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.

[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.

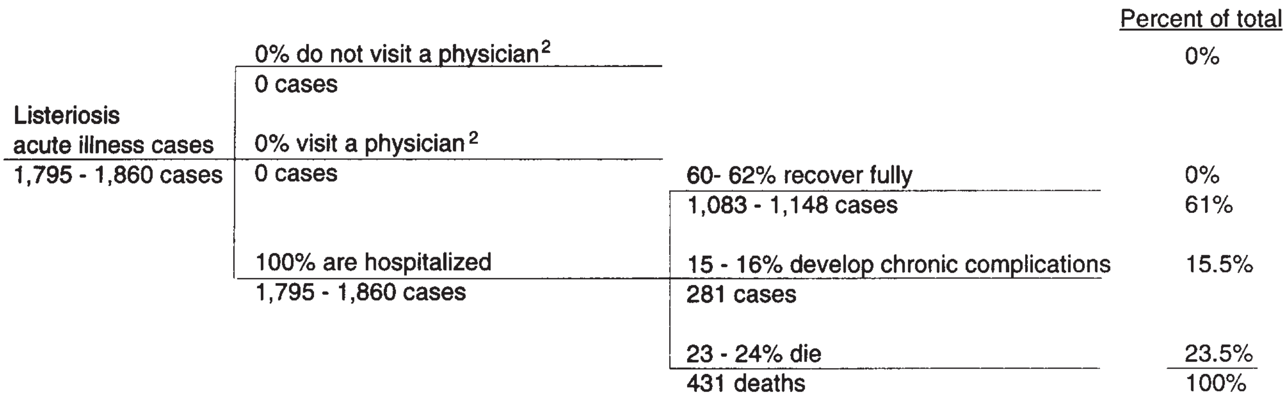
Table 22—Estimated U.S. listeriosis cases, 1993[1]

Severity of illness	Cases Low	Cases 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-

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.

[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.

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 percent, 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	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 40ºC (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 40ºC (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.

References

American Gastroenterological Association. "Consensus Conference Statement on *E. coli* 0157:H7 Infections, An Emerging National Health Crisis," July 11-13, 1994. *Gastroenterology*. 108(1995):1923-1934.

Archer, D. L. "Diarrheal Episodes and Diarrheal Disease: Acute Disease with Chronic Implications," *J. Food Prot.* 47(1984):321-328.

Archer, D. L. "Enteric Microorganisms in Rheumatoid Diseases: Causative Agents and Possible Mechanisms," *J. Food Prot.* 48(1985):538-545.

Archer, D. L., and J. E. Kvenberg. "Incidence and Cost of Foodborne Diarrheal Disease in the United States," *J. Food Prot.* 48(1985):887-894.

Archer, Douglas L., and Frank E. Young. "Contemporary Issues: Diseases with a Food Vector," *Clinical Microbiology Reviews*. 1(1988):377-398.

Armstrong, D. "*Listeria monocytogenes*." In Mandell, G. L., R. G. Douglas, Jr., and J. E. Bennett (eds.), *Principles and Practice of Infectious Diseases*. 2nd ed. Wiley Medical, New York, 1985.

Aserkoff, B., S. A. Schroeder, and P. S. Brachman. "Salmonellosis in the United States—A Five Year Review," *Am. J. Epidemiol*. 92(1970):13-24.

Bean, N. H., and P. M. Griffin. "Foodborne Disease Outbreaks in the United States, 1973-1987: Pathogens, Vehicles, and Trends," *J. Food Prot.* 53(1990):804-817.

Bean, N. H., P. M. Griffin, J. S. Goulding, and C. B. Ivey. "Foodborne Disease Outbreaks, 5 Year Summary, 1983-1987," *CDC Surveill. Summ. Morb. Mort. Weekly Rep.* (MMWR). 39, SS-1(March 1990):15-59 and J. Food Prot. 53(1990):711-728.

Bjerkedal, T., and J. D. Erickson. "Association of Birth Outcome with Subsequent Fertility," *Am. J. Obstet. Gynecol.* 147,4(Oct. 15, 1983):399- 404.

Belongia, E. A., M. T. Osterholm, J. T. Soler, D. A. Ammend, J. E. Braun, and K. L. MacDonald. "Transmission of *Escherichia coli* O157:H7 Infection in Minnesota Child Day-care Facilities," *J. Am. Med. Assoc.* 269,7(Feb. 17, 1993):883-888.

Benenson, Abram S. (ed.), *Control of Communicable Diseases in Man.* Amer. Public Health Assoc., 15th edition, 1990.

Bennett, John V., Scott D. Holmberg, Martha F. Rogers, and Steven L. Solomon. "Infectious and Parasitic Diseases." In Robert W. Amler and H. Bruce Dull (eds.), *Closing the Gap: The Burden of Unnecessary Illness*. New York: Oxford University Press, 1987, pp. 102-114.

Bergdoll, Merlin S. "*Staphylococcus aureus*." Chapter 11 in Doyle, Michael P. (ed.), *Foodborne Bacterial Pathogens*. New York: Marcel Dekker, Inc. 1989.

Blaser, Martin J., D. N. Taylor, R. A. Feldman. "Epidemiology of *Campylobacter jejuni* Infections," *Epidemiologic Reviews*. 5(1983a):157-165.

Blaser, Martin J., J. G. Wells, R. A. Feldman, R. A. Pollard, J. R. Allen, and the Collaborative Diarrheal Disease Study Group. "*Campylobacter* enteritis in the United States; A Multi-center Study," *Ann Intern. Med*. 98(1983b): 360-365.

Blaser, M. J., I. D. Berkowitz, F. M. LaForce *et al*. "*Campylobacter enteritis*: Clinical and Epidemiologic Features." *Ann Intern. Med*. 91(1979):175-185.