries, most individuals develop immunity to *Campylobacter* in their first year of life (1990, p. 70). This may also be true in developed countries. In developed countries such as the United States, infants have the highest reported incidence of campylobacteriosis, with young adults in the second highest risk category (Tauxe *et al.* 1988, p. 11). In developing countries, children under 2 years of age are the most likely to have *Campylobacter* infections (Blaser *et al.* 1983a) and illnesses (Benenson 1990, p. 69). Up to age 45, males have higher isolation rates for *Campylobacter* than do females, but this difference has not been adequately explained (Tauxe 1992, p. 10). Figure 5 shows the reported *Campylobacter* isolates by age and sex between 1982 and 1986.

[33]Of the remaining *Campylobacter jejuni* infections, 6.3 percent were from pets, 9 percent from foreign travel (which could also be food related), and 7.6 percent from surface water.

Figure 5

Reported *Campylobacter* isolates by age and sex of patient, United States 1982-86



Source: Tauxe, R. V., "Epidemiology of *Campylobacter jejuni* Infection in the United States and Other Industrialized Nations." Chapter 2 in Nachamkin, Irving, Martin J. Blaser, and Lucy S. Tompkins, eds. *Campylobacter jejuni: Current Status and Future Trends.* Washington, DC: American Association of Microbiology, 1992, p. 11.

Estimates of Cases

The discovery of the extent of infections with *Campylobacter* was made possible in the late 1970's by the development of an isolation technique that requires incubator conditions and a specific medium (Tauxe 1992, p. 9; Helmick *et al.* 1994, p. 109). Helmick *et al.* (1994, p. 109) report that in laboratories that test for foodborne pathogens including *Campylobacter*, *Campylobacter* is the most commonly isolated bacterial pathogen from persons with diarrhea in the United States, and *C. jejuni* is the most commonly isolated *Campylobacter* species.[34] In 5-year CDC surveillance, 91 percent of the isolates reported the species and 99 percent of these specified *C. jejuni* as the reported species (Tauxe *et al.* 1988, p. 9).

Although there has been a national surveillance for campylobacteriosis since 1982, participation is voluntary, and there is tremendous variation in internal reporting requirements between States (Tauxe 1992, p. 9). Unlike *Salmonella*, isolates of *Campylobacter* are not routinely referred for confirmation or serotyping except when an unusual isolate is found or in outbreak situations (Tauxe 1992, p. 9). But even during outbreaks, not all physicians routinely order diagnostic laboratory testing for patients sick with diarrheal illnesses. With better surveillance, *Campylobacter* infections would likely outnumber *Salmonella* infections (Tauxe 1992, p. 9).[35]

The limitations of *Campylobacter* surveillance are especially critical because the vast majority of cases are sporadic and not the result of outbreaks (Tauxe 1992, p. 11). Individuals sick with campylobacteriosis may be more likely to seek medical care (and have diagnostic testing) during outbreaks than when cases are sporadic, especially when there is widespread publicity and the possibility of legal action.

In 1980, a Collaborative Diarrheal Disease Study Group (conducted by CDC) studied the relative frequency with which *Campylobacter*, *Shigella*, and *Salmonella* were isolated from stool cultures at eight hospitals over a 15-month period (Blaser *et al.* 1983b). They found that, for all age groups, *Campylobacter* species were isolated 4.6 times more frequently than *Shigella* species and twice as often as *Salmonella* species (Blaser *et al.* 1983b, p. 360).[36] This supports the hypothesis that if both *Campylobacter* and *Salmonella* infections had equal surveillance efforts, *Campylobacter* isolates would be more common (Tauxe 1992, p. 12). If *Campylobacter* were analyzed in the same fashion as *Shigella* or *Salmonella*, then the estimated isolation rate would be 36-40 per 100,000 (Tauxe 1992, p. 12).[37]

Rosenberg *et al.* (1977, p. 459) used national surveillance data to estimate that as few as 33 percent of physician visits for patients sick with shigellosis resulted in a stool culture. This low proportion that has diagnostic testing further documents the extent of potential underreporting of foodborne illnesses. Following Tauxe (1992, p. 12), we conservatively assumed that 67 percent of patients who visit physicians with complaints of diarrheal illnesses have stool cultures ordered. This raises the estimated isolation rate for *Campylobacter* from 36-40 per 100,000 to 54-60 per 100,000 (Tauxe 1992, p. 12).

Sacks *et al.* (1986) report results from an investigation of a campylobacteriosis outbreak associated with a contaminated community water supply in Florida. They found that of 865 cases, roughly 5.4 percent (or 47) visited a physician for acute gastroenteritis (p. 425). Tauxe (1992, p. 12) uses this percentage combined with his estimated isolation rate for *Campylobacter* (54-60 per 100,000) to estimate the rate of *C. jejuni* infection of roughly 1 percent of the U.S. population annually (not including asymptomatic cases). Given a 1993 residential U.S. population of 257,908,000 (U.S. Dept. Comm., Bureau of the Census 1993), there were over 2.5 million estimated cases of campylobacteriosis in 1993. Helmick *et al.* (1994, p. 109) state that the true number of annual cases of *Campylobacter* infections each year in the

[34] *C. jejuni* is the main reported isolate in stool cultures but this may be because the stool culture media is more appropriate for *C. jejuni* than for other C*ampylobacter* species (Tauxe *et al.* 1988). In general, isolation methods and methods used to identify species other than *C. jejuni* are expensive and cumbersome, which means less is known about the extent and severity of human illness caused by these species.

[35] Underreporting occurs for a host of other reasons previously described (*e.g.*, many ill people do not seek medical care). Another reporting problem for *Campylobacter* is that it has only recently been assigned a code in the International Classification of Disease (ICD) system, which means that many otherwise useful medical databases (*e.g.*, the National Hospital Discharge Survey) cannot provide information on incidence.

[36] Note that Tauxe (1992, p. 12) says that *Campylobacter* was isolated 4.5 times more often than *Shigella*.

[37] The reported isolation rate of *Shigella* species is 8/100,000 and 20/100,000 for *Salmonella* species (Tauxe 1992, p. 12).

United States is likely 2 million to 10 million cases. We (conservatively) assume 2.5 million cases of campylobacteriosis each year in the United States in our update of Lin *et al.*'s (1993) COI estimate for campylobacteriosis (table 2).

Table 8 presents the estimated U.S. campylobacteriosis cases, broken down by the four disease severity categories used throughout this report. Figure 6 presents the distribution of estimated annual cases of campylobacteriosis and disease outcomes.

While the distribution of disease severity is similar to that of salmonellosis, campylobacteriosis is generally less deadly than salmonellosis, leading to an estimated 200 to 730 deaths annually versus an estimated 800 to 4,000 deaths for salmonellosis. Tauxe (1992) reports that Smith and Blaser (1985) used surveillance data to estimate a death rate of 24 per 10,000 culture-confirmed cases of *Campylobacter* infections. Tauxe (1992, p. 14) applied this death rate to the estimated annual number of culture-confirmed *Campylobacter* infections to calculate an estimated 200 deaths from campylobacteriosis each year. Tauxe also used data from a series of *Campylobacter* outbreaks to estimate an upper bound on the number of premature deaths due

Table 8—Estimated U.S. campylobacteriosis cases, 1993

Severity of illness	Estimated cases	
	Low	High
	Number	
No physician visit[1]	2,352,300	2,351,770
Physician visit[2]	135,000	135,000
Hospitalized[3]	12,500	12,500
Deaths[4]	200	730
Total[5]	2,500,000	2,500,000

[1] Cases in this category were calculated as a residual.

[2] Assuming 5.4% of all cases visit a physician (Sacks *et al.* 1986).

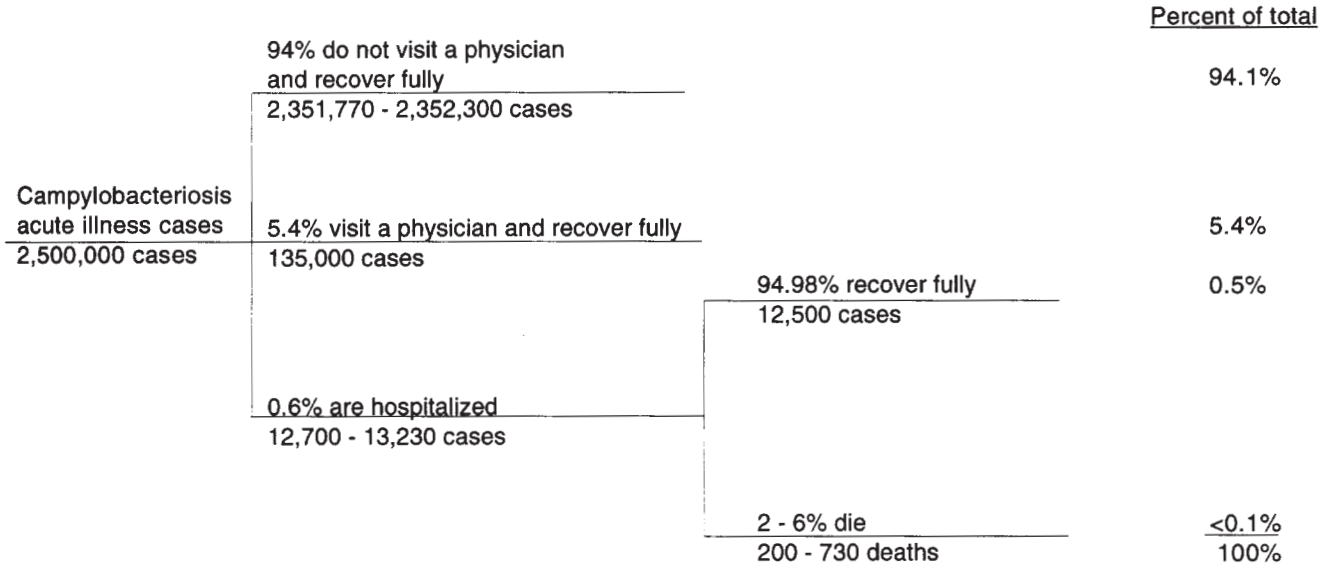
[3] This category is for those who were hospitalized and survived. Assuming 0.5% of all cases are hospitalized (Sacks *et al.* 1986).

[4] The low estimate of 200 deaths was calculated in Tauxe (1992) using Smith and Blaser's (1985) case fatality rate of 24/10,000 culture-confirmed cases. The high estimate of 730 deaths was calculated in Tauxe (1992) using his case fatality rate of 3/10,000 outbreak-associated illnesses. Those who die are assumed to be hospitalized prior to their deaths. Therefore, the total number of salmonellosis patients that are hospitalized each year is 12,700 in the low estimate and 13,230 in the high estimate.

[5] The total number of campylobacteriosis cases is 1% (Tauxe 1992) of the U.S. 1993 population (U.S. Bur. of the Census) rounded down to 2.5 million cases.

Figure 6

Distribution of estimated annual U.S. campylobacteriosis cases and disease outcomes[1]



[1] Percentages are rounded.
Prepared by Economic Research Service, USDA.

to *Campylobacter* in the United States of 730 per year (ibid.). The current study considers a range of 200 to 730 deaths from *Campylobacter* infections annually.

Sacks *et al*. (1986, p. 425) in their study on the *Campylobacter*-contaminated community water supply found that 0.5 percent of cases were hospitalized (4 out of 865 cases). Applying this rate to the annual number of 2.5 million *Campylobacter* infections, we obtain an estimated 12,500 hospitalizations each year for campylobacteriosis. Assuming that the 200-730 who die from the illness are first hospitalized, an estimated 12,700 to 13,230 cases of campylobacteriosis cases are hospitalized each year.

We used Sacks *et al.'s* (1986, p. 425) finding that roughly 5.4 percent visited a physician for campylobacteriosis during the contaminated-water outbreak to estimate the annual number of people in the United States who visit a physician for *Campylobacter* infections. When this rate is applied to the 2.5 million estimated annual infections, this yields an estimate of 135,000 physician visits for *Campylobacter* infections each year.

The estimated number of campylobacteriosis cases where no medical care was sought was computed as a residual (total cases minus all hospitalizations, including deaths, and physician visits). The number of cases in this category are estimated to range between 2,352,300 and 2,351,770 cases annually.

Costs of Campylobacteriosis from All Sources

Nolan and Harris (1984, p. 166) comment that the illness severity of campylobacteriosis mirrors that of salmonellosis. In our analyses of these two illnesses, the breakdown of the severity categories is comparable; the percentage that visit a physician is around 5 percent, the percentage that are hospitalized is around 1 percent, and the percentage that die is ≤ 0.1 percent.

Given the similarity in the four severity groups for campylobacteriosis and salmonellosis and given that there is no parallel cost study like Cohen *et al*. (1978) for campylobacteriosis, we assumed that per-patient costs of illness for each of the four severity groups are identical to the costs of salmonellosis. We used Cohen *et al.* (1978) estimates for all four categories of campylobacteriosis and LS VOSL estimates for the productivity loss from those who die prematurely. As previously mentioned, Cohen *et al.* (1978) did not separate medical costs from productivity losses. Therefore, one cannot divide per-patient or total costs into medical costs and costs of lost productivity. Table 9 presents the cost summary for annual cases of campylobacteriosis, broken down by disease severity category.

- No physician visited. As with salmonellosis, estimated per-patient costs for campylobacteriosis patients who did not visit a physician are roughly $371.[38] For the estimated 2,351,770 to 2,352,300 campylobacteriosis cases in this category, estimated annual costs total $871.7-$871.9 million.

- Physician visit only. As with salmonellosis, estimated per-patient costs for campylobacteriosis patients who visited a physician for their illness are $794.[39] This includes office visits, laboratory charges, and some productivity loss. For the estimated 135,000 cases in the category, estimated costs total $107.2 million annually.

- Hospitalized. As with salmonellosis, estimated per-patient costs for campylobacteriosis patients who were hospitalized for their illness are $9,087.[40] This includes the costs of emergency plus regular room charges, hospital doctors' fees, medication, and operations. For the estimated 12,500 cases who were hospitalized and survived, estimated costs total $113.6 million annually.

- Deaths. As for the estimated 200 to 730 annual deaths from campylobacteriosis, per patient costs are the sum of Cohen *et al.'s* (1978) per patient costs of $9,087 (updated to 1993 as above) plus

[38]Per-case costs increase from $125 (Cohen *et al.* 1978) to roughly $370.65 after adding 39 percent to account for fringe benefits (U.S. Dept. of Comm., Bureau of the Census 1995, table 677) and updating to 1993 dollars. Because Cohen *et al.* (1978) state that "these costs were primarily accountable to loss of salary or output," we updated costs to 1993 dollars with BLS's average weekly earnings for all production or nonsupervisory workers in private nonagricultural industries in 1993 (*Economic Indicators*, July 1994).

[39]Because Cohen *et al.* (1978) state that the costs per case for this category are "mainly . . . attributed to medical care," we update their estimate of $222 per case to $794 using BLS's CPI for the physician services component (U.S. Dept. of Comm., Bureau of the Census 1993, tables 151 and 163).

[40]Because Cohen *et al.* (1978) explain that their estimate of $1,750 per case for this category is mainly comprised of medical costs, we updated this amount to $9,087 using BLS's CPI for the hospital room component (U.S. Dept. of Comm., Bureau of the Census 1993, table 163).

LS's VOSL. We assumed that the age distribution of deaths due to campylobacteriosis mirrors that of salmonellosis. Applying the age distribution of deaths to Landefeld and Seskin's VOSL estimates by age, we obtained an average VOSL of $376,268. When LS VOSL costs are combined with per patient costs ($9,087) from Cohen *et al.* (1978), the per patient costs for those who died are $385,355 (table 9). For the 200-730 campylobacteriosis deaths annually, lost productivity adds up to $77.1-$281.3 million.

- Total. For all patients with campylobacteriosis, costs are estimated at $1,169.8-$1,373.8 million annually. The difference between the low- and the high-cost estimates is completely due to the range of 200-730 deaths.

Very few studies have estimated the costs of campylobacteriosis (Sockett and Stanwell-Smith 1986; Roberts 1989; Todd 1989[b]), partly because only recently has *Campylobacter* been attributed to causing substantial foodborne illnesses. None of these studies are detailed cost analyses for campylobacteriosis in the United States. While it is not an unreasonable assumption to apply the costs per salmonellosis case to those of campylobacteriosis, better estimates are needed.

Sockett and Stanwell-Smith (1986) provide the most detailed cost study of campylobacteriosis to date. They estimated costs incurred by health-care services per case of campylobacteriosis in the United Kingdom (UK) (1985, in £). Because the structure of health care in the UK differs considerably from that in the United States, these costs are not directly

Table 9—Cost summary for U.S. campylobacteriosis cases, 1993

Severity of illness	Cost per case		Estimated cases and total costs			
			Low		High	
	Cohen *et al.*	This analysis	Cases	Costs	Cases	Cost
	1976$	*1993$*	*Number*	*Mil. Dollars*	*Number*	*Mil. Dollars*
No physician visit[1]	125	371	2,352,300	871.9	2,351,770	871.7
Physician visit[2]	222	794	135,000	107.2	135,000	107.2
Hospitalized[3]	1,750	9,087	12,500	113.6	12,500	113.6
Deaths[4]	N/A	385,355	200	77.1	730	281.3
Total[5]	N/A	N/A	2,500,000	1,169.8	2,500,000	1,373.8
If 55-70% are foodborne, foodborne costs are $0.6-1.0 billion annually.[6]						

N/A = Not applicable.
Note: Some numbers have been rounded for this table.

[1] Cases in this category were calculated as a residual. We use Cohen *et al.'s* (1978) estimate that the costs per case are $125 (1976 dollars), after we increase this value by 39% to account for fringe benefits and update to 1993 dollars using average weekly earnings for nonagricultural workers from the U.S. Bureau of Labor Statistics (BLS).

[2] Assuming 5.4% of all cases visit a physician (Sacks *et al.* 1986). Cost per case is from Cohen *et al.'s* (1978) estimate of $222 (1976 dollars), updated to 1993 dollars using BLS's CPI for physician services (U.S. Dept. of Comm., Bur. of the Census).

[3] This category is for those who were hospitalized and survived. Assuming 0.5% of all cases are hospitalized (Sacks *et al.* 1986). Cost per case is from Cohen *et al.'s* (1978) estimate of $1,750 (1976 dollars), updated to 1993 dollars using BLS's CPI for hospital rooms (U.S. Dept. of Comm., Bur. of the Census).

[4] The low estimate of 200 deaths was calculated in Tauxe (1992) using Smith and Blaser's (1985) case fatality rate of 24/10,000 culture-confirmed cases. The high estimate of 730 deaths was calculated in Tauxe (1992) using his case fatality rate of 3/10,000 outbreak-associated illnesses. Those who die are assumed to be hospitalized prior to their deaths. Therefore, the total number of salmonellosis patients that are hospitalized each year is 12,700 for the low estimate and 13,230 for the high estimate. Costs for those who die are the sum of the cost per hospitalized case ($9,087) and Landefeld and Seskin's (1982) average value of a statistical life for the age distribution ($376,268 after averaging across gender and updating to 1993 values using the average weekly earnings.)

[5] The total number of campylobacteriosis cases is 1% (Tauxe 1992) of the U.S. 1993 population (U.S. Dept. of Comm., Bur. of the Census) rounded down to 2.5 million cases.

[6] The 55% foodborne estimate is from the Seattle-King County study (1984) and the 70% foodborne estimate is from Deming *et al.* (1987).

applicable to our analysis.[41] However, if we assumed that costs are similar in the United States and UK, the average cost estimates from the current analysis are roughly $468-$550 per case whereas the Sockett and Stanwell-Smith (1986) estimates would suggest a range of $339-$370 per case (in 1993 U.S. dollars).[42] Their estimates were lower because they assume a lower death rate.

Costs of Foodborne Campylobacteriosis

We assumed that 55-70 percent of all estimated human illness cases of *Campylobacter* in the United States are foodborne (1,375,000 to 1,750,000 cases)(see page 70 of text). Estimates of those who do not visit a physician range from 1,293,765 to 1,646,239 cases annually. A low of 74,250 and a high of 94,500 visit a physician. The number of hospitalized cases (including those who died) ranges from 6,985 to 9,261. Foodborne deaths caused by *Campylobacter* range from 110 to 511 annually.

Given our assumption that 55-70 percent of all U.S. campylobacteriosis cases are attributed to food, estimated costs of foodborne campylobacteriosis range from $0.6-$1.0 billion annually. Due to the limitations of the Cohen *et al.* (1978) data for salmonellosis and the lack of current and detailed cost information for campylobacteriosis, medical costs and the costs of lost productivity cannot be separated.

Remarks

As previously mentioned, poultry is the most common cause of sporadic cases of campylobacteriosis in the United States. This is largely because poultry naturally harbors *Campylobacter* in the crop and gut. Mass mechanized processing can cause heavy cross-contamination (Skirrow and Blaser 1992, p. 6). Cleaning practices at the slaughterhouse and packing plant may influence the *Campylobacter* contamination rate; Harris *et al.* report a progressive increase in contamination of poultry carcasses slaughtered from Monday through Wednesday after a weekend cleanup (1986, p. 403). Park *et al.* (1991, p. 102S) recommend that *Campylobacter* contamination of raw chicken be reduced by improving processing procedures at slaughter to minimize fecal contamination and by reducing available water on the carcass. Washing carcasses in a strong brine solution may be helpful in reducing *Campylobacter* contamination (Park *et al.* 1991, p. 102S). *Campylobacter* tends to be found more frequently on moist meat rather than on dry meat because *Campylobacter* is sensitive to drying (Park *et al.* 1991, p. 102S). Perhaps, air-chilled chicken would have fewer *Campylobacter* than ice-bath-chilled chicken.

According to CDC, approximately 90 percent of *C. jejuni* outbreaks would not occur with universal pasteurization of milk and improved drinking water treatment (Tauxe 1992, p. 12). Raw milk often harbors a wide range of pathogens such as *C. jejuni*, *Salmonella* serotypes, and *Listeria*. For this reason it is illegal to sell raw milk in most locations in the United States (CAST 1994, p. 32).

Additional gains in reducing the annual number of cases of campylobacteriosis could be made through improved food-handling practices at both the retail and household levels. Tauxe (1992, p. 16) states that "ingestion of a small drop of raw chicken juice could easily be the infective dose." That being the case, leaky packages of chicken purchased at supermarkets may be causing illnesses. As previously mentioned, *Campylobacter* needs moisture to survive; reducing free water in poultry packages would seem to have the double benefit of encouraging the die-off of existing *Campylobacter* and of reducing potential kitchen contamination levels.

At the household level, *Campylobacter* infections could be reduced by greater education of consumers on kitchen hygiene for handling and cooking poultry. Hopkins and Scott (1983) reported that "handling raw chicken appeared to be a strong risk factor" for getting campylobacteriosis. Deming *et al.* (1987, p. 532) hypothesize that errors in food handling increase the risk of illness from eating cooked chicken. Tauxe *et al.* (1992) state that the 1984 Seattle study found the risk of campylobacteriosis "was inversely associated with the frequency of using soap to clean the kitchen cutting board."

[41]Regardless of differences in health care, it is interesting that a British study by Kendall and Tanner (1982, p. 155) found that the annual incidence of *Campylobacter* infections in a general practice population in Great Britain was 1.1 percent as compared with Tauxe's (1992) incidence rate of 1 percent in the United States.

[42]The estimated $468-$550 average costs were calculated by dividing the estimated total annual costs of $1,169.8-$1,373.8 million by the estimated 2.5 million U.S. cases (table 9). The estimated $339-$370 average costs were calculated from the Sockett and Stanwell-Smith (1986) estimates by using the exchange rate of £1 to U.S. $1.53 (Riggs Bank, Washington, DC, Nov. 15, 1994) and by updating to 1993 dollars (using BLS CPI for all items).

Consumption patterns affect the risks of foodborne illnesses. Poultry consumption increased 35 percent during the 10-year period between 1982 and 1992, as consumers substituted chicken for other meats (Lin *et al.* 1993, p. 38). This increase is partly because of concerns over dietary fat content, and partly because chicken has become cheaper than other meats. A recent consumer survey showed that 95 percent of the chicken bought for home consumption consisted of fresh products, such as fresh chicken parts (Lin *et al.* 1993, p. 38). The prevalence of *Campylobacter jejuni* and *Salmonella* in raw poultry means that this new consumption trend may lead to increasing numbers of foodborne illness cases.

COI Estimates of *Escherichia Coli* O157:H7 Disease

E. coli O157:H7 was first isolated by CDC in 1975 (FDA Consumer 1994, p. 9) but was not identified as a cause of human illnesses until 1982 when two outbreaks of gastrointestinal illness in Michigan and Oregon were investigated and linked to consumption of contaminated hamburgers (Riley *et al.* 1983)(fig. 7). There has been worldwide detection of *E. coli* O157:H7 and its associated illnesses. Bovine isolates or human cases of *E. coli* O157:H7 have been documented in over 16 countries and on 6 continents (USDA:APHIS:VS 1994, p. 2). Benenson (1990, p. 137) states that infections from enterohemorrhagic strains of *E. coli* (mainly O157:H7) are recognized as important health problems in Europe, southern South America, and North America. The following analysis updates the 1992 COI estimates found in Roberts and Marks (1995) to 1993 dollars.

E. coli O157:H7 and its link to an associated life-threatening illness called hemolytic uremic syndrome (HUS) became well known to the public as a result of the 1993 *E. coli* O157:H7 disease outbreak caused by contaminated hamburger in Washington, California, Idaho, and Nevada. The American Gastroenterological Association's (AGA) Consensus Conference Statement on *E. coli* O157:H7 Infections (1995, p. 1923) indicated that this outbreak led to over 700 illness cases (primarily children) and of these cases, 195 were hospitalized (28 percent), 4 died (0.57 percent), and 55 developed HUS (7.86 percent). In recent years, an increasing number of *E. coli* O157:H7 outbreaks and sporadic cases have been documented (AGA 1995, p. 1923).

E. coli O157:H7 is a hardy organism. Although bile acids can help kill some microorganisms such as *Clostridium botulinum*, *Escherichia is* resistant to these acids (CAST 1994, p. 25). *E. coli* O157:H7 can also survive some acid environments in food such as that found in apple cider (FDA Consumer 1994, p. 8). *E. coli* O157:H7 can grow and multiply slowly at temperatures as low as 44°F and can even survive freezing (FDA Consumer 1994, p. 9). *E. coli* O157:H7 can also survive in water for extended periods (USDA:APHIS:VS 1994, p. 1). However, *E. coli* O157:H7 is easily killed by heat used in pasteurization and cooking (USDA:APHIS:VS 1994, p. 1). The 1993 outbreak of *E. coli* O157:H7 infections indicated that the infectious dose is less than 1,000 organisms (AGA 1995, p. 1925). The CAST report estimates that the infectious illness dose is in the range of 10 to 1,000 colony-forming units (1994, p. 12).

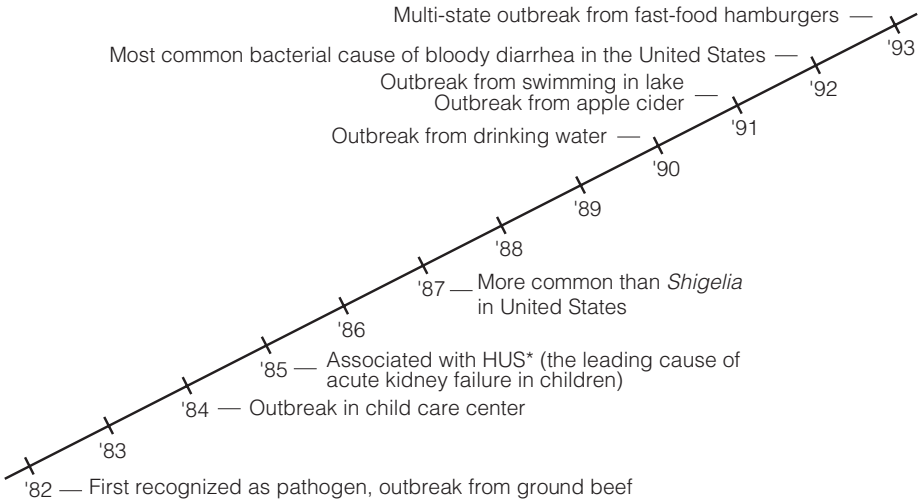
E. coli O157:H7 is a toxicoinfective microorganism because it causes human illnesses through the toxins that it produces (CAST 1994, p. 19). *E. coli* O157:H7 toxins cause human illnesses by adhering to receptors in the kidney, intestine, and central nervous system where it prevents protein synthesis and kills cells (CAST 1994, p. 19). The bloody diarrhea and abdominal cramping typically found in symptomatic cases of *E. coli* O157:H7 disease are caused by the toxins that *E. coli* O157:H7 produces and by the partial destruction of the colon's mucosal lining (USDA:APHIS:VS 1994, p. 1). In the United States, *E. coli* O157:H7 is a major cause of bloody diarrhea (AGA 1995, p. 1924).

E. coli O157:H7 causes a wide range of illness severities in humans from mild cases of acute diarrhea to premature death. Acute illness from *E. coli* O157:H7 disease is manifested by abdominal cramps, vomiting, diarrhea (often bloody), and sometimes fever. Ostroff *et al.* (1989, p. 355) found that 95 percent of the 93 reported sporadic cases of *E. coli* O157:H7 disease in Washington State in 1987 had bloody diarrhea. Griffin and Tauxe (1991, p. 64), in reviewing the literature, speculated that bloody diarrhea is the most commonly reported symptom, because persons with bloody diarrhea are more likely to seek medical care and because physicians are more likely to culture stools if patients report bloody stools.

The incubation period for *E. coli* O157:H7 in humans is typically 3 to 5 days (AGA 1995, p. 1925).

Figure 7

Emergence of *Escherichia coli* 0157:H7



*Hemolytic Uremic Syndrome

Source: Centers for Disease Control and Prevention. Addressing Emerging Infectious Disease Threats: A Prevention Strategy for the United States. Atlanta, Georgia: U.S. Dept. of Health and Human Services, Public Health Service. p. 11., 1994.

Benenson (1990, p. 137) states that the incubation period may be as short as 12 hours but the median is 48 hours. On average, the acute illness ends 6 to 8 days after onset (CDC April 16, 1993, p. 262).

Although most *E. coli* O157:H7 infections are mild and do not require medical care, *E. coli* O157:H7 infections can result in hemorrhagic colitis (bloody inflammation of the colon).[43] Symptoms of hemorrhagic colitis may include the sudden onset of severe abdominal cramps, little or no fever, and watery diarrhea (Riley *et al.* 1983; Pai *et al.* 1984; Ostroff *et al.* 1989) that may become so grossly bloody that it has been described as "all blood and no stool." Vomiting occurs in roughly half of the affected individuals (Griffin and Tauxe 1991, p. 64).

Most cases of hemorrhagic colitis fully recover 6 to 8 days after onset (Griffin and Tauxe 1991, p. 64). Patients with more severe symptoms are hospitalized. Physicians may misdiagnose hemorrhagic colitis as appendicitis, inflammatory bowel disease, or various forms of colitis, and these misdiagnoses could lead to unnecessary and/or inappropriate surgery, antibiotic therapy, and therapeutic procedures. Although most patients with *E. coli* O157:H7-induced hemorrhagic colitis recover without developing sequelae, others develop HUS (Griffin and Tauxe 1991, p. 65).[44]

Although less than 5 percent of *E. coli* O157:H7 disease cases develop HUS, outcomes from HUS are severe. HUS is a life-threatening disease characterized by red blood cell destruction, kidney failure, and neurological complications, such as seizures and strokes (McCarthy 1993, p. 10A; AGA 1995, p. 1923). Those who develop chronic kidney failure may require lifelong dialysis or a kidney transplant.[45] Other neurological complications such as central nervous system deterioration, blindness, or partial paralysis may also result (Merck 1992). Many HUS patients die.

[43]Hemorrhagic colitis can be the result of several different diseases.

[44]Another condition that may follow *E. coli* O157:H7 infection is thrombotic thrombocytopenic purpura (TTP), which is similar to HUS but Griffin and Tauxe suggest that TTP may have more prominent abnormalities in the central nervous system and may be relatively more common in *E. coli* O157:H7 disease patients who are adults (1991, pp. 84-85). Remuzzi (1987, p. 294) believes "that none of the proposed differentiating features can clearly separate these two clinical syndromes." The current study focused on HUS in children because of the preponderance of *E. coli* O157:H7 infections among the very young.

[45]During dialysis such as hemodialysis, the blood is removed from the patient, sent through a machine that balances its water and mineral content while removing toxic waste products, and then is returned to the patient.

HUS especially strikes children under 5 years of age and the immunocompromised elderly (Griffin *et al.* 1988; Griffin and Tauxe 1991; Martin *et al.* 1990). *E. coli* O157:H7 disease may be the leading cause of acute kidney failure and HUS in young children and infants. Tarr *et al*. (1989, p. 585) found that *E. coli* O157:H7 disease is the leading cause of HUS in the Pacific Northwest. Siegler *et al.*'s (1994) results from a 20-year population-based study of HUS in children in Utah were consistent with Tarr *et al.*

Other risk factors for *E. coli* O157:H7 disease include a previous gastrectomy, recent antimicrobial use, and occupational exposure to ground beef, cattle, or clinical stool specimens (Griffin and Tauxe 1991, p. 65). Spika *et al.* (1986, p. 290) and Martin *et al.* (1990, p. 1161) found that attendance at day care may be a risk factor.[46] In 1991, a swimming-associated outbreak of hemorrhagic colitis and HUS was traced to *E. coli* O157:H7-contaminated lake water (Keene *et al.* 1994, p. 579).

Over 67 percent of sporadic *E. coli* O157:H7 cases have occurred between May and September, while 88 percent of all outbreak cases have occurred between May and November (USDA:APHIS:VS 1994, p. 2). This seasonality may be related to the summer barbecue season.

A 2-year study of stool samples showed that a significantly lower percentage of stool samples tested positive for *E. coli* O157:H7 in the South than in the Western and Northern United States (USDA:APHIS:VS 1994, p. 2). Yet, there is no strong evidence suggesting a geographical pattern for *E. coli* O157:H7 disease. The documentation of the incidence of *E. coli* O157:H7 infections in humans is hindered by the variation in State reporting requirements to the CDC. As of the summer of 1993, 17 States had reporting requirements for *E. coli* O157:H7, 20 States were amending their public health regulations to require such reporting, 10 States and the District of Columbia were seriously considering this requirement, and the remaining three States were not addressing the issue (Vogt 1994, p. CRS-7).

As with *Salmonella* and *Campylobacter*, *E. coli* O157:H7 can live harmlessly in the gastrointestinal tracts of farm animals and poultry and later contaminate meat and poultry products during slaughter.

[46]Belongia *et al.* (1993, p. 883) found that "person-to-person transmission of *E. coli* O157:H7 is common when infected preschool children attend day care while symptomatic."

Most outbreak cases associated with food in the United States are linked to bovine products (USDA:APHIS:VS 1994; Griffin and Tauxe 1991, p. 71). Some outbreaks are suspected or have been confirmed as originating in the cross contamination of other foods such as mayonnaise, apple cider, and vegetables by meat products or manure (USDA: APHIS:VS 1994, p. 1).[47] Other foods associated with human *E. coli* O157:H7 disease outbreaks and sporadic cases include hot dogs, raw milk, raw potatoes, turkey roll, and salad bar items such as ranch dressing, pea salad, and cantaloupe (Griffin and Tauxe 1991; USDA:APHIS:VS 1994; AGA 1995, p. 1923).

Sporadic cases of *E. coli* O157:H7 disease have also been attributed to person-to-person transmission and to contaminated water (Griffin and Tauxe 1991, p. 73). Outbreaks from contaminated water have also occurred. Swerdlow *et al.* (1992) examined a large outbreak of *E. coli* O157:H7 infections traced to contaminated water in a Missouri municipal water system. Keene *et al.* (1994) investigated a 1991 swimming-associated outbreak of hemorrhagic colitis caused by *E. coli* O157:H7 contaminated water.

Bennett *et al.* (1987, p. 109) found that in 1985 potentially 5 percent of *E. coli* O157:H7 infections were attributed to attendance at day care centers. Because *E. coli* O157:H7 is not spontaneously generated, it is possible that many of these person-to-person cases originated with consumption of food contaminated with *E. coli* O157:H7. Several other studies also report or suggest that *E. coli* O157:H7 disease can be caused by person-to-person transmission (Ratnam *et al*. 1986; Spika *et al.* 1986). In the 1993 outbreak in the Northwest, more than 50 of the 500-plus cases were attributed to person-to-person contact, especially taking place among infants in child care facilities (FDA Consumer 1994, p. 8). In addition to food, water, and human sources of transmission of *E. coli* O157:H7, Renwick *et al.* (1993) report transmission from calves to a child, presumably through oral contact with feces.

Estimates of Cases

Laboratory screening for *E. coli* O157:H7 is relatively straightforward (Griffin *et al.* 1988, p. 711) and pro-

[47]Apple cider contaminated with *E. coli* O157:H7 is believed to result from making cider with apples that have fallen from orchard trees and that are contaminated with manure fertilizer or feces from farm animals or deer.

vides the opportunity to compare the frequency of isolation of this pathogen to frequencies of other pathogens causing diarrheal illnesses in humans. Gransden *et al.* (1986, p. 523) found that *E. coli* O157:H7 was the second leading bacterial cause of diarrhea (following *Campylobacter*) in 1,425 school children in British Columbia who had stool cultures taken. MacDonald *et al.* (1988, p. 3567) report that out of 6,485 stool specimens from a health maintenance organization in Washington State, researchers isolated *E. coli* O157:H7 less frequently than *Salmonella* or *Campylobacter*, but more frequently than *Shigella*.[48]

We updated Roberts and Marks' (1995) COI estimates for *E. coli* O157:H7. As with the other foodborne pathogens studied here, this analysis considers four main patient categories, those who: do not visit a physician, visit a physician, are hospitalized, and die. However, the COI analysis for *E. coli* O157:H7 infections is more complicated than for salmonellosis and campylobacteriosis, because hospitalized acute illness cases and deaths are subdivided into those who have hemorrhagic colitis and those with HUS. The COI analysis for *E. coli* O157:H7 is further complicated in that some HUS cases develop chronic illnesses and some of these chronic illness cases die prematurely. For simplicity, our analysis will first discuss medical costs, subdivided into acute and chronic cases, followed by a discussion of the costs of lost productivity, also subdivided into acute and chronic cases. Table 10 presents the estimated acute and chronic *E. coli* O157:H7 disease cases in the United States, broken down by the four disease severity categories used throughout this report. Figure 8 presents the distribution of estimated annual cases of *E. coli* O157:H7 disease and disease outcomes. Table 11 presents the assumptions used here to estimate annual costs of *E. coli* O157:H7 disease.

To simplify the analysis, all cases are assumed to be 4 years of age at death or at the onset of the illness. This was roughly the average age (3.8 years) in Martin *et al.* (1990), which is the largest U.S. study of children with HUS. They studied 117 children under age 18 with HUS in Minnesota. This is also the average age in Siegler *et al.'s* (1994, p. 36) 20-year population-based study. Several studies also identified age less than 4 or 5 years as a risk factor for HUS from *E. coli* O157:H7 disease (Pai *et al.* 1984, p. 590; Griffin

[48]Isolation rates were as follows: 7/100,000 persons for *Shigella*; 8/100,000 persons for *E. coli* O157:H7; 21/100,000 persons for *Salmonella*; and 50/100,000 persons for *Campylobacter*.

Table 10—Estimated U.S. *Escherichia coli* O157:H7 disease cases, 1993[1]

Severity of illness	Cases	
	Low	High
	Number	
Acute:		
No physician visit[2]	5,000	10,000
Visited physician[2]	3,200	6,400
Hospitalized and survived[3]	1,600	3,100
Hemorrhagic colitis	1,340	2,630
HUS	260	470
Deaths (during hospitalization)[4]	200	500
Hemorrhagic colitis deaths	100	250
HUS deaths	100	250
Total acute cases[5]	10,000	20,000
Chronic:		
No physician visit	0	0
Visited physician	0	0
Hospitalized and survived (all are HUS)[6]	11	25
Deaths (all are HUS)[7]	19	37
Total chronic cases	30	62

[1] We assumed no chronic conditions resulted from hemorrhagic colitis (HC) and assumed both chronic and acute conditions resulted from hemolytic uremic syndrome (HUS). For both acute and chronic *E. coli* O157:H7 illness, we estimate there is a total of 219-537 deaths each year (see below).

[2] Of the 82% of all *E. coli* O157:H7 acute illness cases that are not hospitalized, we assume that 50% of all cases do not seek any medical attention and the remaining 32% visit a physician.

[3] Griffin and Tauxe (1991) found that 18% (p. 69) of all acute illness cases are hospitalized (1,800 to 3,600 cases) and 20% (calculated from Table 2 on p. 70) of the hospitalized cases (360-720) develop HUS. After subtracting the 100-250 HUS acute illness deaths, there were 260-470 hospitalized HUS cases who survived. We categorize the remainder of the hospitalized cases (80%) as those that develop HC (1,440-2,880). After subtracting the 100-250 HC acute illness deaths, there were 1,340-2,630 hospitalized HC cases who survived.

[4] The American Gastroenterological Association's (AGA) 1994 Consensus Conference on *E. coli* O157:H7 Infections estimate the annual number of *E. coli* O157:H7 acute illness deaths as ranging between 200 and 500. We assume that 50% of all *E. coli* O157:H7 acute illness deaths were HC patients and 50% were HUS patients.

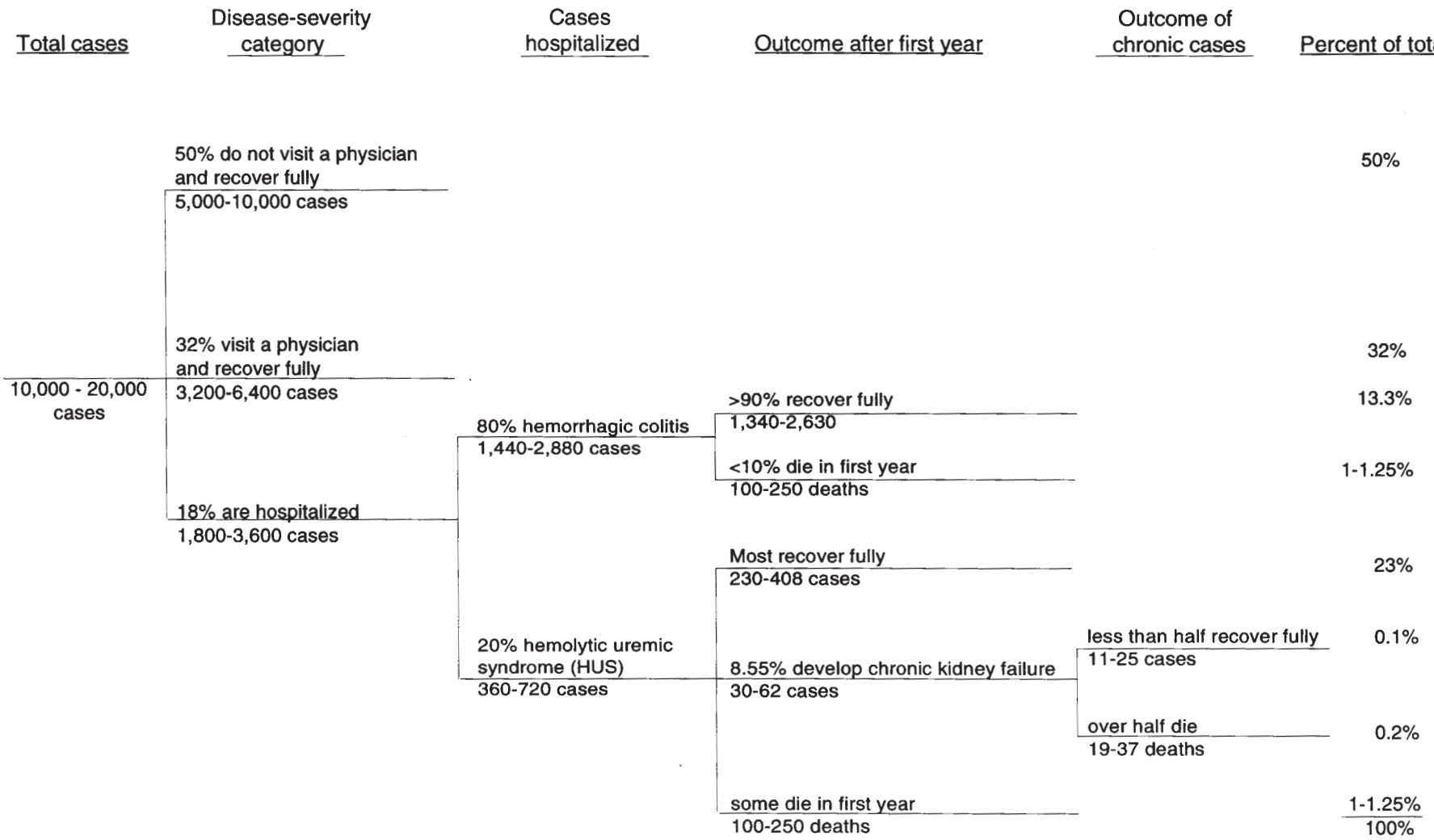
[5] The AGA's 1994 Consensus Conference on *E. coli* O157:H7 Infections (p. 7) estimate the annual number of *E. coli* O157:H7 disease cases as ranging between 10,000 and 20,000 cases.

[6] In Martin *et al.* (1990), 8.55 percent of HUS patients had kidney failure and we use this percentage to represent the proportion of acute illness HUS cases that developed chronic complications. Out of the 360-720 HUS cases, we estimate that 30-62 developed chronic complications.

[7] Using the HCFA's data on the rates of kidney transplantation, survival after the operation, and survival on dialysis for pediatric patients, life tables for the 30-62 chronic illness cases were estimated (Eggers, personal communication with Marks). We estimate that 19-37 die prematurely from chronic illness due to HUS.

Figure 8

Distribution of estimated annual U.S. *Escherichia coli* O157:H7 disease cases and outcomes[1]



[1]Percentages and cases may be rounded.

Prepared by Economic Research Service, USDA.

Table 11—Assumptions used to estimate annual costs of illness for *E. coli* O157:H7 disease, 1993

Cost category & severity	Costs during acute illness	Costs during chronic illness
Overview: Incremental costs due to foodborne disease	Estimates of new cases annually are divided into severity level categories to estimate costs. Acute illness costs are not discounted, except for productivity losses for deaths occurring during the acute illness.	Some survivors develop chronic conditions. All lifetime costs are discounted at 3% per year to calculate the 1993 present value.
Medical costs		
No physician visit	No medical costs estimated. (Although some may self-medicate.)	Not relevant.
Visited physician	Physician visit cost calculated by dividing the updated Health Care Financing Administration annual national expenditures on physician services by the National Center for Health Statistics annual number of physician visits. Laboratory expenses are computed separately.	Not relevant.
Hospitalized	Hospital room cost is the American Hospital Association's average cost per day. An intensive care room is assumed to be double the cost of a regular room. Total fees for physician care, laboratory tests, and medications during hospitalization are assumed to be equal to hospital room costs. Costs of dialysis are computed separately.	For known chronic conditions associated with the foodborne illness, chronic costs are computed the same as acute costs, except that they are computed for the remaining life of an individual and discounted back to 1993 using a 3% discount rate. Discounted costs of kidney transplants and drug therapy were also included.
Productivity losses	If ill person is a child under age 16, productivity loss is calculated for one parent/caretaker.	For children, the productivity loss is calculated for one parent/caretaker's time estimated for care of chronically ill child until age 16. After the age of 16, the ill individual's productivity loss is estimated.
No physician visit	Productivity loss uses the BLS average weekly earnings for all nonagricultural workers (pre-tax, no fringe benefits) multiplied by 39% to account for fringe benefits, divided by 5 to get a daily rate, and multiplied by the estimated days lost from work.	The average weekly earnings are multiplied by 52 weeks, adjusted by the labor force participation rate for the age of the patent, and multiplied by the percentage of productive capacity lost. Or, an estimate of the proportion of productivity lost because of the disability is multiplied by Landefeld and Seskin's (1982) value of life according to the age of the patient to get the marginal lifetime productivity lost.
Visited physician	Time away from work was estimated either by assuming the average duration of illness or by using estimates from survey data. The cost per day is estimated by adjusting BLS average weekly earnings as above.	
Hospitalized	Time away from work is assumed to be 3 times the days in the hospital, adjusted for weekends. The cost per day is estimated by adjusting BLS average weekly earnings as above.	
Death	The present value of a statistical life lost is computed as the average of male and female values given by Landefeld and Seskin (1982) for each age, updated to 1993 values using the change in average weekly earnings.	The value of a statistical life lost to chronic illness is Landefeld and Seskin (1982) value for the age of the person in the year he/she dies, discounted back to 1993.
Other costs: education, nursing home, lost leisure, pain & suffering, transportation to medical care	Not estimated.	Not estimated

et al. 1988, p. 706; Ostroff *et al.* 1989, p. 355; Pavia *et al.* 1990, p. 549; Cimolai *et al.* 1990, p. 590). Figure 9 presents the age-specific rates of infection with *E. coli* O157:H7 for 93 surveillance cases in Washington State in 1987. Note that the highest infection rate is for children less than 5 years old.

The annual estimated incidence of *E. coli* O157:H7 disease is between 2.1 and 8 cases per 100,000 persons (Ostroff *et al.* 1989, p. 355; and MacDonald *et al.* 1988, p. 3567, respectively). Participants of the AGA's 1994 Consensus Conference on *E. coli* O157:H7 infections (1995, p. 1924) believed that the best estimate of *E. coli* O157:H7 disease cases was between 10,000 and 20,000 cases per year (a rate of approximately 4 to 8 cases per 100,000 persons in 1993). We use these consensus estimates for this analysis.

Using data on 12 U.S. outbreaks of *E. coli* O157:H7 disease between 1982 and 1990, Griffin and Tauxe (1991, p. 69) found that 18 percent of all cases are hospitalized and 20 percent of the hospitalized cases develop HUS (calculated from table 2 on p. 70).[49]

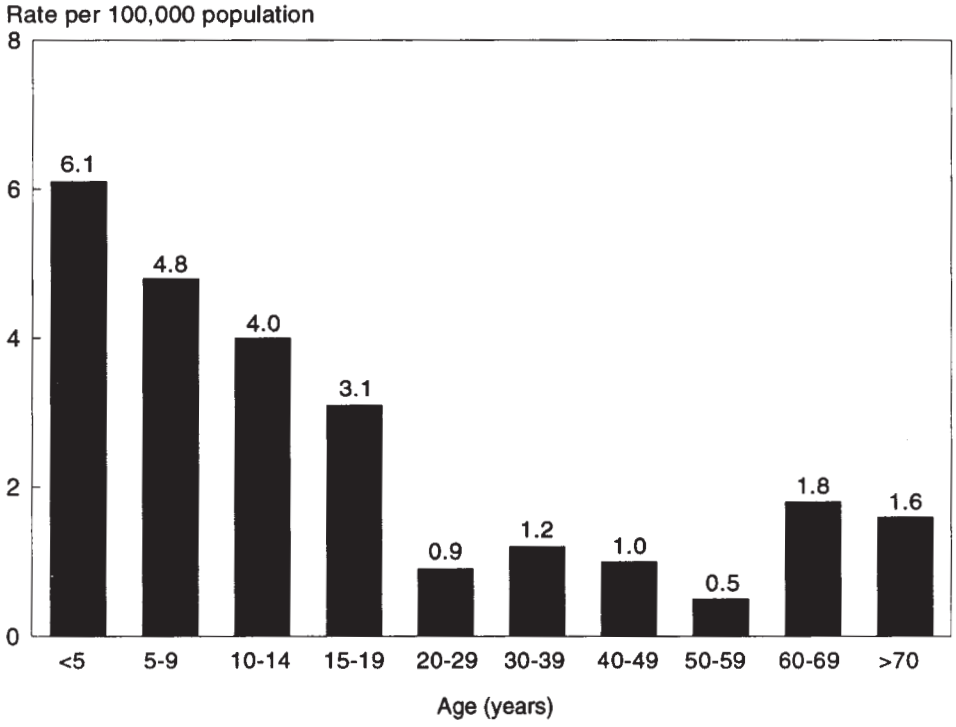
These percentages are used in this analysis. The remainder of the hospitalized cases (80 percent) are categorized as those who develop hemorrhagic colitis. Using these percentages along with the estimated range of 10,000-20,000 E. coli O157:H7 disease cases, an estimated 1,800-3,600 cases are hospitalized. This includes hospitalized patients who survive and those who die prematurely because of acute *E. coli* O157:H7 disease. Of these 1,800 to 3,600 cases, 360 to 720 (or 20 percent) develop HUS, and 1,440 to 2,880 (or 80 percent) develop hemorrhagic colitis.

In Martin *et al.*'s (1990, p. 1164) study of 117 children who had HUS, 9 children had renal failure and survived, and one child required a kidney transplant.[50] Here, we assumed that these 10 renal failure and transplant cases (or 10/117=8.55 percent) constitute those HUS patients who remain chronically ill with kidney failure. Using this percentage (8.55 percent), we estimated that of the 360 to 720 cases who contract HUS in our analysis, approximately 30 to 62 remain chronically ill.

[49]This translates into 3.6 percent of all *E. coli* O157:H7 cases develop HUS. Our estimate is conservative when compared with Karmali *et al.* (1985, p. 778) who found that roughly 10 percent of all *E. coli* O157:H7 infections develop HUS.

[50]Martin *et al.'s* (1990, p. 1164) table 3 indicates 10 cases of renal failure, but one of these is linked to the sepsis death which would have first had renal failure.

Figure 9
E. coli O157:H7 infection rates by age, 1987



Prepared by Economic Research Service, USDA, based on personal communication with Stephen Ostroff from the Centers for Disease Control and Prevention on February 7, 1996. Data for 93 *E. coli.* O157:H7 cases in Washington State.

We assumed that all of the 30 to 62 chronic illness cases required dialysis and some had kidney transplants, and that there were premature deaths resulting from both of these procedures. Because kidney failure is the major chronic complication of HUS in children, end-stage renal disease (ESRD) data were used in the cost estimation. We used data on the percentage of ESRD children receiving kidney transplants (Eggers, personal communication with Marks (ERS) 1993) and HCFA's Medicare data on survival rates after kidney transplantation and survival rates on dialysis for pediatric patients (HCFA 1992, tables 35-37) to develop life tables for kidney transplant and dialysis survivors, and to estimate the number of premature deaths due to chronic illness from HUS. Table 12 shows the breakdown of the estimated 19 to 37 premature deaths from chronic *E. coli* O157:H7 illness, by age at death. The estimated number of chronic illness deaths is the sum of the estimate of premature deaths from complications during kidney transplantation and the estimate of premature deaths from complications during dialysis. None of these deaths occurred during the first year of illness but were spread out over subsequent years.[51] Age at death and number of deaths depend upon both kidney transplant survival rates and dialysis survival rates.

Not all kidney transplants take place within the first few years following the onset of the chronic illness. A variety of reasons, such as the patient's health and the availability of a suitable kidney, may delay kidney transplants or remove this procedure as an option for patients. Paul Eggers of HCFA provided data on the cumulative percentage of children receiving transplants within the first 6 months of ESRD and the percentage receiving transplants for each of the following 5 years after ESRD was diagnosed (personal communication between Eggers and Marks (ERS), 1993). This cumulative rate of receiving a transplant increases over time as more kidney transplants are performed. From these data, the cumulative percentage receiving transplants for the remaining years in the average life span of 77 years was estimated, as was the annual percentage receiving transplants (decreasing) for each of the years in this timeframe. Using these annual percentages, out of the 30 to 62 chronic illness cases, an estimated 26 to 53 cases had kidney transplants. Table 12 also shows the breakdown of the estimated range of 26 to 53 transplant recipients by year.[52]

Survivability after a transplant depends on the type of kidney received, with higher survival rates for transplant recipients of a kidney from a "living-related" donor versus a kidney from a cadaver. For the representative age used in this study, an estimated 56 percent of the kidney transplant patients had cadaver donors and 44 percent had living-related donors (personal communication between Eggers and Marks (ERS), 1993).

Two groups of deaths from *E. coli* O157:H7 disease were considered: acute illness deaths and chronic illness deaths. In the literature, human deaths attributed to *E. coli* O157:H7 disease generally refer to acute illness deaths and do not include chronic illness deaths. Griffin and Tauxe (1991, p. 69) found a 1.9-percent death rate (op. cit.). However, participants of the Consensus Conference on *E. coli* O157:H7 generally agreed that an estimated 200 to 500 deaths occur from *E. coli* O157:H7 disease each year (Notes by Roberts for this conference), which in our study translates into a death rate of 2 to 2.5 percent.[53] This death rate is high compared with other microbial infections.

We were unable to find published data that specified what percentage of the estimated 200 to 500 *E. coli* O157:H7 acute illness deaths were from hemorrhagic colitis cases and what percentage were from HUS. Therefore, we assumed that 50 percent of all acute *E. coli* O157:H7 disease deaths were hemorrhagic colitis patients and 50 percent were HUS patients. Of the estimated 1,440 to 2,880 cases of hemorrhagic colitis, an estimated 100 to 250 cases died prematurely from the acute illness. The remaining 1,340 to 2,630 patients hospitalized with hemorrhagic colitis achieved a complete recovery. And of the estimated 360 to 720 cases that contract HUS, an estimated 100 to 250 cases died prematurely from their acute illness. These proportions of the percentage of acute illness deaths from HUS and hemorrhagic colitis reflect the greater severity of HUS.

To estimate the number of HUS deaths attributed to chronic complications from kidney transplants, HCFA data on cadaver-donor transplant patient survival

[51]This "first year" is really only 6 months, because it was assumed that the patients became ill in the middle of the year, on average.

[52]All kidney transplants were performed within the 6 full years following the originating illness at age 4, because, over time, the proportion that received a transplant each year declines sharply.

[53]This range of deaths was agreed upon during the conference yet does not appear in the written statement.

Table 12—Chronic illness: Deaths, dialysis recipients, and transplant survivors

Age	Chronic deaths[1]		Dialysis recipients		Transplant recipients		Transplant survivors	
	Low	High	Low	High	Low	High	Low	High
				Numbers				
4 in 1993	0	0	30	62	0	0	0	0
5	2	4	15	31	15	31	14	29
6	1	3	8	17	6	12	19	39
7	2	0	5	11	3	5	21	44
8	1	3	3	8	1	3	21	44
9	1	2	2	7	1	1	21	44
10	1	1	2	5	0	1	20	44
11	0	2	2	5	0	0	20	42
12	0	0	2	5	0	0	20	42
13	1	1	2	5	0	0	19	41
14	0	0	2	5	0	0	19	41
15	0	0	2	5	0	0	19	41
16	0	0	2	5	0	0	19	41
17	1	0	2	5	0	0	18	41
18	0	1	2	5	0	0	18	40
19	0	0	2	5	0	0	18	40
20	0	1	2	5	0	0	18	40
21	0	0	2	4	0	0	18	40
22	0	1	2	4	0	0	18	39
23	0	3	2	4	0	0	18	36
24	1	0	2	4	0	0	17	36
25	1	0	2	4	0	0	16	36
26	0	0	2	4	0	0	16	36
27	0	0	2	4	0	0	16	36
28	0	0	2	4	0	0	16	36
29	0	1	2	4	0	0	16	35
30	0	0	2	4	0	0	16	35
31	0	0	2	4	0	0	16	35
32	0	0	2	4	0	0	16	35
33	0	0	2	4	0	0	16	35
34	0	0	2	4	0	0	16	35
35	0	1	2	4	0	0	16	34
36	1	0	2	4	0	0	15	34
37	0	0	2	4	0	0	15	34
38	0	1	2	4	0	0	15	33
39	0	1	2	4	0	0	15	32
40	1	2	2	4	0	0	15	31
41	0	0	1	3	0	0	15	31
42	0	1	1	3	0	0	15	30
43	0	0	1	3	0	0	15	30
44	0	0	1	3	0	0	15	30
45	0	0	1	3	0	0	15	30
46	0	0	1	3	0	0	15	30
47	0	0	1	3	0	0	15	30
48	0	0	1	3	0	0	15	30
49	1	0	1	3	0	0	14	30
50	0	1	1	3	0	0	14	29
51	0	0	1	3	0	0	14	29
52	1	0	1	3	0	0	13	29
53	0	0	1	3	0	0	13	29
54	0	0	1	3	0	0	13	29
55	0	0	1	3	0	0	13	29
56	0	0	1	3	0	0	13	29
57	0	0	1	3	0	0	13	29

See notes at end of table.

--Continued

Table 12—Chronic illness: Deaths, dialysis recipients, and transplant survivors--Continued

Age	Chronic deaths[1]		Dialysis recipients		Transplant recipients		Transplant survivors	
	Low	High	Low	High	Low	High	Low	High
				Numbers				
58	0	0	1	3	0	0	13	29
59	0	2	1	3	0	0	13	27
60	0	1	1	3	0	0	13	26
61	0	0	1	3	0	0	13	26
62	0	0	1	3	0	0	13	26
63	1	0	1	3	0	0	12	26
64	0	0	1	3	0	0	12	26
65	0	1	1	3	0	0	12	25
66	0	0	1	3	0	0	12	25
67	0	0	1	3	0	0	12	25
68	0	0	1	3	0	0	12	25
69	0	2	1	3	0	0	12	23
70	0	0	1	3	0	0	12	23
71	0	0	1	3	0	0	12	23
72	0	0	1	3	0	0	12	23
73	1	0	1	3	0	0	11	23
74	0	0	1	3	0	0	11	23
75	1	0	1	3	0	0	10	23
76	0	1	1	3	0	0	10	22
77	0	0	1	3	0	0	10	22
Total	19	37	*	*	26	53	*	*

*=These could not be totaled as they would overcount the numbers of recipients or survivors over time.

[1] Of the estimated 19 to 37 chronic illness deaths, 3 to 6 occur from complications from dialysis and 16 to 31 occur from complications arising from the kidney transplants.

(1992, table 36, p. 41) and HCFA data on living-related donor transplant patient survival were used (1992, table 37, p. 42). For both types of kidney transplants, these HCFA cumulative survival rates show that transplant patient survival rate decreases over time as more kidney transplant patients die. These data on the survivability following the two types of kidney transplants were available only for the first full 5 years after the kidney transplant. From these 5 years of data, the survival rates were estimated as well as the number of transplant survivors for both types of kidney transplants for each year in the average life-span of 77 years. Table 12 provides estimates of the total number of transplant survivors from operations using both cadaver and living-related donor kidneys. Given the estimated 26 to 53 kidney transplants and the number of transplant survivors, an estimated 16 to 31 premature deaths occur as a result of complications from the kidney transplants.

To estimate the number of HUS deaths attributed to complications from dialysis, HCFA data on ESRD were used (1992, table 35, p. 40). As with the kidney transplant survival data, the HCFA cumulative estimates of dialysis patient survival declined over time as more patients died prematurely. These data only provided for the first full 5 years after the initiation of dialysis and were used to estimate the cumulative dialysis survival rate for each of the remaining years in the average life span of 77 years. Once all cumulative dialysis survival rates were determined, they were used to develop the percentage of dialysis patients that die each year over the 77-year life span. These annual death rates for dialysis patients were used to estimate that three to six patients with chronic illness due to HUS die prematurely from complications during dialysis.

Out of the 30 to 62 chronic illness cases, an estimated 19 to 37 died prematurely (table 12) from chronic complications over their lifetime (3 to 6 from dialysis and 16 to 31 from transplants). Adding these estimated chronic illness deaths to the estimated 200 to 500 acute illness deaths provides an annual estimate of 219 to 537 deaths caused by *E. coli* O157:H7 disease.

Of the 82 percent of all *E. coli* 1057:H7 disease cases that are not hospitalized, we assumed that 50 percent of all cases do not seek any medical attention (5,000

to 10,000 cases) and that the remaining 32 percent of all cases visit a physician (3,200 to 6,400 cases). This is a higher rate of physician visits than for salmonellosis and campylobacteriosis, but *E. coli* O157:H7's bloody diarrhea is likely to scare people into seeing a physician.

Costs of *E. Coli* O157:H7 Disease

As previously mentioned, the COI analysis for *E. coli* O157:H7 disease differs from those for salmonellosis and campylobacteriosis. *E. coli* O157:H7 disease cases were divided into acute and chronic cases, and *E. coli* O157:H7 disease had two categories of illness that required hospitalization, hemorrhagic colitis and HUS.

Medical Costs for Acute E. Coli O157:H7 Disease

Acute illness medical costs consisted of the costs of hemodialysis, hospital room charges, and physician fees. Hospital room charges include regular hospital rooms and intensive care unit (ICU) rooms. Several nationwide data bases were used. For example, the American Hospital Association's Hospital Statistics provided data on daily costs of hospitalization. The National Hospital Discharge Survey (NHDS) implemented by HCFA's National Center for Health Statistics was used to provide estimates for hospital length of stay. The study also used HCFA's estimates of per capita expenditures on physician services and HCFA's medicare reimbursement rates for the annual costs of ESRD and the costs of kidney transplants.[54] Table 13 presents the estimated annual medical costs of acute illness from *E. coli* O157:H7 disease by severity category.

- No physician visited. For the estimated 5,000 to 10,000 *E. coli* O157:H7 disease cases who do not seek medical care, the study assumed that they have abdominal discomfort and non-bloody diarrhea (often lasting several days) yet do not purchase over-the-counter medications and do not miss work because of their illnesses. For the cases in this category, no medical costs were computed.

- Physician visited. For the estimated 3,200 to 6,400 cases who visited a physician for *E. coli* O157:H7 disease but were not hospitalized, it was assumed that these cases had diarrhea (often bloody and lasting several days) and that they visited a physician once or twice and had one or two laboratory tests. Prescribed medications and medication costs were not included in the estimated costs.

  The costs of physician visits was estimated at $109.57 per visit.[55] This number reflects the per-visit cost of a doctor visit for all reasons, not specifically for the foodborne illness, and includes the portion paid by insurance. Laboratory tests were estimated at $50 per case. Medical costs for those *E. coli* O157:H7 disease cases who visited a physician for their illness but did not require hospitalization are estimated at between $0.5 million and $2.0 million annually.

- Hospitalized for Hemorrhagic Colitis. For the estimated 1,440 to 2,880 cases of hemorrhagic colitis, we assumed that these cases were hospitalized for their bloody diarrhea, dehydration, and severe abdominal cramps. The estimated length of stay (LOS) in a hospital for patients with hemorrhagic colitis is 6.5 days (the average from the NHDS range of 5 to 8 days, Steahr 1993). To compute hospitalization costs, the average cost to community hospitals per patient per day in 1993 dollars was used ($887.20).[56]

- Fees for laboratory tests, supplies, medications, and physician visits while hospitalized are assumed to equal the costs of hospitalization (following Roberts and Pinner 1990) but were updated using the physician services CPI, for a total cost of $843.74 per

[54]Medicare billing records provide a major source of information on the medical costs of specific diseases. However, such information is specific to the Medicare population and may understate the treatment costs of diseases affecting the non-Medicare population.

[55]In 1990, the average number of physician and dental contacts per person per year was 4.7 for males and 6.4 for females (*Statistical Abstract of the United States 1993*: table 174), for an average of 5.55 visits per person. The average cost of a physician visit was estimated by dividing per capita annual natjioal expenditures on physicians' services, $542 in 1991 (*Statistical Abstract of the United States 1993*: table 151), by the average number of annual physician visit (5.55), and updating the resulting number to 1993 dollars (using the 1991 physician services CPI from the *Statistical Abstract of the United States 1993*: table 163, and the 1993 physician services CPI from personal correspondence with BLS on June 16, 1994).

[56]In 1991, the daily hospitalization cost per person was estimated at $752 per patient (American Hospital Association in *Statistical Abstract of the United States 1993*: table 182. This estimate was updated to 1993 dollars using the change in the hospital room CPI (1991 CPI from the *Statistical Abstract of the United States 1993*: table 163, and the 1993 CPI from personal correspondence with BLS in June 1994).

Table 13—Estimated medical costs of acute *E. coli* O157:H7 disease, 1993

Severity of illness	Unit cost[8]	Service/ case	Cost/ case[8]	Cases		Total costs[8]	
				Low	High	Low	High
	Dollars	*Number*	*Dollars*	*Number*		*Million Dollars*	
No physician visit	0	0	0	5,000	10,000	0	0
Visited physician:							
Physician visits[2]	110/visit	1-2	110-219				
Laboratory tests	50/case	1-2	50-100				
Subtotal			160-319	3,200	6,400	0.5	2.0
Hospitalized with hemorrhagic colitis:							
Hospital room3	887/day	6.5	5,767				
Physician fees, lab tests, etc.[4]	844/day	6.5	5,484				
Subtotal			11,251	1,440	2,880	16.2	32.4
Hospitalized with HUS:[1]							
Hospital room[5]	1,183/day	15	17,744	360	720	6.4	12.8
Physician fees, lab tests, etc.[6]	1,125/day	15	16,875	360	720	6.1	12.1
Dialysis and medication[7]	130/day	12	1,566	169	338	0.3	0.5
Subtotal			36,185			12.7	25.5
Total	N/A	N/A	N/A	10,000	20,000	29.4	59.9

N/A = Not applicable.

[1] Medical costs are for those who survive and those who die (after hospitalization) from the acute illness.

[2] The average cost of a physician visit was estimated by dividing per capita annual national expenditures on physician services, $542 in 1991 (*Statistical Abstract of the United States 1993*: table 151), by the average number of annual physician visits (table 174, averaged across gender), and updating the resulting number to 1993 dollars using the physician services CPI (table 163 and personal correspondence with BLS on June 16, 1994). We estimate these cases visit a physician one to two times for their illness.

[3] In 1991, the daily hospitalization cost per person was estimated at $752 per patient (American Hospital Association in *Statistical Abstract of the United States 1993*: (table 182). This estimate was updated to 1993 dollars using the change in the hospital room CPI (Table 163 and personal correspondence with BLS in June 1994). The average hospital length of stay is 6.5 days (average from NHDS data, Steahr 1993).

[4] Fees for laboratory tests, supplies, medications, and physician visits while hospitalized are assumed to equal the costs of hospitalization (following Roberts and Pinner 1990) but were updated using the physician services CPI (as above). Medical costs exclude costs of neurological procedures and gastrointestinal procedures.

[5] Martin *et al.* (1990) found that HUS patients stay on average 15.4 days in a hospital, which we round down to 15 days. We assume the patient stays in a regular hospital room 10 days at the same daily room rate as above, and stays in an intensive care unit (ICU) 5 days at double the regular room rate.

[6] Fees calculated in the same fashion for ICU days as for days in a regular hospital room.

[7] Daily rate of medicare reimbursements for dialysis (Eggers 1994, table 48), updated to 1993 dollars using the general medical care CPI (table 163 and personal correspondence with BLS in June 1994).

[8] Some costs have been rounded for this table.

patient per day.[57] The total costs of hospitalization and fees are estimated at $1,730.94 per patient per day. For the estimated 1,440 to 2,880 cases of hemorrhagic colitis, total costs for this medical category ranged from $16.2 million to $32.4 million. We assumed that these cases recovered fully.

- Hospitalized for acute HUS. Of the estimated 360 to 720 *E. coli* O157:H7 disease cases hospitalized for HUS (which included the 100 to 250 who died prematurely from the acute illness), 30 to 62 of these patients later developed chronic illnesses (which includes 19 to 37 who die from chronic illness due to HUS). The acute and chronic medical costs are not mutually exclusive, because those who develop chronic illnesses first bear the costs incurred during HUS. Additional medical costs incurred by the 32 to 60 patients who develop chronic illness due to HUS illness are discussed in the next section.

In Martin *et al.*'s (1990, p. 1163) study of 117 HUS cases in Minnesota, the average hospital length of stay for HUS patients was 15.4 days. Following Martin *et al.*, we assumed an average patient stay of 15 days (after rounding) in the hospital. We also assumed that 5 of these days would be spent in an ICU. We used an estimate for ICU room costs of $1,774/ICU day, or twice the normal hospital room charge of $887/day. Thus the average cost equals $1,183 per day for the duration of hospitalization. Total annual costs of the regular and ICU hospital rooms for the 360 to 720 acute HUS cases range from $6.4 million to $12.8 million.

We also assumed that the physician fees, laboratory tests, and other charges during hospitalization would be similar to the hospital room and ICU room fees, but were updated using the physician services CPI (updated as described under physician visits) to get an average cost of $1,125 per day. Estimated total annual costs of physician fees, laboratory tests, etc. for the 360 to 720 acute HUS cases range from $6.1 million to $12.1 million.

Martin *et al.*'s (1990, p. 1163) found that 47 percent of HUS cases required dialysis for an average of 12 days. For the current analysis, this translates into 169 to 338 acute HUS cases requiring dialysis. The annual medicare reimbursement rate for kidney dialysis for children in 1993 dollars was $130.50 per day.[58] For the estimated 169 to 338 children who required dialysis, estimated total annual costs of dialysis ranged from $0.3-$0.5 million.

Estimated medical costs for the 360 to 720 hospitalized acute HUS cases ranged from $12.7-$25.5 million annually. This includes the costs of hospitalization, dialysis, physician fees, laboratory tests, and other charges during hospitalization.

- Deaths. We assumed that the estimated 200 to 500 patients who died prematurely from acute *E. coli* O157:H7 disease incurred hospitalization costs prior to their deaths. As previously mentioned, these deaths were divided among those hospitalized for hemorrhagic colitis (50 percent of deaths) and those hospitalized for HUS (50 percent of deaths).[59] The acute illness medical costs associated with these deaths are included in the two hospitalization categories above.

- Subtotal. Acute illness medical costs for the four disease severity categories were estimated to total between $29.4 million and $59.9 million annually.

Medical Costs for Chronic Illness Due to HUS

As previously mentioned, HUS may lead to chronic kidney failure, requiring lifelong dialysis or a kidney transplant. We estimated costs for chronic kidney-related disease, but did not estimate costs for the chronic neurological complications or intestinal operations (laparotomies or colostomies).

[57]As before, we use the 1991 hospital cost of $752 per day, but we updated this cost with the physician services CPI (1991 CPI from *Statistical Abstract of the United States 1993*: table 163 and the 1993 CPI from personal communication with BLS in June 1994).

[58]In 1990, the average Medicare End Stage Renal Disease Program expenditures per dialysis patient were $38,502 per year (Eggers 1993, table 48). This cost estimate was updated to 1993 dollars using the general medical care CPI (1990 CPI from *Statistical Abstract of the United States 1993*: table 163; 1993 CPI from personal communication with BLS in June 1994) to get 1993 annual costs of $47,630.85 per patient or $130.50 per patient per day.

Peritoneal dialysis such as Continuous Ambulatory Peritoneal Dialysis (CAPD) and Continuous Cyclic Peritoneal Dialysis (CCPD) results in one infection every 9 months, on average. Consequently, the infection may be treated with antibiotics in the hospital for 2 days or at home, depending on the severity of the infection. In addition, the children must visit a physician once a month for a checkup. We assumed that the HCFA costs of dialysis for pediatric patients include some, if not all, of these costs.

[59]Patricia Griffin, personal communication July 1993, estimates that 5 percent of deaths occur in nonhospitalized cases which would mean that our assumptions used here overestimated hospitalization costs by 5 percent.

Estimated annual medical costs for chronic illness due to HUS were calculated by adding the costs of three separate medical services for these cases: dialysis, kidney transplants, and drug therapy. For each of these three categories, costs for each year of service were determined by multiplying the average cost per service by the number of patients receiving that service. A total cost for each type of service was then computed by summing annual costs of the service. After the total costs for each of these three subcategories were estimated and combined, total medical costs for chronic illness due to HUS cases were discounted at a rate of 3 percent.

Once chronic kidney failure occurred, our representative 4-year-old patient either continued hemodialysis at the hospital on an outpatient basis, received a transplant, or switched to peritoneal dialysis (performed within the abdominal cavity). In practice, the child has the option to continue hemodialysis at the hospital as an outpatient, yet most receive a kidney transplant or eventually switch to some form of peritoneal dialysis because it can be carried on a person while going about normal activities. If there is no medical reason for choosing one form over another, the decision is generally left up to the parents. Some patients with skin infections or perforations in their peritoneum (*i.e.*, from an operation or other medical condition) have no choice but to continue hemodialysis. HCFA's statistics (1986-89) for children under 15 years old with ESRD show that by the end of year one, 24 percent were undergoing outpatient hemodialysis, 23 percent were undergoing peritoneal dialysis at home, 6 percent died, and 47 percent received a kidney transplant (HCFA 1992, table 7 on p. 11).

In general, for each year, we computed total costs of dialysis for patients with chronic illness due to HUS by multiplying the average annual cost of dialysis by the estimated number of chronic *E. coli* O157:H7 disease cases who required dialysis. We then summed these annual dialysis costs over the 77 years in the average life span to estimate the total costs of dialysis. Because the costs of in-facility hemodialysis are reimbursed at the same rate as that of at-home peritoneal dialysis, the costs for pediatric dialysis patients reflect the same costs for both types of dialysis (as previously mentioned, $130.50 per patient per day or roughly $47,631 per year in 1993 dollars).[60]

Assuming that the onset of illness occurs halfway through the initial year and that no chronic patients receive a transplant during the acute phase (Eggers personal communication with Marks (ERS) 1993), chronic patients require 6 months of dialysis in the initial year (minus 12 days that were accounted for in the acute phase), for a total cost of $22,249/case. The annual costs of dialysis per case for subsequent years is estimated at $47,631.

All patients who had chronic illness due to HUS received dialysis in the first year. A declining number received dialysis in subsequent years as more kidney transplants were performed and as the number of premature deaths from complications from dialysis and kidney transplants increased over time.[61] Table 14 shows the low and high estimates of the number of dialysis recipients each year after onset of HUS illness at 4 years old. The estimated total costs of dialysis for the 30 to 62 cases with chronic illness due to HUS range from $7.0 million to $16.6 million. We later combined these estimated dialysis costs with the estimated costs of kidney transplants and drug therapy to calculate the total chronic medical costs, which were then discounted using a 3-percent rate.

The total cost of the kidney transplants for the cases with chronic illness due to HUS is the product of the number of transplant recipients and the average cost per transplant. Table 15 provides the breakdown of the 26 to 53 kidney transplants by year of operation (as previously described).[62] All transplants were estimated to occur within the 6 years following the *E. coli* O157:H7 infection. The average cost of a kidney transplant was from medicare reimbursement data and was updated to 1993 dollars to get an average of $110,844.23 per transplant.[63] The total costs for the 26 to 53 cases that had kidney transplants ranged from $2.9 million to $5.9 million. As previously mentioned, we combined these estimated costs with the estimated costs of dialysis and drug therapy, and then discounted them using a 3-percent rate.

[60]For simplicity, most of this manuscript uses the generic word "Dialysis" to represent the many kinds of dialysis.

[61]We assumed that dialysis is no longer needed after kidney transplants.

[62]Often, a second or third transplant or a return to dialysis is necessary. Our analysis does not include the additional medical expenses due to additional transplants.

[63]Eggers (1993, table 49) provides an estimate of $89,600 per kidney transplant in 1991. This number was updated to 1993 dollars using the general medical care CPI (1991 CPI from *U.S. Statistical Abstract of the United States 1993*: table 163; 1993 CPI from personal communication with BLS in June 1994). Eggers does distinguish between the costs of a transplant using a cadaver kidney and a transplant using a living-related kidney.

Table 14—Estimated dialysis costs for chronic illness from *E. coli* O157:H7 disease, 1993[1]

Year	Age	Dialysis		Dialysis costs/case[2]	Total costs of dialysis	
		Low	High		Low[2]	High[2]
		Number			*Dollars*	
0	4	30	62	22,249	667,484	1,379,468
1	5	15	31	47,631	714,463	1,476,556
2	6	8	17	47,631	381,047	809,724
3	7	5	11	47,631	238,154	523,939
4	8	3	8	47,631	142,893	381,047
5	9	2	7	47,631	95,262	333,416
6	10	2	5	47,631	95,262	238,154
7	11	2	5	47,631	95,262	238,154
8	12	2	5	47,631	95,262	238,154
9	13	2	5	47,631	95,262	238,154
10	14	2	5	47,631	95,262	238,154
11	15	2	5	47,631	95,262	238,154
12	16	2	5	47,631	95,262	238,154
13	17	2	5	47,631	95,262	238,154
14	18	2	5	47,631	95,262	238,154
15	19	2	5	47,631	95,262	238,154
16	20	2	5	47,631	95,262	238,154
17	21	2	4	47,631	95,262	190,523
18	22	2	4	47,631	95,262	190,523
19	23	2	4	47,631	95,262	190,523
20	24	2	4	47,631	95,262	190,523
21	25	2	4	47,631	95,262	190,523
22	26	2	4	47,631	95,262	190,523
23	27	2	4	47,631	95,262	190,523
24	28	2	4	47,631	95,262	190,523
25	29	2	4	47,631	95,262	190,523
26	30	2	4	47,631	95,262	190,523
27	31	2	4	47,631	95,262	190,523
28	32	2	4	47,631	95,262	190,523
29	33	2	4	47,631	95,262	190,523
30	34	2	4	47,631	95,262	190,523
31	35	2	4	47,631	95,262	190,523
32	36	2	4	47,631	95,262	190,523
33	37	2	4	47,631	95,262	190,523
34	38	2	4	47,631	95,262	190,523
35	39	2	4	47,631	95,262	190,523
36	40	2	4	47,631	95,262	190,523
37	41	1	3	47,631	47,631	142,893
38	42	1	3	47,631	47,631	142,893
39	43	1	3	47,631	47,631	142,893
40	44	1	3	47,631	47,631	142,893
41	45	1	3	47,631	47,631	142,893
42	46	1	3	47,631	47,631	142,893
43	47	1	3	47,631	47,631	142,893
44	48	1	3	47,631	47,631	142,893
45	49	1	3	47,631	47,631	142,893
46	50	1	3	47,631	47,631	142,893
47	51	1	3	47,631	47,631	142,893
48	52	1	3	47,631	47,631	142,893
49	53	1	3	47,631	47,631	142,893
50	54	1	3	47,631	47,631	142,893
51	55	1	3	47,631	47,631	142,893
52	56	1	3	47,631	47,631	142,893

See footnotes at end of table.

--Continued

Table 14—Estimated dialysis costs for chronic illness from *E. coli* O157:H7 disease, 1993[1]--Continued

Year	Age	Dialysis		Dialysis costs/case[2]	Total costs of dialysis	
		Low	High		Low[2]	High[2]
		Number			*Dollars*	
53	57	1	3	47,631	47,631	142,893
54	58	1	3	47,631	47,631	142,893
55	59	1	3	47,631	47,631	142,893
56	60	1	3	47,631	47,631	142,893
57	61	1	3	47,631	47,631	142,893
58	62	1	3	47,631	47,631	142,893
59	63	1	3	47,631	47,631	142,893
60	64	1	3	47,631	47,631	142,893
61	65	1	3	47,631	47,631	142,893
62	66	1	3	47,631	47,631	142,893
63	67	1	3	47,631	47,631	142,893
64	68	1	3	47,631	47,631	142,893
65	69	1	3	47,631	47,631	142,893
66	70	1	3	47,631	47,631	142,893
67	71	1	3	47,631	47,631	142,893
68	72	1	3	47,631	47,631	142,893
69	73	1	3	47,631	47,631	142,893
70	74	1	3	47,631	47,631	142,893
71	75	1	3	47,631	47,631	142,893
72	76	1	3	47,631	47,631	142,893
73	77	1	3	47,631	47,631	142,893
Total	N/A	N/A	N/A	N/A	6,954,757	16,621,341

N/A = Not applicable.
[1] At this stage, costs have not been discounted.
[2] Costs were rounded for this table.

Table 15—Estimated kidney transplant costs for chronic illness from *E. coli* O157:H7 disease, 1993

Year	Transplant recipients		Transplant cost/case[2]	Total cost of transplants	
	Low[1]	High[1]		Low[3]	High[3]
	Number			*Dollars*	
0	0	0	110,844	0	0
1	15	31	110,844	1,622,663	3,436,171
2	6	12	110,844	665,065	1,330,131
3	3	5	110,844	332,533	554,221
4	1	3	110,844	110,844	332,533
5	1	1	110,844	110,844	110,844
6	0	1	110,844	0	110,844
Total	26	53	110,844	2,881,950	5,874,744

[1] Given an estimated 30 to 62 cases of chronic illness due to HUS, transplant recipients were determined using HCFA data on end stage renal disease in children (Eggers, personal communication with Marks, 1993).
[2] Eggers (1993, table 49) provides an estimate of $89,600 per kidney transplant in 1991. This number was updated to 1993 dollars using the general medical care CPI (1991 CPI from *U.S. Statistical Abstract of the United States 1993*: table 163: 1993 CPI from personal communication with BLS in June 1994).
[3] At this stage, costs have not been discounted.

Transplant recipients require immunosuppressant drug therapy for the remainder of their lives to prevent the body from attacking the foreign kidney cells. While advances in this type of drug therapy have occurred over recent years, the possibility of rejection of the new kidney still exists. Drug therapy for survivors costs $4,237.77 per year in 1993 dollars.[64] The total costs of drug therapy for the 30 to 62 cases of chronic illness due to HUS is $4.7 million to $10.0 million (not discounted at this stage) (table 16).

- Subtotal. Estimated total medical costs for kidney transplants, dialysis, and drug therapy for the 30 to 62 cases of chronic kidney failure caused by *E. coli* O157:H7 disease were discounted at a rate of 3 percent to total $9.0-$19.5 million (table 17).

Productivity Losses for Acute E. Coli O157:H7 Disease

For those who do not die, the value of time lost is derived by estimating the amount of time lost from regular activities and multiplying it by the rate of daily earnings. Time spent by parents caring for sick children, as well as payment to paid caretakers, is included in the productivity loss estimates. For cases that required hospitalization, days of lost productivity during recuperation were also considered.

Productivity losses because workers stayed home with their sick children were approximated by the average weekly earnings for production or nonsupervisory workers in private nonagricultural jobs published by BLS, plus estimated fringe benefits.[65] Pre-tax wages and fringe benefits are used because they approximate the worker's full marginal product. We assumed fringe benefits of 39 percent to cover health plans, vacations, and retirement benefits.[66] The average age of the parent or paid caretaker was assumed to be 25-44 years of age. The value of an hour of time was assumed to be the same for everyone, regardless of gender or race. Assuming a civilian labor force participation rate of 84 percent for a typical labor force aged 25 to 44 years (personal conversation between U.S. BLS and Buzby, June 1994), the average daily loss of productivity is $87.58. Table 18 presents the costs of lost productivity during acute illness caused by *E. coli* O157:H7 by severity category.

- No physician visited. For each of the estimated 5,000 to 10,000 children who had a mild illness and did not visit a physician or a hospital, we assumed that a parent or paid caretaker stayed home to take care of the child and missed 2 days of work. Griffin and Tauxe (1991, p. 64) estimate that on average, hemorrhagic colitis caused by *E. coli* O157:H7 lasts from 6 to 8 days. Because those cases that did not seek medical care are even milder than hemorrhagic colitis, we assumed that these mild cases experienced 4 days of illness. Evaluated at the average private sector wage rate of roughly $88 per day, this productivity loss totals $0.9-$1.8 million annually.

- Physician visit only. For those 3,200 to 6,400 children who visited a physician but were not hospitalized, we assumed 4 work days would be missed by a parent or caretaker to take care of the sick child. Evaluated at the average private sector wage rate of $88 per day, the productivity loss totals between $1.1 million and $2.2 million annually.

- Hospitalized for hemorrhagic colitis. We assumed that time spent at home recovering from hemorrhagic colitis was twice as long as the number of days of hospitalization. Therefore, children with hemorrhagic colitis were ill for a total of 19.5 days (6.5 days in the hospital as previously mentioned, 13 days at home). We assumed parent or paid caretaker to be with the child in the hospital and home with the child until the child is well. Adjusting for weekends, the average time lost from work would be 14 days which was evaluated at the average wage. For the estimated 1,340 to 2,630 cases with hemorrhagic colitis who did not die, total productivity losses ranged from $1.6 million to $3.2 million.[67]

[64]Cost estimate of $4,000 in 1990 is from conversation with Eggers (and Marks, 1993), but was updated to 1993 dollars using the general medical care CPI (1990 CPI from *Statistical Abstract of the United States 1993*: table 163; 1993 CPI from personal communication with BLS in June 1994).

[65]BLS reports that average weekly earnings in 1993 were $373.64 (BLS, *Economic Indicators*, July 1994). This translates into roughly $74.73 per day.

[66]The *Statistical Abstract of the United States 1993* (table 677) provides employer costs for employee compensation per hour worked and divides this total compensation into wage/salary (71.8 percent) and total benefit (28.2 percent) components. Fringe benefits equal to 39 percent of wages were calculated by dividing the proportion attributed to total benefits by the proportion attributed to wage/salary (28.2/71.8 = 39.3 percent).

[67]Out of the low estimate of 1,440 patients with hemorrhagic colitis, 100 died and 1,340 patients recovered. Similarly, out of the high estimate of 2,880 patients with hemorrhagic colitis, 250 died and 2,630 recovered. Productivity losses for those who died are discussed in the deaths section.

Table 16—Estimated drug therapy costs for kidney transplant survivors, 1993[1]

Year	Age	Transplant survivors		Drug therapy	Total costs, drug therapy	
		Low[2]	High[2]	costs/year[3]	Low	High
	Years	*-----Number-----*		*----------Dollars----------*		
0	4	0	0	0	0	0
1	5	14	29	4,238	59,329	122,895
2	6	19	39	4,238	80,518	165,273
3	7	21	44	4,238	88,983	186,462
4	8	21	44	4,238	88,983	186,462
5	9	21	44	4,238	88,983	186,462
6	10	20	44	4,238	84,755	186,462
7	11	20	42	4,238	84,755	177,986
8	12	20	42	4,238	84,755	177,986
9	13	19	41	4,238	80,518	173,749
10	14	19	41	4,238	80,518	173,749
11	15	19	41	4,238	80,518	173,749
12	16	19	41	4,238	80,518	173,749
13	17	18	41	4,238	76,280	173,749
14	18	18	40	4,238	76,280	169,511
15	19	18	40	4,238	76,280	169,511
16	20	18	40	4,238	76,280	169,511
17	21	18	40	4,238	76,280	169,511
18	22	18	39	4,238	76,280	165,273
19	23	18	36	4,238	76,280	152,560
20	24	17	36	4,238	72,042	152,560
21	25	16	36	4,238	67,804	152,560
22	26	16	36	4,238	67,804	152,560
23	27	16	36	4,238	67,804	152,560
24	28	16	36	4,238	67,804	152,560
25	29	16	35	4,238	67,804	148,322
26	30	16	35	4,238	67,804	148,322
27	31	16	35	4,238	67,804	148,322
28	32	16	35	4,238	67,804	148,322
29	33	16	35	4,238	67,804	148,322
30	34	16	35	4,238	67,804	148,322
31	35	16	34	4,238	67,804	144,084
32	36	15	34	4,238	63,567	144,084
33	37	15	34	4,238	63,567	144,084
34	38	15	33	4,238	63,567	139,846
35	39	15	32	4,238	63,567	135,609
36	40	15	31	4,238	63,567	131,371
37	41	15	31	4,238	63,567	131,371
38	42	15	30	4,238	63,567	127,133
39	43	15	30	4,238	63,567	127,133
40	44	15	30	4,238	63,567	127,133
41	45	15	30	4,238	63,567	127,133
42	46	15	30	4,238	63,567	127,133
43	47	15	30	4,238	63,567	127,133
44	48	15	30	4,238	63,567	127,133
45	49	14	30	4,238	59,329	127,133
46	50	14	29	4,238	59,329	122,895
47	51	14	29	4,238	59,329	122,895
48	52	13	29	4,238	55,091	122,895
49	53	13	29	4,238	55,091	122,895
50	54	13	29	4,238	55,091	122,895
51	55	13	29	4,238	55,091	122,895
52	56	13	29	4,238	55,091	122,895
53	57	13	29	4,238	55,091	122,895

See footnotes at end of table.

--Continued

Table 16—Estimated drug therapy costs for kidney transplant survivors, 1993[1]--Continued

Year	Age	Transplant survivors Low[2]	Transplant survivors High[2]	Drug therapy costs/year[3]	Total costs, drug therapy Low	Total costs, drug therapy High
	Years	*-----Number-----*		*----------Dollars----------*		
54	58	13	29	4,238	55,091	122,895
55	59	13	27	4,238	55,091	114,420
56	60	13	26	4,238	55,091	110,182
57	61	13	26	4,238	55,091	110,182
58	62	13	26	4,238	55,091	110,182
59	63	12	26	4,238	50,853	110,182
60	64	12	26	4,238	50,853	110,182
61	65	12	25	4,238	50,853	105,944
62	66	12	25	4,238	50,853	105,944
63	67	12	25	4,238	50,853	105,944
64	68	12	25	4,238	50,853	105,944
65	69	12	23	4,238	50,853	97,469
66	70	12	23	4,238	50,853	97,469
67	71	12	23	4,238	50,853	97,469
68	72	12	23	4,238	50,853	97,469
69	73	11	23	4,238	46,615	97,469
70	74	11	23	4,238	46,615	97,469
71	75	10	23	4,238	42,378	97,469
72	76	10	22	4,238	42,378	93,231
73	77	10	22	4,238	42,378	93,231
Total	N/A	N/A	N/A	N/A	4,674,260	9,958,759

N/A = Not applicable.

[1]At this stage, costs have not been discounted. Note that no transplants occurred in year 0.

[2]Transplant survivors in this table is the sum of those surviving with cadaver donor kidneys and living-related donor kidneys. Given the number of transplants in the previous table, we use HCFA data on living-related donor transplant patient survival (1992, table 37, p. 42) and on cadaver donor transplant patient survival (1992, table 36, p. 41), we assumed 56% of transplants used cadaver donors and 44% had living-related donors (personal communication; Eggers and Marks, 1993).

[3]Cost estimate of $4,000 in 1990 is from conversation with Eggers and Marks, (1993), but was updated to 1993 using the general medical care CPI (*Statistical Abstract of the United States 1993*: table 163 for 1990 CPI; personal communication with BLS in June 1994 for 1993 CPI).

- Hospitalized cases with acute HUS. Of the estimated 260-470 children with acute HUS who were hospitalized but did not die, 230 to 408 recovered and 30 to 62 developed chronic illness due to HUS. Productivity losses for the chronic cases are discussed in the next section. Productivity losses for the acute HUS cases were estimated in a parallel fashion to those hospitalized for hemorrhagic colitis where recuperation at home is estimated to be twice the time spent in the hospital (15 days in the hospital as previously mentioned, 30 days at home). Adjusting for weekends, parents and paid caretakers missed an estimated 32 days per case. The total acute illness productivity losses for the 260 to 470 acute HUS cases who did not die were estimated to range from $0.7 million to $1.3 million.

- Deaths. For each of the 200 to 500 persons estimated to die prematurely from acute *E. coli* O157:H7 disease each year, the value of life was estimated at approximately $1.2 million in 1993 dollars, an average of the values given for male and female children 4 years old, according to Landefeld and Seskin's adjusted human capital/willingness-to-pay method.[68] The total productivity loss associated with deaths from acute *E. coli* O157:H7 disease cases was estimated to range from $241.7 million to $604.2 million annually.

- Subtotal. Productivity losses for the four disease severity categories of acute *E. coli* O157:H7 disease were estimated to total between $246.1 million and $612.8 million annually.

[68]Updated as previously described.

Table 17—Estimated medical costs of chronic *E. coli* O157:H7 disease, 1993

Year	Age	Undiscounted medical costs		Discounted medical costs	
		Low[1]	High[1]	Low[2]	High[2]
	Years			*Dollars*	
0	4	667,484	1,379,488	667,484	1,379,468
1	5	2,436,455	5,035,623	2,365,490	4,888,954
2	6	1,126,630	2,305,128	1,061,957	2,172,804
3	7	659,680	1,264,622	603,701	1,157,309
4	8	342,730	900,041	304,511	799,675
5	9	295,099	630,722	254,555	544,066
6	10	180,017	535,460	150,761	448,440
7	11	180,017	416,141	146,370	338,360
8	12	180,017	416,141	142,107	328,505
9	13	175,779	411,903	134,720	315,689
10	14	175,779	411,903	130,796	306,494
11	15	175,779	411,903	126,987	297,567
12	16	175,779	411,903	123,288	288,900
13	17	171,542	411,903	116,811	280,486
14	18	171,542	407,665	113,409	269,515
15	19	171,542	407,665	110,106	261,665
16	20	171,542	407,665	106,689	254,043
17	21	171,542	360,034	103,785	217,827
18	22	171,542	355,796	100,763	208,993
19	23	171,542	343,083	97,828	195,656
20	24	167,304	343,083	92,632	189,957
21	25	163,066	343,083	87,656	184,424
22	26	163,066	343,083	85,103	179,053
23	27	163,066	343,083	82,624	173,837
24	28	163,066	343,083	80,218	168,774
25	29	163,066	338,845	77,881	161,834
26	30	163,066	338,845	75,613	157,121
27	31	163,066	338,845	73,411	152,544
28	32	163,066	338,845	71,272	148,101
29	33	163,066	338,845	69,196	143,788
30	34	163,066	338,845	67,181	139,600
31	35	163,066	334,608	65,224	133,839
32	36	158,828	334,608	61,679	129,941
33	37	158,828	334,608	59,882	126,156
34	38	158,828	330,370	58,138	120,930
35	39	158,828	326,132	56,445	115,902
36	40	158,828	321,894	54,801	111,064
37	41	111,197	274,263	32,249	91,872
38	42	111,197	270,026	36,164	87,819
39	43	111,197	270,026	35,111	85,262
40	44	111,197	270,026	34,088	82,778
41	45	111,197	270,026	33,095	80,367
42	46	111,197	270,026	31,132	78,026
43	47	111,197	270,026	31,196	75,754
44	48	111,197	270,026	30,287	73,547
45	49	106,960	270,026	28,284	71,405
46	50	106,960	265,788	27,460	68,237
47	51	106,960	265,788	26,661	66,250
48	52	102,722	265,788	24,859	64,320
49	53	102,722	265,788	24,135	62,447
50	54	102,722	265,788	23,432	60,628
51	55	102,722	265,788	22,749	58,862
52	56	102,722	265,788	22,087	57,148
53	57	102,722	265,788	21,443	55,483
54	58	102,722	265,788	20,819	53,867

See footnotes at end of table.

—Continued

Table 17—Estimated medical costs of chronic *E. coli* O157:H7 disease, 1993--Continued

Year	Age	Undiscounted medical costs		Discounted medical costs	
		Low[1]	High[1]	Low[2]	High[2]
	Years			*Dollars*	
55	59	102,722	257,312	20,212	50,631
56	60	102,722	253,075	19,624	48,346
57	61	102,722	253,075	19,052	46,938
58	62	102,722	253,075	18,497	45,571
59	63	98,484	253,075	17,217	44,244
60	64	98,484	253,075	16,716	42,955
61	65	98,484	248,837	16,229	41,006
62	66	98,484	248,837	15,756	39,811
63	67	98,484	248,837	15,298	38,652
64	68	98,484	248,837	14,852	37,526
65	69	98,484	240,361	14,419	35,192
66	70	98,484	240,361	13,999	34,167
67	71	98,484	240,361	13,592	33,172
68	72	98,484	240,361	13,196	32,206
69	73	94,246	240,361	12,260	31,268
70	74	94,246	240,361	11,903	30,357
71	75	90,009	240,361	11,037	29,473
72	76	90,009	236,123	10,715	28,110
73	77	90,009	236,123	10,403	27,291
Total		14,501,967	32,454,843	8,977,515	19,482,273

[1] These costs have not been discounted and they are the sum of the costs of dialysis, kidney transplants, and drug therapy for chronic *E. coli* O157:H7 disease patients, by year.

[2] Discounted at 3 percent.

Table 18—Estimated productivity losses of acute *E. coli* 0157:H7 disease, 1993[1]

Severity of illness	Daily wage rate[2]	Work missed	Rate/ case[2]	Cases		Total costs[2]	
				Low	High	Low	High
	Dollars	*Days*	*Dollars*	*Number*		*Million dollars*	
No physician visit[3]	88	2	175	5,000	10,000	0.9	1.8
Visited physician[3]	88	4	350	3,200	6,400	1.1	2.2
Hospitalized (and survived)[4]							
Hemorrhagic colitis	88	14	1,220	1,340	2,630	1.6	3.2
HUS	88	32	2,815	260	470	0.7	1.3
Death during acute illness (present value)[5]	1,208,488	all	1,208,488	200	500	241.7	604.2
Total	N/A	N/A	N/A	10,000	20,000	246.1	612.8

N/A = Not applicable.

[1] For those cases who do not die, lost productivity is derived by multiplying the amount of time lost from regular activities and by the rate of daily earnings. We adjust BLS's average weekly earnings for all private, nonagricultural jobs (BLS, *Economic Indicators*, July 1994) for fringe benefits of 39% (of earnings, *Statistical Abstract of the United States 1993*: table 677) to cover health plans, vacations, and retirement benefits, the civilian labor force participation rate of 84% for a typical work force aged 25-44 years (personal conversation with BLS and Buzby, June 1994), and five work days per week to get the average daily loss of productivity is $87.58.

[2] Figures were rounded for this table.

[3] Average duration of illness 6-8 days; (Griffin and Tauxe). We assume that parents and caretakers miss 2 days of work for those cases with no physician visit and 4 days for cases with physician visit.

[4] Assume work missed for 3 times the number of days hospitalized adjusted for weekends by multiplying by 5/7.

[5] Landefeld and Seskin's (1982) adjusted willingness to pay per human capital estimate for 4-year-olds, updated to 1993 prices using the change in average weekly earnings (BLS).

Productivity Losses for Chronic Illness Due to HUS

The annual productivity loss due to chronic illness from HUS is the sum of the value of those who died prematurely because of chronic illness due to HUS and the survivors' lost productivity (until the age of 16, the parents or caretakers' time is valued for staying home to take care of the sick child and to take the child to medical treatments).

- HUS survivors. This category consists of two components; productivity losses of caretakers of children under 16 with HUS and productivity losses of HUS patients over 16 years of age. A parent or paid caretaker is assumed to spend 18 hours out of a 40-hour work week with their child's hemodialysis treatment as a hospital out-patient, or a loss of 45 percent of work time during the initial year of illness.[69] In the second year, all children who did not yet receive a transplant are assumed to have switched to peritoneal dialysis, resulting in a 1-percent decline in productivity until the child is age 16 (Conversation with Mary O'Shay, nurse in the pediatric ESRD unit in a hospital in Buffalo, New York, and Marks of ERS).[70] Assuming the parent was in the 25 to 29-year-old age group when the child was born (the modal age group for first birth—*Statistical Abstract of the United States 1993*: table 93), an average age of 31 is assumed when the child reaches the age of 4. The value of annual productivity lost is computed as the 45-percent (first year) and 1-percent (subsequent years) productivity loss times BLS' average weekly earnings times 52 for a 31-year-old in year 1 (for a 32-year-old in year 2, and so on) multiplied by BLS' labor force participation rate by age group (personal conversation, BLS and Buzby, June 14, 1994) until year 12 when the child is 16. The reduced stream of earnings is converted into present values.

At age 16 and after, productivity losses were computed by adjusting the patient's annual earnings by age. Transplant recipients 16 to 40 years of age have a 23-percent productivity loss from what they would have earned without any illness, 40-64 year olds a 39-percent loss, and 65 plus a 13-percent loss (Garner 1984). Dialysis patients aged 16 to 40 encounter a 37-percent

[69]Productivity losses for a parent or caretaker of a sick child (less than 16 years of age) are based on the time necessary to obtain treatment. Because over 80 percent of the chronically ill children receive transplants by the fourth year after acute illness, these productivity losses mostly involve taking the child to the hospital for hemodialysis or caring for a child on peritoneal dialysis until the transplant operation. Hemodialysis involves 4-hour treatments three times per week at a hospital. Allowing a half hour before and after each treatment for scheduling variability, 15 hours per week are required for hemodialysis. In addition, there is travel time to and from the hospital (estimated at 1 hour for each trip) and time missed from school (3 half days per week). Most facilities have Monday through Saturday hours, so conceivably treatments can be scheduled after school or on Saturdays to avoid missing school. (However, the 4-hour duration of treatments and the limited number of dialysis machines limits the possibility of after-school time). Some facilities do not have flexible scheduling. Others offer tutoring to compensate for time missed from school. Moreover, since children must go to hospital facilities and not to free-standing facilities as adults can, travel time may be increased to get to a limited number of facilities. Assuming 1 hour per trip and no loss of school time, the minimum amount of time required for children on hemodialysis is 18 hours per week. Since children are encouraged to switch to peritoneal dialysis and then transplantation as soon as possible, all of the patients' parents/caretakers require this time commitment for the half year of dialysis in the acute phase and 24 percent require this time commitment by the end of year 1, with the remainder assumed to be on peritoneal dialysis by end of year 2. For a hemodialysis patient's parents/caretakers, 18 hours out of a 40-hour productive week results in a 45 percent productivity loss.

[70]Among the two major types of peritoneal dialysis, Continuous Ambulatory Peritoneal Dialysis (CAPD) and Continuous Cyclic Peritoneal Dialysis (CCPD), CCPD is preferred for younger patients and CAPD for older patients. CCPD requires a machine which fills and drains solution into the child's peritoneum while she/he sleeps (10 to 12 hours per night every night). This requires the help of a parent/caretaker to connect the catheter to the child at night and disconnect it in the morning. While parents and the child can sleep during the treatment, the child must be monitored (blood pressure, weight, check for infections) during the day. Most, if not all, parents can relegate these responsibilities, possibly to a school nurse, so that they can still work full time. In rare instances, the parent may decide to pull the child from school and oversee her/his care. This may happen in 1 to 2 percent of cases. We assume a 1 percent productivity loss for a parent/caretaker of a child on CCPD peritoneal dialysis until age 16. CAPD does not require a machine and, as such, provides greater freedom. Instead, the solution required for dialysis is emptied into a bag attached to the catheter leading to the peritoneum. The solution is left in the abdomen for 4 hours and then emptied into a bag. This draining process is done five times per day for children (4 times per day for adults) and takes 30 to 40 minutes each time (totaling about 3 hours per day or 21 hours per week). Generally, a child needs help by a parent/caretaker (possibly by the school nurse) with this process until she/he is mature enough to do it by her/himself. Although the age of maturity depends on the child, estimates are that between ages 11 and 16 the child can perform the exchange by her/himself. We assume that by age 16, children will have switched from CCPD to CAPD peritoneal dialysis and that there will be no productivity loss for a parent/caretaker since the child will be performing the procedure by her/himself. While the child must also be monitored (blood pressure, etc.) with CAPD, we assume parents will be able to work full-time with this form of dialysis.

loss, 40-64 have a 46-percent loss, and 65 plus a 5-percent loss. At and after time period 12, when the patients are age 16 and over, 88 percent of all survivors have received transplants, while 12 percent remain on dialysis. The disability loss per year was computed as the appropriate percentage productivity loss times the average weekly earnings times 52 weeks multiplied by the labor force participation rate by age group. Given that the average life span in the United States is 77 years, over this life span productivity lost for survivors of chronic illness due to HUS, discounted at 3 percent annually, ranged from $2.7 million to $5.9 million.

Table 19 shows the present value of lost productivity of survivors of chronic illness from *E. coli* O157:H7 disease for a typical year in 1993 dollars (undiscounted and discounted at 3 percent).

- Chronic illness deaths. As previously mentioned, of the 30 to 62 cases with chronic illness due to HUS (*i.e.*, kidney failure), 19 to 37 died prematurely of complications during dialysis or a kidney transplant operation (and an estimated 10 to 17 of these children died before the age of 16)(HCFA Medicare data, personal communication with Eggers and Marks (ERS), 1991). For those who die prematurely from chronic illness due to HUS, LS's VOSL was used to represent the cost of lost productivity.[71] Table 20 shows the present value of lost lives due to chronic illness from *E. coli* O157:H7 disease for a typical year in 1993 dollars. After discounting by 3 percent, the present value of the productivity loss for the 19 to 37 premature deaths from chronic illness due to HUS was estimated at $14.5-$27.9 million.

- Subtotal. The total productivity loss due to chronic illness deaths and lost productive output ranged from $17.3-$33.9 million annually.

Total Costs of E. Coli O157:H7 Disease from All Sources

Total annual costs of *E. coli* O157:H7 disease in the United States were estimated to range between $301.8 million and $726.0 million (table 21). Estimated medical costs total $38.4-$79.4 million and are small relative to the estimated productivity losses which total $263.3-$646.6 million. Of the estimated medical costs, costs for acute illness account for $29.4-$59.9 million annually and chronic costs range from $9.0-$19.5 million. Of the estimated productivity losses, costs for acute illness account for $246.1-$612.8 million, while chronic illness productivity losses total between $17.3 million and $33.9 million (discounted at a rate of 3 percent). Deaths during the acute phase of the illness are the largest cost component accounting for roughly 81 percent of all costs.

Note that these cost estimates vary from those found in Roberts and Marks (1995) largely because we: (1) used improved incidence estimates, (2) divided acute illness deaths differently, and (3) reported estimates in 1993 dollars as opposed to 1992 dollars.

Medical costs are only 12 percent of total estimated costs, roughly 9 percent during the acute illness and 3 percent during chronic illness due to HUS (*i.e.*, kidney failure). Productivity losses account for 88 percent of estimated costs: 81 percent for persons who die during the acute phase of the illness, 2 percent for persons who survive the acute illness, 4 percent for persons who die during the chronic illness, and 1 percent for survivors with reduced productivity because of chronic illness due to HUS.[72]

Costs of Foodborne E. Coli O157:H7 Disease

If we assume that 80 percent of the estimated human illnesses due to *E. coli* O157:H7 are attributed to food, the estimated total costs of foodborne *E. coli* O157:H7 disease ranges from $0.2-$0.6 billion annually. The assumption that 80 percent of all *E. coli* O157:H7 cases are from food (CDC unpublished outbreak data) appears reasonable in light of the relatively low number of cases from contaminated water and Martin *et al.*'s (1990) estimate that an upper bound of 16 percent of cases are from person-to-person transmission in day care centers.

Remarks

Some HUS cases have more than one transplant operation but only one was included in the costs. A few HUS cases have multiple complications, including blindness, cardiac involvement, respiratory com-

[71]LS's VOSL updated to 1993 dollars and averaged across gender, as previously described.

[72]These are approximations of the ranges used in the analysis.

Table 19—Present value of lost productivity of survivors due to chronic illness from *E. coli* O157:H7 disease, 1993

Year	Age	Total survivors		Dialysis					Transplant					Productivity loss			
				Recipient		Dis. loss/ recipient	Disability loss		Survivors		Dis. loss/ case	Disability loss		Undiscounted		Discounted	
		Low	High	Low	High		Low	High	Low	High		Low	High	Low[1]	High[1]	Low[2]	High[2]
		Number				*Dollars*			*Number*		*Dollars*						
0	4	30	62	30	62	5,906	177,175	366,162						177,175	366,162	177,175	366,162
1	5	28	58	15	31	5,879	88,183	182,245	14	29	281	3,933	8,148	92,116	190,393	89,433	184,847
2	6	27	55	8	17	281	2,248	4,776	19	39	281	5,338	10,957	7,586	15,734	7,150	14,830
3	7	25	55	5	11	281	1,405	3,091	21	44	281	5,900	12,362	7,305	15,453	6,685	14,141
4	8	24	52	3	8	341	1,023	2,728	21	44	341	7,162	15,007	8,185	17,735	7,273	15,757
5	9	23	50	2	7	341	682	2,387	21	44	341	7,162	15,007	7,844	17,394	6,767	15,004
6	10	22	49	2	5	341	682	1,705	20	44	341	6,821	15,007	7,503	16,712	6,284	13,996
7	11	22	47	2	5	341	682	1,705	20	42	341	6,821	14,324	7,503	16,030	6,101	13,034
8	12	22	47	2	5	341	682	1,705	20	42	341	6,821	14,324	7,503	16,030	5,923	12,654
9	13	21	46	2	5	341	682	1,705	19	41	341	6,480	13,983	7,162	15,689	5,489	12,024
10	14	21	46	2	5	341	682	1,705	19	41	341	6,480	13,983	7,162	15,689	5,329	11,674
11	15	21	46	2	5	341	682	1,705	19	41	341	6,480	13,983	7,162	15,689	5,174	11,334
12	16	21	46	2	5	1,455	2,910	7,275	19	41	1,455	27,644	59,653	30,554	66,928	21,430	46,942
13	17	20	46	2	5	1,455	2,910	7,275	18	41	1,455	26,189	59,653	29,099	66,928	19,815	45,574
14	18	20	45	2	5	2,247	4,494	11,235	18	40	2,247	40,445	89,877	44,939	101,112	29,710	66,847
15	19	20	45	2	5	2,247	4,494	11,235	18	40	2,247	40,445	89,877	44,939	101,112	28,844	64,900
16	20	20	44	2	5	5,708	11,417	28,542	18	40	5,708	102,750	228,333	114,166	256,874	71,145	160,076
17	21	20	44	2	4	5,708	11,417	22,833	18	40	5,708	102,750	228,333	114,166	251,166	69,073	151,960
18	22	20	43	2	4	5,708	11,417	22,833	18	39	5,708	102,750	222,624	114,166	245,458	67,061	144,181
19	23	20	40	2	4	5,708	11,417	22,833	18	36	5,708	102,750	205,499	114,166	228,333	65,107	130,215
20	24	19	40	2	4	5,708	11,417	22,833	17	36	5,708	97,041	205,499	108,458	228,333	60,051	126,422
21	25	18	40	2	4	10,397	20,794	41,587	16	36	10,397	166,349	374,284	187,142	415,871	100,598	223,551
22	26	18	40	2	4	10,397	20,794	41,587	16	36	10,397	166,349	374,284	187,142	415,871	97,668	217,040
23	27	18	40	2	4	10,397	20,794	41,587	16	36	10,397	166,349	374,284	187,142	415,871	94,823	210,719
24	28	18	40	2	4	10,397	20,794	41,587	16	36	10,397	166,349	374,284	187,142	415,871	92,061	204,581
25	29	18	39	2	4	10,397	20,794	41,587	16	35	6,580	105,285	230,312	126,079	271,899	60,216	129,860
26	30	18	39	2	4	10,397	20,794	41,587	16	35	6,580	105,285	230,312	126,079	271,899	58,462	126,078
27	31	18	39	2	4	10,397	20,794	41,587	16	35	6,580	105,285	230,312	126,079	271,899	56,759	122,406
28	32	18	39	2	4	10,397	20,794	41,587	16	35	6,580	105,285	230,312	126,079	271,899	55,106	118,841
29	33	18	39	2	4	10,397	20,794	41,587	16	35	6,580	105,285	230,312	126,079	271,899	53,501	115,379
30	34	18	39	2	4	10,397	20,794	41,587	16	35	6,580	105,285	230,312	126,079	271,899	51,943	112,019
31	35	18	38	2	4	12,621	25,242	50,483	16	34	7,988	127,808	271,591	153,049	322,074	61,218	128,826
32	36	17	38	2	4	12,621	25,242	50,483	15	34	7,988	119,820	271,591	145,061	322,074	56,333	125,073
33	37	17	38	2	4	12,621	25,242	50,483	15	34	7,988	119,820	271,591	145,061	322,074	54,692	121,431
34	38	17	37	2	4	12,621	25,242	50,483	15	33	7,988	119,820	263,603	145,061	314,086	53,099	114,970
35	39	17	36	2	4	12,621	25,242	50,483	15	32	7,988	119,820	255,615	145,061	306,099	51,552	108,782
36	40	16	34	2	4	12,621	25,242	50,483	15	31	7,988	119,820	247,627	145,061	298,111	50,051	102,858
37	41	16	34	1	3	12,621	12,621	37,862	15	31	7,988	119,820	247,627	132,440	285,490	44,365	95,634
38	42	16	33	1	3	12,621	12,621	37,862	15	30	7,988	119,820	239,639	132,440	277,502	43,073	90,251
39	43	16	33	1	3	12,621	12,621	37,862	15	30	7,988	119,820	239,639	132,440	277,502	41,819	87,622
40	44	16	33	1	3	12,621	12,621	37,862	15	30	7,988	119,820	239,639	132,440	277,502	40,601	85,070
41	45	16	33	1	3	15,984	15,984	47,953	15	30	13,464	201,958	403,916	217,942	451,869	64,866	134,489
42	46	16	33	1	3	15,984	15,984	47,953	15	30	13,464	201,958	403,916	217,942	451,869	62,976	130,572
43	47	16	33	1	3	15,984	15,984	47,953	15	30	13,464	201,958	403,916	217,942	451,869	61,142	126,769

See footnotes at end of table

--Continued

Table 19—Present value of lost productivity of survivors due to chronic illness from *E. coli* O157:H7 disease, 1993--Continued

				Dialysis					Transplant					Productivity loss			
		Total survivors		Recipient		Dis. loss/	Disability loss		Survivors		Dis. loss/	Disability loss		Undiscounted		Discounted	
Year	Age	Low	High	Low	High	recipient	Low	High	Low	High	case	Low	High	Low[1]	High[1]	Low[2]	High[2]
		Number				*Dollars*			*Number*		*Dollars*						
44	48	16	33	1	3	15,984	15,984	47,953	15	30	13,464	201,958	403,916	217,942	451,869	59,361	123,076
45	49	15	33	1	3	15,984	15,984	47,953	14	30	13,464	188,494	403,916	204,478	451,869	54,072	119,492
46	50	15	32	1	3	15,984	15,984	47,953	14	29	13,464	188,494	390,452	204,478	438,405	52,497	112,555
47	51	15	32	1	3	15,984	15,984	47,953	14	29	13,464	188,494	390,452	204,478	438,405	50,968	109,276
48	52	14	32	1	3	15,984	15,984	47,953	13	29	13,464	175,030	390,452	191,015	438,405	46,225	106,093
49	53	14	32	1	3	15,984	15,984	47,953	13	29	13,464	175,030	390,452	191,015	438,405	44,879	103,003
50	54	14	32	1	3	15,984	15,984	47,953	13	29	13,464	175,030	390,452	191,015	438,405	43,572	100,003
51	55	14	32	1	3	9,667	9,667	29,002	13	29	8,143	105,858	236,145	115,525	265,147	25,585	58,720
52	56	14	32	1	3	9,667	9,667	29,002	13	29	8,143	105,858	236,145	115,525	265,147	24,839	57,010
53	57	14	32	1	3	9,667	9,667	29,002	13	29	8,143	105,858	236,145	115,525	265,147	24,116	55,350
54	58	14	32	1	3	9,667	9,667	29,002	13	29	8,143	105,858	236,145	115,525	265,147	23,414	53,737
55	59	14	30	1	3	9,667	9,667	29,002	13	27	8,143	105,858	219,859	115,525	248,861	22,732	48,968
56	60	14	29	1	3	9,667	9,667	29,002	13	26	8,143	105,858	211,716	115,525	240,718	22,070	45,986
57	61	14	29	1	3	9,667	9,667	29,002	13	26	8,143	105,858	211,716	115,525	240,718	21,427	44,646
58	62	14	29	1	3	9,667	9,667	29,002	13	26	8,143	105,858	211,716	115,525	240,718	20,803	43,346
59	63	13	29	1	3	9,667	9,667	29,002	12	26	8,143	97,715	211,716	107,383	240,718	18,773	42,084
60	64	13	29	1	3	9,667	9,667	29,002	12	26	8,143	97,715	211,716	107,383	240,718	18,226	40,858
61	65	13	28	1	3	129	129	387	12	25	317	3,799	7,915	3,928	8,302	647	1,368
62	66	13	28	1	3	129	129	387	12	25	317	3,799	7,915	3,928	8,302	628	1,328
63	67	13	28	1	3	129	129	387	12	25	317	3,799	7,915	3,928	8,302	610	1,290
64	68	13	28	1	3	129	129	387	12	25	317	3,799	7,915	3,928	8,302	592	1,252
65	69	13	26	1	3	129	129	387	12	23	317	3,799	7,282	3,928	7,669	575	1,123
66	70	13	26	1	3	129	129	387	12	23	317	3,799	7,282	3,928	7,669	558	1,090
67	71	13	26	1	3	129	129	387	12	23	317	3,799	7,282	3,928	7,669	542	1,058
68	72	13	26	1	3	129	129	387	12	23	317	3,799	7,282	3,928	7,669	526	1,028
69	73	12	26	1	3	129	129	387	11	23	317	3,483	7,282	3,612	7,669	470	998
70	74	12	26	1	3	129	129	387	11	23	317	3,483	7,282	3,612	7,669	456	969
71	75	11	26	1	3	129	129	387	10	23	317	3,166	7,282	3,295	7,669	404	940
72	76	11	25	1	3	129	129	387	10	22	317	3,166	6,965	3,295	7,352	392	875
73	77	11	25	1	3	129	129	387	10	22	317	3,166	6,965	3,295	7,352	381	850
Total in millions		N/A	N/A	N/A	N/A	1.0	2.4	N/A	N/A	N/A	N/A	6.2	13.3	7.2	15.6	2.7	5.9

N/A = Not applicable.

[1] These costs have not been discounted.

[2] Discounted at 3 percent.

Table 20—Present value of lost productivity of lost lives due to chronic illness from *E. coli* O157:H7 disease, 1993

Year	Age	Total deaths		Lifetime earnings in 1993 $	Discounted lifetime earnings in 1993 $[1]	Productivity loss due to deaths	
		Low	High			Low	High
		Number		*Dollars*			
1	5	2	4	1,232,869	1,196,960	2,393,920	4,787,840
2	6	1	3	1,257,249	1,185,078	1,185,078	3,555,234
3	7	2	0	1,281,630	1,172,873	2,345,745	0
4	8	1	3	1,308,213	1,162,330	1,162,330	3,486,991
5	9	1	2	1,334,796	1,151,407	1,151,407	2,302,814
6	10	1	1	1,361,379	1,140,134	1,140,134	1,140,134
7	11	0	2	1,387,962	1,128,541	0	2,257,081
8	12	0	0	1,414,546	1,116,655	0	0
9	13	1	1	1,438,530	1,102,513	1,102,513	1,102,513
10	14	0	0	1,462,514	1,088,247	0	0
11	15	0	0	1,486,497	1,073,877	0	0
12	16	0	0	1,510,481	1,059,421	0	0
13	17	1	0	1,534,465	1,044,896	1,044,896	0
14	18	0	1	1,544,493	1,021,092	0	1,021,092
15	19	0	0	1,554,521	997,788	0	0
16	20	0	1	1,564,549	974,975	0	974,975
17	21	0	0	1,574,577	952,645	0	0
18	22	0	1	1,584,605	930,789	0	930,789
19	23	0	3	1,574,730	898,047	0	2,694,140
20	24	1	0	1,564,855	866,422	866,422	0
21	25	1	0	1,554,980	835,878	835,878	0
22	26	0	0	1,545,105	806,379	0	0
23	27	0	0	1,535,229	777,888	0	0
24	28	0	0	1,506,486	741,091	0	0
25	29	0	1	1,477,742	705,778	0	705,778
26	30	0	0	1,448,998	671,893	0	0
27	31	0	0	1,420,254	639,383	0	0
28	32	0	0	1,391,510	608,197	0	0
29	33	0	0	1,361,425	577,716	0	0
30	34	0	0	1,331,340	548,495	0	0
31	35	0	1	1,301,255	520,485	0	520,485
32	36	1	0	1,271,170	493,642	493,642	0
33	37	0	0	1,241,085	467,922	0	0
34	38	0	1	1,205,340	441,208	0	441,208
35	39	0	1	1,169,594	415,654	0	415,654
36	40	1	2	1,133,849	391,215	391,215	782,429
37	41	0	0	1,098,104	367,846	0	0
38	42	0	1	1,062,358	345,507	0	345,507
39	43	0	0	1,018,773	321,681	0	0
40	44	0	0	975,188	298,950	0	0
41	45	0	0	931,602	277,271	0	0
42	46	0	0	888,017	256,601	0	0
43	47	0	0	844,431	236,899	0	0
44	48	0	0	803,427	218,831	0	0
45	49	1	0	762,423	201,614	201,614	0

See footnotes at end of table.

–Continued

Table 20—Present value of lost productivity of lost lives due to chronic illness from *E. coli* O157:H7 disease, 1993--Continued

Year	Age	Total deaths		Lifetime earnings	Discounted lifetime earnings	Productivity loss due to deaths	
		Low	High	in 1993 $	in 1993 $[1]	Low	High
		Number		*Dollars*			
46	50	0	1	721,418	185,214	0	185,214
47	51	0	0	680,414	169,599	0	0
48	52	1	0	639,410	154,736	154,736	0
49	53	0	0	598,929	140,719	0	0
50	54	0	0	558,449	127,386	0	0
51	55	0	0	517,969	114,711	0	0
52	56	0	0	477,489	102,666	0	0
53	57	0	0	437,009	91,226	0	0
54	58	0	0	401,484	81,369	0	0
55	59	0	2	365,960	72,009	0	144,018
56	60	0	1	330,436	63,125	0	63,125
57	61	0	0	294,911	54,698	0	0
58	62	0	0	259,387	46,708	0	0
59	63	1	0	237,002	41,434	41,434	0
60	64	0	0	214,617	36,428	0	0
61	65	0	1	192,232	31,678	0	31,678
62	66	0	0	169,847	27,174	0	0
63	67	0	0	147,462	22,905	0	0
64	68	0	0	136,672	20,611	0	0
65	69	0	2	125,881	18,431	0	36,861
66	70	0	0	115,090	16,360	0	0
67	71	0	0	104,300	14,394	0	0
68	72	0	0	93,509	12,529	0	0
69	73	1	0	86,870	11,301	11,301	0
70	74	0	0	80,231	10,133	0	0
71	75	1	0	73,592	9,024	9,024	0
72	76	0	1	66,953	7,971	0	7,971
73	77	0	0	60,314	6,971	0	0
Total	N/A	19	37	N/A	N/A	14,531,290	27,933,531

N/A = Not applicable.
[1] Discounted at 3%.

plications, neurological damage, pancreatic destruction, and intestinal surgery such as colostomy. One mother wrote that her surviving child's medical bills during his intensive care were $300,000 (Heersink 1994).

The January 1993 *E. coli* O157:H7 outbreak in the Northwest demonstrates the difficulty of identifying the incidence of foodborne diseases and the need for new data collection systems. CDC reported: "Despite the magnitude of this outbreak (with 500 culture-confirmed cases and 4 deaths in four States), the problem may not have been recognized in three States if the epidemiological link had not been established in Washington" (CDC April 16, 1993, p. 262).[73] CDC claims that reports of subsequent *E. coli* O157:H7 outbreaks are increasing, largely because of increased public awareness (FDA Consumer 1994, p. 1923).

[73]As previously mentioned, the 1994 AGA Consensus Conference (1995, p. 1923) estimates that this outbreak caused over 700 cases.

Table 21—Cost summary for U.S. *E. coli* O157:H7 disease cases, 1993[1]

Cost category	Table	Estimated cost	
		Low	High
		Million dollars	
Medical costs:[2]			
Acute illness medical costs—			
No physician visit		0.0	0.0
Physician visit		0.5	2.0
Hospitalized-hemorrhagic colitis		16.2	32.4
Hospitalized-HUS		12.7	25.5
Subtotal	13	29.4	59.9
Chronic illness medical costs			
Chronic cases (present value)	17	9.0	19.5
Total medical costs		38.4	79.4
Productivity losses:[3]			
Acute illness productivity losses—			
No physician visit		0.9	1.8
Visited physician		1.1	2.2
Hospitalized-hemorrhagic colitis		1.6	3.2
Hospitalized-HUS		0.7	1.3
Deaths (present value)		241.7	604.2
Subtotal	18	246.1	612.8
Chronic illness productivity losses—			
Survivors (present value)	19	2.7	5.9
Deaths (present value)	20	14.5	27.9
Subtotal		17.3	33.9
Total productivity losses		263.3	646.6
Total		301.8	726.0

If 80% are foodborne, foodborne costs are $0.2-0.6 billion annually.

[1]Numbers may not total due to rounding.

[2]Medical costs were estimated using data from the American Hospital Association's Hospital Statistics and the U.S. Health Care Financing Administration.

[3]Productivity losses were estimated using data from the U.S. Bureau of Labor Statistics and Landefeld and Seskin's (1982) estimated values of statistical life. The 219-537 premature deaths include 200-500 deaths from the acute illness and 19-37 deaths from chronic complications.

COI Estimates of Listeriosis

Listeriosis is the disease caused by the infectious bacterium, *Listeria monocytogenes*. Listeriosis may have a bimodal distribution of severity with most cases being either mild or severe (CAST 1994, p. 51). Milder cases of listeriosis are characterized by a sudden onset of fever, severe headache, vomiting, and other influenza-type symptoms. Reported cases of listeriosis are often manifested as septicemia and/or meningoencephalitis and may also involve delirium and coma (Benenson 1990, p. 250). Listeriosis may cause premature death in fetuses, newborns, and some adults or cause developmental complications for fetuses and newborns.

Listeria can grow at refrigeration temperatures (CAST 1994, p. 32; Pinner *et al.* 1992, p. 2049). There is no consensus as to the infectious dose of *Listeria*, though research has shown that humans can be exposed to high doses by consuming some common contaminated foods. For example, *Listeria* can grow to extremely high cell count levels in hot dogs, soft cheeses, and pâté (Pinner *et al.* 1992, p. 2049).

The incubation period for listeriosis is 4 days to several weeks. The duration of illness may last a few days or several weeks (CAST 1994, p. 12). The United States has a regulatory policy of zero tolerance of *Listeria monocytogenes* in all ready-to-eat foods (CAST 1994, p. 65). At any given time, a large percentage of all people will have *Listeria* organisms in their bodies without becoming ill. In addition to a bimodal distribution of severity, there appears to be a bimodal age distribution as well with the majority of cases occurring in the very young or in those older than 40 years old. Benenson (1990, p. 251) states that 30 percent of clinical cases of listeriosis occur in individuals younger than 3 weeks old and that most adults with listeriosis are older than 40 years of age. This age distribution is largely because *Listeria* is more likely to cause severe illnesses and death in persons with compromised immune systems (*i.e.*, people with AIDS, cancer, diabetes, heart disease, or renal disease) or in those with immature immune systems (*e.g.*, fetuses) (Schwartz *et al.* 1988 in CAST 1994, p. 52).

Listeriosis may appear mild in healthy adults and more severe in the elderly and the immunocompromised. Illnesses identified by CDC's hospital surveillance shows three well-defined risk groups: pregnant women, newborn/fetal cases, and other adults (*i.e.*, adults who are not pregnant women)(Roberts and Pinner 1990). Listeriosis in pregnant women is usually relatively mild and may be manifested as a flu-like syndrome or placental infection. They are hospitalized for observation. Because of data limitations, the less severe cases are not considered here.

Infected pregnant women can transmit the disease to their newborns/fetuses either before or during delivery. Infected newborns/fetuses may be stillborn, develop meningitis (inflammation of the tissue surrounding the brain and/or spinal cord) in the neonatal period, or are born with septicemia (syndrome of decreased blood pressure and capillary leakage) (Benenson 1990, p. 250).[74] Septicemia and meningitis can both be serious and life-threatening. A portion of babies with meningitis will go on to develop chronic neurological complications.

Other adults with listeriosis typically develop sepsis or meningitis syndromes. Almost 90 percent of these adults were estimated to have one or more underlying diseases, including cancer, diabetes, renal disease, heart disease, and AIDS (Schwartz *et al.* 1988). Occasionally, milder disease syndromes, such as abscesses or other local infections will occur but these may remain undetected by CDC's active surveillance, which counts specimens taken from normally sterile locations, namely blood and cerebrospinal fluid.

Of all listeriosis cases, roughly 85-95 percent are attributed to food (Schuchat 1994). *Listeria* has been isolated on foods such as raw milk products, vegetables, seafood, poultry, red meat, and liquid whole egg (CAST 1994, p. 32). Consuming non-reheated hot dogs and undercooked poultry were implicated as risk factors for listeriosis in a 1988 CDC study (Tappero *et al.* 1995, p. 1119). In samples of uncooked meat and poultry from seven countries, up to 70 percent had detectable levels of *Listeria* (Farber 1993 and Shelef 1989 in CAST 1994, p. 32). Schuchat *et al.* (1992, p. 2041) found that 32 percent of the 165 culture-confirmed listeriosis cases could be attributed to eating food purchased from store delicatessen counters or soft cheeses. In Pinner *et al.*'s (1992, p. 2047) microbiologic survey of refrigerated foods specimens obtained from households with listeriosis patients, 36 percent of the beef samples and 31 percent of the poultry samples were contaminated with *Listeria*.

[74] *Listeria* infections can cause spontaneous abortions.

Estimates of Cases

We update Roberts and Pinner's (1990) COI analysis to estimate the annual costs of listeriosis. We do not have estimates for mild cases, only hospitalized cases. The estimate of 1,860 listeriosis cases occurring annually in the United States originates from an extrapolation to the U.S. population of incidence data from a CDC-conducted surveillance study of hospitals in six geographic regions in 1986 and 1987 (Gellin *et al.* 1987).[75] This is the largest population-based listeriosis study in the United States. The case estimate of 1,860 includes 65 fetal cases (stillbirths or spontaneous abortions). If fetal cases were excluded, the estimated number of cases would decline to 1,795. We considered an estimated range of 1,795-1,860 cases annually.[76]

The CDC study also estimated incidence rates by disease syndrome, age group, and outcome (whether the patient lived or died). This information was used to define the three risk groups. In this analysis, maternal cases and all other adult cases are classified as acute cases and do not develop chronic complications. All newborn/fetal cases are initially considered acute and some develop chronic complications. All acute and chronic listeriosis cases are assumed to require hospitalization. This is a reasonable assumption because all the observed cases were diagnosed by hospitals. Roberts and Pinner (1990) applied the CDC estimates to the U.S. population to get national estimates for each risk group. Their estimates were used in this analysis. The annual number of pregnant women who have listeriosis is estimated at 252. The estimated annual number of newborn/fetal cases ranges between 295 and 360.[77] An estimated 1,248 other adults have listeriosis per year. Table 22 presents the annual cases of acute and chronic listeriosis, divided into disease severity categories (no physician visit, visited a physician, hospitalized, and died). Figure 10 presents listeriosis cases and disease outcomes.

Table 22—Estimated U.S. listeriosis cases, 1993[1]

Severity of illness	Cases	
	Low	High
	Number	
Acute:		
No physician visit	0	0
Visited physician	0	0
Hospitalized (and survived)[2]		
Maternal	252	252
Newborn/fetal	281	281
Other adult	817	817
Deaths (during hospitalization)[3]		
Maternal	0	0
Newborn/fetal	14	79
Other adult	431	431
Total acute cases	1,795	1,860
Chronic:		
No physician visit	0	0
Visited physician	0	0
Hospitalized (and survived)[3]		
Maternal	0	0
Newborn/fetal	43	43
Other adult	0	0
Deaths		
Maternal	0	0
Newborn/fetal	0	0
Other adult	0	0
Total chronic cases	43	43

[1] Following Roberts and Pinner (1990) Ch. 22 in (*Foodborne Listeriosis*), we assume that each year, there are 252 maternal listeriosis cases, 295 to 360 newborn/fetal cases, and 1,248 other adult cases. Cases that do not require hospitalization are not included because of data limitations.

[2] Total hospitalized and survived are shown in this section. Those who died were also hospitalized and when combined with this section, there are 1,795-1,860 hospitalized cases.

[3] Total deaths range from 445 to 510. High estimate for new born/fetal cases includes 65 fetal deaths. Hospitalization costs for the newborn/fetal deaths are for the mother.

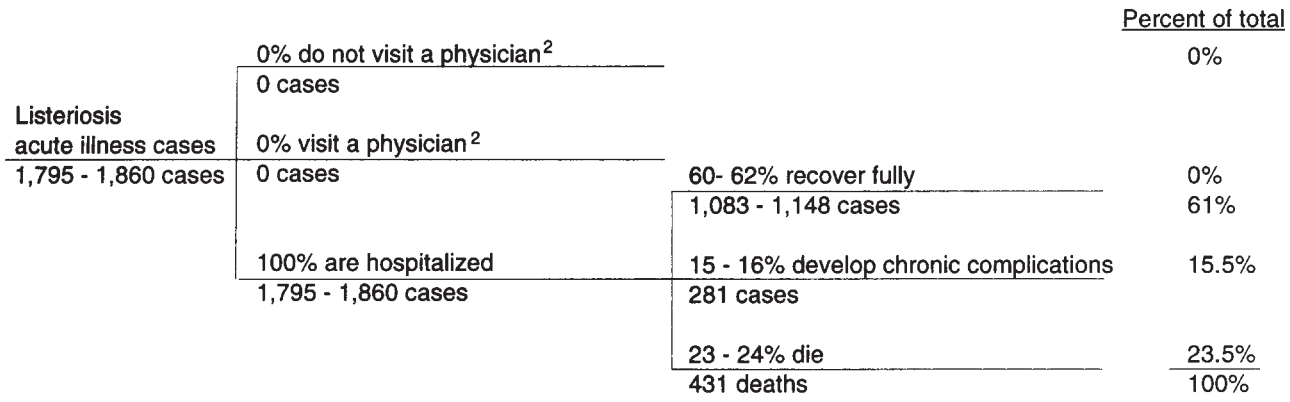
Of the estimated 252 pregnant women with listeriosis each year, all cases are acute and expected to survive their illness. Of the estimated 295 to 360 newborn/fetal acute illness cases each year, 14 to 79 die prematurely because of the acute illness and 281 survive. Of the 281 newborn/fetal cases who survive the acute illness, 43 develop chronic complications that leave them with some level of permanent disabili-

[75]These areas included the States of Missouri, New Jersey, Oklahoma, Tennessee, and Washington, as well as Los Angeles County.

[76] Tappero *et al.* (1995) found that the incidence of listeriosis had decreased since the 1960's and that projections from surveillance data suggest that there were 1,092 listeriosis cases and 248 deaths in 1993. Tappero *et al.* was published after this analysis was concluded.

[77]The number of newborn/fetal cases is larger than the number of maternal cases, because the mother is often asymptomatic although she transmits the disease to her infant.

Figure 10
Distribution of estimated annual U.S. listeriosis cases and outcomes[1]



[1] Percentages are rounded.
[2] Cases that do not require hospitalization are not included because of data limitations.
Prepared by Economic Research Service, USDA.

ty. Of the estimated 1,248 other adults with acute listeriosis, 817 survive the illness and 431 die each year. This death rate of 34.5 percent for other adults is close to the 33-percent death rate given by Benenson for non-pregnant adults with listeriosis (1990, p. 250).

Costs of Listeriosis

As in the COI for *E. coli* O157:H7 disease, listeriosis cases are divided into acute and chronic disease categories. Again, several nationwide databases were used in this analysis, such as the American Hospital Association's Hospital Statistics, which provided data on daily costs of hospitalization. Table 23 presents the assumptions used for the COI analysis for listeriosis.

Medical Costs for Acute Listeriosis

Acute illness medical costs include the costs of regular hospital rooms, ICU rooms, physician services, and other fees associated with both types of hospital rooms. Table 24 presents the estimated medical costs of acute listeriosis by severity category.

- No physician visited. No estimate was made for milder illnesses.
- Physician visit only. No estimate was made for milder illnesses.
- Hospitalized. CDC case estimates are based on finding *Listeria* in spinal and brain fluid in hospitalized patients. As previously mentioned, the three demographic groups of listeriosis patients identified are maternal cases, newborn/fetal cases, and other adults. As in the COI analysis on *E. coli* O157:H7 disease, we used the average cost to community hospitals per patient per day in 1993 dollars ($887).[78] As in Roberts and Pinner (1990), fees for laboratory tests, supplies, medications, and physician visits while hospitalized are assumed to equal the costs of hospitalization but were updated using

[78] In 1991, the daily hospitalization cost per person was estimated at $752 per patient (American Hospital Association in *Statistical Abstract of the United States 1993* (table 182). This estimate was updated to 1993 dollars using the change in the hospital room CPI (1991 CPI from the *Statistical Abstract of the United States 1993*: table 163, and the 1993 CPI from personal correspondence with BLS in June 1994).

Table 23—Assumptions used to estimate annual costs of illness for listeriosis, 1993

Cost category & severity	Costs during acute illness	Costs during chronic illness
Overview: Incremental costs due to foodborne disease	Estimates of new cases annually are divided into severity level categories to estimate costs. Acute illness costs are not discounted, except for productivity losses for deaths occurring during the acute illness.	Some survivors develop chronic conditions. All lifetime costs are discounted at 3 percent per year to calculate the 1993 present value.
Medical costs		
No physician visit	No cases or medical costs estimated.	Not estimated.
Visited physician	No cases or medical costs estimated.	Not estimated.
Hospitalized	Hospital room cost is the American Hospital Association's average cost per day. An intensive care room is assumed to be double the cost of a regular room. Total fees for physician care, laboratory tests, and medications during hospitalization are assumed to be equal to hospital room costs.	For known chronic conditions associated with the foodborne illness, chronic costs are computed the same as acute costs, except that they are computed for the remaining life of an individual and discounted back to 1993 using a 3 percent discount rate.
Productivity losses		
No physician visit	No cases or productivity losses estimated.	Not estimated.
Visited physician	No cases or productivity losses estimated.	Not estimated.
Hospitalized	Time away from work is assumed to be three times the days in the hospital, adjusted for weekends. The cost per day is estimated by adjusting BLS average weekly earnings as above.	The average weekly earnings are multiplied by 52 weeks, adjusted by the labor force participation rate for the age of the patient, and multiplied by the percentage of productive capacity lost. Or, an estimate of the proportion of productivity lost because of the disability is multiplied by Landefeld and Seskin's (1982) value of life according to the age of the patient to get the marginal lifetime productivity lost.
Death	The present value of a statistical life lost is computed as the average of male and female values given by Landefeld and Seskin (1982) for each age, updated to 1993 values using the change in average weekly earnings.	The value of a statistical life lost to chronic illness is Landefeld and Seskin (1982) value for the age of the person in the year he/she dies, discounted back to 1993.
Other costs: education, nursing home, lost leisure, pain & suffering, transportation to medical care	Not estimated.	Not estimated

Table 24—Estimated medical costs from acute listeriosis, 1993[1]

Severity of illness	Unit cost	Days/ case	Cost/ case	Cases		Total costs	
				Low	High	Low	High
	Dollars	*Days*	*Dollars*	*-----Number-----*		*---Mil. dollars---*	
No physician visit	0	0	0	0	0	0	0
Visited physician	0	0	0	0	0	0	0
Hospitalized							
Maternal							
Regular hospital room[2]	887	7	6210	252	252	1.6	1.6
Physician fees etc.[3]	844	7	5906	252	252	1.5	1.5
Subtotal	1,731	N/A	12,117	252	252	3.1	3.1
Newborn/fetal[4]							
Regular hospital room[2]	887	14	12,421	295	360	3.6	4.4
Regular room physician fees[3]	844	14	11,812	295	360	3.6	4.4
ICU hospital room[5]	1,774	7	12,421	295	360	3.6	4.4
ICU room physician fees[5]	1,687	7	11,812	295	360	3.5	4.2
Subtotal	N/A	N/A	48,466	295	360	14.3	17.4
Other adult							
Moderate							
Regular hospital room[2]	887	7	6,210	42	42	.26	.26
Regular room physician fees[3]	844	7	5,906	42	42	.25	.25
Severe[6]							
Regular hospital room[2]	887	7	6,210	1,206	1,206	7.5	7.5
Regular room physician fees[3]	884	7	5,906	1,206	1,206	7.1	7.1
ICU hospital room[5]	1,774	7	12,421	1,206	1,206	15.0	15.0
ICU room physician fees[5]	1,687	7	11,812	1,206	1,206	14.2	14.2
Subtotal (other adult)	N/A	N/A	N/A	1,248	1,248	44.3	44.3
Total	N/A	N/A	N/A	1,795	1,860	61.7	64.8

N/A = Not applicable.

[1] Subtotals and totals here may not total because of rounding. Unit costs and costs per case have been rounded for this table. Includes those who survive and those who die during the acute illness.

[2] Costs of regular hospital room in 1991, updated to 1993 using the CPI for hospital rooms from BLS.

[3] Assumes physician fees, lab tests, etc. are comparable to the hospital room charge but were updated to 1993 using the CPI for physician services from BLS.

[4] Assumes regular hospital room two-thirds of time, intensive care one-third of time. The 295-360 newborn/fetal cases include the 14-79 cases where the newborn or infant died prematurely because of the illness. Hospitalization costs for the newborn/fetal deaths are for the mother.

[5] The costs of the ICU hospital room and ICU room-related fees are assumed to be double the costs of regular hospital rooms and regular hospital room-related fees.

[6] The 1,206 other adult cases with severe listeriosis include the 431 who die prematurely because of their illness.

the physician services CPI, for a total cost of $844 per patient per day.[79] Estimated total costs of hospitalization in a regular hospital room, including physician services and other fees, are $1,731 per patient per day.

One component of medical expenses for the 252 maternal cases of listeriosis is 7 days of hospitalization for observation of the pregnant mother and her fetus (in addition to hospitalization for the delivery) at a rate of roughly $887 per day or $6,210 per case. The cost of $844 per day for physician fees, medication, and treatments for each day spent in the hospital, translates into $5,906 per maternal listeriosis patient. Combining these two components results in a total of $12,117 per case. Estimated medical expenses for the 252 maternal cases total $3.1 million annually.

Acute medical expenses for all 295 to 360 newborn/fetal cases include the costs of 7 days in intensive care at twice the rate of a regular room ($1,774 per day) and 14 days in the hospital at a regular room rate ($887 per day).[80] Daily fees associated with a regular hospital room are $844 and daily fees associated with an ICU room are $1,687. The total medical cost per newborn/fetal case with listeriosis is $48,466. Estimated medical costs for the newborn/fetal cases range between $14.3 million and $17.4 million annually.

Following Roberts and Pinner (1990), prior to calculating costs, we divided the 1,248 other adult acute illness cases (non-maternal, non-newborn) into two severity levels: (1) severe cases of meningitis or sepsis (1,206 cases), and (2) more moderate cases (42 cases). All 42 moderate cases survived and of the 1,206 severe cases, 431 died prematurely and 775 survived. Those who died were assumed to incur medical costs for listeriosis before dying.

Moderate cases incur the costs of 7 days in a regular hospital room (Roberts and Pinner 1990), plus a similar daily amount for physician's fees, as previously described. The average medical cost for these milder cases is roughly $12,117 per case, which sums to $0.5 million annually for all 42 cases.

The severe cases require 7 days in intensive care at $1,774 per day and 7 days in a regular hospital room ($887 per day), which totals to roughly $36,350 per case, including physician fees as previously described. The total medical costs for the 1,206 severe cases is $43.8 million annually. Estimated medical expenses for both severe and moderate cases total $44.3 million annually.

- Deaths. All listeriosis patients who died from the acute illness were assumed to incur medical costs prior to death. Medical costs for acute listeriosis patients who died were accounted for in the hospitalization item above.

- Subtotal. Medical costs for acute listeriosis were estimated to range from $61.7 million to $64.8 million.

Medical/Special Education Costs for Chronic Illness from Listeriosis

Of the three categories of listeriosis patients considered here, only among the newborn/fetal cases did some patients develop chronic complications. Following the advice of Dr. Robert Pinner, then an M.D. in CDC's Special Pathogens Branch, and as reported in Roberts and Pinner (1990), we assumed that the incidence and severity of listeriosis in the newborn/fetal cases is parallel to the estimates for neonatal group B streptococcal patients in the Institute of Medicine (IOM) study (1985). This means that 43 of the newborn/fetal cases develop chronic sequelae. An Institute of Medicine (IOM, 1985) study of neonatal group B streptococcal patients found that chronic sequelae, such as seizure disorders, visual or hearing impairment, developmental retardation, or spasticity, occurred following meningitis.

The 43 newborn/fetal cases with chronic illness are divided into three categories: (1) 9 mild chronic disability cases (20 percent, Cochi *et al.* 1985), (2) 26 moderate to severe chronic disability cases (60 per-

[79]As before, we used the 1991 hospital cost of $752 per day to represent the cost of physician services, but we updated this cost with the physician services CPI (1991 CPI from *Statistical Abstract of the United States 1993*: table 163; 1993 CPI from personal communication with BLS in June 1994).

[80]Hospitalization costs for the newborn/fetal deaths are for the mother.

cent, IOM Study 1985), and (3) 8 total impairment cases (the remaining 20 percent).[81] Table 25 presents the estimated medical costs of chronic listeriosis by severity category. Note that these medical costs include the costs of special education, because they cannot be separated with the data used here.

Nine listeriosis patients were assumed to have a mild chronic disability from their illness. Persons in this category might have a seizure disorder that required regular medication and physician visits or a hearing impairment that required medical care or special attention in school. The present value of the sum of these costs is $43,237 per case ($2,000 per year in 1988 dollars for 20 years from Cochi *et al.* (1985), updated to 1993 dollars and discounted at 3 percent) for a total of $0.4 million each year for the nine mild disability cases.

Twenty-six listeriosis patients were assumed to have a moderate to severe chronic disability from their illness. Persons in this category might have a significant learning problem requiring special education. On average, the cost of special education for this category is estimated at $108,092 per case ($5,000 per year in 1988 dollars for 20 years from IOM (1985), updated to 1993 dollars and discounted at 3 percent). For the 26 moderate to severe chronic cases who survive, the present value of the special education costs total $2.8 million annually.

Eight listeriosis patients were assumed to have a total impairment (physical or mental) from their illness. Persons in this category require institutional or continual total care at a cost of $506,062 ($20,000 per year in 1988 dollars for 25 years from Cochi *et al.* (1985), updated to 1993 dollars and discounted at 3 percent). For the eight total impairment cases, this amounts to a present value of $4.0 million annually.

- Subtotal. Estimated medical and special education costs for chronic listeriosis total $7.2 million annually.

Productivity Losses for Acute Listeriosis

Table 26 presents the productivity losses for acute listeriosis by disease severity category (no physician

[81]The 8 cases were rounded down from 8.6 so that there were a total of 43 cases. This category was rounded down, instead of the mild category, so the cost estimates would be more conservative.

Table 25—Estimated medical costs and special education costs from chronic listeriosis, 1993[1]

Severity of illness	Cost/ case	Cases		Total costs	
		Low	High	Low	High
	Dollars	*-----Number-----*		*-----Million dollars-----*	
No physician visit[1]	0	0	0	0	0
Visited physician	0	0	0	0	0
Hospitalized					
Maternal	0	0	0	0	0
Newborn/fetal[2]					
Mild disability	43,237	9	9	0.4	0.4
Moderate to severe disability	108,092	26	26	2.8	2.8
Total impairment	506,062	8	8	4.0	4.0
Subtotal	N/A	43	43	7.2	7.2
Other adult	0	0	0	0	0
Total	N/A	43	43	7.2	7.2

N/A means not applicable.

[1] Subtotals and total may not add because of rounding. Medical costs and the costs of special education are combined in this table, because they cannot be separated with the data used here.

[2] The breakdown of the 43 newborn/fetal cases into disability sub-categories follows Roberts and Pinner (1990). Cost per case is extrapolated from Cochi *et al.* (1985) and the Institute of Medicine Study (1985).

visit, visited a physician, hospitalized, and died) and by patient category for those hospitalized (maternal, newborn/fetal, other-adult).

- No physician visited. No estimate was made for milder cases.

- Physician visit only. No estimate was made for milder cases.

- Hospitalized. As with the medical costs, productivity losses for listeriosis were divided into three categories of patients: (1) pregnant women, (2) newborns/fetal cases, and (3) other adults. As previously mentioned, pregnant women and other adults face only acute illness from *Listeria*, whereas all newborn/fetal cases have acute illness and some develop chronic complications. There were no productivity losses for acute listeriosis cases of newborns/fetuses, because they are not part of the labor force.

The per-person productivity loss for pregnant women with listeriosis was estimated by multiplying the number of work days missed times the appropriate daily wage for each age category that was provided by surveillance data (Gellin *et al.* 1987).[82] As previously mentioned, pregnant women with listeriosis were assumed to stay in the hospital for 7 days until they and their fetus recovered from the infection. As with

[82]The surveillance reports that 14 percent are less than 21 years old, 63 percent are between 21 and 30 years old, and 23 percent are between 31 and 40 years old.

Table 26—Estimated productivity losses from acute listeriosis, 1993[1]

Severity of illness	Base rate[2]	Work days missed	Rate/ case	Cases		Total costs	
				Low	High	Low	High
	Dollars	*Number*	*Dollars*	*- - - - -Number- - - - -*		*- - Million dollars- -*	
No physician visit	0	0	0	0	0	0	0
Visited physician	0	0	0	0	0	0	0
Hospitalized (and survived)							
Maternal[2]	N/A	15	1,166	252	252	0.3	0.3
Newborn/fetal[3]	0	0	0	0	0	0	0
Other adult[4]							
Moderate	N/A	15	N/A	42	42		
Severe	N/A	30	N/A	754	754		
Subtotal	N/A	N/A	N/A	817	817	1.2	1.2
Deaths:[5]							
Maternal	0	0	0	0	0	0	0
Newborn/fetal	1,097,792	N/A	1,097,792	5.6	31.6	6.1	34.7
Other adult	N/A	N/A	N/A	431	431	118.2	118.2
Subtotal	N/A	N/A	N/A	437	463	124.3	152.9
Total	N/A	N/A	N/A	1,506	1,532	125.8	154.4

[1] Subtotals and totals may not add due to rounding.

[2] Average daily earnings for production or non-supervisory workers in private non-agricultural jobs were reported by the U.S. Bureau of Labor Statistics (BLS) by age group were increased by 39 percent to add benefits, and then multiplied by the number of pregnant women having listeriosis in each age group (Gellin *et al.* 1987) and by the BLS labor force participation rate (74.7 percent) for females aged 25-34 (personal conversation with BLS and Buzby, June 1994).

[3] There were no productivity losses for acute listeriosis cases of newborns/fetuses in this category, because they are not part of the workforce.

[4] Demographic information is from CDC's active surveillance, and labor market information is from average daily earnings for production or non-supervisory workers in private non-agricultural jobs were reported by the BLS and from personal communication between BLS and Buzby (June 1994). Base rate per day and rate per case are not included here because it depends on the age category. The remaining 21 other adult cases were younger than 20 years old and we assumed no lost productivity for these cases.

[5] Demographic information is from CDC's active surveillance and cost information is from Landefeld and Seskin's (1982) adjusted willingness-to-pay/human capital estimates updated to 1993 prices using the change in average weekly earnings (BLS). Base rate per day and rate/case are not included here because they depend on the age category. Forty percent (Bjerkedal and Erickson 1983) of 14-79 infants are not replaced by another birth. Landefeld and Seskin's (1982) estimate for an infant, updated to 1993 prices using the change in average weekly earnings (BLS) is equal to roughly $1,097,792.

the other studies in this report, it was assumed that twice as many days were spent at home recuperating (14 days) as the number of days spent in the hospital (7 days). After adjusting for weekends, maternal listeriosis patients missed 15 work days on average. As in the COI on *E. coli* O157:H7, lost productivity for those who missed work and later returned to work was calculated using average daily earnings for production or nonsupervisory workers in private nonagricultural jobs reported by the BLS (by age group), adjusted by 39 percent to include fringe benefits (to cover health plans, vacations, and retirement benefits),[83] and by the BLS labor force participation rate (74.7 percent) for females aged 25-34 (personal conversation between U.S. BLS and Buzby, June 1994). Estimated productivity losses for pregnant women with listeriosis were $1,166 per case, or a total of $0.3 million annually for the 252 cases.

Productivity losses for the 817 other adult acute cases (non-maternal, non-newborn/fetal) who survive (65 percent of the 1,248 cases) include the value of time spent in the hospital plus the time spent at home recuperating. Demographic information is from CDC's active surveillance.

Acute productivity costs were calculated after dividing the 817 other adult cases who survived into two sub-categories: 42 moderate cases and 754 severe cases (meningitis and sepsis cases). Productivity losses for the 21 patients younger than 21 years of age were assumed to be zero, because it was assumed that they are not yet in the labor force. Each of the 733 (754 minus 21 cases) severe cases younger than 21 years of age was assumed to lose 6 work weeks of productivity, while the 42 moderate cases lose only 3 work weeks each.[84] This time is valued by summing the product of the average weekly earnings by the percentage of each age group in the labor force, and by the number of weeks out of work for each age group (personal conversation with U.S. BLS and Buzby, June 1994). Productivity losses amount to $1.2 million for the other adults who had acute listeriosis and survived.

- Deaths. Norwegian data (Bjerkedal and Erickson 1983) have been evaluated for the likelihood that a stillbirth or infant death will be replaced by another pregnancy. Although the likelihood varies by maternal age, a replacement child is conceived 60 percent of the time. We assume that families in the United States respond similarly. Thus, for fetal or infant deaths, we assume that 60 percent of the deaths will by replaced by siblings who fully compensate for the earlier loss and that 40 percent will not be replaced. In other words, for the fetal or infant death category, roughly 6 to 32 (of the 14 to 79) cases are not replaced by another birth and we estimate the productivity loss for these cases. Emotional costs of losing a fetus or baby (Peppers and Knapp 1980; Tomsyck 1988) and the costs of a delay in having a replacement child are all omitted from the estimates. We used the LS estimate for the VOSL of an infant, which was $1,097,792 after averaging across gender and updating to 1993 dollars. We estimated the productivity loss for the fetal/newborn deaths (not replaced by another birth) at $6.1-$34.7 million annually.

For the 431 other adult listeriosis patients who die (about 35 percent of 1,248 cases), valuation of the lives at the age of death was determined by using Landefeld and Seskin's estimates and the age distribution of other adult listeriosis patients from CDC's active surveillance. Productivity losses for those who died totaled $118.2 million.

- Subtotal. Productivity losses for all acute listeriosis cases are estimated to cost $125.8-$154.4 million annually. This includes $0.3 million for the maternal cases, $119.4 million for acute other adult cases (including those who survived and those who died), and $6.1-$34.7 million for the newborn/fetal cases.

Productivity Losses for Chronic Illness from Listeriosis

As previously mentioned, costs of lost productivity from chronic complications were calculated for only some of the cases in the newborn/fetal category. Table 27 presents the productivity losses for chronic listeriosis by severity category.

[83]The *Statistical Abstract of the United States 1993* (table 677) provides employer costs for employee compensation per hour worked and divides this total compensation into wage/salary (71.8 percent) and total benefit (28.2 percent) components. Fringe benefits of 39 percent were calculated by dividing the proportion attributed to total benefits by the proportion attributed to wage/salary (28.2/71.8 = 39.3 percent).

[84]This analysis differs from Roberts and Pinner (1990) in that, as for the other COI studies in this document, we assumed 2 days spent recuperating at home for each day spent in the hospital. Roberts and Pinner (1990, p. 143) assumed 1 day of home rest for each day in the hospital.

- No physician visited. No estimate was made for milder cases.

- Physician visit only. No estimate was made for milder cases.

- Hospitalized. Chronic productivity losses for three severity levels of the 43 newborn/fetal listeriosis cases are estimated as the sum of the value of lives lost. As above, we used the LS estimate for the VOSL of an infant ($1,097,792).

In an exhaustive study (Conley 1973) of costs of mental retardation in the United States in 1973, mildly retarded adults (IQ, 50 to 70) were able to find jobs at wages close to the average income of the general population. Moderately retarded persons (IQ, 40 to 49) frequently found jobs, but their wages were only 19 percent of the average. Few retardates with IQ below 40 were employed. Combining the income loss as a result of lower wages and the loss as a result of greater unemployment, Roberts and Frenkel (1990) calculated the total income loss for mildly retarded men at 18 percent, for mildly retarded women at 36 percent, for moderately retarded men at 91 percent, for moderately retarded women at 95 percent, and for the severely retarded of both genders at 100 percent. We averaged these data and calculations across gender to estimate that 27 percent is the earnings loss for someone with mild mental retardation and 93 percent is the earnings loss for someone with moderate to severe mental retardation.

Of the 43 newborn/fetal cases, we assumed the 9 cases who had chronic illness classified as a mild disability lost 27 percent of their lifelong productivity. Given the LS estimate for the VOSL of an infant, the productivity loss for each of these nine cases is $296,404. This translates into an estimated total of $2.7 million annually for all nine cases.

Of the 43 newborn/fetal cases, the 26 chronic illness cases classified as a moderate to severe disability were assumed to lose 93 percent of their lifelong productivity. Each of these 26 cases cost $1,020,946 for an estimated total of $26.5 million each year.

The remaining 8 newborn/fetal cases with chronic illness classified as totally impaired were assumed to lose 100 percent of their lifelong productivity or $1,097,792 each for an estimated total of $8.8 million annually. For the three categories of newborn/fetuses

Table 27—Estimated productivity losses from chronic listeriosis, 1993

Severity of Illness	Percent prod. lost	Base rate/case	Cases		Total costs	
			Low	High	Low	High
	Percent	*Dollars*	*-----Number-----*		*---Million dollars---*	
No physician visit	0	0	0	0	0	0
Visited physician	0	0	0	0	0	0
Hospitalized:						
Maternal	0	0	0	0	0	0
Newborn/fetal[1]						
Mild disability	27	296,404	9	9	2.7	2.7
Moderate to severe disability	93	1,020,946	26	26	26.5	26.5
Total impairment	100	1,097,792	8	8	8.8	8.8
Subtotal	N/A	N/A	43	43	38.0	38.0
Other adult	0	0	0	0	0	0
Deaths	0	0	0	0	0	0
Total	N/A	N/A	43	43	38.0	38.0

N/A= Not applicable.

[1] Landefeld and Seskin's (1982) adjusted willingness to pay/human capital estimate for an infant, updated to 1993 prices using the change in average weekly earnings (BLS) is equal to $1,097,792. Mild disability cases are assumed to lose 27% of their lifelong productivity and moderate disability cases lose 93% of their lifelong productivity (Conely 1973).

with chronic illness due to listeriosis, including the deaths, estimated total productivity losses are $38.0 million each year.

- Deaths. No estimate was made for premature deaths from chronic listeriosis.

- Subtotal. Productivity losses for the chronic listeriosis cases are estimated at $38.0 million.

Total Costs of Listeriosis from All Sources

Estimates of total costs for the 1,795 to 1,860 cases of listeriosis range from $232.7 million to $264.4 million annually. This includes acute illness medical costs of $61.7-$64.8 million, chronic illness medical costs/special education and residence costs of $7.2 million, acute illness productivity losses of $125.8-$154.4 million, and chronic illness productivity losses of $38.0 million annually. Table 28 presents the cost summary for listeriosis.

The above cost estimates vary from Roberts and Pinner (1990) in that: 1993 dollars (versus 1988 dollars) were used, psychic losses were not included, and we used 2 days of recovery at home for each day hospitalized (instead of 1 day at home for each day hospitalized).

When comparing the costs of listeriosis with the costs of other foodborne bacterial diseases estimated in this analysis, listeriosis has a relatively high per-case cost. Listeriosis has a relatively high percentage of estimated premature deaths (*i.e.*, for the newborn/fetal cases and the other adult cases) and these deaths led to large COI estimates.

Costs of Foodborne Listeriosis

For the current study, we assumed 85 to 95 percent of U.S. listeriosis cases were attributed to food (see page 70 in text). This results in an estimated range of 1,526 to 1,767 cases of which 378 to 485 die prematurely because of their illness. Estimated total annual costs of foodborne listeriosis ranged from $0.2-$0.3 billion.

Table 28—Cost summary for U.S. listeriosis cases, 1993[1]

Cost category	Table	Estimated costs Low	Estimated costs High
		Million dollars	
Medical costs[2]			
Acute			
Maternal		3.1	3.1
Newborn/fetal		14.3	17.4
Other adult		44.3	44.3
Subtotal	24	61.7	64.8
Chronic[3]			
Maternal		0	0
Newborn/fetal		7.2	7.2
Other adult		0	0
Subtotal	25	7.2	7.2
Productivity losses[4]			
Acute			
Maternal		0.3	0.3
Newborn/fetal		6.1	34.7
Other adults			
Survivors		1.2	1.2
Deaths		118.2	118.2
Subtotal	26	125.8	154.4
Chronic			
Maternal		0	0
Newborn/fetal			
Mild disability		2.7	2.7
Moderate disability[2]		6.5	26.5
Total impaired		8.8	8.8
Other adults		0	0
Subtotal	27	38.0	38.0
Total		232.7	264.4
If 85-95% are foodborne, foodborne costs are $0.2-0.3 billion annually.[5]			

N/A = Not applicable.

[1] Subtotals and totals are subject to rounding errors. Main source is Roberts and Pinner (1990).

[2] Medical costs were estimated using data from the American Hospital Association's Hospital Statistics and the U.S. Health Care Financing Administration.

[3] Includes some special education and residential care expenses for children with neurological damage.

[4] Productivity losses were estimated using data from Landefeld and Seskin's (1982) estimated values of statistical life and average weekly earnings for production or nonsupervisory workers in private nonagricultural jobs (BLS).

[5] Schuchat 1994.

COI Estimates of *Staphylococcus Aureus* Intoxications

Staphylococci are common in the air, milk, sewage, and water, although main reservoirs are animals and humans (Bergdoll 1989, p. 464). Staphylococci cause a wide range of human infections leading to disease. They also cause staphylococcal food poisoning or intoxication, which is of interest in this analysis.[85] "Staphylococcal food poisoning is the only staphylococcal disease not associated with staphylococci growing in or on the human body" (Bergdoll 1989, p. 465). Rather, food poisoning occurs when *Staphylococcus* multiplies in food and produces enterotoxin, which, when consumed in sufficient quantity, causes human illness.[86] Ingestion of relatively small amounts of the enterotoxin causes human illness (Bergdoll 1989, p. 506). *Staphylococcus aureus* (*S. aureus*) is the species most implicated in causing foodborne illness, though 50-70 percent of the other strains may also be enterotoxigenic (Bergdoll 1989, pp. 465 and 512).

Onset of illness following consumption of *S. aureus* enterotoxin is usually within 1-6 hours (Bergdoll 1989, p. 492; CAST 1994, p. 19), which is far less than the incubation period for microbial pathogens that are consumed and cause human illnesses. Onset of symptoms may occur as quickly as 30 minutes after consumption of the *S. aureus* enterotoxins (Benenson 1990, p. 172). Intoxication by *S. aureus* enterotoxin is characterized by severe nausea, vomiting, cramps, and diarrhea (Benenson 1990, p. 171). 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 (Benenson 1990, p. 171).

Most staphylococcal food poisoning outbreaks are caused by human carriers contaminating food during processing, preparation, and packaging (Bergdoll 1989, p. 498). *S. aureus* is commonly found in the nose, throat, and mouth of humans and transmission to foods may occur via purulent discharges such as from an infected finger or even from apparently normal skin (Benenson 1990, pp. 172 and 339). At any given time, 30-50 percent of all healthy people harbor the organism, while 15-35 percent are persistent carriers (Bergdoll 1989, p. 498). Reported deaths from *S. aureus* food poisoning typically have occurred in children and older immunocompromised people (Bergdoll 1989, p. 494).

Foods most likely to be contaminated with *S. aureus* and its enterotoxin are high-protein foods that come in contact with workers' hands and then are served or are served after improper heating or improper refrigeration (Benenson 1990, p. 172; CAST 1994, p. 13). Examples are milk, custard- or cream-filled baked goods, sliced meats, potato and meat salads, sandwiches, and pastries (Benenson 1990, p. 172; CAST 1994, p. 13). *S. aureus* also tolerates a high salt content such as that found in ham (CAST 1994, p. 13). Bergdoll states that staphylococci in food are poor competitors against other organisms "unless they outnumber the other organisms present, such as in milk from a mastitic cow" (1989, p. 474).

Unlike most microbial pathogens including *S. aureus*, enterotoxin from *S. aureus* can survive temperatures as high as 250°F (CAST 1994, p. 36). Also, pasteurization does not inactivate *S. aureus* enterotoxin (Bergdoll 1989, p. 495).

Estimates of Cases and Costs

Staphylococcus aureus in food was estimated by Bennett *et al.* (1987, pgs. 104 and 109) to cause approximately 1,513,000 cases of illness and 1,210 deaths annually.[87] This study followed Roberts (1989) in estimating the annual costs of *Staphylococcus aureus*. Roberts calculated an approximation of average costs of *S. aureus*, *Clostridium perfringens*, and other bacterial pathogens by extrapolating the cost estimates for salmonellosis and listeriosis from the death rate. Roberts estimated that the average cost for *S. aureus* in 1987 dollars was $600. This value was updated to 1993 dollars using the CPI for all items (annual average) from BLS to obtain an estimate of $763 per case. Therefore, annual human illness costs from *Staphylococcus aureus* infections

[85]Staphylococcal disease or infection causes syndromes ranging from pustules to septicemia and premature death (Benenson 1990, p. 402).

[86] Ingestion of *S. aureus* is not required to cause human illness (Bergdoll 1989, p. 474).

[87]As previously mentioned, Staphylococci cause both human infections and food poisoning or intoxication. Bennett *et al.* (1987, p. 104) estimate that each year there are 8,900,000 cases of illness from these two categories. They also estimate that 17 percent (p. 109) of these 8,900,000 cases (or 1,513,000 cases) are attributed to food sources. These 1,513,000 cases are interpreted here as food poisoning or intoxication cases. Whether the death rate varies by type of case is not available and a constant death rate is assumed.

and intoxications are estimated at $6.8 billion from all sources and $1.2 billion from foodborne sources only.[88]

COI Estimates of *Clostridium Perfringens* Intoxications

Clostridium perfringens (*C. perfringens*) is a toxicoinfective microorganism, because it causes human illness by producing toxins as it grows in the intestinal tract (CAST 1994, p. 19). Almost all food poisoning outbreaks are caused by the Type A strains (*C. Welchii*) (Labbe 1989, p. 193), while Type C strains are associated with necrotizing enteritis (Benenson 1990, p. 174).

C. perfringens is a hardy organism in that it forms spores that allow it to survive adverse conditions and food preservation treatments (CAST 1994, p. 16). These spores in food are not killed by normal cooking temperatures, and resume normal vegetative cell germination and multiplication later under inadequate temperature control during cooling, storage, and reheating (Benenson 1990, p. 174; Labbe 1989, p. 198).

In fact, *C. perfringens* spores "will often germinate optimally only if they are mildly heated" and the optimal sporulation temperature ranges between 35 and 40°C (Labbe 1989, pp. 199 and 203) which, not coincidentally, frame the average temperature of the human body. Labbe (1989, p. 207) states that "the incidence of *C. perfringens* food poisoning due to preformed enterotoxin is rare" and that the ingested cells must sporulate in the human intestines for enterotoxin to reach levels capable of causing human illness (p. 199).

In one study reported by Labbe, a mixture of *C. perfringens* strains had an average generation time of 13 minutes in ground beef held at 40°C (1989, p. 196). *C. perfringens* is one of the fastest multiplying bacteria.

The incubation period of *C. perfringens* ranges from 8 to 24 hours after ingestion of food bearing large vegetative cell counts (Labbe 1989, p. 206).[89] The illness in humans is typically mild, lasting only about a day (CAST 1994, p. 11). Symptoms are generally diarrhea, abdominal pain, and sometimes nausea, while vomiting and fever are uncommon (Labbe 1989, p. 207; Benenson 1990, p. 174). Deaths have occurred in institutionalized or debilitated people, particularly the elderly (Labbe 1989, p. 207).

Estimates of Cases and Costs

C. perfringens in food was estimated by Bennett *et al.* (1987, p. 104) to cause approximately 10,000 cases of human illness and 100 deaths annually. Following Bennett *et al.* (p. 109) all *C. perfringens* illnesses in humans are assumed to be foodborne. Although *C. perfringens* is commonly found on raw animal and plant products (CAST 1994, p. 31), Canadian and U.S. outbreak data suggest that 100 percent of foodborne *C. perfringens* infections are caused by mishandling in food service establishments, homes, etc. (CAST 1994, p. 58). Most outbreaks are linked to inadequately cooked or reheated meats, gravies, and meat products (Benenson 1990, p. 174).

As with the COI analysis for *S. aureus*, we followed Roberts (1989) in estimating the annual costs of *Clostridium perfringens*. Assuming costs are a function of the death rate, Roberts estimated that the average cost per case for *C. perfringens* in 1987 dollars was $5,100. After updating to 1993 dollars using the CPI for all items, annual average, from BLS, the estimated cost per case is $6,487. Estimated annual costs of illness from *C. perfringens* infections, all foodborne, are $64.9 million.[90]

Summary of the COI Estimates

Table 29 presents a cost summary of the medical costs and productivity losses for the selected bacterial pathogens and presents the costs attributable to foodborne sources.

We estimated the annual cost-of-illness for the six bacterial foodborne illnesses at $2.9 billion to $6.7 billion (in 1993 dollars). Salmonellosis is the most costly. The acute foodborne costs are estimated to range from $0.6 billion to $3.5 billion annually.

[88]This is comparable to Todd's estimate in CAST (1994, p. 58) of 1,155,000 *S. aureus* cases in the United States from foodborne sources and total foodborne costs of $1.5 billion.

[89]Isolated cases indicate that symptoms may appear within two hours (Labbe 1989, p. 207).

[90]This compares with Todd's (1989) estimates of 652,000 *C. perfringens* cases in the United States from foodborne sources and total foodborne costs of $87 million.

Table 29—Cost summary for selected bacterial pathogens in the United States, 1993[1]

Pathogen	Total cases	Total deaths	Total costs	Percent foodborne	Foodborne cases	Foodborne deaths	Foodborne costs
	-------Number-------		*Bil. $*	*Percent*	*-----Number-----*		*Bil. $*
Campylobacter jejuni or *coli*	2,500,000	200-730	1.2-1.4	55-70	1,375,000 - 1,750,000	110-511	0.6-1.0
Clostridium perfringens	10,000	100	0.1	100	10,000	100	0.1
Escherichia coli O157:H7[2]	10,000-20,000	200-500	0.3-0.7	80	8,000 - 16,000	160-400	0.2-0.6
Listeria monocytogenes[3]	1,795-1,860	445-510	0.2-0.3	85-95	1,526-1,767	378-485	0.2-0.3
Salmonella (non-typhoid)	800,000-4,000,000	800-4,000	0.7-3.6	87-96	696,000 - 3,840,000	696-3,840	0.6-3.5
Staphylococcus aureus	8,900,000	7,120	6.8	17	1,513,000	1,210	1.2
Total	12,221,795-15,431,860	8,865-12,960	9.3-12.9	N/A	3,603,526 - 7,130,767	2,654-6,546	2.9-6.7

[1]Totals are subject to rounding.

[2]*E. coli* O157:H7 deaths are for acute illness only and do not include chronic illness deaths.

[3] Cases that do not require hospitalization are not included because of data limitations.
N/A = Not applicable

Foodborne disease from *Staphylococcus aureus* is next, roughly estimated at $1.2 billion annually. The acute illness costs of foodborne campylobacteriosis are estimated at $0.6-$1 billion annually. Next in economic importance is foodborne disease, acute and chronic, caused by *E. coli* O157:H7 at $0.2-$0.6 billion annually. Foodborne listeriosis is estimated at $0.2-$0.3 billion annually; while foodborne disease caused by *Clostridium perfringens* is estimated at $0.1 billion annually in 1993 dollars.

Extension to Other Bacterial Diseases

The estimates of the annual costs of foodborne illnesses to society would increase considerably if all foodborne pathogens were included in the analysis and if all chronic illnesses triggered by foodborne diseases were considered. Bennett *et al.* (1987) mention other major bacterial diseases for which costs have not yet been estimated (in order of high to low incidence in the United States): *Streptococcus Group A, Shigella, Yersinia, Bacillus cereus, Salmonella typhi, Brucella,* and *Clostridium botulinum*.[91] *B. cereus* has been determined to be entirely foodborne in origin, while the rest only have a component confirmed to be caused by food. With over 10 million cases annually and 3,000 deaths (of which 5 percent are estimated to be foodborne)(Bennett et al. 1987, pp. 104 and 109), *Streptococcus Group A* may be another costly disease. In addition, the CAST report (1994, pp. 11-14) lists other bacteria that cause human foodborne illness: *Aeromonas hydrophila, Coxiella burnetii,* other types of *E. coli* besides *E. coli* O157:H7, *Mycobacterium bovis, avium,* and *tuberculosis, Vibrio parahaemolyticus,* and *Vibrio vulnificus*.

[91]Several hundred thousand Americans died from Cholera-01 during the 1800's and early 1900's, but now cases and outbreaks are seldom reported in the United States (Jones 1992, p. 130). While no longer a problem in the United States, *Vibrio cholerae* (cholera) is one of the most important and deadly bacterial diseases internationally. Cholera is responsible for thousands of deaths in Asian countries each year and killed 3,000 people in South and Central America in 1991 (Jones 1992, p. 131). As such, it is costly to many developing countries in terms of lost productivity. The death rate may be greater than 50 percent and death can occur within hours (Benenson 1990, p. 90). Areas plagued by poverty are the most likely to be affected by cholera, because in these areas many people cannot afford to buy equipment and fuel to adequately heat water and food (Jones 1992, p. 131). Cholera, indirectly linked to food through water, occurs in seafood produced in sewage-contaminated areas (Benenson 1990, p. 89). Without precautionary measures, importing seafood and produce from these areas could cause cholera in the United States (Jones 1992, p. 131).

Discussion

Although technological and informational advances in food manufacturing and marketing (*i.e.*, refrigerating, pasteurizing, labeling) continue to expand our ability to control foodborne pathogens, the annual number of foodborne illnesses could increase in the United States. First, the number of people in the United States who are highly susceptible to microbial foodborne illnesses is growing. In general, the U.S. population is increasing at a little over 1 percent each year (Putnam and Allshouse 1994, p. 4) and part of this growth is attributed to a greater number of children and elderly people, two categories most affected by many foodborne illnesses. Advances in medicine have extended the average lifespan, which in turn increases the number of years an individual may become ill from foodborne diseases. Live births in the early 1990's are at the highest levels since 1964 (Putnam and Allshouse 1994, p. 4). This implies that there is also a greater number of pregnant women and their offspring, two other categories of people who face higher health risks from some foodborne diseases such as listeriosis and toxoplasmosis. Also, the spread of chronic illnesses (*e.g.*, AIDS) that suppress immune systems increases the pool of people who are highly susceptible to foodborne diseases (Roberts and Unnevehr 1994).

Second, new pathogen tests and improved epidemiological methods allow us to recognize and report more human illnesses with foodborne sources. Future advances in science can be expected to discover new links between microbial pathogens and chronic human illnesses. For example, in 1982 *E. coli* O157:H7 was identified as causing acute human illness and in 1985, *E. coli* O157:H7 was identified as causing chronic kidney failure.

Third, the short lifespan of the pathogens encourages improved virulence through quick adaptation to changes in their environment (*e.g.*, temperature, and oxygen and water levels).[92] For example, researchers are concerned about a new and particularly virulent *E. coli* O157:H7 strain associated with a recent outbreak from dry salami. This new strain appears to be more acid-tolerant and can survive at higher temperatures than some other previously studied *E. coli* strains. Also, the annual number of foodborne illnesses in the

[92]Under favorable conditions, some bacteria reproduce every 15-30 minutes.

United States might increase if importing food from other countries introduces new pathogen strains.

Fourth, the trend toward consumption of convenience foods and meals and snacks outside the home poses increased food safety risks. Microwave heating of foods may be uneven, potentially allowing some bacteria to survive (Heddleson and Doores 1994). Eating food away from home (*e.g.*, restaurants, fast-food outlets, nursing homes, and schools) means that consumers have less control over how food is stored, handled, and cooked. This is important because consumers (especially the immunocompromised) will not know when they are placing themselves at risk.[93] The counter argument could also be advanced that commercial establishments are more knowledgeable and produce safer food than do food preparers at home.

On a more positive note, food safety controls can occur at many points along the food chain from the farm to the consumer. Progress has been made in reducing some foodborne illnesses. 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 (Tappero *et al.* 1995, p. 1118).

New regulations are addressing food safety issues. For example, safe handling labels are now required on all raw meat and poultry sold at retail or handled by the food service industry. Florida, California, and Louisiana require restaurants selling raw shellfish to display warnings to customers about potential risks of consuming raw shellfish. As previously mentioned, other new food safety regulations have been promulgated such as the FSIS's Hazard Analysis Critical Control Point (HACCP) rule (*Federal Register* July 25, 1996) for meat and poultry and an FDA seafood HACCP rule (*Federal Register* Dec. 18, 1994).

The COI estimates reported here can be used in three main ways. First, the COI estimates can be used to evaluate the economic impact of foodborne diseases on the United States. This study estimated that annual costs of human illness for 6 of 40 known microbial pathogens that cause foodborne illnesses range between $9.3 billion and $12.9 billion, in terms of illness from all sources. Of these costs, between $2.9 billion and $6.7 billion are attributed to foodborne causes each year. These estimates have helped highlight the importance of bacterial health hazards and the need for private and public actions to control foodborne pathogens.

Second, the COI estimates can be used to target pathogen reduction efforts toward the most costly diseases. For example, the relatively high costs of salmonellosis may indicate that this pathogen should be among the first targeted for risk reduction.

Third, the COI estimates can be used to compare benefits and costs of control efforts, such as irradiation and HACCP, to determine the most cost-effective interventions.[94] The $606 million annual budget for the USDA meat and poultry inspection program annually (GAO 1996) is considerably below the total estimated costs for just these six pathogens. Greater expenditures on food inspection may reduce the number of annual cases of foodborne disease and, in turn, reduce the annual costs of foodborne illness to society.[95]

When using the COI estimates presented here, one should bear in mind that they underestimate the true economic value of bacterial foodborne illnesses to society because they exclude costs such as: (1) pain, suffering, and lost leisure time of the victim and her/his family, (2) lost business and costs and liabilities of lawsuits affecting agriculture and the food industry, (3) the value of self-protective behaviors undertaken by industry and consumers, and (4) resources spent by Federal, State, and local governments to investigate the source and epidemiology of the outbreak. The missing parts listed earlier, when available, can be added to the present analysis to provide a more complete picture of the costs of bacterial foodborne illnesses.

[93] Workers in the food industry may also be unaware of when they are placing themselves at risk from foodborne illness. For example, *E. coli* O157:H7 may be found in all types of meat products. Over 12 million people work in the food industry and are potentially involved in the handling and preparation of meat products (AGA Consensus Conference 1995, p. 1928), and as such, may be at higher risk of exposure to *E. coli* O157:H7.

[94] Better identification of which pathogens are the most costly would pinpoint which pathogens should be targeted for benefit/cost analyses for control onfarm, during processing, during marketing, at food service establishments, and at home.

[95] It may cost $8 million per year or more to build an adequate foodborne disease surveillance database to identify new pathogens and estimate annual foodborne disease incidence rates (Roberts and Smallwood 1991).

This study used Landefeld and Seskin's VOSL estimates. Had alternative methods of valuing lost lives been used, the COI estimates would be substantially higher. Viscusi (1993) summarizes the results from 24 principal labor market studies and found that the majority of the VOSL estimates lie between $3 million and $7 million per life in 1990 dollars. Fisher *et al.'s* survey of the wage-risk-premium literature on the willingness to pay to prevent death concluded that reasonably consistent estimates of the value of a statistical-life range from $1.6 million to $8.5 million (1986 dollars) (Fisher *et al.* 1989). Updated to 1993 dollars using the change in average weekly earnings (GPO 1994), Fisher e*t al.'s* range becomes $2.0 million to $10.4 million for each statistical-life lost and Viscusi's range becomes $3.2 million to $7.6 million. Viscusi and the Fisher *et al.'s* estimates are greater than the highest LS VOSL estimate of $1,584,605 in 1993 dollars (table 5, see estimate for a 22-year-old).

ERS's COI analyses performed to date could be improved with better data and the scope could be expanded to new foodborne diseases or to associated chronic complications. These improvements should give more credibility to the estimated costs. For example, the current COI estimates could be enhanced by obtaining and using better data on incidence, including measures of nonwage income, and revising age and gender differences.[96] Also, as knowledge about the connection between acute bacterial illnesses and chronic disease expands, the costs of these chronic diseases need to be added to the estimates.

The incidence estimates can be improved by more training of physicians and lab technicians to recognize bacterial foodborne diseases and by requiring mandatory reporting of illnesses to the CDC for the most common diseases. FSIS, FDA, and the CDC are collaborating on a 6-month pilot project to improve estimates of which pathogens are responsible for diarrheal diseases and to identify which foods are the sources of *Salmonella* and *E. coli* O157:H7 (FDA, FSIS, CDC joint release 1995). Other pathogens will be included as the project gets underway. Improved surveillance systems can enable researchers to have a better understanding of the frequency and extent of foodborne illness outbreaks and perhaps can aid in preventing similar outbreaks from occurring or alternatively remove contaminated foods from the market to limit the number of cases in an outbreak.

Up-to-date detailed cost per case estimates would also vastly improve the current COI estimates. Better identification of who is at high risk of foodborne diseases would help develop more suitable disease-severity categories for our COI analyses and would also enable the degree of food safety (*i.e.*, development of niche markets) and the target of food safety education campaigns to be tailored to these high-risk groups. It may be possible to define severity levels for each disease and then compile and apply a database of common costs across illnesses.

Prior to allocating increased public and private resources toward foodborne disease reduction, evaluation is needed as to the degree to which individuals would prefer to control these hazards themselves (*i.e.*, through their consumption choices, through improved food-handling techniques at home to reduce cross-contamination, or by thoroughly cooking meat to kill all pathogens) rather than have the Federal Government mandate stricter regulations to reduce levels of microbial pathogens in the food chain.[97] FDA researchers estimate that 30 percent of all foodborne-illness cases in the United States are attributed to unsafe food-handling practices in the home (Layden 1992, p. 56).

In the United States, a mix of regulatory and self-protective actions are likely to be preferred: First, the U.S. Congress delegated authority for inspecting food to the Federal Government at the turn of the century (Meat Inspection Acts of August 30, 1890, April 1, 1891, March 2, 1895, and June 30, 1906; 1906 Food and Drugs Act). State and city governments were delegated roles even earlier (Hutt and Hutt 1984). This delegation implies that U.S. consumers do not want to be burdened with evaluating the scientific evidence on food safety. Second, not all microbial pathogens can be prevented by the consumer. Thorough cooking does not eliminate heat-stable toxins produced by such pathogens as *Staphylococcus aureus* and *Bacillus cereus*.

Third, Shogren and Hayes and other Iowa State University colleagues, in a series of elegant studies,

[96]Averaging the LS VOSL values for males and females by age will overestimate productivity for males and underestimate productivity for females, based on market output.

[97]Better identification of high-risk foods would also enable consumers to make informed decisions about their food-handling and food consumption practices to protect themselves.

have estimated that consumers are willing to pay $0.70 per meal to upgrade to a safer meal in experimental auction markets (Shogren 1993, Hayes *et al.* 1995). Moreover, consumers are not homogeneous; increasingly, special populations such as people with HIV/AIDS, the immunocompromised elderly, and pregnant women face higher risk of acquiring foodborne diseases than others. These groups may be willing to pay even more than $0.70 for a safer meal.

The costs to society of foodborne diseases as computed by the COI method may comprise only a portion of society's willingness to pay to reduce such diseases. However, government agencies can act pragmatically to estimate the individual cost components of foodborne diseases while continuing to develop new theory, methods, and tools to estimate the value of food safety more comprehensively.

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