
Foodborne Illness Acquired in the United States—Major Pathogens

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Estimates of foodborne illness can be used to direct food safety policy and interventions. We used data from active and passive surveillance and other sources to estimate that each year 31 major pathogens acquired in the United States caused 9.4 million episodes of foodborne illness (90% credible interval [CrI] 6.6–12.7 million), 55,961 hospitalizations (90% CrI 39,534–75,741), and 1,351 deaths (90% CrI 712–2,268). Most (58%) illnesses were caused by norovirus, followed by nontyphoidal *Salmonella* spp. (11%), *Clostridium perfringens* (10%), and *Campylobacter* spp. (9%). Leading causes of hospitalization were nontyphoidal *Salmonella* spp. (35%), norovirus (26%), *Campylobacter* spp. (15%), and *Toxoplasma gondii* (8%). Leading causes of death were nontyphoidal *Salmonella* spp. (28%), *T. gondii* (24%), *Listeria monocytogenes* (19%), and norovirus (11%). These estimates cannot be compared with prior (1999) estimates to assess trends because different methods were used. Additional data and more refined methods can improve future estimates.

Estimates of the overall number of episodes of foodborne illness are helpful for allocating resources and prioritizing interventions. However, arriving at these estimates is challenging because food may become contaminated by many agents (e.g., a variety of bacteria, viruses, parasites, and chemicals), transmission can occur by nonfood mechanisms (e.g., contact with animals or consumption of contaminated water), the proportion of disease transmitted by food differs by pathogen and by host factors (e.g. age and immunity), and only a small proportion of illnesses are confirmed by laboratory testing and reported to public health agencies.

Laboratory-based surveillance provides crucial information for assessing foodborne disease trends. However,

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because only a small proportion of illnesses are diagnosed and reported, periodic assessments of total episodes of illness are also needed. (Hereafter, episodes of illness are referred to as illnesses.) Several countries have conducted prospective population-based or cross-sectional studies to supplement surveillance and estimate the overall number of foodborne illnesses (1). In 2007, the World Health Organization launched an initiative to estimate the global burden of foodborne diseases (2).

In 1999, the Centers for Disease Control and Prevention provided comprehensive estimates of foodborne illnesses, hospitalizations, and deaths in the United States caused by known and unknown agents (3). This effort identified many data gaps and methodologic limitations. Since then, new data and methods have become available. This article is 1 of 2 reporting new estimates of foodborne diseases acquired in the United States (hereafter referred to as domestically acquired). This article provides estimates of major known pathogens; the other provides estimates for agents of acute gastroenteritis not specified in this article (4).

Methods

Adequate data for preparing national estimates were available for 31 pathogens. We estimated the number of foodborne illnesses, hospitalizations, and deaths caused by these 31 domestically acquired pathogens by using data shown in the online Appendix Table (www.cdc.gov/EID/content/17/1/7-appT.htm) and online Technical Appendix 1 (www.cdc.gov/EID/content/17/1/7-Techapp1.pdf).

Data were mostly from 2000–2008, and all estimates were based on the US population in 2006 (299 million persons). Estimates were derived from statistical models with many inputs, each with some measure of uncertainty (5). To reflect this uncertainty, we used probability distributions to describe a range of plausible values for all model

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inputs. We expressed model outputs as probability distributions summarized by a mean point estimate with 90% credible intervals (CrIs). We used 2 types of modeling approaches for different types of data: 1) models that began with counts of laboratory-confirmed illnesses and were adjusted for undercounts (because of underreporting and underdiagnosis) and thus scaled up to the estimated number of illnesses and 2) models that began with a US population and used incidence data to scale down to the estimated number of illnesses (Table 1). The modeling approaches used and parameters of these probability distributions are detailed in online Technical Appendixes 2 and 3 (www.cdc.gov/EID/content/17/1/7-Techapp2.pdf and www.cdc.gov/EID/content/17/1/7-Techapp3.pdf, respectively); the proportions cited are modal values.

Illnesses

Laboratory-based surveillance data were available for 25 pathogens (online Appendix Table). The following events must occur for an illness to be ascertained and included in laboratory-based surveillance: the ill person must seek medical care, a specimen must be submitted for laboratory testing, the laboratory must test for and identify the causative agent, and the illness must be reported to public health authorities. If a break occurs in any of the first 3 steps of this surveillance chain, the causative agent will not be laboratory confirmed (underdiagnosis). Furthermore, although all laboratory-confirmed illnesses are reported by active surveillance, some will not be reported by passive surveillance (underreporting). Therefore, to estimate the number of illnesses caused by pathogens under public health surveillance, we determined the number of laboratory-confirmed illnesses and adjusted for underdiagnosis and, if necessary, for underreporting by using a series of component multipliers.

Laboratory-confirmed illnesses for these 25 pathogens were reported through 5 surveillance programs: the Foodborne Diseases Active Surveillance Network (Food-

Net) for *Campylobacter* spp., *Cryptosporidium* spp., *Cyloclopora cayetanensis*, Shiga toxin-producing *Escherichia coli* (STEC) O157, STEC non-O157, *Listeria monocytogenes*, nontyphoidal *Salmonella* spp., *Salmonella enterica* serotype Typhi, *Shigella* spp., and *Yersinia enterocolitica*; the National Notifiable Diseases Surveillance System (NNDSS) for *Brucella* spp., *Clostridium botulinum*, *Trichinella* spp., hepatitis A virus, and *Giardia intestinalis*; the Cholera and Other *Vibrio* Illness Surveillance (COVIS) system for toxigenic *Vibrio cholerae*, *V. vulnificus*, *V. parahaemolyticus*, and other *Vibrio* spp.; the National Tuberculosis Surveillance System (NTSS) for *Mycobacterium bovis*; and the Foodborne Disease Outbreak Surveillance System (FDOSS) for *Bacillus cereus*, *Clostridium perfringens*, enterotoxigenic *E. coli* (ETEC), *Staphylococcus aureus*, and *Streptococcus* spp. group A (online Appendix Table; online Technical Appendix 1). When data were available from >1 surveillance system, we used active surveillance data from FoodNet, except for *Vibrio* spp., for which we used COVIS because of geographic clustering of *Vibrio* spp. infections outside FoodNet sites. We used data on outbreak-associated illnesses from FDOSS only for pathogens for which no data were available from other systems.

Because FoodNet conducts surveillance at 10 sites (6), we estimated the number of laboratory-confirmed illnesses in the United States by applying incidence from FoodNet to the estimated US population for 2006 (7). We constructed a probability distribution based on extrapolation of rates by year (2005–2008) in each FoodNet site (online Technical Appendix 3). We used data from 2005–2008 because the FoodNet surveillance area was constant during that period and because FoodNet began collecting information on foreign travel in 2004. We used data from 2000–2007 for NNDSS, COVIS, and FDOSS and annual counts of reported illnesses for our probability distributions. Some evidence of trend was found for illness caused by hepatitis A virus, *S. aureus*, and *Vibrio* spp.; therefore, recent years were weighted more heavily (online Technical Appendixes

Table 1. Modeling approaches used to estimate the total number of illnesses for different types of data, United States*

Pathogens for which laboratory-confirmed illnesses were scaled up			Pathogens for which US population was scaled down
Active surveillance data	Passive surveillance data	Outbreak surveillance data	
<i>Campylobacter</i> spp.	<i>Brucella</i> spp.	<i>Bacillus cereus</i>	Astrovirus
<i>Cryptosporidium</i> spp.	<i>Clostridium botulinum</i>	<i>Clostridium perfringens</i>	Norovirus
<i>Cyloclopora cayetanensis</i>	<i>Giardia intestinalis</i>	ETEC†	Rotavirus
STEC O157	Hepatitis A virus	<i>Staphylococcus aureus</i>	Sapovirus
STEC non-O157	<i>Mycobacterium bovis</i>	<i>Streptococcus</i> spp. group A	<i>Toxoplasma gondii</i>
<i>Listeria monocytogenes</i>	<i>Trichinella</i> spp.		
<i>Salmonella</i> spp., nontyphoidal‡	<i>Vibrio cholera</i> , toxigenic		
<i>S. enterica</i> serotype Typhi	<i>Vibrio parahaemolyticus</i>		
<i>Shigella</i> spp.	<i>Vibrio vulnificus</i>		
<i>Yersinia enterocolitica</i>	<i>Vibrio</i> spp., other		

*ETEC, enterotoxigenic *Escherichia coli*; STEC, Shiga toxin-producing *E. coli*.

†Numbers of *E. coli* other than STEC or ETEC assumed to be same as for ETEC.

‡Includes all serotypes other than Typhi.

2, 3). NTSS was used to determine the number of reported illnesses caused by *M. bovis* during 2004–2007.

We assumed that all laboratory-confirmed illnesses were reported to FoodNet active surveillance in the relevant catchment areas. Because COVIS and NNDSS conduct passive surveillance, we applied an underreporting multiplier (1.1 for bacteria and 1.3 for parasites) derived by comparing incidence of all nationally notifiable illnesses ascertained through FoodNet with that reported to NNDSS (online Technical Appendix 4, www.cdc.gov/EID/content/17/1/7-Techapp4.pdf). For the 5 bacteria for which only outbreak data were available, we estimated the number of laboratory-confirmed illnesses by creating an underreporting multiplier as follows. We determined the proportion of illnesses ascertained through FoodNet that were caused by *Campylobacter* spp., *Cryptosporidium* spp., *C. cayatanensis*, *L. monocytogenes*, *Salmonella* spp., *Shigella* spp., STEC, *Vibrio* spp., and *Y. enterocolitica* that were also reported to FDOSS as outbreak associated and applied the inverse of this proportion, 25.5, to those pathogens (online Technical Appendix 4). We assumed that all illnesses caused by *M. bovis* were reported to NTSS.

To adjust for underdiagnosis resulting from variations in medical care seeking, specimen submission, laboratory testing, and test sensitivity, we created pathogen-specific multipliers. To adjust for medical care seeking and specimen submission, we pooled data from FoodNet Population Surveys in 2000–2001, 2002–2003 (8), and 2006–2007 (Centers for Disease Control and Prevention, unpub. data) from which we estimated the proportion of persons who in the past month reported an acute diarrheal illness (≥ 3 loose stools in 24 hours lasting >1 day or resulting in restricted daily activities) and sought medical care and submitted a stool sample for that illness. Because persons with more severe illness are more likely to seek care (9), we estimated pathogen-specific proportions of persons with laboratory-confirmed infections who had severe illness (e.g., bloody diarrhea) and used medical care seeking and stool sample submission rates for bloody (35% and 36%, respectively) and nonbloody (18% and 19%, respectively) diarrhea as surrogates for severe and mild cases of most illnesses (online Technical Appendix 3). However, for infections with *L. monocytogenes*, *M. bovis*, and *V. vulnificus* and severe infections with hepatitis A virus, we assumed high rates of medical care seeking (i.e., we assumed that 100% of persons with *M. bovis* infection and 90% with *L. monocytogenes*, *V. vulnificus*, or severe hepatitis A virus infections sought care) and specimen submission (100% for hepatitis A virus and *M. bovis*, 80% for others). We accounted for percentage of laboratories that routinely tested for specific pathogens (25%–100%) and test sensitivity (28%–100%) by using data from FoodNet

(10,11) and other surveys of clinical diagnostic laboratory practices (online Technical Appendix 3). For the 5 pathogens for which data were from outbreaks only, we used the nontyphoidal *Salmonella* spp. underdiagnosis multiplier.

Alternative approaches were used for infections not routinely reported by any surveillance system (i.e., diarrheagenic *E. coli* other than STEC and ETEC, *T. gondii*, astrovirus, rotavirus, sapovirus, and norovirus) (online Technical Appendixes 1–3). We assumed diarrheagenic *E. coli* other than STEC and ETEC to be as common as ETEC. Illnesses caused by *T. gondii* were estimated by using nationally representative serologic data from the 1999–2004 National Health and Nutrition Examination Survey (12) and an estimate that clinical illness develops in 15% of persons who seroconvert (13). We assumed that 75% of children experience an episode of clinical rotavirus illness by 5 years of age, consistent with findings from other studies (14), and used this estimate for astrovirus and sapovirus. We estimated norovirus illnesses by applying mean proportion of all acute gastroenteritis caused by norovirus (11%) according to studies in other industrialized countries (15–18) to estimates of acute gastroenteritis from FoodNet Population Surveys (online Appendix Table; online Technical Appendixes 1–3) (4).

Hospitalizations and Deaths

For most pathogens, numbers of hospitalizations and deaths were estimated by determining (from surveillance data) the proportion of persons who were hospitalized and the proportion who died and applying these proportions to the estimated number of laboratory-confirmed illnesses (online Appendix Table; online Technical Appendixes 1, 3). Rates of hospitalization and death caused by *G. intestinalis* and *T. gondii* were based on the 2000–2006 Nationwide Inpatient Sample. Because some persons with illnesses that were not laboratory confirmed would also have been hospitalized and died, we doubled the number of hospitalizations and deaths to adjust for underdiagnosis, similar to the method used by Mead et al. (3) but applied an uncertainty distribution (online Technical Appendix 3). For diarrheagenic *E. coli* other than STEC and ETEC, total numbers of hospitalizations and deaths were assumed to be the same as those for ETEC. For rotavirus, we used previous estimates (14). For astrovirus and sapovirus, we assumed that the number was 25% that of rotavirus (19,20). Numbers of norovirus hospitalizations and deaths were determined by multiplying the estimated number of hospitalizations and deaths caused by acute gastroenteritis, estimated by using national data on outpatient visits resulting in hospitalization, hospital discharge surveys, and death certificates (online Appendix Table; online Technical Appendixes 1–3)

(4), by the same norovirus proportion (11%) used to estimate illnesses (15–18).

Domestically Acquired Foodborne Illnesses

Data from published studies and surveillance were used to determine, for each pathogen, the proportion of illnesses acquired while the person had been traveling outside the United States (online Technical Appendixes 1, 3). The remaining proportion was considered domestically acquired. We based our estimates of the proportion of domestically acquired foodborne illnesses caused by each pathogen on data from surveillance, risk factor studies, and a literature review (online Technical Appendixes 1, 3).

Uncertainty Analysis

We used empirical data, when available, to define entire distributions or parameters of distributions (online Technical Appendix 3). When data were sparse, we made reasoned judgments based on context, plausibility, and previously published estimates. The parametric distribution used for almost all multipliers was a 4-parameter beta (modified PERT) distribution (21). The first 3 parameters are low, modal, and high. The fourth parameter is related to the variability of the distribution. We typically fixed this last parameter at 4, which yields the simple PERT distribution (21). However, when describing the outbreak reporting multiplier, we used a value of 20 (online Technical Appendix 4).

Uncertainty in the estimates is the cumulative effect of uncertainty of each of the model inputs. We iteratively generated sets of independent pathogen-specific adjustment factors and used these multipliers to estimate illnesses, hospitalizations, and deaths (Figure; online Technical Appendix 2). On the basis of 100,000 iterations, we obtained empirical distributions of counts corresponding to Bayesian posterior distributions and used these posterior distributions to generate a point estimate (posterior mean) and upper and lower 5% limits for 90% CrIs. Because incidence of illnesses differed by location and over time,

we included these variations in the models, which led to wider CrIs than if we had assumed that inputs represented independent random samples of a fixed US population. We used SAS version 9.2 (SAS Institute, Cary, NC, USA) for these analyses.

Results

Foodborne Illnesses

We estimate that each year in the United States, 31 pathogens caused 37.2 million (90% CrI 28.4–47.6 million) illnesses, of which 36.4 million (90% CrI 27.7–46.7 million) were domestically acquired; of these, 9.4 million (90% CrI 6.6–12.7 million) were foodborne (Table 2; expanded version available online, www.cdc.gov/EID/content/17/1/7-T2.htm). We estimate that 5.5 million (59%) foodborne illnesses were caused by viruses, 3.6 million (39%) by bacteria, and 0.2 million (2%) by parasites. The pathogens that caused the most illnesses were norovirus (5.5 million, 58%), nontyphoidal *Salmonella* spp. (1.0 million, 11%), *C. perfringens* (1.0 million, 10%), and *Campylobacter* spp. (0.8 million, 9%).

Hospitalizations

We estimate that these 31 pathogens caused 228,744 (90% CrI 188,326–275,601) hospitalizations annually, of which 55,961 (90% CrI 39,534–75,741) were caused by contaminated food eaten in the United States (Table 3; expanded version available online, www.cdc.gov/EID/content/17/1/7-T3.htm). Of these, 64% were caused by bacteria, 27% by viruses, and 9% by parasites. The leading causes of hospitalization were nontyphoidal *Salmonella* spp. (35%), norovirus (26%), *Campylobacter* spp. (15%), and *T. gondii* (8%).

Deaths

We estimate that these 31 pathogens caused 2,612 deaths (90% CrI 1,723–3,819), of which 1,351 (90% CrI

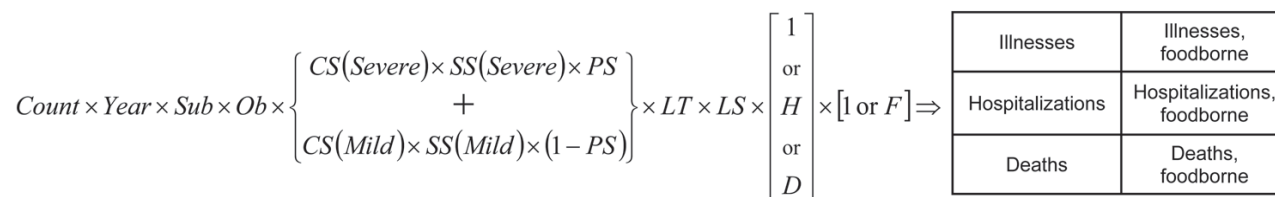


Figure. Example schematic diagram of the estimation and uncertainty model used to estimate episodes of illness, hospitalizations, and deaths in the United States. *Count*, data (empirical distribution); *Year*, factor to standardize non-2006 counts to 2006 (constant); *Sub*, expansive factor to scale area surveillance to the entire US population (constant); *Ob*, expansive factor to scale outbreak counts up to outbreak plus sporadic counts (beta distribution); *CS*, expansive factor to scale care seekers to all ill, with severe and mild illness versions (PERT distribution); *SS*, expansive factor to scale submitted samples to all visits, with severe and mild illness versions (PERT distribution); *PS*, estimated proportion of illnesses that are severe (PERT distribution); *LT*, expansive factor to scale tests performed up to samples submitted (PERT distribution); *LS*, expansive factor to scale positive test results up to true positive specimens (PERT distribution); *H*, contractive factor to scale illnesses down to hospitalized illnesses (PERT distribution); *D*, contractive factor to scale illnesses down to deaths (PERT distribution); *F*, contractive factor to scale illnesses down to foodborne illnesses (PERT distribution).

712–2,268) were caused by contaminated food eaten in the United States (Table 3). Of these, 64% were caused by bacteria, 25% by parasites, and 12% by viruses. The leading causes of death were nontyphoidal *Salmonella* spp. (28%), *T. gondii* (24%), *L. monocytogenes* (19%), and norovirus (11%).

Table 2. Estimated annual number of episodes of domestically acquired foodborne illnesses caused by 31 pathogens, United States*

Pathogen	Laboratory confirmed	Multipliers		Travel related, %	Foodborne, %†	Domestically acquired foodborne, mean (90% credible interval)
		Under-reporting	Under-diagnosis			
Bacteria						
<i>Bacillus cereus</i> , foodborne	85‡	25.5	29.3	<1	100	63,400 (15,719–147,354)
<i>Brucella</i> spp.	120§	1.1	15.2	16	50	839 (533–1,262)
<i>Campylobacter</i> spp.	43,696¶	1.0	30.3	20	80	845,024 (337,031–1,611,083)
<i>Clostridium botulinum</i> , foodborne	25§	1.1	2.0	<1	100	55 (34–91)
<i>Clostridium perfringens</i> , foodborne	1,295‡	25.5	29.3	<1	100	965,958 (192,316–2,483,309)
STEC O157	3,704¶	1.0	26.1	4	68	63,153 (17,587–149,631)
STEC non-O157	1,579¶	1.0	106.8	18	82	112,752 (11,467–287,321)
ETEC, foodborne	53‡	25.5	29.3	55	100	17,894 (24–46,212)
Diarrheagenic <i>E. coli</i> other than STEC and ETEC	53	25.5	29.3	<1	30	11,982 (16–30,913)
<i>Listeria monocytogenes</i>	808¶	1.0	2.1	3	99	1,591 (557–3,161)
<i>Mycobacterium bovis</i>	195¶	1.0	1.1	70	95	60 (46–74)
<i>Salmonella</i> spp., nontyphoidal	41,930¶	1.0	29.3	11	94	1,027,561 (644,786–1,679,667)
<i>S. enterica</i> serotype Typhi	433¶	1.0	13.3	67	96	1,821 (87–5,522)
<i>Shigella</i> spp.	14,864¶	1.0	33.3	15	31	131,254 (24,511–374,789)
<i>Staphylococcus aureus</i> , foodborne	323‡	25.5	29.3	<1	100	241,148 (72,341–529,417)
<i>Streptococcus</i> spp. group A, foodborne	15‡	25.5	29.3	<1	100	11,217 (15–77,875)
<i>Vibrio cholerae</i> , toxigenic	8§	1.1	33.1	70	100	84 (19–213)
<i>V. vulnificus</i>	111§	1.1	1.7	2	47	96 (60–139)
<i>V. parahaemolyticus</i>	287§	1.1	142.4	10	86	34,664 (18,260–58,027)
<i>Vibrio</i> spp., other	220§	1.1	142.7	11	57	17,564 (10,848–26,475)
<i>Yersinia enterocolitica</i>	950¶	1.0	122.8	7	90	97,656 (30,388–172,734)
Subtotal						3,645,773 (2,321,468–5,581,290)
Parasites						
<i>Cryptosporidium</i> spp.	7,594¶	1.0	98.6	9	8	57,616 (12,060–166,771)
<i>Cyclospora cayetanensis</i>	239¶	1.0	83.1	42	99	11,407 (137–37,673)
<i>Giardia intestinalis</i>	20,305§	1.3	46.3	8	7	76,840 (51,148–109,739)
<i>Toxoplasma gondii</i>		1.0	0.0	<1	50	86,686 (64,861–111,912)
<i>Trichinella</i> spp.	13§	1.3	9.8	4	100	156 (42–341)
Subtotal						232,705 (161,923–369,893)
Viruses						
Astrovirus	NA	NA	NA	0	<1	15,433 (5,569–26,643)
Hepatitis A virus	3,576§	1.1	9.1	41	7	1,566 (702–3,024)
Norovirus	NA	NA	NA	<1	26	5,461,731 (3,227,078–8,309,480)
Rotavirus	NA	NA	NA	0	<1	15,433 (5,569–26,643)
Sapovirus	NA	NA	NA	0	<1	15,433 (5,569–26,643)
Subtotal						5,509,597 (3,273,623–8,355,568)
Total						9,388,075 (6,641,440–12,745,709)

*All estimates based on US population in 2006. Modal or mean value shown unless otherwise stated; see online Technical Appendix 3 (www.cdc.gov/EID/content/17/1/7-Techapp3.pdf) for the parameters of these distributions. STEC, Shiga toxin-producing *Escherichia coli*; ETEC, enterotoxigenic *E. coli*; NA, not applicable. An expanded version of this table is available online (www.cdc.gov/EID/content/17/1/7-T2.htm).

†Percentage foodborne among domestically acquired illnesses.

‡Passive surveillance data on outbreak-associated illnesses from the Foodborne Disease Outbreak Surveillance System. Estimates based on the number of foodborne illnesses ascertained in surveillance and therefore assumed to reflect only foodborne transmission.

§Passive surveillance data from Cholera and Other *Vibrio* Illness Surveillance or the National Notifiable Disease Surveillance System.

¶Active surveillance data from Foodborne Diseases Active Surveillance Network, adjusted for geographic coverage; data from the National Tuberculosis Surveillance System for *M. bovis*.

Discussion

We estimate that foods consumed in the United States that were contaminated with 31 known agents of foodborne disease caused 9.4 million illnesses, 55,961 hospitalizations, and 1,351 deaths each year. Norovirus caused the most illnesses; nontyphoidal *Salmonella* spp., norovirus, *Campylobacter* spp., and *T. gondii* caused the most hospitalizations; and nontyphoidal *Salmonella* spp., *T. gondii*, *L. monocytogenes*, and norovirus caused the most deaths. Scarce data precluded estimates for other known infectious

and noninfectious agents, such as chemicals. Foodborne diseases are also caused by agents not yet recognized as being transmitted in food and by unknown agents (22). The numbers of illnesses caused by these unspecified agents are estimated elsewhere (4).

Studies estimating the overall number of foodborne illnesses have been conducted in England and Wales and in Australia (23,24). Similar to our findings, in Australia norovirus was the leading cause of foodborne illness, accounting for 30% of illnesses caused by known pathogens.

Table 3. Estimated annual number of domestically acquired foodborne hospitalizations and deaths caused by 31 pathogens, United States*

Pathogen	Hospitalization rate, %†	Hospitalizations, mean (90% credible interval)	Death rate, %†	Deaths, mean (90% credible interval)
Bacteria				
<i>Bacillus cereus</i> , foodborne‡	0.4	20 (0–85)	0	0
<i>Brucella</i> spp.	55.0	55 (33–84)	0.9	1 (0–2)
<i>Campylobacter</i> spp.	17.1	8,463 (4,300–15,227)	0.1	76 (0–332)
<i>Clostridium botulinum</i> , foodborne‡	82.6	42 (19–77)	17.3	9 (0–51)
<i>Clostridium perfringens</i> , foodborne‡	0.6	438 (44–2,008)	<0.1	26 (0–163)
STEC O157	46.2	2,138 (549–4,614)	0.5	20 (0–113)
STEC non-O157	12.8	271 (0–971)	0.3	0 (0–0)§
ETEC, foodborne	0.8	12 (0–53)	0	0
Diarrheagenic <i>E. coli</i> other than STEC and ETEC	0.8	8 (0–36)	0	0
<i>Listeria monocytogenes</i>	94.0	1,455 (521–3,018)	15.9	255 (0–733)
<i>Mycobacterium bovis</i>	55.0	31 (21–42)	4.7	3 (2–3)
<i>Salmonella</i> spp., nontyphoidal	27.2	19,336 (8,545–37,490)	0.5	378 (0–1,011)
<i>S. enterica</i> serotype Typhi	75.7	197 (0–583)	0	0
<i>Shigella</i> spp.	20.2	1,456 (287–3,695)	0.1	10 (0–67)
<i>Staphylococcus aureus</i> , foodborne‡	6.4	1,064 (173–2,997)	<0.1	6 (0–48)
<i>Streptococcus</i> spp. group A, foodborne‡	0.2	1 (0–6)	0	0
<i>Vibrio cholerae</i> , toxigenic	43.1	2 (0–5)	0	0
<i>V. vulnificus</i>	91.3	93 (53–145)	34.8	36 (19–57)
<i>V. parahaemolyticus</i>	22.5	100 (50–169)	0.9	4 (0–17)
<i>Vibrio</i> spp., other	37.1	83 (51–124)	3.7	8 (3–19)
<i>Yersinia enterocolitica</i>	34.4	533 (0–1,173)	2.0	29 (0–173)
Subtotal		35,796 (21,519–53,414)		861 (260–1,761)
Parasites				
<i>Cryptosporidium</i> spp.	25.0	210 (58–518)	0.3	4 (0–19)
<i>Cyclospora cayetanensis</i>	6.5	11 (0–109)	0.0	0
<i>Giardia intestinalis</i>	8.8	225 (141–325)	0.1	2 (1–3)
<i>Toxoplasma gondii</i>	2.6	4,428 (2,634–6,674)	0.2	327 (200–482)
<i>Trichinella</i> spp.	24.3	6 (0–17)	0.2	0 (0–0)
Subtotal		4,881 (3,060–7,146)		333 (205–488)
Viruses				
Astrovirus	0.4	87 (32–147)	<0.1	0
Hepatitis A virus	31.5	99 (42–193)	2.4	7 (3–15)
Norovirus	0.03	14,663 (8,097–23,323)	<0.1	149 (84–237)
Rotavirus	1.7	348 (128–586)	<0.1	0
Sapovirus	0.4	87 (32–147)	<0.1	0
Subtotal		15,284 (8,719–23,962)		157 (91–245)
Total		55,961 (39,534–75,741)		1,351 (712–2,268)

*All estimates were based on US population in 2006. STEC, Shiga toxin-producing *Escherichia coli*; ETEC, enterotoxigenic *E. coli*. An expanded version of this table is available online (www.cdc.gov/EID/content/17/1/7-T3.htm).

†For laboratory-confirmed illnesses. Unadjusted hospitalization and death rates are presented here. These rates were doubled to adjust for underdiagnosis before being applied to the number of laboratory-confirmed cases to estimate the total number of hospitalizations and deaths. The hospitalization and death rates for astrovirus, norovirus, rotavirus, and sapovirus presented here are the percentage of total estimated illness and were not subject to further adjustment.

‡Estimates based on the number of foodborne illnesses ascertained in surveillance, therefore assumed to reflect only foodborne transmission.

§We report median values instead of means for the distributions of deaths caused by STEC non-O157 because of extremely skewed data.

In England and Wales, norovirus accounted for only 8% of known foodborne illnesses; however, stool sample reexamination using molecular techniques documented higher rates (18). Nontyphoidal *Salmonella* spp. and *Campylobacter* spp. were leading causes of foodborne illnesses in all 3 countries (England and Wales, Australia, and the United States), although nontyphoidal *Salmonella* spp. accounted for a greater proportion of illness in the United States. Recent serologic data from Europe suggest that *Salmonella* spp. infections are more common than estimated by our methods; however, many infections may be asymptomatic (25). Our estimates did not capture mild illnesses associated with some pathogens. For example, mild cases of botulism are often recognized as part of outbreaks, but affected persons seldom seek medical care and are not captured by surveillance except during outbreaks (26,27). Likewise, *L. monocytogenes* is rarely diagnosed as the cause of gastroenteritis and fever, partly because this organism is not detected by routine stool culture (28). Early spontaneous abortion or miscarriage associated with listeriosis may also be underdiagnosed.

Accurately estimating hospitalizations and deaths caused by foodborne pathogens is particularly challenging. National data on outpatient visits resulting in hospitalization, hospital discharges, and death certificates probably substantially underestimate pathogen-specific cases because for pathogen-specific diagnoses to be recorded, health care providers must order the appropriate diagnostic tests and coding must be accurate. Particularly in vulnerable populations, dehydration or electrolyte imbalance from a gastrointestinal illness may exacerbate a chronic illness, resulting in hospitalization or death well after resolution of the gastrointestinal illness; thus, the gastrointestinal illness may not be coded as a contributing factor. Moreover, if a pathogen is not detected, infections may be coded as non-infectious illnesses (29). For norovirus, we estimated the number of hospitalizations and deaths by applying the estimated proportion of acute gastroenteritis illnesses caused by norovirus to overall estimates of hospitalizations and deaths from acute gastroenteritis; this choice is supported by studies of hospitalizations for norovirus (30,31). For most other pathogens, we used data from surveillance to estimate pathogen-specific hospitalizations and deaths and doubled the numbers to adjust for underdiagnosis. More precise information about the degree of undercounting of hospitalizations and deaths for each pathogen would improve these estimates.

Our methods and data differed from those used for the 1999 estimates (3). Our estimate of medical care seeking among persons with a diarrheal illness, derived from the 3 most recent FoodNet Population Surveys conducted during 2000–2007, was higher than that estimated from the 1996–1997 FoodNet Population Survey used for the

1999 estimates (35% and 18% among persons reporting bloody and nonbloody diarrhea, respectively, compared with 15% and 12% in the earlier [1999] study) (8). These data resulted in lower underdiagnosis multipliers, which contributed to lower estimates of number of illnesses. The biggest change from the earlier estimate was the estimated number of norovirus illnesses, which decreased for 2 reasons. First, the number of acute gastrointestinal illnesses estimated from the FoodNet Population Survey and used in the current study was lower than the estimated number of acute gastrointestinal illnesses used in the 1999 assessment. The earlier study used data from 1996–1997; the sample size was one fifth as large as ours and incorporated data from US studies conducted before 1980 (32,33). Both estimates excluded persons reporting concurrent cough or sore throat, but the proportion of persons reporting these signs and symptoms was higher in the FoodNet Population Surveys we used than that in the older US studies (38% vs. 25%), contributing to a lower estimated prevalence of acute gastroenteritis (0.60 vs. 0.79 episodes/person/year) (4,32,33). Additionally, the current study excluded persons with vomiting who were ill for <1 day or whose illness did not result in restricted daily activities, whereas the earlier study included all vomiting episodes. These factors contributed to the new estimate of acute gastroenteritis being 24% lower than the earlier estimate, more likely the result of increased accuracy than a true decrease in illnesses (4). Second, the lower current estimate for norovirus illnesses resulted from a lower proportion of norovirus estimated to be foodborne (decreased from 40% to 26%); this lower proportion is similar to that estimated in recent studies from other countries (23,24). Because of these reasons and use of other data sources and methods, our estimate cannot be compared with the 1999 estimate for the purpose of assessing trends. FoodNet provides the best data on trends over time (34).

Data used in the current study came from a variety of sources and were of variable quality and representativeness. FoodNet sites, from which we used data for 10 pathogens, are not completely representative of the US population, but 1 study indicated that demographic data from FoodNet and from the 2005 US census did not differ much (6). For 5 pathogens, only data on foodborne outbreak-related cases were available. No routine surveillance data were available for most viruses, forcing us to use a different modeling approach for viruses than for most other pathogens. Given the large number of norovirus illnesses in these estimates, the paucity of supporting data is a major limitation. Moreover, combining different methods is not optimal because methods themselves may affect the estimates. We chose our modeling approach and used the PERT distribution for many inputs because data were sometimes limited and subjective decisions were required. Other investigators could

have chosen other distributions, for good reasons, and arrived at different estimates.

Our assumptions about the proportion of illnesses transmitted by food profoundly affect our estimates, but data on which to base these estimates were often lacking. We used data from surveillance, risk factor studies, and the current literature to estimate the proportion of pathogen-specific illnesses caused by consumption of contaminated food (35), but it is not known how representative these data are of total illnesses and whether the foodborne proportion is similar across age groups. For example, the proportion of some illnesses acquired from animals (e.g., STEC O157) may be higher among children than adults (36), and the proportions that spread person-to-person (e.g., norovirus) may be higher among institutionalized elderly persons (37). Because a higher proportion of cases are reportedly associated with hospitalization or death in these vulnerable groups, we may have overestimated the total contribution of foodborne transmission for these outcomes.

The methods used for this study could be adapted to estimate the proportion of illnesses attributable to other modes of transmission, such as waterborne and direct animal contact. The estimates from this study can be used to help direct policy and interventions; to conduct other analyses (e.g., evaluation of economic cost of these diseases and attribution to various food commodities); and as a platform for developing estimates of effects of disease caused by sequelae of foodborne infections.

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Foodborne Illness Acquired in the United States—Major Pathogens

Technical Appendix 1

Overview of Methods and Summary of Data Sources

This appendix provides a summary of data sources and methods used to estimate the annual number of illnesses, the annual number of hospitalizations, the annual number of deaths, the proportion travel-related, and the proportion foodborne for 31 major known pathogens transmitted through food

**This appendix includes only modal values.
Technical Appendix 2 (www.cdc.gov/EID/content/17/1/7-Techapp2.pdf)
contains a full description of the uncertainty model parameters.**

Pathogen: Astrovirus	
Estimate	Data source(s)
Number of illnesses	There is evidence suggesting high seroprevalences of astroviruses in young children (1); therefore, we assumed that 75% of children experience an episode of clinical illness due to astrovirus by 5 years of age similar to other childhood gastroenteritis viruses such as rotavirus (2). The person-time at risk for 2006 was estimated as the 0-4 year population (20,417,636) divided by 5 and rounded (4,084,000) (3).
Number of hospitalizations	Assumed to equal 25% of number of hospitalizations for rotavirus based on published studies (4).
Number of deaths	Assumed to be very low: <10 deaths per year.
Proportion travel-related	Assumed to be 100% domestically acquired.
Proportion foodborne	Very low (<1%) based on published review (5).
Comments	Significant illness assumed to occur only among children <5 years of age. Very few foodborne outbreaks reported (CDC, unpublished data).

Pathogen: <i>Bacillus cereus</i>	
Estimate	Data source(s) and method
Number of illnesses	Annual number of <i>Bacillus cereus</i> outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000–2007) (6), adjusted for underreporting due to surveillance type (see outbreak surveillance underreporting multiplier described in online Technical Appendixes 2 and 4 (www.cdc.gov/EID/content/17/1/zzz-Techapp4.pdf) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion hospitalized in <i>Bacillus cereus</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion who died in <i>Bacillus cereus</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Because of the rapid onset and short duration of <i>Bacillus cereus</i> illnesses, we assumed that almost all <i>Bacillus cereus</i> illnesses occurring in the United States were domestically acquired.
Proportion foodborne	Our estimate of the number of illnesses was based on outbreak-associated <i>Bacillus cereus</i> illnesses reported to CDC through the Foodborne Disease Outbreak Surveillance System. Because all these outbreaks were foodborne, our estimate of the number of illnesses was based solely on foodborne outbreak-associated illnesses. Therefore, 100% of the estimated number of illnesses was considered foodborne.

Pathogen: <i>Brucella</i> spp.	
Estimate	Data source(s)
Number of illnesses	Annual number of brucellosis illnesses reported to CDC's National Notifiable Disease Surveillance System (NNDSS) (2000–2007) (7); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion (55%) hospitalized in <i>Brucella</i> spp. outbreaks reported to the CDC (CDC, unpublished data) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Death rate among persons with brucellosis was 0.9% in studies in California and Texas (8, 9). This proportion was applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	16% of cases of brucellosis reported to NNDSS (2000-2007) were reported to have acquired their infection outside the United States.
Proportion foodborne	We used the estimate of 50% foodborne used by Mead <i>et al.</i> (1999) (10). Overall, consumption of milk or cheese products from Mexico was implicated in 45% of cases reported from California from 1973 to 1992 (9). Because the proportion of cases due to foodborne transmission was higher in the latter half of this period, 50% of cases were assumed to be foodborne.
Comments	Reports from California and Texas account for most illnesses.

Pathogen: <i>Campylobacter</i> spp.	
Estimate	Data source(s)
Number of illnesses	Annual incidence of campylobacteriosis reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of <i>Campylobacter</i> spp. infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of <i>Campylobacter</i> spp. infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	20% based on surveillance data from FoodNet (2005–2008). Cases of <i>Campylobacter</i> spp. infection in FoodNet were queried about international travel in the seven days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	80% based on a FoodNet case-control study of sporadic <i>Campylobacter</i> illnesses (12). We assumed a total population attributable fraction of 100% and subtracted from this the non-foodborne population attributable fractions from the case-control study (non-foodborne risk factors included: Had contact with animal stool [6%]; Had pet puppy [5%]; Had contact with farm animals [6%]; Drank untreated water from a lake, river, or stream [3%]). The remaining fraction (80%) was assumed to be due to contaminated food.

Pathogen: <i>Clostridium botulinum</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of foodborne botulism illnesses reported to CDC's National Notifiable Disease Surveillance System (NNDSS) (2000–2007) (7); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion hospitalized in foodborne botulism outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) (6) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion who died in foodborne botulism outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Almost all cases reported to CDC's botulism surveillance were domestically acquired.
Proportion foodborne	Estimates based on the number of illnesses reported as foodborne botulism (as opposed to wound botulism or infant botulism); therefore, assumed to be 100% foodborne.
Comments	Almost all cases of foodborne botulism reported to CDC are in persons hospitalized for life-threatening manifestations. Mild cases of botulism are often recognized as part of outbreaks (13, 14), but these persons seldom seek medical care and so are not likely to be captured in routine surveillance.

Pathogen: <i>Clostridium perfringens</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of <i>Clostridium perfringens</i> outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000–2007) (6); adjusted for underreporting due to surveillance type (see outbreak surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion hospitalized in <i>Clostridium perfringens</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion who died in <i>Clostridium perfringens</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Because of the rapid onset and short duration of <i>Clostridium perfringens</i> illnesses, we assumed that 100% <i>Clostridium perfringens</i> illnesses occurring in the United States were domestically acquired.
Proportion foodborne	Our estimate of the number of illnesses was based on outbreak-associated <i>Clostridium perfringens</i> illnesses reported to CDC through the Foodborne Disease Outbreak Surveillance System. Because all these outbreaks were foodborne, our estimate of the number of illnesses was based solely on foodborne outbreak-associated illnesses. Therefore, 100% of the estimated number of illnesses was considered foodborne.

Pathogen: <i>Cryptosporidium</i> spp.	
Estimate	Data source(s)
Number of illnesses	Annual incidence of cryptosporidiosis reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of <i>Cryptosporidium</i> spp. infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of <i>Cryptosporidium</i> spp. infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	9% based on surveillance data from FoodNet (2005–2008). Cases of <i>Cryptosporidium</i> spp. infection in FoodNet were queried about international travel in the 15 days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	We estimated that 8% of cases were foodborne based on data from a Canadian study (15).

Pathogen: <i>Cyclospora cayetanensis</i>	
Estimate	Data source(s)
Number of illnesses	Annual incidence of <i>Cyclospora cayetanensis</i> infection reported to CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of <i>Cyclospora cayetanensis</i> infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of <i>Cyclospora cayetanensis</i> infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	42% based on surveillance data from FoodNet (2005–2008). Cases of <i>Cyclospora cayetanensis</i> infection in FoodNet were queried about international travel in the 15 days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	99% based on outbreaks reported to CDC; foodborne outbreaks have been identified during most years since the mid 1990’s and have been associated with various types of imported fresh produce (16, 17).
Comments	<i>Cyclospora cayetanensis</i> infection appears to be most common in tropical and subtropical regions and is not thought to be endemic in the United States (localized, low-level endemicity cannot be excluded). The main identified risk factor for domestic acquisition of infection is consumption of contaminated fresh produce imported from cyclosporiasis-endemic areas. Importation, distribution, and consumption of contaminated produce are not uniform in place or time. The “true” number of affected persons could range from 0 to many thousands from year to year. (In some years, documented cases have exceeded 1,000). FoodNet data/estimates were used for methodologic consistency but should be interpreted with caution, as marked geographic and temporal variability (both “true” and artifactual) confound

	attempts to generalize from particular sites and years.
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Pathogen: <i>E. coli</i>, enterotoxigenic (ETEC)	
Estimate	Data source(s)
Number of illnesses	Annual number of ETEC outbreak-associated illnesses reported to CDC’s Foodborne Disease Outbreak Surveillance System (2000–2007) (6); adjusted for underreporting due to surveillance type (see outbreak surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion hospitalized in ETEC outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion who died in ETEC outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	55% based on surveillance data from Minnesota FoodNet site (Minnesota Department of Health, unpublished data). Estimates were based on cases with a known travel history.
Proportion foodborne	Our estimate of the number of illnesses was based on outbreak-associated ETEC illnesses reported to CDC through the Foodborne Disease Outbreak Surveillance System. Because all these outbreaks were foodborne, our estimate of the number of illnesses was based solely on foodborne outbreak-associated illnesses. Therefore, 100% of the estimated number of illnesses was considered foodborne.
Comments	Many sporadic cases are associated with travel to other countries where both water and foodborne exposures are likely.

Pathogen: <i>Escherichia coli</i> O157, Shiga toxin–producing (STEC O157)	
Estimate	Data source(s)
Number of illnesses	Annual incidence of STEC O157 infections reported to CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of STEC O157 infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of STEC O157 infection who died (2005–2008) applied the number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	3.5% based on surveillance data from FoodNet (2005–2008). Cases of STEC O157 infection in FoodNet were queried about international travel in the seven days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	68% based on outbreak-associated illnesses from outbreaks reported to CDC from 1982-2002 (18) for which a mode of transmission was known.

Pathogen: <i>E. coli</i>, Shiga-toxin-producing (STEC), non-O157	
Estimate	Data source(s)
Number of illnesses	Annual incidence of non-O157 STEC reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2). Laboratory testing and test sensitivity multipliers based on evidence that non-O157 STEC is at least as common as STEC O157 (19-21).
Number of hospitalizations	Proportion of FoodNet cases of non-O157 STEC infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of non-O157 STEC infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	18% based on surveillance data from FoodNet (2005–2008). Cases of non-O157 STEC infection in FoodNet were queried about international travel in the seven days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	82% based outbreak-associated illnesses from outbreaks reported to CDC from 1990-2008 (22).
Comments	There is good evidence that, when appropriate laboratory methods are employed, non-O157 STEC infections are as common as STEC O157 infections (19-21). Non-O157 STEC infections are, however, less likely to cause bloody diarrhea (21).

Pathogen: <i>E. coli</i>, diarrheagenic other than STEC and ETEC	
Estimate	Data source(s)
Number of illnesses	Assumed to be as common as ETEC
Number of hospitalizations	Assumed to be as common as ETEC
Number of deaths	Assumed to be as common as ETEC
Proportion travel-related	Assumed to be almost 100% domestically acquired.
Proportion foodborne	Very little data available; a few foodborne outbreaks have been reported. Assumed to be 30% foodborne (10).
Comments	Includes enteropathogenic <i>E. coli</i> , enteroaggregative <i>E. coli</i> , enteroinvasive <i>E. coli</i> , and other poorly defined pathogenic groups. Little data are available on the incidence of these infections in the United States; however, some studies suggest that these pathogens are under-recognized (23, 24).

Pathogen: <i>Giardia intestinalis</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of cases of <i>Giardia intestinalis</i> infection reported to CDC's National Notifiable Disease Surveillance System (NNDSS) (2002–2007) (7); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Estimated based on national estimates of hospital discharge from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) (2002-2006) (25) using ICD-9-CM code 007.1 (Giardiasis) and doubled to adjust for under-diagnosis.
Number of deaths	Estimated based on national estimates of inpatient deaths from NIS (2002-2006) using ICD-9-CM code 007.1 (Giardiasis) and doubled to adjust for under-diagnosis.
Proportion travel-related	8% based on a published study (26).
Proportion foodborne	7% based on outbreaks reported to CDC (CDC, unpublished data).
Comments	<i>Giardia intestinalis</i> only became nationally notifiable in 2002.

Pathogen: Hepatitis A	
Estimate	Data source(s)
Number of illnesses	Annual number of cases of hepatitis A infection reported to CDC's National Notifiable Disease Surveillance System (NNDSS) (2000–2007) (7, 27) with an adjustment for trend (recent years were weighted more heavily) (see online Technical Appendix 3, www.cdc.gov/EID/content/17/1/zzz-Techapp2.pdf); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of hepatitis A cases reported to NNDSS (2001–2007) who were hospitalized applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis. Data from 2001 were used because hospitalizations were more carefully evaluated since 2001.
Number of deaths	Number of deaths estimated using data from the National Center for Health Statistics (NCHS) multiple cause-of-death data from the National Vital Statistics System (28) and doubled to adjust for under-diagnosis.
Proportion travel-related	41% based on enhanced surveillance in 6 US states (2005-2007) (29).
Proportion foodborne	6% based on exposure data from NNDSS (2000-2007).

Pathogen: <i>Listeria monocytogenes</i>	
Estimate	Data source(s)
Number of illnesses	Annual incidence of listeriosis reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2). All invasive cases of listeriosis reported to FoodNet were included (including cases of congenital and acquired listeriosis). A case of invasive listeriosis was defined as isolation of <i>Listeria monocytogenes</i> from a normally sterile site (e.g., blood, cerebrospinal fluid, or amniotic fluid) or from the placenta or products of conception. Mother-infant pairs were counted separately.
Number of hospitalizations	Proportion of FoodNet cases of <i>Listeria monocytogenes</i> infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of <i>Listeria monocytogenes</i> infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	3% based on surveillance data from FoodNet (2005–2008). Cases of listeriosis in FoodNet were queried about international travel in the 30 days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	Almost 100%. Microbiologic and epidemiologic data demonstrate that food is the source of infection almost all cases (30-34).
Comments	<i>Listeria monocytogenes</i> can cause febrile gastroenteritis (35), but these illnesses are rarely diagnosed, at least partly because clinical laboratories do not routinely test stool specimens for <i>Listeria</i> . Listeriosis can result in spontaneous abortion or miscarriage; these infections may also be under-represented here.

Pathogen: <i>Mycobacterium bovis</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of cases of tuberculosis reported to CDC's National Tuberculosis Surveillance System (NTSS) (2004–2007) (36); adjusted for the proportion of tuberculosis attributable to <i>Mycobacterium bovis</i> (37) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Limited data available on <i>Mycobacterium bovis</i> . Proportion hospitalized assumed to be 55% based on a study of hospitalizations among persons with tuberculosis (38).
Number of deaths	Limited data available on <i>Mycobacterium bovis</i> . Assumed to be equal the proportion of tuberculosis cases reported to NTSS (2004–2007) who died.
Proportion travel-related	Limited data available on <i>Mycobacterium bovis</i> . The majority of persons who have tuberculosis come from countries where the infection is prevalent in cattle and where they presumably acquired infection (39). 70% of cases assumed to be travel-related.
Proportion foodborne	Most cases (95%) assumed to be foodborne (39). Historically, <i>Mycobacterium bovis</i> disease in humans was associated with consumption of unpasteurized milk from infected cattle. Successful <i>Mycobacterium bovis</i> eradication programs have nearly eradicated the disease in industrialized countries. In the United States, the disease is almost exclusively confined to Mexican-born adults and US-born Hispanic children. <i>Mycobacterium bovis</i> is still found in Mexican dairy herds and one study reported that consumption of Mexican dairy products, especially cheese and cream, is common among patients with <i>Mycobacterium bovis</i> infection (39).
Comment	Nationally, 1.4% of TB cases were attributed to <i>Mycobacterium bovis</i> . However, in the San Diego, California the incidence of <i>Mycobacterium bovis</i> has been noted to be increasing. In a retrospective analysis of TB case surveillance data between 1994 and 2005, the annual proportion of culture-positive TB cases attributed to <i>Mycobacterium bovis</i> increased from 5 to 11%. From 2001-2005, <i>Mycobacterium bovis</i> accounted for 10% of reported cases (40).

Pathogen: Norovirus	
Estimate	Data source(s)
Number of illnesses	<ul style="list-style-type: none"> • Proportion of acute gastroenteritis due to norovirus (11%) estimated from studies in the Netherlands (41), England and Wales (42, 43), and Australia (44) was applied to the estimated number of acute gastroenteritis illnesses in the United States. • Rate of acute gastroenteritis illnesses in the United States was estimated using combined data from FoodNet Population Surveys in 2000–2001, 2002–2003, and 2006–2007 (CDC, unpublished data). The FoodNet Population Surveys are random-digit-dial telephone surveys of the general FoodNet population conducted over 12-month periods. Information was collected on episodes of gastrointestinal symptoms in the past month. Methods are described in detail elsewhere (45). • Average annual rate of acute gastroenteritis was derived by multiplying the average monthly prevalence by 12, where an episode of acute gastroenteritis was defined as diarrhea (≥ 3 loose stools in 24 hours) or vomiting in the past month with both lasting >1 day or resulting in restricted daily activities. Persons with a chronic condition in which diarrhea or vomiting was a major symptom and persons with concurrent symptoms of cough or sore throat were excluded. Data were weighted to compensate for unequal probabilities of selection and to reflect the surveillance population by age and sex. • Number of acute gastroenteritis illnesses was estimated by applying the average rate of acute gastroenteritis from the combined surveys (0.6 episodes per person per year) to the 2006 US Census population estimate (299 million persons) (3). The rate from individual surveys was 0.49 (2000-2001), 0.54 (2002-2003), and 0.73 episodes per person per year (2006-2007).
Number of hospitalizations	<ul style="list-style-type: none"> • Proportion of acute gastroenteritis due to norovirus (11%) estimated from studies in the Netherlands (41), England and Wales (42, 43), and Australia (44) was applied to the estimated number of acute gastroenteritis hospitalizations in the United States. The decision to apply this proportion to hospitalizations was supported by published studies (46, 47). • The hospitalization rate for acute gastroenteritis was estimated using 2000-2006 data from three sources:

	1) CDC’s National Center for Health Statistics (NCHS) National Hospital Discharge System (NHDS) (48, 49)
Estimate	Data source(s)
	<p>2) Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) (25); and</p> <p>3) Combined data from CDC’s NCHS National Ambulatory and National Hospital Ambulatory Medical Care Surveys (NAMCS/NHAMCS) (50)</p> <ul style="list-style-type: none"> • The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes were used to extract hospital discharges from NHDS and NIS where acute gastroenteritis was listed as one of the first three diagnoses. Acute gastroenteritis was defined as ICD-9-CM diagnostic codes 001–008 (infectious gastroenteritis of known cause); 009 (infectious gastroenteritis); 558.9 (other and unspecified noninfectious gastroenteritis and colitis); or 787.9 (other symptoms involving digestive system: diarrhea); excluding 008.45 (<i>Clostridium difficile</i> colitis) and 005.1 (botulism). Hospital discharge records were selected on the basis of the first three listed diagnoses as a compromise between limiting the analysis to hospitalizations where acute gastroenteritis was listed as the primary cause and including all hospitalizations in which it was listed. This approach has been taken in other studies (51, 52). National estimates from NHDS and NIS were obtained for each year (2000-2006) by weighting the sample data according to the NCHS and HCUP criteria. • To estimate acute gastroenteritis hospitalizations from NAMCS/NHAMCS from 2000-2006, we combined data across the two surveys and extracted patient visits to clinical settings, including physician offices, hospital emergency and outpatient departments with a diagnosis of acute gastroenteritis resulting in hospitalization. Acute gastroenteritis was defined using the same ICD-9-CM codes as described above for NHDS and NIS. Hospitalization rates for each year were obtained by weighting the sample data according to the NCHS criteria. • We estimated the number of hospitalizations by applying the mean (166 per 100,000) of these 21 annual hospitalization rates to the 2006 US Census population estimate. The mean rate from 2000-2006 NHDS data was 203 per 100,000 persons; the mean rate from 2000-2006 NIS data was 187 per 100,000, the rate from combined NAMCS/NHAMCS data was 109 per 100,000 persons.

Pathogen: Norovirus (continued)	
Estimate	Data source(s)
Number of deaths	<ul style="list-style-type: none"> • Proportion of acute gastroenteritis due to norovirus (11%) estimated from studies in the Netherlands (41), England and Wales (42, 43), and Australia (44) was applied to an estimate of the number of acute gastroenteritis deaths in the United States. • The death rate for acute gastroenteritis was estimated using multiple cause-of-death data from the National Vital Statistics System (2000–2006) (28, 53) where acute gastroenteritis was listed as the underlying or a contributing cause. Acute gastroenteritis was defined as ICD-10 diagnostic codes A00.9–A08.5 (infectious gastroenteritis of known cause); A09 (diarrhea and gastroenteritis of presumed infectious origin); and K52.9 (noninfectious gastroenteritis and colitis, unspecified)]; excluding A04.7 (enterocolitis due to <i>Clostridium difficile</i>) and A05.1 (botulism). • We estimated the number of acute gastroenteritis deaths by applying the mean death rate from 2000-2006 (1.5 per 100,000 population) to the 2006 US Census population estimate.
Proportion travel-related	<ul style="list-style-type: none"> • Important cause of traveler’s diarrhea, but this proportion is estimated to be small (<1% of illnesses) given the large number of domestically acquired illnesses and the short incubation period.
Proportion foodborne	<ul style="list-style-type: none"> • Based on 179 norovirus outbreaks examined by CDC from 2000-2005. Of 13,944 persons ill, 3,628 (26%) were in foodborne outbreaks (CDC, unpublished data).

Pathogen: Rotavirus	
Estimate	Data source(s)
Number of illnesses	We assumed that 75% of children experience an episode of clinical illness due to rotavirus by 5 years of age based on a published study (2). The person-time at risk for 2006 was estimated as the 0-4 year population (20,417,636) divided by 5 and rounded (4,084,000) (3).
Number of hospitalizations	Based on published studies (2).
Number of deaths	Very low: 20 to 40 deaths per year (2).
Proportion travel-related	Assumed to be almost 100% domestically acquired since international travel-associated illness among young children is likely small compared to the domestic burden.
Proportion foodborne	Assumed to be very low (<1% of illnesses) based on the number of foodborne outbreaks reported to CDC (6)

Pathogen: <i>Salmonella enterica</i>, non-typhoidal serotypes	
Estimate	Data source(s)
Number of illnesses	Annual incidence of salmonellosis reported to CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005–2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2). In all analyses in this paper, serotype Paratyphi is grouped with non-typhoidal <i>Salmonella</i> .
Number of hospitalizations	Proportion of FoodNet cases of non-typhoidal <i>Salmonella</i> infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of non-typhoidal <i>Salmonella</i> infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	11% based on surveillance data from FoodNet (2005–2008). Cases of non-typhoidal <i>Salmonella</i> infection in FoodNet were queried about international travel in the seven days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	94% based on FoodNet case-control study of sporadic illness (54) and outbreaks reported to CDC from 1996–2006 (CDC, unpublished data). In the FoodNet study, 6% of cases of non-typhoidal <i>Salmonella</i> infections were attributed to reptile exposure; questions were asked about other animals and water, but no illnesses were attributed to these exposures. Adding all of the outbreak-associated illnesses reported to CDC from 1996–2006, 96% were associated with foodborne transmission, 3% with animal contact, and 1% with water. Considering all of these sources, we chose 94% as the proportion foodborne.
Comments	Although also associated with exposure to reptiles, contaminated water, and other sources, non-typhoidal <i>Salmonella</i> is primarily a foodborne disease.

Pathogen: <i>Salmonella enterica</i> serotype Typhi	
Estimate	Data source(s)
Number of illnesses	Annual incidence of <i>Salmonella</i> serotype Typhi infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of serotype Typhi infections hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of serotype Typhi infections that died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	67% based on surveillance data from FoodNet (2005–2008). Cases of serotype Typhi infection in FoodNet were queried about international travel in the 30 days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	76% (13/17) of all domestically acquired outbreaks reported to the CDC between 1980 and 1999 were foodborne; 100% (13/13) of outbreaks with a known route of transmission (55).
Comments	Although waterborne and sexually transmitted outbreaks have been reported in the United States, foodborne transmission is believed to account for most cases.

Pathogen: Sapovirus	
Estimate	Data source(s)
Number of illnesses	We assumed that 75% of children experience an episode of clinical illness due to sapovirus by 5 years of age similar to other childhood gastroenteritis viruses such as rotavirus (2). The person-time at risk for 2006 was estimated as the 0-4 year population (20,417,636) divided by 5 and rounded (3).
Number of hospitalizations	Assumed to equal 25% of number of hospitalizations for rotavirus.
Number of deaths	Very low: 0-10 deaths per year.
Proportion travel-related	Assumed to be almost 100% domestically acquired since international travel-associated illness among children is likely small compared to the domestic burden.
Proportion foodborne	Significant illness assumed to occur only among children <5 years of age, although very occasionally foodborne; very few foodborne outbreaks reported (<1% of illnesses) (6).

Pathogen: <i>Shigella</i> spp.	
Estimate	Data source(s)
Number of illnesses	Annual incidence of shigellosis reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of <i>Shigella</i> spp. infection hospitalized (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of <i>Shigella</i> spp. infection who died (2005–2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	15% based on surveillance data from FoodNet (2005–2008). Cases of <i>Shigella</i> spp. infection in FoodNet were queried about international travel in the seven days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	31% based on 2005 FoodNet survey of risk factors for sporadic shigellosis. Persons who responded negatively to all risk-exposure questions were considered to represent an estimate of the proportion of sporadic shigellosis infections that may have been acquired through consumption of contaminated food in the United States (56).

Pathogen: <i>Staphylococcus aureus</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of <i>Staphylococcus aureus</i> outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000–2007) (6) with an adjustment for trend (recent years were weighted more heavily) (see online Technical Appendix 3); adjusted for underreporting due to surveillance type (see outbreak surveillance underreporting multiplier described in online Technical Appendix 3 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion hospitalized in outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion who died in outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Because of the rapid onset and short duration of illness, we assumed that 100% of <i>Staphylococcus aureus</i> illnesses occurring in the United States were domestically acquired.
Proportion foodborne	Our estimate of the number of illnesses was based on outbreak-associated <i>Staphylococcus aureus</i> illnesses reported to CDC through the Foodborne Disease Outbreak Surveillance System. Because all these outbreaks were foodborne, our estimate of the number of illnesses was based solely on foodborne outbreak-associated illnesses. Therefore, 100% of the estimated number of illnesses was considered foodborne.

Pathogen: <i>Streptococcus</i> spp., Group A	
Estimate	Data source(s)
Number of illnesses	Annual number of <i>Streptococcus</i> spp., Group A outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (1996-2007) (6); adjusted for underreporting due to surveillance type (see outbreak surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2). Data from 1996-2007 used because of a paucity of data.
Number of hospitalizations	Proportion hospitalized in <i>Streptococcus</i> spp., Group A outbreaks reported to the Foodborne Disease Outbreak Surveillance System (1981-2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis. Data from 1981-2007, included 12 years when outbreaks occurred.
Number of deaths	Proportion who died in <i>Streptococcus</i> spp., Group A outbreaks reported to the Foodborne Disease Outbreak Surveillance System (1981-2007) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis. Data from 1981-2007, included 12 years when outbreaks occurred.
Proportion travel-related	Because of the rapid onset and short duration of <i>Streptococcus</i> spp., Group A illnesses, we assumed that 100% of <i>Streptococcus</i> spp., Group A illnesses occurring in the United States are domestically acquired.
Proportion foodborne	Our estimate of the number of illnesses was based on outbreak-associated <i>Streptococcus</i> spp., Group A illnesses reported to CDC through the Foodborne Disease Outbreak Surveillance System. Because all these outbreaks were foodborne, our estimate of the number of illnesses was based solely on foodborne outbreak-associated illnesses. Therefore, 100% of the estimated number of illnesses was considered foodborne.

Pathogen: <i>Toxoplasma gondii</i>	
Estimate	Data source(s)
Number of illnesses	Illnesses due to <i>Toxoplasma gondii</i> were estimated using nationally representative serologic data from the National Health and Nutrition Examination Survey (NHANES) (1999-2004) (57) and an estimate of seroconversion associated with clinical illness. The annual number of illnesses was modeled as the estimated symptomatic fraction of the estimated number of incident cases within the US population during a 1-year period. Incident cases were estimated using NHANES prevalence data. Specifically, the estimated prevalence for person aged 40-49 years reported in Jones <i>et al.</i> (57) was assumed to be the cumulative result of 45 years of constant incidence. The symptomatic fraction was estimated to be 15% (58).
Number of hospitalizations	Estimated based on national estimates of hospital discharge from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) (2000-2006) (25) using ICD-9-CM code 130 (Toxoplasmosis) and doubled to adjust for under-diagnosis.
Number of deaths	Estimated based on national estimates of inpatient deaths from NIS (2000-2006) using ICD-9-CM code 130 (Toxoplasmosis) and doubled to adjust for under-diagnosis.
Proportion travel-related	Assumed to be 100% domestically acquired.
Proportion foodborne	50% based on published studies (59, 60).
Comments	Although the proportion associated with eating contaminated food varies geographically, we assume an overall average of 50% (59, 60).

Pathogen: <i>Trichinella</i> spp.	
Estimate	Data source(s)
Number of illnesses	Annual number of cases of <i>Trichinella</i> spp. infection reported to CDC's National Notifiable Disease Surveillance System (NNDSS) (2000–2007) (7, 61); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion hospitalized in <i>Trichinella</i> spp. outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000–2007) (6) applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	0.2% based on published study (62).
Proportion travel-related	4% based on surveillance data (61).
Proportion foodborne	Assumed to be 100% foodborne based on a published study (63).

Pathogen: <i>Vibrio cholerae</i>, toxigenic	
Estimate	Data source(s)
Number of illnesses	Annual number of toxigenic <i>Vibrio cholerae</i> illnesses reported to CDC’s Cholera and Other <i>Vibrio</i> Illness Surveillance System (COVIS) (2000–2007) (64) with an adjustment for trend (recent years were weighted more heavily) (see online Technical Appendix 3; adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2). Non-toxigenic <i>Vibrio cholerae</i> infections are included in “ <i>Vibrio</i> spp., other”.
Number of hospitalizations	Proportion of cases of toxigenic <i>Vibrio cholerae</i> infection reported to COVIS (2000-2007) who were hospitalized applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of cases of toxigenic <i>Vibrio cholerae</i> infection reported to COVIS (2000-2007) who died applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Proportion of travel-related cases reported to COVIS (2000–2007). Cases were queried about international travel before in the seven days before their illness began. Estimates were based on those with a known travel history.
Proportion foodborne	100% of these cases reported to COVIS (2000–2007) were classified as foodborne.
Comments	FoodNet conducts surveillance for <i>Vibrio</i> infections; however, because of the geographical clustering of cases of <i>Vibrio</i> infection in non-FoodNet states, CDC’s passive <i>Vibrio</i> surveillance system, COVIS, was used.

Pathogen: <i>Vibrio vulnificus</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of <i>Vibrio vulnificus</i> illnesses reported to CDC's Cholera and Other <i>Vibrio</i> Illness Surveillance System (COVIS) (2000–2007) (64) with an adjustment for trend (recent years were weighted more heavily) (see online Technical Appendix 3); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS (2000–2007) who were hospitalized applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS (2000–2007) who died applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Proportion of travel-related cases reported to COVIS (2000–2007). Cases were queried about international travel in the seven days before their illness began. Estimates were based on those with a known travel history.
Proportion foodborne	Proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS (2000–2007) that were classified as foodborne.
Comments	FoodNet conducts surveillance for <i>Vibrio</i> infections; however, because of the geographical clustering of cases of <i>Vibrio</i> infection in non-FoodNet states, CDC's passive <i>Vibrio</i> surveillance system, COVIS, was used.

Pathogen: <i>Vibrio parahaemolyticus</i>	
Estimate	Data source(s)
Number of illnesses	Annual number of <i>Vibrio parahaemolyticus</i> illnesses reported to CDC's Cholera and Other <i>Vibrio</i> Illness Surveillance System (COVIS) (2000–2007) (64) with an adjustment for trend (recent years were weighted more heavily) (see online Technical Appendix 3; adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of cases of <i>Vibrio parahaemolyticus</i> infection reported to COVIS (2000-2007) who were hospitalized applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of cases of <i>Vibrio parahaemolyticus</i> infection reported to COVIS (2000-2007) who died applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Proportion of travel-related cases reported to COVIS (2000–2007). Cases were queried about international travel before their illness began. Estimates were based on those with a known travel history.
Proportion foodborne	Proportion of <i>Vibrio parahaemolyticus</i> cases reported to COVIS (2000–2007) were classified as foodborne.
Comments	FoodNet conducts surveillance for <i>Vibrio</i> infections; however, because of the geographical clustering of cases of <i>Vibrio</i> infection in non-FoodNet states, CDC's passive <i>Vibrio</i> surveillance system, COVIS, was used.

Pathogen: <i>Vibrio</i> spp., other	
Estimate	Data source(s)
Number of illnesses	Annual number of <i>Vibrio</i> illnesses other than toxigenic <i>Vibrio cholerae</i> , <i>Vibrio vulnificus</i> , and <i>Vibrio parahaemolyticus</i> illnesses to CDC's Cholera and Other <i>Vibrio</i> Illness Surveillance System (COVIS) (2000-2007) (64) with an adjustment for trend (recent years were weighted more heavily) (see online Technical Appendix 3); adjusted for underreporting due to surveillance type (see passive surveillance underreporting multiplier described in online Technical Appendixes 2 and 4) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of cases of <i>Vibrio</i> infection other than toxigenic <i>Vibrio cholerae</i> , <i>Vibrio vulnificus</i> , and <i>Vibrio parahaemolyticus</i> reported to COVIS (2000–2007) who were hospitalized applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of cases of <i>Vibrio</i> infection other than toxigenic <i>Vibrio cholerae</i> , <i>Vibrio vulnificus</i> , and <i>Vibrio parahaemolyticus</i> reported to COVIS (2000–2007) who died applied to the estimated number of reported illnesses (after adjusting for underreporting) and doubled to adjust for under-diagnosis.
Proportion travel-related	Proportion of travel-related cases reported to COVIS (2000-2007). Cases were queried about international travel before their illness began. Estimates were based on those with a known travel history.
Proportion foodborne	Proportion of <i>Vibrio</i> infection other than toxigenic <i>Vibrio cholerae</i> , <i>Vibrio vulnificus</i> , and <i>Vibrio parahaemolyticus</i> reported to COVIS (2000–2007) that were classified as foodborne.
Comments	FoodNet conducts surveillance for <i>Vibrio</i> infections; however, because of the geographical clustering of cases of <i>Vibrio</i> infection in non-FoodNet states, CDC's passive <i>Vibrio</i> surveillance system, COVIS, was used.

Pathogen: <i>Yersinia enterocolitica</i>	
Estimate	Data source(s)
Number of illnesses	Annual incidence of <i>Yersinia enterocolitica</i> infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) sites (2005-2008) (11); adjusted for geographical coverage (FoodNet is in 10 sites around the United States) and under-diagnosis resulting from the following surveillance steps: medical care seeking, specimen submission, laboratory testing, and test sensitivity (see online Technical Appendix 2).
Number of hospitalizations	Proportion of FoodNet cases of <i>Yersinia enterocolitica</i> infection hospitalized (2005-2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Number of deaths	Proportion of FoodNet cases of <i>Yersinia enterocolitica</i> infection who died (2005-2008) applied the estimated number of reported cases (after adjusting for geographical coverage) and doubled to adjust for under-diagnosis.
Proportion travel-related	7% based on surveillance data from FoodNet (2005-2008). Cases of <i>Yersinia enterocolitica</i> infection in FoodNet were queried about international travel in the seven days before illness began. Estimates were based on cases with known travel history.
Proportion foodborne	We assumed that 90% of cases were foodborne based on limited data from published studies (65).
Comments	Nearly all reported outbreaks in United States have been linked to contaminated foods.

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Foodborne Illness Acquired in the United States—Major Pathogens

Technical Appendix 2

Model Structures Used to Make Estimates

Background

Our choices for model structures were derived from a viewpoint about how to combine basic data on counts of illness, hospitalizations, and deaths with objective and subjective knowledge of the processes that might link those data to the true burden of illnesses, hospitalizations, and deaths. The following explanation describes our general approach and philosophy, and some of the key choices we made in assigning distributions. We started with the basic observation that the process of estimating the burden of foodborne illness requires using many disparate data sources and making subjective decisions about how to combine them. Therefore, we considered it important to take account of both statistical and non-statistical uncertainty.

We chose the 4-parameter beta distribution as our basic descriptive distribution because it allowed us to specify a minimum, maximum, and modal value, as well a fourth parameter that controls the spread (variance) of the distribution within those limits. This family of distributions is widely used in problems of expert elicitation and risk assessment, particularly in the forms known as the PERT distribution and the Modified PERT distribution (*1*). (We use PERT to refer to both the PERT and Modified PERT distributions). Because of the intuitive nature of its inputs, it is an attractive choice for problems in which many estimates and sources of uncertainty need to be combined.

Naturally, much of the source data for our estimates was in the form of counts. We found that using standard parametric distributions, such as the Poisson and Negative Binomial families, to describe our count data generally masked important features, such as left-skewness and multimodality. We decided to use nonparametric descriptions instead, and extended that choice

to other data, such as observed proportions, as indicated in online Technical Appendix 3 (www.cdc.gov/EID/content/17/1/7-Techapp3.pdf). Typically, we chose to use empirical distributions in describing surveillance data and data that had features that we thought should not be smoothed via summary reduction; the 4-parameter beta was used in situations that incorporated multiple distinct subjective elements. For example, we often combined multiple values from published literature, and wanted to incorporate their reported and often unreported statistical uncertainties, and the non-statistical uncertainties associated with their differing data sources and methodologies. Our choice to preserve features of the data using empirical distributions is discussed further below.

Much of the data we used could have been treated as if they were derived from simple sampling models; in statistical terms, we could have assumed that observations were identically distributed and independent. For example, the FoodNet surveillance data for a given pathogen for 2005-2008 might be aggregated to annual counts and the resulting 4 counts treated as a random sample from the target population. The same approach might be applied to the annual outbreak-associated case counts, and the annual national surveillance case counts (online Technical Appendix 1, www.cdc.gov/EID/content/17/1/7-Techapp1.pdf). We could treat uncertainty in the usual statistical sense and operate, for example, with standard errors calculated as estimated population standard deviations divided by square roots of sample sizes.

We chose not to treat uncertainty in that way. The above approach makes two suspect assumptions. First, it assumes that the aggregated data represent a single sample of multiple counts from a homogeneous population (as opposed to a set of single count samples from distinct annual populations with different characteristics). This is the identically distributed part. Second, it assumes that the single sample is a random sample. This is the independently distributed part. While these assumptions might be approximately valid for some of our data, our historical experience with both our own and other surveillance and survey data, input from experts, and an examination of the data themselves, have convinced us that these assumptions are not likely to be valid in most cases. Moreover, we have no reliable way to distinguish those for which these assumptions are valid.

Therefore, we chose to treat, for example, an outbreak case count series of 8 years as representing 8 distinct population means which likely span the unknown mean of the target

population. This leads to an estimate that is still the mean of the observed data, but with an uncertainty described by the standard deviation of that data, and not a nominal standard error. In keeping with this idea that the data do not necessarily directly represent the characteristic being estimated, we chose to use empirical distributions as descriptions, thus preserving individual data points. We extended this approach beyond surveillance data to the population surveys and other data sources. Every data source indicated in Table 1 reflects multiple years of data collection, except for the Census data which identifies the target 2006 US resident population. [Even that has some visible uncertainty associated with it, in that one might argue to include or exclude non-resident or institutionalized or military populations, under specific circumstances.]

The outputs of our models are summarized by features of posterior distributions calculated by Monte Carlo simulation. While we were not able to perform a complete analysis of the uncertainty associated with the simulation itself (Monte Carlo error), the 100,000 replicate uniform basis for our distributions appears to generally achieve an error of less than 0.5% and frequently less than 0.1%, based on examining multiple simulations for non-typhoidal *Salmonella* and *Giardia*.

Model structures

We used different modeling structures, depending on data type, to estimate the total number of illnesses, hospitalizations, and deaths due to 31 known foodborne pathogens.

The model structures are of the following two broad types:

- Model type A: This model scales counts of laboratory-confirmed (reported) illnesses up to an estimated number of ill persons, accounting for underreporting and under-diagnosis factors that contribute to an illness not being reported to public health agencies (Box 1).
- Model type B: This model scales populations at risk down to an estimated number of ill persons (Box 2).

All models described here are multiplicative; successive factors are applied by multiplication to obtain proportional increases or decreases in the count. This tends to produce wider ranges in the final distribution estimates than additive models.

Each of these models has subtypes that reflect the available data. The figures describe mathematical multipliers in the key models. Figures 2, 2a, 3 and 5 consist of a series of histograms that describe the distributions of simulated individual multiplicative factors as they are successively applied to elements of the burden estimates. More details on the variations applied to these models are described in online Technical Appendix 3.

Multiplication of distributions is accomplished using Monte Carlo simulation. Simulation of the empirical distributions corresponds to simple nonparametric bootstrapping (2), which is the random re-sampling of observed data, with replacement, to obtain a series of new samples that simulate the variability in the original chance process that gave rise to the data. Bootstrapping provides the initial link to the approximate Bayesian interpretation of the model outputs (3,4).

Box 1: Pathogens for which laboratory-confirmed illnesses were scaled up to estimate the total number of illnesses		
Active surveillance data	Passive surveillance data	Outbreak surveillance data
<ul style="list-style-type: none"> • <i>Campylobacter</i> spp. • <i>Cryptosporidium</i> spp. • <i>Cyclospora cayetanensis</i> • <i>Escherichia coli</i>, Shiga toxin-producing (STEC) O157 • <i>E. coli</i>, Shiga toxin-producing (STEC), non-O157 • <i>Listeria monocytogenes</i> • <i>Salmonella</i>, non-typhoidal • <i>Salmonella</i> serotype Typhi • <i>Shigella</i> spp. • <i>Yersinia enterocolitica</i> 	<ul style="list-style-type: none"> • <i>Brucella</i> spp. • <i>Clostridium botulinum</i>, foodborne • <i>Giardia intestinalis</i> • Hepatitis A • <i>Mycobacterium bovis</i> • <i>Trichinella</i> spp. • <i>Vibrio cholerae</i>, toxigenic • <i>Vibrio parahaemolyticus</i> • <i>Vibrio vulnificus</i> • <i>Vibrio</i> spp., other 	<ul style="list-style-type: none"> • <i>Bacillus cereus</i> • <i>Clostridium perfringens</i> • <i>E. coli</i>, enterotoxigenic (ETEC)* • <i>Staphylococcus aureus</i> • <i>Streptococcus</i> spp., Group A

* *E. coli*, other than STEC or ETEC assumed to be equal to ETEC (online Technical Appendix 3)

<p>Box 2: Pathogens for which populations were scaled down to estimate the total number of illnesses</p> <ul style="list-style-type: none"> • Astrovirus • Norovirus • Rotavirus • Sapovirus • <i>Toxoplasma gondii</i>

Figure 1 provides a schematic representation of the modeling process for pathogens for which reported counts of illness are scaled up. Some factors in the schematic are stochastic (*italic font*) and some factors are deterministic (**bold font**). Some factors are applied generally and some are applied as needed, depending on data source.

Note that the schematic shows 6 primary model outputs, as identified in the box at the right and obtained by inclusion of specific elements from the rightmost two model factors, column (1or H or D) and row (1 or F). For example, choice of D and F yields the output for

foodborne deaths. Each factor represents a probability distribution, either an empirical distribution based on observed or estimated data, or a parametric distribution. Details of the choices made to define these distributions are provided in online Technical Appendix 3. The model outputs are the resulting probability distributions from the multiplication of the component factor distributions. All factors for a given output are stochastically independent except for those making up the two-part mixture of mild and severe illness.

Figure 1: Schematic illustration of model type A, which scales case counts up

$$Count \times \begin{bmatrix} \text{Year} \\ \&/\text{or} \\ \text{Geo} \end{bmatrix} \times Dom \times Und \times Ob \times \left\{ \begin{array}{c} CS(Severe) \times SS(Severe) \times PS \\ + \\ CS(Mild) \times SS(Mild) \times (1 - PS) \end{array} \right\} \times LT \times LS \times \begin{bmatrix} \mathbf{1} \\ \text{or} \\ H \\ \text{or} \\ D \end{bmatrix} \times \overline{\mathbf{1} \text{ or } F} \Rightarrow$$

<i>Illnesses</i>	<i>Foodborne Illnesses</i>
<i>Hospitalizations</i>	<i>Foodborne Hospitalizations</i>
<i>Deaths</i>	<i>Foodborne Deaths</i>

Where:

Count refers to data in the form of cases of reported illnesses.

Year is a deterministic factor to standardize non-2006 counts to 2006. Applied as needed

Geo is a deterministic expansive factor to scale FoodNet counts up to the entire US population. Applied as needed.

Dom is a contractive factor to scale total counts down to counts that are domestically acquired. Applied as needed.

Und is an expansive factor to scale passive surveillance case counts up to active surveillance counts. Applied as needed.

Ob is an expansive factor to scale outbreak case counts up to laboratory confirmed counts. Applied as needed.

CS is an expansive factor to scale care seekers up to all ill, with severe and mild illness versions.

SS is an expansive factor to scale submitted samples up to all ill visits, with severe and mild illness versions.

PS is the proportion of actual illness that is severe.

LT is an expansive factor to scale tests performed up to samples submitted.

LS is an expansive factor to scale positive tests up to true positive specimens.
 H is a contractive factor to scale illnesses down to hospitalized illnesses.
 D is a contractive factor to scale illnesses down to deaths.
 F is a contractive factor to scale overall counts down to counts that are foodborne.

Figures 2, 2a, and 3 illustrate the stochastic model structures for *Campylobacter*, which provides an example of a pathogen for which reported cases are scaled up.

Figure 2: Model distributions for *Campylobacter* illnesses. The histogram of observed laboratory-confirmed illnesses reflects annual counts from each of the 10 sites in the FoodNet catchment from 2005 to 2008.

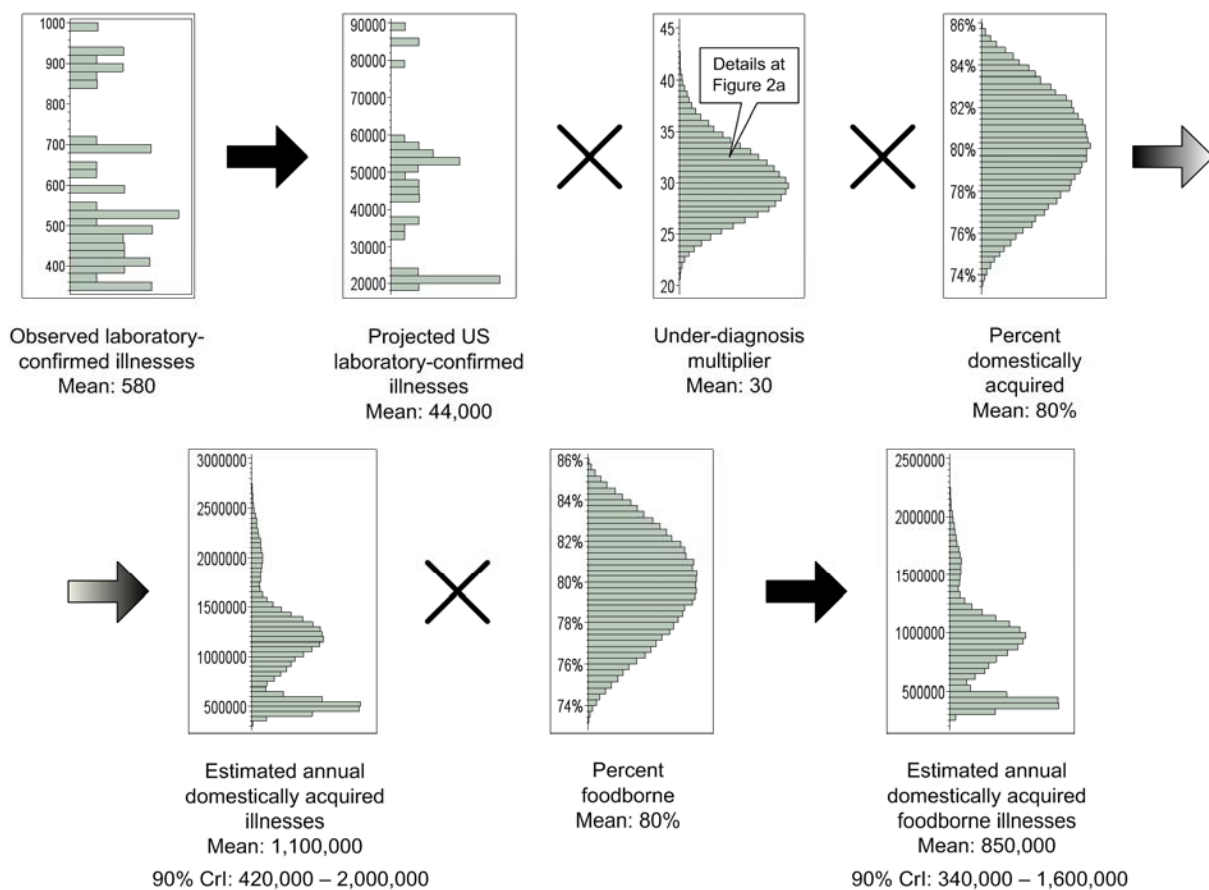


Figure 2a: Detailed structure of under-diagnosis multiplier for *Campylobacter* illnesses

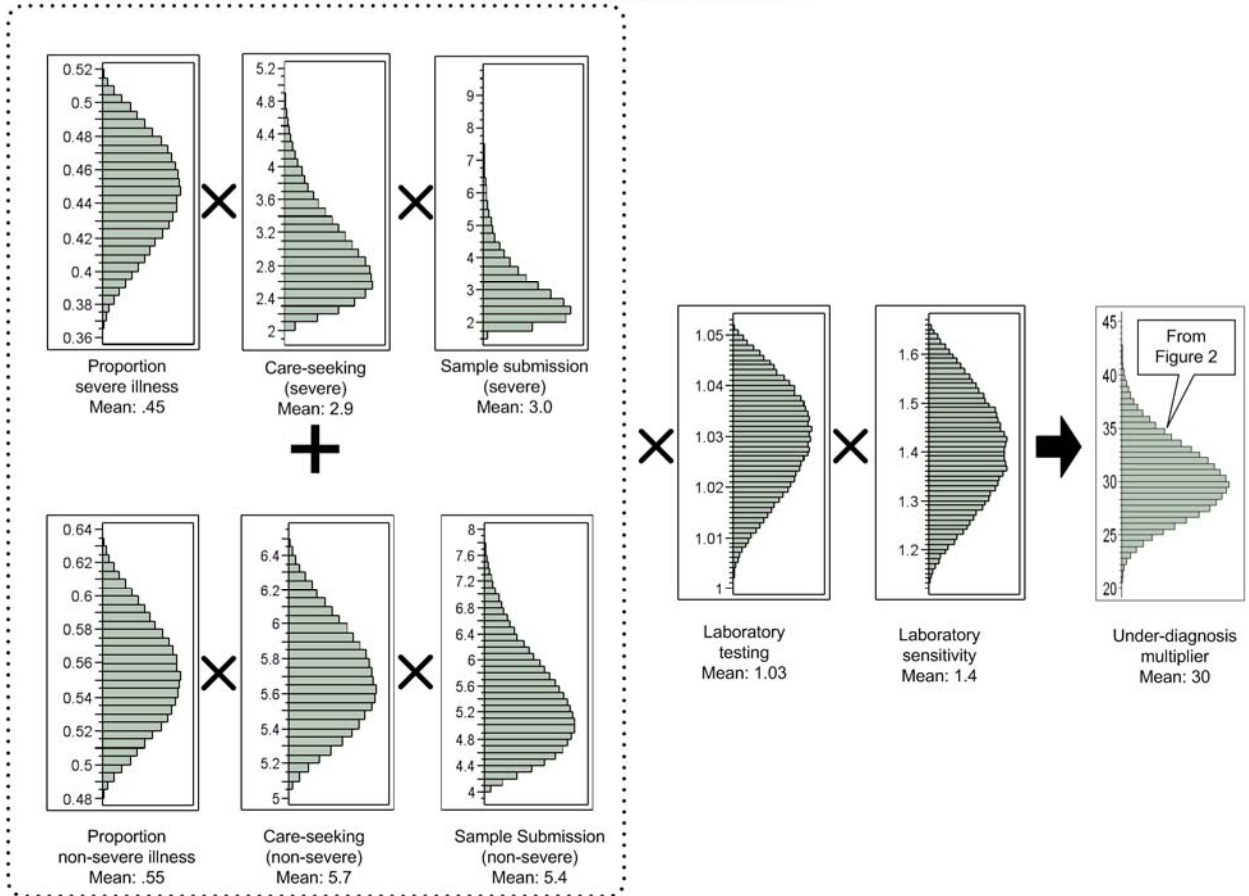
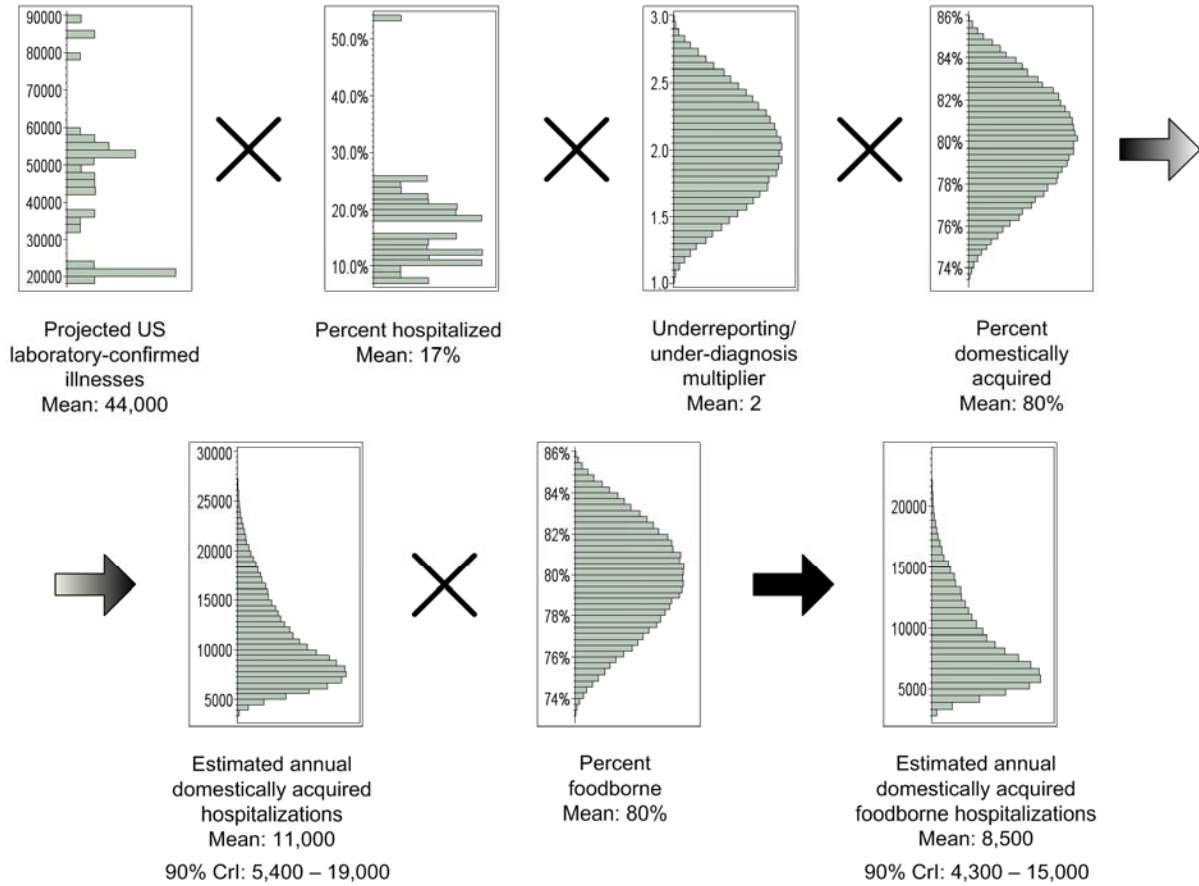


Figure 3: Model distributions for *Campylobacter* hospitalizations. Note that the first histogram shown is that of projected US laboratory-confirmed illnesses rather than observed laboratory-confirmed illnesses, as in Figure 2.



The empirical nature of the source data is apparent in the first panel of Figure 2, as is the parametric nature of the other factors. Note the complex multimodal nature of the output distribution of foodborne illnesses, a common feature among the pathogens whose burden is scaled up from reported cases. The best way to summarize the distribution is not obvious, e.g. mean, median, mode, or some more complex aggregating function of the data. We chose to summarize using the mean and the limits of a 90% credible interval (Tables 2 and 3 of the manuscript). The mode is obviously not possible. The mean is the most familiar measure and has the property that, under independence, the mean of the product is equal to the product of the means, which is not true of the median. That property makes the results of the analysis more transparent. We decided that by using both the mean and quantiles, we capture a broad picture of the distribution, applicable across a wide array of distributional shapes. Note that we treat the output distribution as a Bayesian posterior distribution. While our analysis is not fully Bayesian in that a full likelihood is not specified, bootstrapping of observed sample data has a

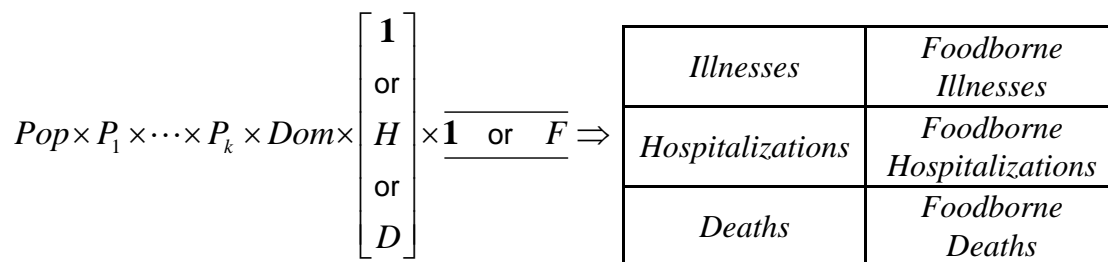
nonparametric Bayesian interpretation and many other elements of the models can be viewed as variously elicited prior distributions or even empirical Bayes posterior distributions. The other FoodNet pathogens from Box 1 were modeled in the same way. Each reported illness in the FoodNet data carries a field for whether the illness was outbreak-related, involved international travel, included hospitalization, and included death. Whether the illness occurred as part of a reported outbreak was determined for all FoodNet pathogens for 2004-2008. Travel status, hospitalization status, and death status were missing sufficiently often to warrant treatment, although some FoodNet sites had negligible missingness across most pathogens. Comparisons between FoodNet sites with differing levels of missingness suggested that an assumption of missingness at random (MAR) was reasonable, and so all three variables were treated so. That is, the status of each variable was predicted based on the relative proportions observed in cases for which that variable was not missing. Because missingness of travel status was high and variable, we used a PERT distribution based on overall known pathogen travel proportions and a generic uncertainty. For each pathogen's hospitalizations and deaths we predicted the value of missing status using the known proportions at the level of year and FoodNet site (i.e., the aggregation level of the FoodNet data chosen for all analyses), at each iteration of the bootstrap. (See Figure 3 panels for percent hospitalized and percent domestically acquired). We note two specific additional issues involving missingness. Six percent of *Salmonella* specimens were either not serotyped or only partially serotyped. We classified them as *Salmonella*, non-typhoidal because less than 1% of serotyped *Salmonella* were serotype Typhi. Relative to an MAR assumption, the potential bias from this decision would be expected to be on the order of 0.05%, negligible relative to the other sources of uncertainty in the *Salmonella* model. Eight percent of specimens of *Yersinia* were not speciated. We classified them as *enterocolitica* because only 9% of speciated *Yersinia* were other species. Relative to an MAR assumption, that potential bias would be expected to be on the order of 0.7%, negligible relative to the other sources of uncertainty in the *Yersinia* model.

Some different elements were used for passive surveillance and outbreak surveillance pathogens collectively and individually. Passive and outbreak surveillance pathogens were adjusted for underreporting, but in different ways (online Technical Appendix 4, www.cdc.gov/EID/content/17/1/7-Techapp4.pdf). Bootstrapping of the reported annual counts of Hepatitis A and each of the *Vibrio* categories was done on a weighted basis, where by weighted

we mean here that 2006 was treated as a distinct time point and bootstrapping was done ‘around’ this point. This was done because these pathogens showed apparent trends over the years 2000-2007. To account for this we fit simple linear regression lines to the data series and used the ordinate values of the fitted lines at year 2006 as the predicted mean counts. Bootstrapping was then performed on the regression residuals, scaled for the uncertainty of the linear fit, plus the constant predicted mean counts. This yielded a process that was very similar in terms of output distributions to the simple bootstrapping of the other pathogens. The data series were sufficiently short and patterns sufficiently simple that we did not consider more complicated trend models.

Figure 4 provides a schematic representation of the modeling process for pathogens for which populations at risk of illness were scaled down to estimate case counts. It is much simpler in basic form than the process for pathogens that are scaled up. Again, the schematic shows 6 primary model outputs, as identified in the box at the right and obtained by inclusion of specific elements from the rightmost two model factors, column (1 or H or D) and row (1 or F). Each stochastic factor represents a probability distribution. Details of the choices made to define these distributions are provided in online Technical Appendix 3. The model outputs are the resulting probability distributions from the multiplication of the component factor distributions. All factors for a given output are stochastically independent.

Figure 4: Schematic illustration of model structure for scaling populations down



Where:

Pop refers to the particular population at risk of illness.

$P_1 - P_k$ is a generic set of contractive factors. (e.g., percent of episodes of AGI due to norovirus)

Dom is a contractive factor to scale total counts down to counts that are domestically acquired.

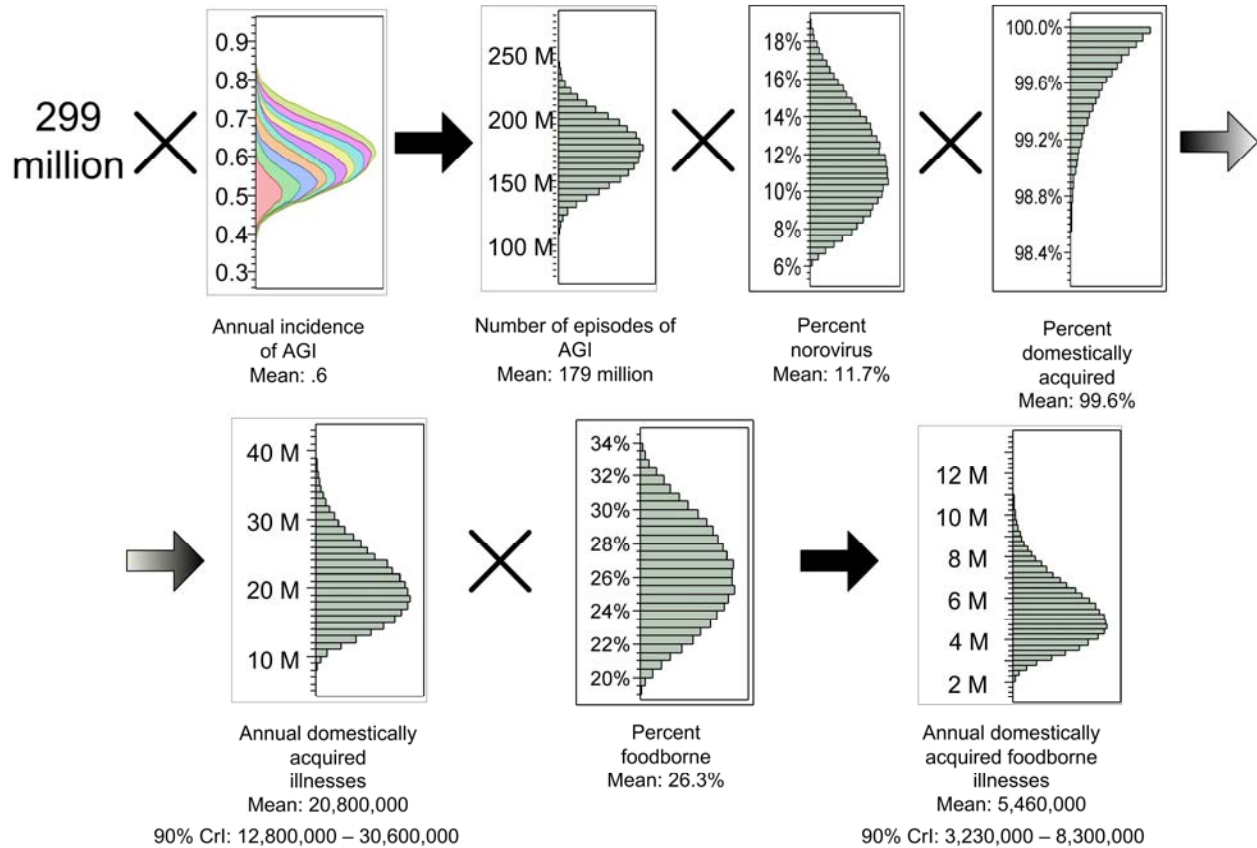
H is a contractive factor to scale illnesses down to hospitalized illnesses.

D is a contractive factor to scale illnesses down to deaths.

F is a contractive factor to scale overall counts down to counts that are foodborne.

Figure 5 (next page) illustrates model structures for norovirus, which provides an example of a pathogen for which populations at risk are scaled down. The only new element of the norovirus model relative to *Campylobacter* is reflected in the “Annual Incidence of AGI” panel. Multiple cycles of the FoodNet Population Survey were used to estimate monthly prevalence and in turn annual incidence of acute gastrointestinal illness (AGI). The survey data showed variation among the three surveys and by FoodNet site, with site being the largest source of variation. We computed estimates of site-level AGI incidence for the 10 sites contributing data across the three surveys. These estimates were bootstrapped and a normal error component was added, based on the standard errors of the site-level AGI estimates. The net effect was a “mixture of normal distributions” uncertainty model for AGI incidence. This is reflected in the colored segments of the Figure 5 panel. They combine to show a composition of densities. That is, at each value of incidence, the height of the density is partitioned into segments whose relative lengths reflect the conditional probability that a given site contributed the incidence value across the bootstrap replications. The ordering of the segments is from smallest site AGI incidence to largest site AGI incidence, and shows the ‘smearing’ of the distribution due to site-to-site variation.

Figure 5: Model distributions for norovirus illnesses. The size of the US population is modeled as a constant. "M" denotes millions. "AGI" denotes acute gastrointestinal illness.



The remaining “scale down” pathogen models were constructed in a very similar fashion. Astrovirus, rotavirus, and sapovirus models were simpler than norovirus, with the chief distinction being that they all start from a population at risk defined to be the birth cohort for 2006. We simply applied distributions for the fractions that become infected, develop symptomatic illness, become hospitalized, and die. The *Toxoplasma gondii* model is based on a mathematical incidence model applied to the US population as a whole, and has complex uncertainties associated with applying such an incidence model across an entire population when the incidence dynamic has changed over time and the serology data that forms the basis of the model is cross-sectional. That said, the structure of the uncertainty distribution is not different from that of the other pathogens.

Final comments

We mentioned in the background section that we did not assume observed counts or ratios were identically distributed and independent. We did use means as best estimates, but retained the individual observations and their associated variability. It is worth noting that the retention of source data variability generally means that source data is the dominant component of the variance in the posterior distributions. This means that, in our models, widths of credible intervals are robust to the specification of *variability* for model elements such as underreporting and the components of under-diagnosis, percent domestically acquired, and percent foodborne. That robustness is particularly desirable because the total number of parameters to be specified is very large and the amount of pathogen-specific data is relatively small. Specifying a large number of distinct values, some based on subjective judgments and sparse data, is not desirable in the same sense that over-fitting of regression models is not desirable. The robustness of the model allowed us to use some common specifications. For example, we used laboratory test sensitivity inputs based on data for *Salmonella* to describe features relating to some other pathogens because pathogen-specific data were not available. This choice had little effect on the overall result for any pathogen.

Consider the last (lower right) panel of Figure 2. This panel shows a histogram that reflects our beliefs about the burden of annual domestically acquired foodborne illness from *Campylobacter* infection. It is distinctly multimodal and has a large coefficient of variation. An assumption that the FoodNet sites are a random sample of the United States as a whole would allow this distribution to be smoothed, and produce a unimodal posterior distribution, still with a mean of 850,000 but with a much smaller coefficient of variation. But because FoodNet is not a random sample and shows a very large degree of geographical variation in infection rates it is quite possible that the country as whole looks more like the three states that produced the lowest mode, Georgia, Maryland, and Tennessee, than the other seven sites under surveillance. We think that this is the most defensible presentation of burden uncertainty as derived from the available surveillance data. It explicitly acknowledges a substantial component of non-statistical uncertainty in the modeling process.

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Foodborne Illness Acquired in the United States—Major Pathogens

Technical Appendix 3

Estimation and Uncertainty Model Inputs for 31 Major Known Pathogens Transmitted Through Food

Pathogen: Astrovirus			
Model input	Data source(s)	Distribution	Parameters
Person-time at risk	The person-time at risk for 2006 was estimated as the 0-4 year population (20,417,636) divided by 5 and rounded (1).	Constant	4,123,000
Proportion ill	75% of children assumed to experience an episode of clinical illness due to astrovirus by 5 years of age based on studies of rotavirus (2). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.75 on an odds scale.	Uniform	Low, high values: 0.55, 0.95
Proportion hospitalized	Hospitalization rate estimated as 25% of rotavirus using data from a published study (3).	PERT	Low, modal, high values: 0.003, 0.004, 0.006
Proportion who died	Very low: <10 deaths per year.	Uniform	Low, high values: 0.000, 0.0000024
Proportion travel-related	Assumed to be 100% domestically acquired.	PERT	Low, modal, high values: 0.000, 0.000, 0.001
Proportion foodborne	Very low (<1%) based on published review (4).	PERT	Low, modal, high values: 0.000, 0.005, 0.010

Pathogen: <i>Bacillus cereus</i>			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of <i>Bacillus cereus</i> outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000-2007) (5).	Empirical	By year (2000-2007): 64, 76, 104, 85, 131, 69, 35, 100
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratio by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Outbreak surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4, www.cdc.gov/EID/content/17/1/7-Techapp4.pdf).	PERT	Low, modal, high, [precision] values: 5,16, 237, [20]
Proportion severe	Non-typhoidal <i>Salmonella</i> under-diagnosis multiplier used because of a lack of data on under-diagnosis factors. See Table 3.5 in this online Technical Appendix.		
Medical care seeking (severe)			
Medical care seeking (mild)			
Specimen submission (severe)			
Specimen submission (mild)			
Laboratory testing			
Test sensitivity			
Proportion hospitalized	Proportion of cases hospitalized in <i>Bacillus cereus</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.016, 0.000, 0.000, 0.000, 0.080, 0.000, 0.000, 0.010
Proportion who died	Proportion of cases who died in <i>Bacillus cereus</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3

Proportion travel-related	Because of the rapid onset and short duration of <i>Bacillus cereus</i> illnesses, we assumed that almost 100% of <i>Bacillus cereus</i> illnesses occurring in the United States are domestically acquired.	PERT	Low, modal, high values: 0.00, 0.00, 0.02
Proportion foodborne	Estimates based on outbreak-associated illnesses from foodborne outbreaks reported to the Foodborne Disease Outbreak Surveillance System, therefore, estimated illnesses assumed to be 100% foodborne.	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Brucella</i> spp.			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of illnesses caused by <i>Brucella</i> spp. reported to CDC's National Notifiable Disease Surveillance System (NNDSS) (2000-2007) (6).	Empirical	By year (2000-2007): 87, 136, 125, 104, 114, 120, 121, 131
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratio by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Proportion severe	Assumed to be 80% severe. Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.80 on an odds scale.	PERT	Low, modal, high values: 0.73, 0.80, 0.86
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20

Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	We assumed that most persons with brucellosis who submitted a specimen for testing would be tested for brucellosis.	PERT	Low, modal, high values: 0.94, 0.97, 1
Test sensitivity	Laboratory test sensitivity estimated to be between 85-95% based on blood culture (7).	PERT	Low, modal, high values: 0.85, 0.90, 0.95
Proportion hospitalized	55% of cases hospitalized in outbreaks reported to the CDC (CDC, unpublished data). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.55 on an odds scale.	PERT	Low, modal, high values: 0.45, 0.55, 0.65
Proportion who died	0.9% based on studies in Texas and California (8, 9). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.009 on an odds scale.	PERT	Low, modal, high values: , 0.006, 0.009, 0.013
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	16% of cases estimated to have acquired their infection outside the United States from NNDSS (2000-2007). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.16 on an odds scale.	PERT	Low, modal, high values: 0.11, 0.16, 0.22
Proportion foodborne	50% estimated based on published studies (9). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.50 on an odds scale.	PERT	Low, modal, high values: 0.40, 0.50, 0.60

Pathogen: <i>Campylobacter</i> spp.			
Model input	Data source(s)	Distribution	Parameters
Reported/projected US illnesses	Number of illnesses caused by <i>Campylobacter</i> spp. infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Tables 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of <i>Campylobacter</i> infection in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier; we assumed that all laboratory-confirmed <i>Campylobacter</i> illnesses were enumerated by FoodNet active surveillance.	-	-
Proportion severe	Proportion of cases by site reporting bloody diarrhea from FoodNet case-control study of sporadic laboratory-confirmed <i>Campylobacter</i> infections (11). We used uniform minimum variance unbiased (UMVU) estimators for lower and upper endpoints.	PERT	Low, modal, high values 0.36, 0.45, 0.52
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25

Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for <i>Campylobacter</i> from the FoodNet Laboratory Survey (12). Uncertainty with this proportion (97%) was based on a 50% relative increase/decrease from 0.97 on an odds scale.	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Test sensitivity	We used a laboratory test sensitivity rate of 70% based on studies of <i>Salmonella</i> (13, 14). We assumed a lower bound of 60% and an upper bound of 90%.	PERT	Low, modal, high values: 0.60, 0.70, 0.90
Proportion hospitalized	Proportion of FoodNet cases of <i>Campylobacter</i> infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of <i>Campylobacter</i> infection who died (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of <i>Campylobacter</i> infection who reported travel outside the United States within 7 days of illness onset (2005-2008). Uncertainty with this proportion (20%) was based on a 50% relative increase/decrease from 0.20 on an odds scale.	PERT	Low, modal, high values: 0.14, 0.20, 0.27
Proportion foodborne	1 – total non-foodborne population attributable fractions from FoodNet case-control study (11). Uncertainty with this proportion (80%) was based on a 50% relative increase/decrease from 0.80 on an odds scale.	PERT	Low, modal, high values: 0.73, 0.80, 0.86

Pathogen: <i>Clostridium botulinum</i>			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of foodborne botulism illnesses reported to CDC's National Notifiable Diseases Surveillance System (NNDSS) (2000-2007) (6).	Empirical	By year (2000-2007): 23, 39, 28, 20, 16, 19, 20, 32
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Proportion severe	Almost all cases of foodborne botulism assumed to be severe. Most cases of foodborne botulism reported to CDC's botulism surveillance are persons hospitalized for life-threatening manifestations.	PERT	Low, modal, high values: 0.95, 1.00, 1.00
Medical care seeking (severe)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Medical care seeking (mild)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Specimen submission (severe)	Assumed to have a high rate of specimen submission.	PERT	Low, modal, high values: 0.70, 0.80, 0.90
Specimen submission (mild)	Assumed to have a high rate of specimen submission.	PERT	Low, modal, high values: 0.70, 0.80, 0.90
Laboratory testing	Because persons hospitalized with botulism are often misdiagnosed with other serious illnesses, including Guillain-Barre syndrome and stroke, we assumed that only 70% would be tested appropriately for botulism (15).	PERT	Low, modal, high values: 0.61, 0.70, 0.78
Test sensitivity	Test sensitivity is 67% based on a published study (16); however, our estimates are based on counts that include epidemiologically linked cases that were not confirmed by a laboratory test but were part of recognized outbreaks.	PERT	Low, modal, high values: 0.999, 1.000, 1.000
Proportion hospitalized	Proportion of cases hospitalized in foodborne botulism outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007) (5).	Empirical	By year (2000-2007): 1.000, 0.591, 0.643, 1.000, 1.000, 0.600, 0.769, 1.000

Proportion who died	Proportion of cases who died in foodborne botulism outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.200, 0.000, 0.000, 1.000, 0.000, 0.100, 0.077, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Almost all cases reported to CDC's botulism surveillance were domestically acquired, proportion of travel-related cases assumed to be very low.	PERT	Low, modal, high values: 0.00, 0.00, 0.02
Proportion foodborne	Illnesses reported to NNDSS as foodborne botulism, therefore, assumed to be 100% foodborne.	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Clostridium perfringens</i>			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of <i>Clostridium perfringens</i> outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000-2007) (5).	Empirical	By year (2000-2007): 802, 1235, 2243, 2070, 1276, 416, 732, 1334
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Outbreak surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4)	PERT	Low, modal, high, [precision] values: 5,16, 237, [20]

Proportion severe	Non-typhoidal <i>Salmonella</i> under-diagnosis multiplier used because of a lack of data on under-diagnosis factors. See Table 3.5 in this online Technical Appendix.		
Medical care seeking (severe)			
Medical care seeking (mild)			
Specimen submission (severe)			
Specimen submission (mild)			
Laboratory testing			
Test sensitivity			
Proportion hospitalized	Proportion of cases hospitalized in <i>Clostridium perfringens</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	PERT	By year (2000-2007): 0.002, 0.006, 0.001, 0.018, 0.004, 0.007, 0.003, 0.005
Proportion who died	Proportion of cases who died in foodborne <i>Clostridium perfringens</i> outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	PERT	By year (2000-2007): 0.000, 0.002, 0.000, 0.000, 0.001, 0.000, 0.000, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Because of the rapid onset and short duration of illness caused by <i>Clostridium perfringens</i> , we assumed that almost 100% of illnesses occurring in the United States are domestically acquired.	PERT	Low, modal, high values: 0.00, 0.00, 0.02
Proportion foodborne	Estimates based on outbreak-associated illnesses from foodborne outbreaks reported to the Foodborne Disease Outbreak Surveillance System, therefore, estimated illnesses assumed to be 100% foodborne.	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Cryptosporidium</i> spp.			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Incidence of illnesses due to <i>Cryptosporidium</i> spp. infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Tables 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of <i>Cryptosporidium</i> spp. in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier, we assumed that all laboratory-confirmed <i>Cryptosporidium</i> spp. illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Assumed to be mostly mild (17).	PERT	Low, modal, high values: 0.0, 0.0, 0.05
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for <i>Cryptosporidium</i> spp. from the FoodNet Laboratory Survey (18). Uncertainty with this proportion (36%) was based on a 50% relative increase/decrease from 0.36 on an odds scale.	PERT	Low, modal, high values: 0.27, 0.36, 0.46

Test sensitivity	Average from published studies (18-22). Uncertainty with this proportion (87%) was based on a 50% relative increase/decrease from 0.87 on an odds scale.	PERT	Low, modal, high values: 0.81, 0.87, 0.91
Proportion hospitalized	Proportion of FoodNet cases of <i>Cryptosporidium</i> spp. infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of <i>Cryptosporidium</i> spp. infection who died (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of <i>Cryptosporidium</i> spp. infection who reported travel outside the United States within 15 days of illness onset (2005-2008). Uncertainty with this proportion (9%) was based on a 50% relative increase/decrease from 0.09 on an odds scale.	PERT	Low, modal, high values: 0.06, 0.09, 0.13
Proportion foodborne	Estimated based on data from a Canadian study (23). Uncertainty with this proportion (8%) was based on a 50% relative increase/decrease from 0.08 on an odds scale.	PERT	Low, modal, high values: 0.06, 0.08, 0.12

Pathogen: <i>Cyclospora cayetanensis</i>			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Incidence of <i>Cyclospora cayetanensis</i> infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Tables 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of <i>Cyclospora cayetanensis</i> in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier, we assumed all laboratory-confirmed <i>Cyclospora cayetanensis</i> illnesses were enumerated by FoodNet active surveillance.	-	-
Proportion severe	<i>Cyclospora cayetanensis</i> can cause severe diarrhea, though bloody diarrhea is rare. Proportion severe assumed to be 65% severe.	PERT	Low, modal, high values: 0.55, 0.65, 0.75

Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Published studies (18, 24-28).	PERT	Low, modal, high values: 0.18, 0.25, 0.33
Test sensitivity	Published studies (18, 24-28).	PERT	Low, modal, high values: 0.73, 0.80, 0.86
Proportion hospitalized	Proportion of FoodNet cases of <i>Cyclospora cayetanensis</i> infection hospitalized (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of <i>Cyclospora cayetanensis</i> infection who died (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of <i>Cyclospora cayetanensis</i> infection who reported travel outside the United States within 15 days of illness onset (2005-2008). Uncertainty with this proportion (42%) based on 50% relative increase/decrease from 0.42 on odds scale.	PERT	Low, modal, high values ; 0.32, 0.42, 0.52
Proportion foodborne	Based on outbreaks reported to CDC (29, 30)	PERT	Low, modal, high values: 0.98, 0.99, 1.00

Pathogen: <i>Escherichia coli</i>, enterotoxigenic (ETEC)			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of ETEC outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000-2007) (5).	Empirical	By year (2000-2007): 100, 42, 49, 55, 62, 39, 0, 66
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Outbreak surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high, [precision] values: 5,16, 237, [20]
Proportion severe	Non-typhoidal <i>Salmonella</i> under-diagnosis multiplier used because of a lack of data on under-diagnosis factors. See Table 3.5 in this online Technical Appendix.		
Medical care seeking (severe)			
Medical care seeking (mild)			
Specimen submission (severe)			
Specimen submission (mild)			
Laboratory testing			
Test sensitivity			
Proportion hospitalized	Proportion of cases hospitalized in ETEC outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.000, 0.000, 0.000, 0.036, 0.016, 0.000, 0.000, 0.015
Proportion who died	Proportion of cases who died in foodborne ETEC outbreaks reported to the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3

Proportion travel-related	55% based on surveillance data from MN FoodNet site (Minnesota Department of Health, unpublished data). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.55 on an odds scale.	PERT	Low, modal, high values: 0.45, 0.55, 0.65
Proportion foodborne	Estimates based on outbreak-associated illnesses from foodborne outbreaks reported to the Foodborne Disease Outbreak Surveillance System, therefore, estimated illnesses assumed to be 100% foodborne.	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Escherichia coli</i>, Shiga toxin-producing (STEC) O157			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Incidence of STEC O157 infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Tables 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of STEC O157 in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier; we assumed that all laboratory-confirmed STEC O157 illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Proportion of cases by site reporting bloody diarrhea from FoodNet case-control study of sporadic laboratory-confirmed STEC O157 infections (31). We used uniform minimum variance unbiased (UMVU) estimators for lower and upper endpoints.	PERT	Low, modal, high values: 0.85, 0.90, 1.00
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51

Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data)	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-7) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for STEC O157 from the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.48, 0.58, 0.67
Test sensitivity	We used a laboratory test sensitivity rate of 70% based on studies of <i>Salmonella</i> (13, 14). We assumed a lower bound of 60% and an upper bound of 90%.	PERT	Low, modal, high values: 0.60, 0.70, 0.90
Proportion hospitalized	Proportion of FoodNet cases of STEC O157 infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of STEC O157 infection who died (2005-2008)	Empirical	By site and year (2005-2008) see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of STEC O157 infection who reported travel outside the United States within 7 days of illness onset (2005-2008). Uncertainty with this proportion (3.5%) was based on a 50% relative increase/decrease from 0.035 on an odds scale.	PERT	Low, modal, high values: 0.02, 0.035, 0.05

Proportion foodborne	Proportion of STEC O157 outbreak-associated illnesses due to foodborne transmission from outbreaks reported to CDC (32). Uncertainty with this proportion (68%) was based on a 50% relative increase/decrease from 0.68 on an odds scale.	PERT	Low, modal, high values: 0.59, 0.68, 0.76
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Pathogen: <i>Escherichia coli</i>, Shiga-toxin-producing (STEC), non-O157			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Incidence of non-O157 STEC infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Tables 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of non-O157 STEC in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier; we assumed that all laboratory-confirmed non-O157 STEC illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Proportion of non-O157 STEC cases of infection with bloody diarrhea from study published in Minnesota FoodNet site (33). Uncertainty with this proportion (54%) was based on a 50% relative increase/decrease from 0.54 on an odds scale.	PERT	Low, modal, high values: 0.44, 0.54, 0.64
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20

Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-7) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Laboratory-confirmed non-O157 STEC illnesses assumed to be at least as common as STEC O157 (34, 35). Laboratory testing proportion estimated based on this assumption.	PERT	Low, modal, high values: 0.18, 0.25, 0.33
Test sensitivity	We used a laboratory test sensitivity rate of 70% based on studies of <i>Salmonella</i> (13, 14). We assumed a lower bound of 60% and an upper bound of 90%.	PERT	Low, modal, high values: 0.60, 0.70, 0.90
Proportion hospitalized	Proportion of FoodNet cases of non-O157 STEC infection hospitalized (2005-2008).	Empirical	By site and year (2005-2008): see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of non-O157 STEC infection who died (2005-2008).	Empirical	By site and year (2005-2008): see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of non-O157 STEC infection who reported travel outside the United States within 7 days of illness onset (2005-2008). Uncertainty with this proportion (18%) was based on a 50% relative increase/decrease from 0.18 on an odds scale.	PERT	Low, modal, high values: 0.13, 0.18, 0.25
Proportion foodborne	Proportion of non-O157 STEC outbreak-associated illnesses due to foodborne transmission from outbreaks reported to CDC (1990-2008) (36). Uncertainty with this proportion (82%) was based on a 50% relative increase/decrease from 0.82 on an odds scale.	PERT	Low, modal, high values: 0.75, 0.82, 0.87

Pathogen: <i>Escherichia coli</i>, diarrheagenic other than STEC and ETEC			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Assumed to be as common as enterotoxigenic <i>E. coli</i> because of a lack of available surveillance data or data on under-diagnosis factors.		
Population adjustment (year)			
Underreporting			
Percent severe			
Medical care seeking (severe)			
Medical care seeking (mild)			
Specimen submission (severe)			
Specimen submission (mild)			
Laboratory testing			
Laboratory test sensitivity			
Proportion hospitalized	Assumed to be the same as ETEC	Empirical	By year (2000-2007): 0.000, 0.000, 0.000, 0.036, 0.016, 0.000, 0.000, 0.015
Proportion who died	Assumed to be the same as ETEC	Empirical	By year (2000-2007): 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Assumed to be almost 100% domestically acquired.	PERT	Low, modal, high values: 0, 0, 0.02
Proportion foodborne	Very little data available, a few foodborne outbreaks have been reported. Assumed to be 30% foodborne (37). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.30 on an odds scale.	PERT	Low, modal, high values: 0.22, 0.30, 0.39

Pathogen: <i>Giardia intestinalis</i>			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of illnesses due to <i>Giardia intestinalis</i> reported to CDC's National Notifiable Diseases Surveillance System (NNDSS) (2002-2007) (6).	Empirical	By year (2002-2007): 21300, 19709, 20965, 19733, 18953, 19417
Population adjustment (year)	Population ratios applied to each year from 2002-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2002-2007): 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 1.0, 1.3, 1.6
Percent severe	Assumed to be mostly mild (17).	PERT	Low, modal, high values: 0.0, 0.0, 0.05
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data)	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-7) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Based on consultations with clinical and billing code experts at CDC, in academia, and laboratories across the United States. Uncertainty with this proportion (80%) was based on a 50% relative increase/decrease from 0.80 on an odds scale.	PERT	Low, modal, high values: 0.73, 0.80, 0.86

Test sensitivity	Average from 10 published studies (19, 21, 38-45). We used uniform minimum variance unbiased (UMVU) estimators for lower and upper endpoints.	PERT	Low, modal, high values: 0.72, 0.83, 0.93
Proportion hospitalized	Proportion of cases hospitalized estimated using annual national estimates from the Nationwide Inpatient Sample (NIS) (2002-2006) using ICD-9-CM code 007.1 (Giardiasis) (46).	Empirical	By year (2002-2006): 0.085, 0.092, 0.083, 0.086, 0.095
Proportion who died	Proportion of cases who died estimated using annual national estimates from the NIS (2002-2006) using ICD-9-CM code 007.1 (Giardiasis).	Empirical	By year (2002-2006): 0.010, 0.0005, 0.0010, 0.0008, 0.0010
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	8% based on a published study (47). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.08 on an odds scale.	PERT	Low, modal, high values: 0.06, 0.08, 0.12
Proportion foodborne	7% based on outbreaks reported to CDC (CDC, unpublished data). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.07 on an odds scale.	PERT	Low, modal, high values: 0.05, 0.07, 0.10

Pathogen: Hepatitis A			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of illnesses due to hepatitis A reported to CDC's National Notifiable Diseases Surveillance System (NNDSS) (2000-2007) (6, 48). Because of an apparent trend over time, the empirical distribution was based on the predicted count for 2006 plus empirical residuals derived from a linear regression of the number of illnesses on year (online Technical Appendix 2, www.cdc.gov/EID/content/17/1/7-Techapp2.pdf).	Empirical	By year (2000-2007): 13397, 10616, 8795, 7653, 5683, 4488, 3579, 2979

Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4)	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Proportion severe	Approximately 70% of infected persons have jaundice. Therefore, assumed to be 70% severe (48).	PERT	0.61, 0.70, 0.78
Medical care seeking (severe)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Assumed to be 100%.	PERT	Low, modal, high values: 0.99, 1.00, 1.00
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	We assumed that most persons with hepatitis A who submitted a specimen for testing would be tested for hepatitis A.	PERT	Low, modal, high values: 0.94, 0.97, 1
Laboratory test sensitivity	Assumed to be almost 100%.	PERT	Low, modal, high values: 0.94, 0.97, 1
Proportion hospitalized	NNDSS data on proportion of cases of hepatitis A infection hospitalized (2001-2007). Data from 2001 were used because of hospitalizations were more carefully evaluated since 2001.	Empirical	By year (2001-2007): 0.288, 0.261, 0.318, 0.328, 0.330, 0.330, 0.350
Proportion who died	Estimated using multiple cause-of-death mortality data from the national vital statistics system (49, 50) and doubled to adjust for under-diagnosis.	Empirical	By year (2004-2007): 0.023, 0.022, 0.022, 0.029
Under-diagnosis (hospitalizations)	Number of hospitalizations doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3

Proportion travel-related	41% based on enhanced surveillance in 6 US states (2005-2007) (51). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.41 on an odds scale.	PERT	Low, modal, high values: 0.32, 0.41, 0.51
Proportion foodborne	6% based on exposure data from NNDSS (2000-2007).	PERT	Low, modal, high values: 0.035, 0.063, 0.16

Pathogen: <i>Listeria monocytogenes</i>			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Incidence of invasive <i>Listeria monocytogenes</i> infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Table 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of <i>Listeria monocytogenes</i> infection in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier, we assumed that all laboratory-confirmed <i>Listeria monocytogenes</i> illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Almost all cases of infection assumed to be severe. Only invasive infections included here.	PERT	Low, modal, high values: 0.95, 1.00, 1.00
Medical care seeking (severe)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Medical care seeking (mild)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Specimen submission (severe)	Assumed to have a high rate of specimen submission.	PERT	Low, modal, high values: 0.70, 0.80, 0.90
Specimen submission (mild)	Assumed to have a high rate of specimen submission.	PERT	Low, modal, high values: 0.70, 0.80, 0.90
Laboratory testing	We assumed that most persons with listeriosis who submitted a specimen for testing would be tested for listeriosis.	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Laboratory test sensitivity	71% based on published study of blood culture sensitivity (52).	PERT	Low, modal, high values: 0.55, 0.71, 0.83

Proportion hospitalized	Proportion of FoodNet cases of <i>Listeria monocytogenes</i> infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of <i>Listeria monocytogenes</i> infection who died (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of <i>Listeria monocytogenes</i> infection who reported travel outside the United States within 30 days of illness onset (2005-2008). Uncertainty with this proportion (3%) was based on a 50% relative increase/decrease from 0.03 on an odds scale.	PERT	Low, modal, high values: 0.02, 0.03, 0.05
Proportion foodborne	Assumed to be almost 100% foodborne (53-57).	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Mycobacterium bovis</i>			
Model input	Data source(s)	Distribution	Parameters
Reported TB illnesses	Number of tuberculosis (58) illnesses reported to CDC's National Tuberculosis Surveillance System (NTSS) (2004-2007) (59).	Empirical	By year (2004-2007): 14500, 14067, 13727, 13288
<i>M. bovis</i> fraction	Fraction of TB attributed to <i>Mycobacterium bovis</i> (60). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.014 on an odds scale.	PERT	Low, modal, high values: 0.011, 0.014, 0.017
Population adjustment (year)	Population ratios applied to each year from 2004-2007 based on US Census population estimates (1).	Degenerate	Ratio by year (2004-2007): 1.019, 1.010, 1.000, 0.990
Underreporting	No underreporting multiplier. We assumed that all cases of <i>Mycobacterium bovis</i> infection were reported to NTSS.	-	-
Proportion severe	Almost all cases assumed to be severe.	PERT	Low, modal, high values: 95, 1.00, 1.00

Medical care seeking (severe)	Assumed to be 100%	PERT	Low, modal, high values: 0.999, 1.00, 1.00
Medical care seeking (mild)	Assumed to be 100%	PERT	Low, modal, high values: 0.999, 1.00, 1.00
Specimen submission (severe)	Assumed to be 100%	PERT	Low, modal, high values: 0.999, 1.00, 1.00
Specimen submission (mild)	Assumed to be 100%	PERT	Low, modal, high values: 0.999, 1.00, 1.00
Laboratory testing	Assumed to be almost 100%	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Test sensitivity	Assumed to be almost 100%	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Proportion hospitalized	Limited data available on <i>Mycobacterium bovis</i> . Assumed to be 55% based on a study of hospitalizations among persons with TB (61). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.55 on an odds scale.	Empirical	Values: 0.45, 0.55, 0.65
Proportion who died	Limited data available on <i>Mycobacterium bovis</i> . Assumed to be equal to the proportion of TB cases who died in NTSS (2004-2007).	Empirical	By year (2004-2007): 0.050, 0.048, 0.046, 0.044
Proportion travel-related	70% of cases assumed to be travel-related. Uncertainty with this proportion (70%) was based on a 50% relative increase/decrease from 0.70 on an odds scale.	PERT	Low, modal, high values: 0.61, 0.70, 0.78
Proportion foodborne	Assumed to be 95% based on published study (62) Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.95 on an odds scale.	PERT	Low, modal, high values: 0.93, 0.95, 0.97

Pathogen: Norovirus			
Model input	Data source(s)	Distribution	Parameters
Population at risk	Estimated using 2006 US Census population estimate.	Constant	299,000,000
Norovirus fraction	The proportion of all acute gastroenteritis illnesses, hospitalizations, and deaths was estimated from published studies of the proportion of acute gastroenteritis illnesses due to norovirus in the Netherlands (58), England and Wales (63, 64), and Australia (65). The proportions from these studies, .06, .11, .11, .20, were used to define low (0.06), modal (0.11) and high (0.20) values. The decision to apply this distribution to estimates of the number of acute gastroenteritis hospitalizations and deaths was supported by published studies of hospitalizations (66, 67).	PERT	Low, modal, high values: 0.06, 0.11, 0.2
Norovirus illnesses	Norovirus fraction (above) applied to estimated number of acute gastroenteritis illness (below)		
Acute gastroenteritis illnesses	Estimated rate per person per year by site using combined data from FoodNet Population Surveys in 2000–2001 (0.49 per person per year), 2002–2003 (0.54 per person per year), and 2006–2007 (0.73 per person per year) (CDC, unpublished data). Uncertainty from the site-specific survey estimates was added by assuming that site estimates were normally distributed with standard deviations equal to survey standard errors.	Mixture of Normals	By FoodNet site: 0.61, 0.63, 0.51, 0.68, 0.51, 0.56, 0.63, 0.63, 0.56, 0.65
Norovirus hospitalizations	Norovirus fraction (above) applied to estimated number of acute gastroenteritis hospitalizations (below).		
Proportion hospitalized	Estimated rate per 100,000 using annual national estimates from the 2000-2006 National Hospital Discharge System (186.3, 205.0, 211.1, 203.8, 203.0, 204.0, and 206.6 per 100,000) (68), the 2000-2006 Nationwide Inpatient Sample (177.1, 181.4, 183.4, 189.3, 183.9, 190.6, and 203.9 per 100,000) (46), and combined data from the 2000-2006 National Ambulatory Medical Care and National Hospital Ambulatory Medical Care Surveys (92.1, 94.7, 138.8, 110.1, 111.7, 90.4, and 126.3 per 100,000) (69). Low, modal, and high values were determined using the lowest (90), mean (166), and highest (211) annual rate per 100,000.	PERT	Low, modal, high values: 0.0015, 0.0028, 0.0035
Norovirus deaths	Norovirus fraction (above) applied to estimated number of acute gastroenteritis deaths (below).		

Proportion who died	Estimated annual rate per 100,000 persons using data from 2000–2006 multiple cause-of-death data from the national vital statistics system (49, 50) (2.4, 1.2, 1.3, 1.3, 1.3, 1.6, and 1.7 per 100,000) (50). Low, modal, and high values were determined using the lowest (1.2), mean (1.5), and highest (2.4) annual rate per 100,000.	PERT	Low, modal, high values: 0.00002, 0.000026, 0.00004
Proportion travel-related	Assumed to be low.	PERT	Low, modal, high values: 0.00, 0.00, 0.02
Proportion foodborne	Based on 179 norovirus outbreaks examined by CDC from 2000–2005. Of 13,944 persons ill, 3,628 (26%) were in foodborne outbreaks (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.26, 0.35

Pathogen: Rotavirus			
Model input	Data source(s)	Distribution	Parameters
Person-time at risk	The person-time at risk for 2006 was estimated as the 0-4 year population (20,417,636) divided by 5 and rounded (1).	Constant	4,123,000
Proportion ill	75% of children assumed to experience an episode of clinical illness due to rotavirus by 5 years of age based on published studies (2). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.75 on an odds scale.	Uniform	Low, high values: 0.55, 0.95
Proportion hospitalized	Based on published study (2).	PERT	Low, modal, high values: 0.012, 0.017, 0.023
Proportion who died	Very low: 20 to 40 deaths per year (2).	Uniform	Low, high values: 0.0000054, 0.00001
Proportion travel-related	Assumed to be 100% domestically acquired.	PERT	Low, modal, high values: 0.000, 0.000, 0.001
Proportion foodborne	Very few foodborne outbreaks reported (0.5% of illnesses).	PERT	Low, modal, high values: 0.000, 0.005, 0.010

Pathogen: <i>Salmonella enterica</i>, non-typhoidal serotypes			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Incidence of <i>Salmonella enterica</i> infections excluding serotype Typhi reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008): See Table 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of non-typhoidal <i>Salmonella</i> in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier, we assumed that all laboratory-confirmed non-typhoidal <i>Salmonella</i> illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Proportion of cases reporting bloody diarrhea in FoodNet case-control studies of sporadic laboratory-confirmed <i>Salmonella</i> infections (70-73). We used uniform minimum variance unbiased (UMVU) estimators for lower and upper endpoints.	PERT	Low, modal, high values: 0.35, 0.45, 0.71
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data)	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25

Laboratory testing	100% of clinical laboratories reported routinely testing stool samples for <i>Salmonella</i> in the FoodNet Laboratory Survey (12). We assumed a slightly lower rate of 97%; uncertainty with this proportion was based on a 50% relative increase/decrease from 0.97 on an odds scale.	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Laboratory test sensitivity	We assumed a laboratory test sensitivity rate of 70% based on studies of <i>Salmonella</i> . (13, 14). We assumed a lower bound of 60% and an upper bound of 90%.	PERT	Low, modal, high values: 0.60, 0.70, 0.90
Proportion hospitalized	Proportion of FoodNet cases of non-typhoidal <i>Salmonella</i> infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008): See Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of non-typhoidal <i>Salmonella</i> infection who died (2005-2008).	Empirical	By site and year (2005-2008): See Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of non-typhoidal <i>Salmonella</i> infection who reported travel outside the United States within 7 days of illness onset (2005-2008). Uncertainty with this proportion (11%) was based on a 50% relative increase/decrease from 0.11 on an odds scale.	PERT	Low, modal, high values: 0.07, 0.11, 0.15
Proportion foodborne	94% based on FoodNet case-control study of sporadic illness (72) and on outbreaks reported to the CDC from 1996-2006 (CDC, unpublished data) (see online Technical Appendix 1). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.94 on an odds scale.	PERT	Low, modal, high values: 0.91, 0.94, 0.96

Pathogen: <i>Salmonella enterica</i>, serotype Typhi			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Incidence of <i>Salmonella</i> serotype Typhi infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008): See Table 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of serotype Typhi in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting multiplier	No underreporting multiplier; we assumed that all laboratory-confirmed serotype <i>Typhi</i> illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Almost all cases of serotype Typhi infections assumed to be severe.	PERT	Low, modal, high values: 0.95, 1.00, 1.00
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	We assumed that almost all persons with serotype Typhi would be tested for serotype Typhi.	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Test sensitivity	60-80% based on published review (74).	PERT	Low, modal, high values: 0.60, 0.70, 0.80

Proportion hospitalized	Proportion of FoodNet cases of serotype Typhi infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008): See Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of Foodnet cases of serotype Typhi infection who died (2005-2008).	Empirical	By site and year (2005-2008): See Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths double to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of serotype Typhi infection who reported travel outside the United States within 30 days of illness onset (2005-2008). Uncertainty with this proportion (67%) was based on a 50% relative increase/decrease from 0.67 on an odds scale.	PERT	Low, modal, high values: 0.58, 0.67, 0.76
Proportion foodborne	100% of domestically acquired outbreaks reported to the CDC between 1980 and 1999 were foodborne (100% of 13 [out of 17] outbreaks with a known route of transmission) (75). Lower bound set at 76% (13 of 17 outbreaks).	PERT	Low, modal, high values: 0.76, 1, 1

Pathogen: Sapovirus			
Model input	Data source(s)	Distribution	Parameters
Person-time at risk	The person-time at risk for 2006 was estimated as the 0-4 year population (20,417,636) divided by 5 and rounded (1).	Constant	4,123,000
Proportion ill	75% of children assumed to experience an episode of clinical illness due to sapovirus by five years of age based on studies of rotavirus (2). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.75 on an odds scale.	Uniform	Low, high values: 0.55, 0.95
Proportion hospitalized	Hospitalization rate derived as 25% of rotavirus.	PERT	Low, modal, high values: 0.003, 0.004, 0.006
Proportion who died	Assumed to be very low: 0–10 deaths per year	Uniform	Low, high values: 0.000, 0.0000024
Proportion travel-related	Assumed to be 100% domestically acquired.	PERT	Low, modal, high values: 0.000, 0.000, 0.001

Proportion foodborne	Very few foodborne outbreaks reported (<1% of all sapovirus illnesses)	PERT	Low, modal, high values: 0.000, 0.005, 0.010
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Pathogen: <i>Shigella</i> spp.			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Incidence of <i>Shigella</i> infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10)	Empirical	By site and year (2005-2008): See Table 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of <i>Shigella</i> spp. in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier; we assumed that all laboratory-confirmed <i>Shigella</i> spp. illnesses were enumerated by FoodNet active surveillance.	-	-
Percent severe	Percent of laboratory-confirmed cases of <i>Shigella</i> spp. infection with bloody diarrhea reported to FoodNet surveillance in Minnesota and New York (Minnesota Department of Health and New York Department of Health, unpublished data). We used uniform minimum variance unbiased (UMVU) estimators for lower and upper endpoints.	PERT	Low, modal, high values: 0.17, 0.35, 0.53
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data)	PERT	Low, modal, high values: 0.15, 0.18, 0.20

Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for <i>Shigella spp.</i> from the FoodNet Laboratory Survey (12). We assumed a slightly lower rate of 97%, uncertainty with this proportion was based on a 50% relative increase/decrease from 0.97 on an odds scale.	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Test sensitivity	We used a laboratory test sensitivity rate of 70% based on studies of <i>Salmonella</i> (13, 14). We assumed a lower bound of 60% and an upper bound of 90%.	PERT	Low, modal, high values: 0.60, 0.70, 0.90
Proportion hospitalized	Proportion of FoodNet cases of <i>Shigella spp.</i> infection who were hospitalized (2005-2008).	Empirical	By site and year (2005-2008): See Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of <i>Shigella spp.</i> infection who died (2005-2008).	Empirical	By site and year (2005-2008): See Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of <i>Shigella spp.</i> infection who reported travel outside the United States within 7 days of illness onset (2005-2008). Uncertainty with this proportion (15%) was based on a 50% relative increase/decrease from 0.15 on an odds scale.	PERT	Low, modal, high values: 0.10, 0.15, 0.21
Proportion foodborne	31% based on FoodNet enhanced surveillance (76) with this proportion was based on a 50% relative increase/decrease from 0.31 on an odds scale.	PERT	Low, modal, high values: 0.23, 0.31, 0.40

Pathogen: <i>Staphylococcus aureus</i>			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Number of <i>Staphylococcus aureus</i> outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (2000-2007) (5). Because of an apparent trend over time, the empirical distribution was based on the predicted count for 2006 plus empirical residuals derived from a linear regression of the number of illnesses on year (see online Technical Appendix 2).	Empirical	By year (2000-2007): 650, 679, 551, 393, 450, 376, 380, 245
Population adjustment (year)	Population ratios applied to each year from 1998-2006 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting multiplier	Outbreak surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4)	PERT	Low, modal, high, [precision] values: 5,16, 237, [20]
Proportion severe	Non-typhoidal <i>Salmonella</i> under-diagnosis multiplier used because of a lack of data on under-diagnosis factors. See Table 3.5 in this online Technical Appendix.		
Medical care seeking (severe)			
Medical care seeking (mild)			
Specimen submission (severe)			
Specimen submission (mild)			
Laboratory testing			
Test sensitivity			
Proportion hospitalized	Proportion of cases hospitalized in <i>Staphylococcus aureus</i> outbreaks from the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.087, 0.115, 0.080, 0.059, 0.044, 0.082, 0.021, 0.020
Proportion who died	Proportion of cases who died in <i>Staphylococcus aureus</i> outbreaks from the Foodborne Disease Outbreak Surveillance System (2000-2007).	Empirical	By year (2000-2007): 0.003, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000

Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Because of the rapid onset and short duration of <i>Staphylococcus aureus</i> illnesses, we assumed that almost 100% of <i>Staphylococcus aureus</i> illnesses occurring in the United States would be domestically acquired.	PERT	Low, modal, high values: 0.00, 0.00, 0.02
Proportion foodborne	Estimates based on outbreak-associated illnesses from foodborne outbreaks reported to the Foodborne Disease Outbreak Surveillance System, therefore, assumed to be 100% foodborne.	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Streptococcus</i> spp., Group A			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Number of <i>Streptococcus</i> spp., Group A outbreak-associated illnesses reported to CDC's Foodborne Disease Outbreak Surveillance System (1996-2007) (5).	Empirical	By year (1996-2007): 0, 122, 4, 0, 0, 0, 0, 0, 37, 0, 0, 0
Population adjustment (year)	Population ratios applied to each year from 1996-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (1996-2007): 1.126, 1.115, 1.105, 1.095, 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Outbreak surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4)	PERT	Low, modal, high, [precision] values: 5,16, 237, [20]

Proportion severe	Non-typhoidal <i>Salmonella</i> under-diagnosis multiplier used because of a lack of data on under-diagnosis factors. See Table 3.5 in this online Technical Appendix.		
Medical care seeking (severe)			
Medical care seeking (mild)			
Specimen submission (severe)			
Specimen submission (mild)			
Laboratory testing			
Test sensitivity			
Proportion hospitalized	Proportion of <i>Streptococcus</i> spp., Group A cases hospitalized from the Foodborne Disease Outbreak Surveillance System (1981-2007, 12 years when outbreaks occurred). Note, the outlier value of 4/4=100 hospitalization in 1998 was shrunk to 0.012, the next highest value in the ordered list of 12 rates.	Empirical	Outbreak years (1981-2007): 0.000, 0.000, 0.012, 0.000, 0.000, 0.000, 0.000, 0.000, 0.004, 0.000, 1.000, 0.000
Proportion who died	Proportion of <i>Streptococcus</i> spp., Group A cases who died from the Foodborne Disease Outbreak Surveillance System (1981-2007, 12 years when outbreaks occurred).	Empirical	Outbreak years (1981-2007): 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Because of the rapid onset and short duration of <i>Streptococcus</i> spp., Group A illnesses, we assumed that almost 100% of <i>Streptococcus</i> spp., Group A illnesses occurring in the United States are domestically acquired.	PERT	Low, modal, high values: 0.00, 0.00, 0.02
Proportion foodborne	Estimates based on outbreak-associated illnesses from foodborne outbreaks reported to CDC, therefore, assumed to be 100% foodborne.	PERT	Low, modal, high values: 0.999, 1.00, 1.00

Pathogen: <i>Toxoplasma gondii</i>			
Model input	Data source(s)	Distribution	Parameters
Prevalence	Prevalence of <i>Toxoplasma gondii</i> infection estimated using nationally representative serologic data from the National Health and Nutrition Examination Survey (NHANES) (1999-2004). Specifically, the estimated prevalence for persons aged 40-49 years reported in Jones <i>et al.</i> (77) was assumed to be the cumulative result of 45 years of constant incidence. Upper and lower limits were based on the published 95% confidence interval.	Constant	Low, modal, high values: 0.137, 0.157, 0.177
Incidence	Prevalence for persons aged 40-49 years reported in Jones <i>et al.</i> (77) was converted to annual incidences using the following formula: $1 - (1 - \text{Prev}\% / 100)^{(1/45)}$. Incidence was applied to 2006 US Census population estimates (299 million persons). Upper and lower limits of the incidence distribution were obtained by direct conversion of the 95% confidence interval.	Degenerate	0.00327, 0.00379, 0.00432
Seroconverison rate	The symptomatic fraction was estimated to be 15% (78). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.15 on an odds scale.	PERT	Low, modal, high values: 0.11, 0.15, 0.21
Proportion hospitalized	Low, modal, and high values estimated from the annual national estimates of the number of toxoplasmosis hospitalizations from the 2000-2006 Nationwide Inpatient Sample (NIS) (46) using ICD-9-CM code 130 (Toxoplasmosis).	PERT	Low, modal, high values: 0.017, 0.026, 0.033
Proportion who died	Low, modal, and high values estimated from the annual national estimates of the number of toxoplasmosis inpatient deaths from the 2000-2006 NIS using ICD-9-CM code 130 (Toxoplasmosis).	PERT	Low, modal, high values 0.0014, 0.0019 , 0.0022
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Assumed to be very low.	PERT	Low, modal, high values: 0, 0, 0.2
Proportion foodborne	50% based on published studies (79, 80). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.50 on an odds scale.	PERT	Low, modal, high values: 0.40, 0.50, .060

Pathogen: <i>Trichinella</i> spp.			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Number of illnesses due to <i>Trichinella</i> spp. reported to CDC's National Notifiable Diseases Surveillance System (NNDSS) (2000-2007) (6, 81).	Empirical	By year (2000-2007): 16, 22, 14, 6, 5, 16, 15, 5
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 1.0, 1.3, 1.6
Percent severe	Assumed to be severe (82).	PERT	0.95, 1.00, 1.00
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	We assumed that most persons with <i>Trichinella</i> who submitted a specimen for testing would be tested for <i>Trichinella</i> .	PERT	Low, modal, high values: 0.95, 0.97, 1
Test sensitivity	Assumed to be 95% based on discussion with CDC experts.	PERT	Low, modal, high values: 0.93, 0.95, 0.97

Proportion hospitalized	Proportion from the CDC's Foodborne Disease Outbreak Surveillance System (2000–2007) (5). ¶No outbreaks reported in 2004 and 2007.	Empirical	Available years (2000-2007): 0.333, 0.286, 0.000, 0.000, ¶, 0.333, 0.500, ¶¶
Proportion who died	0.2% based on published study (83). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.0020 on an odds scale.	PERT	Low, modal, high values: 0.0013, 0.0020, 0.0030
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	3.7% based on surveillance data (81). Uncertainty with this proportion was based on a 50% relative increase/decrease from 0.037 on an odds scale.	PERT	Low, modal, high values: 0.025, 0.037, 0.054
Proportion foodborne	100% foodborne (84).	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Vibrio cholerae</i>, toxigenic			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Number of illnesses due to toxigenic <i>Vibrio cholerae</i> infection reported to CDC's Cholera and Other Vibrio Illness Surveillance (COVIS) System (2000-2007) (85). Because of an apparent trend over time, the empirical distribution was based on the predicted count for 2006 plus empirical residuals derived from a linear regression of the number of illnesses on year (see online Technical Appendix 2).	Empirical	By year (2000-2007): 7, 3, 2, 2, 5, 12, 8, 7
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Percent severe	Almost all cases assumed to be severe.	PERT	Low, modal, high values: 0.95, 1.00, 1.00
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for severe illness (CDC, unpublished data)	PERT	Low, modal, high values: 0.19, 0.35, 0.51

Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	We assumed that most persons with toxigenic <i>Vibrio cholerae</i> who submitted a specimen for testing would be tested.	PERT	Low, modal, high values: 0.95, 0.97, 1
Test sensitivity	Proportion of clinical laboratories using appropriate diagnostic tests to test stool samples for <i>Vibrio</i> spp. the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.21, 0.28, 0.37
Proportion hospitalized	Proportion of cases of toxigenic <i>Vibrio cholerae</i> infection reported to COVIS who were hospitalized (2000-2007).	Empirical	By year (2000-2007): 0.571, 0.333, 0.000, 0.500, 0.400, 0.417, 0.500, 0.714
Proportion who died	Proportion of cases of toxigenic <i>Vibrio cholerae</i> infection reported to COVIS who died (2000-2007).	Empirical	By year (2000-2007): 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Based on proportion of cases of toxigenic <i>Vibrio cholerae</i> infection reported to COVIS who acquired the infection while traveling outside the United States (2000-2007).	PERT	Low, modal, high values: 0.42, 0.69, 1.00
Proportion foodborne	Based on proportion of cases of toxigenic <i>Vibrio cholerae</i> infection reported to COVIS that were classified as foodborne (2000-2007).	PERT	Low, modal, high values: 0.999, 1.000, 1.000

Pathogen: <i>Vibrio vulnificus</i>			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Number of illnesses due to <i>Vibrio vulnificus</i> infection reported to CDC's Cholera and Other Vibrio Illness Surveillance (COVIS) System (2000-2007) (85). Because of an apparent trend over time, the empirical distribution was based on the predicted count for 2006 plus empirical residuals derived from a linear regression of the number of illnesses on year (see online Technical Appendix 2).	Empirical	By year (2000-2007): 67, 89, 89, 119, 125 123, 100, 98
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Percent severe	Almost all cases assumed to be severe.	PERT	Low, modal, high values: 0.95, 1, 1
Medical care seeking (severe)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Medical care seeking (mild)	Assumed to have a high rate of medical care seeking.	PERT	Low, modal, high values: 0.80, 0.90, 1.00
Specimen submission (severe)	Assumed to have a high rate of specimen submission.	PERT	Low, modal, high values: 0.70, 0.80, 0.90
Specimen submission (mild)	Assumed to have a high rate of specimen submission.	PERT	Low, modal, high values: 0.70, 0.80, 0.90
Laboratory testing	We assumed that most persons with <i>Vibrio vulnificus</i> who submitted a specimen for testing would be tested.	PERT	Low, modal, high values: 0.94, 0.97, 1.00
Test sensitivity	Based on sensitivity of blood cultures (86, 87).	PERT	Low, modal, high values: 0.70, 0.85, 1.00
Proportion hospitalized	Proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS who were hospitalized (2000-2007).	Empirical	By year (2000-2007): 0.983, 0.905, 0.907, 0.936, 0.886, 0.895, 0.862, 0.926
Proportion who died	Proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS who died (2000-2007).	Empirical	By year (2000-2007): 0.377, 0.360, 0.402, 0.308, 0.360, 0.253, 0.360, 0.369

Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths double to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Based on proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS who acquired the infection while traveling outside the United States (2000-2007).	PERT	Low, modal, high values: 0, 0.02, 0.03
Proportion foodborne	Based on proportion of cases of <i>Vibrio vulnificus</i> infection reported to COVIS that were classified as foodborne (2000-2007).	PERT	Low, modal, high values: 0.31, 0.48, 0.60

Pathogen: <i>Vibrio parahaemolyticus</i>			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Number of illnesses due to <i>Vibrio parahaemolyticus</i> infection reported to CDC's Cholera and Other Vibrio Illness Surveillance (COVIS) System (2000-2007) (85). Because of an apparent trend over time, the empirical distribution was based on the predicted count for 2006 plus empirical residuals derived from a linear regression of the number of illnesses on year (see online Technical Appendix 2).	Empirical	By year (2000-2007): 139, 155, 156, 170, 276, 219, 408, 239
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Percent severe	Assumed to be a similar illness to non-typhoidal <i>Salmonella</i> infection.	PERT	Low, modal, high values: 0.35, 0.45, 0.71
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20

Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for <i>Vibrio</i> spp. from the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.41, 0.51, 0.61
Test sensitivity	Proportion of clinical laboratories using appropriate diagnostic tests to test stool samples for <i>Vibrio</i> spp. the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.21, 0.28, 0.37
Proportion hospitalized	Proportion of cases of <i>Vibrio parahaemolyticus</i> infection reported to COVIS who were hospitalized (2000-2007).	Empirical	By year (2000-2007): 0.205, 0.254, 0.275, 0.182, 0.241, 0.230, 0.178, 0.238
Proportion who died	Proportion of cases of <i>Vibrio parahaemolyticus</i> infection reported to COVIS who died (2000-2007).	Empirical	By year (2000-2007): 0.007, 0.000, 0.037, 0.007, 0.012, 0.010, 0.003, 0.000
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths double to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Based on proportion of cases of <i>Vibrio. parahaemolyticus</i> infection reported to COVIS who acquired the infection while traveling outside the United States (2000-2007).	PERT	Low, modal, high values: 0.08, 0.10, 0.14
Proportion foodborne	Based on proportion of cases of <i>Vibrio parahaemolyticus</i> infection reported to COVIS that were classified as foodborne (2000-2007).	PERT	Low, modal, high values: 0.76, 0.87, 0.92

Pathogen: <i>Vibrio</i> spp., other			
Model input	Data source(s)	Distribution	Distribution values
Reported illnesses	Number of illnesses due to <i>Vibrio</i> spp. other than toxigenic <i>V. cholerae</i> , <i>V. vulnificus</i> , and <i>V. parahaemolyticus</i> reported to CDC's Cholera and Other Vibrio Illness Surveillance (COVIS) System (2000-2007) (85). Because of an apparent trend over time, the empirical distribution was based on the predicted count for 2006 plus empirical residuals derived from a linear regression of the number of illnesses on year (see online Technical Appendix 2).	Empirical	By year (2000-2007): 98, 132, 208, 201, 179, 209, 227, 218
Population adjustment (year)	Population ratios applied to each year from 2000-2007 based on US Census population estimates (1).	Degenerate	Ratios by year (2000-2007): 1.058, 1.047, 1.038, 1.029, 1.019, 1.010, 1.000, 0.990
Underreporting	Passive surveillance multiplier used to adjust for underreporting (see online Technical Appendix 4).	PERT	Low, modal, high values: 0.9, 1.1, 1.3
Percent severe	Assumed to be a similar illness to non-typhoidal <i>Salmonella</i> infection.	PERT	Low, modal, high values: 0.35, 0.45, 0.71
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as proxy for severe illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.10, 0.36, 0.62

Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) used as a proxy for mild illness (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for <i>Vibrio spp.</i> from the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.41, 0.51, 0.61
Test sensitivity	Proportion of clinical laboratories using appropriate diagnostic tests to test stool samples for <i>Vibrio spp.</i> the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.21, 0.28, 0.37
Proportion hospitalized	Proportion of cases of <i>Vibrio</i> , other infection reported to COVIS who were hospitalized (2000-2007).	Empirical	By year (2000-2007): 0.375, 0.359, 0.369, 0.396, 0.353, 0.437, 0.361, 0.317
Proportion who died	Proportion of cases of <i>Vibrio</i> , other infection reported to COVIS who died (2000-2007).	Empirical	By year (2000-2007): 0.021, 0.015, 0.037, 0.068, 0.035, 0.069, 0.020, 0.032
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths double to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Based on proportion of cases of <i>Vibrio</i> , other infection reported to COVIS who acquired the infection while traveling outside the United States (2000-2007).	PERT	Low, modal, high values: 0.06, 0.11, 0.17
Proportion foodborne	Based on proportion of cases of <i>Vibrio</i> , other infection reported to COVIS that were classified as foodborne (2000-2007).	PERT	Low, modal, high values: 0.48, 0.57, 0.67

Pathogen: <i>Yersinia enterocolitica</i>			
Model input	Data source(s)	Distribution	Parameters
Reported illnesses	Incidence of <i>Yersinia enterocolitica</i> infection reported to CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by FoodNet site (n=10) and year (2005-2008) (10).	Empirical	By site and year (2005-2008) see Tables 3.1 and 3.2 in this online Technical Appendix
Population adjustment (year)	Incidence of <i>Yersinia enterocolitica</i> in each FoodNet site by year applied to 2006 US Census population estimates (1).	Degenerate	Adjustment by year (2005-2008): 1.010, 1.000, 0.990, 0.981
Underreporting	No underreporting multiplier, we assumed all laboratory-confirmed <i>Yersinia enterocolitica</i> illnesses were enumerated by FoodNet active surveillance.	-	-
Proportion severe	Proportion of cases of <i>Yersinia enterocolitica</i> infection with bloody diarrhea from FoodNet study in two sites (88). Uncertainty with this proportion (9%) was based on a 50% relative increase/decrease from 0.09 on an odds scale.	PERT	Low, modal, high values: 0.062, 0.09, 0.129
Medical care seeking (severe)	Proportion (and 95% confidence interval (CI)) of survey respondents with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.19, 0.35, 0.51
Medical care seeking (mild)	Proportion (and 95% CI) of survey respondents with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data)	PERT	Low, modal, high values: 0.15, 0.18, 0.20
Specimen submission (severe)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-2001, 2002-2003, 2006-2007) (CDC, unpublished data).	PERT	Low, modal, high values: 0.11, 0.36, 0.62
Specimen submission (mild)	Proportion (and 95% CI) of survey respondents who submitted a stool specimen among persons with a non-bloody diarrhea who sought medical care from FoodNet Population Surveys (2000-1, 2002-3, 2006-7) (CDC, unpublished data).	PERT	Low, modal, high values: 0.12, 0.19, 0.25
Laboratory testing	Proportion of clinical laboratories routinely testing stool samples for <i>Yersinia enterocolitica</i> from the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.31, 0.40, 0.50

Test sensitivity	Proportion of clinical laboratories using appropriate diagnostic tests to test stool samples for <i>Yersinia enterocolitica</i> the FoodNet Laboratory Survey (12).	PERT	Low, modal, high values: 0.49, 0.59, 0.68
Proportion hospitalized	Proportion of FoodNet cases of <i>Yersinia enterocolitica</i> infection hospitalized (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.3 in this online Technical Appendix
Proportion who died	Proportion of FoodNet cases of <i>Yersinia enterocolitica</i> infection who died (2005-2008).	Empirical	By site and year (2005-2008) see Table 3.4 in this online Technical Appendix
Under-diagnosis (hospitalizations, deaths)	Number of hospitalizations and deaths doubled to account for under-diagnosis.	PERT	Low, modal, high values: 1, 2, 3
Proportion travel-related	Proportion of FoodNet cases of <i>Yersinia enterocolitica</i> infection who reported travel outside the United States within 7 days of illness onset (2005-2008). Uncertainty with this proportion (7%) was based on a 50% relative increase/decrease from 0.07 on an odds scale.	PERT	Low, modal, high values: 0.05, 0.07, 0.10
Proportion foodborne	From a published review (89). Uncertainty with this proportion (90%) was based on a 50% relative increase/decrease from 0.90 on an odds scale.	PERT	Low, modal, high values: 0.80, 0.90, 1.00

Table 3.1: Number of cases of illness reported to CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) by pathogen, year, and FoodNet site

Pathogen	Year	FoodNet site									
		CA	CO	CT	GA	MD	MN	NM	NY	OR	TN
<i>Campylobacter</i> spp.	2005	920	495	543	585	403	843	352	507	641	403
<i>Campylobacter</i> spp.	2006	866	479	532	581	432	899	383	522	634	443
<i>Campylobacter</i> spp.	2007	923	421	493	689	414	907	350	522	705	448
<i>Campylobacter</i> spp.	2008	985	388	530	683	378	884	357	479	690	480
<i>Cryptosporidium</i> spp.	2005	48	25	84	154	32	166	17	708	48	45
<i>Cryptosporidium</i> spp.	2006	47	37	38	276	20	242	41	54	77	47
<i>Cryptosporidium</i> spp.	2007	40	102	42	231	33	302	120	89	129	137
<i>Cryptosporidium</i> spp.	2008	43	27	41	258	55	235	174	114	58	47
<i>Cyclospora cayetanensis</i>	2005	2	0	35	13	3	0	4	1	4	3
<i>Cyclospora cayetanensis</i>	2006	0	0	11	19	2	4	1	0	2	4
<i>Cyclospora cayetanensis</i>	2007	1	0	3	3	1	0	2	2	0	1
<i>Cyclospora cayetanensis</i>	2008	0	0	4	2	3	3	2	0	0	3
<i>E. coli</i> O157 STEC	2005	28	26	43	33	27	121	10	74	66	45
<i>E. coli</i> O157 STEC	2006	42	35	41	41	40	147	20	53	83	88
<i>E. coli</i> O157 STEC	2007	39	32	45	47	22	165	10	58	73	56
<i>E. coli</i> O157 STEC	2008	37	82	26	44	33	120	15	51	56	54
<i>E. coli</i> non-O157 STEC	2005	5	4	20	8	24	35	11	11	8	2
<i>E. coli</i> non-O157 STEC	2006	6	16	34	18	47	44	23	19	9	11
<i>E. coli</i> non-O157 STEC	2007	9	55	26	40	35	41	23	12	5	24
<i>E. coli</i> non-O157 STEC	2008	1	23	17	27	49	53	27	16	5	10
<i>Listeria monocytogenes</i>	2005	10	2	20	22	19	15	4	17	11	10
<i>Listeria monocytogenes</i>	2006	8	5	18	17	28	5	5	19	11	9
<i>Listeria monocytogenes</i>	2007	7	9	11	31	14	6	4	10	8	14
<i>Listeria monocytogenes</i>	2008	19	4	14	21	14	5	5	16	5	12
<i>Salmonella</i> , non-typhoidal*	2005	453	336	460	1920	779	573	251	488	372	813
<i>Salmonella</i> , non-typhoidal*	2006	469	353	502	1836	768	720	258	493	397	841
<i>Salmonella</i> , non-typhoidal*	2007	469	311	423	2030	854	702	283	520	317	850
<i>Salmonella</i> , non-typhoidal*	2008	460	335	491	2276	836	748	516	431	395	905

<i>Salmonella</i> serotype Typhi	2005	14	5	8	8	12	6	1	0	4	3
<i>Salmonella</i> serotype Typhi	2006	17	6	4	5	8	5	1	2	4	1
<i>Salmonella</i> serotype Typhi	2007	9	6	8	17	16	9	0	1	3	1
<i>Salmonella</i> serotype Typhi	2008	17	2	3	9	17	7	2	2	2	4
<i>Shigella</i> spp.	2005	283	101	58	668	99	96	133	66	85	506
<i>Shigella</i> spp.	2006	244	180	67	1375	128	259	172	48	94	198
<i>Shigella</i> spp.	2007	188	79	44	1638	109	237	107	38	66	363
<i>Shigella</i> spp.	2008	159	85	40	1103	117	311	154	33	74	968
<i>Yersinia enterocolitica</i>	2005	28	7	15	28	4	17	2	20	9	18
<i>Yersinia enterocolitica</i>	2006	10	5	16	32	9	22	5	12	12	29
<i>Yersinia enterocolitica</i>	2007	14	4	17	42	8	19	3	14	16	13
<i>Yersinia enterocolitica</i>	2008	10	7	14	42	14	14	2	15	12	21

*In all analyses in this paper, serotype Paratyphi is grouped with non-typhoidal *Salmonella*.

Table 3.2: US cases of illness projected from CDC's Foodborne Diseases Active Surveillance Network (FoodNet) by pathogen, year, and FoodNet site

Pathogen	Year	FoodNet site									
		CA	CO	CT	GA	MD	MN	NM	NY	OR	TN
<i>Campylobacter</i> spp.	2005	85289	57079	46572	19193	21566	49270	54903	35342	52803	20096
<i>Campylobacter</i> spp.	2006	79857	54239	45509	18602	23007	52153	58967	36470	51389	21781
<i>Campylobacter</i> spp.	2007	84281	46720	42149	21586	21983	52219	53160	36526	56309	21738
<i>Campylobacter</i> spp.	2008	88706	42161	45250	21039	20019	50581	53678	33519	54319	23092
<i>Cryptosporidium</i> spp.	2005	4450	2883	7205	5053	1712	9702	2652	49353	3954	2244
<i>Cryptosporidium</i> spp.	2006	4334	4190	3251	8837	1065	14039	6312	3773	6241	2311
<i>Cryptosporidium</i> spp.	2007	3652	11319	3591	7237	1752	17387	18226	6228	10303	6647
<i>Cryptosporidium</i> spp.	2008	3872	2934	3494	7948	2913	13431	26162	7977	4566	2256
<i>Cyclospora cayetanensis</i>	2005	185	0	3002	427	161	0	624	70	330	150
<i>Cyclospora cayetanensis</i>	2006	0	0	941	608	107	232	154	0	162	197
<i>Cyclospora cayetanensis</i>	2007	91	0	256	94	53	0	304	140	0	49
<i>Cyclospora cayetanensis</i>	2008	0	0	341	62	159	171	301	0	0	144

<i>E. coli</i> O157 STEC	2005	2596	2998	3688	1083	1445	7072	1560	5158	5437	2244
<i>E. coli</i> O157 STEC	2006	3873	3963	3507	1313	2130	8528	3079	3703	6728	4327
<i>E. coli</i> O157 STEC	2007	3561	3551	3847	1473	1168	9500	1519	4058	5831	2717
<i>E. coli</i> O157 STEC	2008	3332	8910	2216	1355	1748	6858	2255	3569	4408	2592
<i>E. coli</i> non-O157 STEC	2005	464	461	1715	262	1284	2046	1716	767	659	100
<i>E. coli</i> non-O157 STEC	2006	553	1812	2908	576	2503	2553	3541	1327	730	541
<i>E. coli</i> non-O157 STEC	2007	822	6104	2223	1253	1858	2360	3493	840	399	1165
<i>E. coli</i> non-O157 STEC	2008	90	2499	1449	832	2595	3029	4060	1120	394	480
<i>Listeria monocytogenes</i>	2005	927	231	1715	722	1017	877	624	1185	906	499
<i>Listeria monocytogenes</i>	2006	738	566	1540	544	1491	290	770	1327	892	443
<i>Listeria monocytogenes</i>	2007	639	999	940	971	743	345	608	700	639	679
<i>Listeria monocytogenes</i>	2008	1711	435	1193	647	741	286	752	1120	394	576
<i>Salmonella</i> , non-typhoidal	2005	41995	38744	39453	62993	41686	33490	39150	34017	30644	40542
<i>Salmonella</i> , non-typhoidal	2006	43248	39972	42942	58784	40902	41769	39722	34444	32179	41350
<i>Salmonella</i> , non-typhoidal	2007	42825	34513	36164	63599	45347	40416	42983	36386	25319	41243
<i>Salmonella</i> , non-typhoidal	2008	41426	36402	41841	70111	44276	42751	77585	30160	31095	43447
<i>Salmonella</i> serotype Typhi	2005	1298	577	686	262	642	351	156	0	330	150
<i>Salmonella</i> serotype Typhi	2006	1568	679	342	160	426	290	154	140	324	49
<i>Salmonella</i> serotype Typhi	2007	822	666	684	533	850	518	0	70	240	49
<i>Salmonella</i> serotype Typhi	2008	1531	217	256	277	900	400	301	140	157	192
<i>Shigella</i> spp.	2005	26236	11646	4975	21916	5298	5611	20745	4601	7002	25233
<i>Shigella</i> spp.	2006	22500	20382	5731	44024	6817	15025	26481	3354	7619	9735
<i>Shigella</i> spp.	2007	17167	8767	3762	51318	5788	13645	16252	2659	5272	17613
<i>Shigella</i> spp.	2008	14319	9236	3409	33977	6196	17775	23155	2309	5825	46472
<i>Yersinia enterocolitica</i>	2005	2596	807	1287	919	214	994	312	1394	741	898
<i>Yersinia enterocolitica</i>	2006	922	566	1369	1025	479	1276	770	838	973	1426
<i>Yersinia enterocolitica</i>	2007	1278	444	1453	1316	425	1094	456	980	1278	631
<i>Yersinia enterocolitica</i>	2008	901	761	1193	1294	741	800	301	1050	945	1008

Table 3.3: Proportion of case-patients hospitalized from CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) by pathogen, year, and FoodNet site

Pathogen	Year	FoodNet site									
		CA	CO	CT	GA	MD	MN	NM	NY	OR	TN
<i>Campylobacter</i> spp.	2005	0.1060	0.1087	0.2016	0.2363	0.2141	0.1295	0.1502	0.1584	0.0939	0.2575
<i>Campylobacter</i> spp.	2006	0.1256	0.1006	0.1909	0.2226	0.5370	0.1316	0.1485	0.1862	0.0738	0.2126
<i>Campylobacter</i> spp.	2007	0.1292	0.1041	0.2056	0.1872	0.1959	0.1287	0.2060	0.1437	0.0893	0.2426
<i>Campylobacter</i> spp.	2008	0.1196	0.1111	0.1589	0.1969	0.2235	0.1357	0.1813	0.1809	0.0762	0.2500
<i>Cryptosporidium</i> spp.	2005	0.2444	0.1600	0.1449	0.3650	0.5667	0.2108	0.1875	0.0395	0.1042	0.2750
<i>Cryptosporidium</i> spp.	2006	0.3810	0.1081	0.2143	0.2918	0.8462	0.1777	0.2500	0.1667	0.1739	0.3721
<i>Cryptosporidium</i> spp.	2007	0.2105	0.1237	0.2059	0.3258	0.5161	0.1739	0.1875	0.1591	0.0569	0.1308
<i>Cryptosporidium</i> spp.	2008	0.3030	0.4231	0.1622	0.3347	0.6038	0.1923	0.1557	0.1150	0.0714	0.2750
<i>Cyclospora cayetanensis</i>	2005	0.5000		0.0286	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
<i>Cyclospora cayetanensis</i>	2006			0.1000	0.0000	1.0000	0.0000	0.0000		0.0000	0.0000
<i>Cyclospora cayetanensis</i>	2007	0.0000		0.0000	0.0000			0.0000	0.0000		0.0000
<i>Cyclospora cayetanensis</i>	2008			0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
<i>E. coli</i> O157 STEC	2005	0.4444	0.3846	0.4419	0.4848	0.2800	0.3802	0.1000	0.4384	0.3636	0.6364
<i>E. coli</i> O157 STEC	2006	0.4524	0.4000	0.4390	0.5610	0.9500	0.4150	0.5500	0.4717	0.5060	0.6023
<i>E. coli</i> O157 STEC	2007	0.4872	0.3438	0.3778	0.6170	0.5909	0.4242	0.3333	0.5000	0.3836	0.5636
<i>E. coli</i> O157 STEC	2008	0.3784	0.3537	0.4231	0.6364	0.4545	0.2750	0.5333	0.5400	0.4107	0.5660
<i>E. coli</i> non-O157 STEC	2005	0.0000	0.0000	0.0500	0.2500	0.1818	0.0286	0.5000	0.2727	0.0000	0.0000
<i>E. coli</i> non-O157 STEC	2006	0.0000	0.0000	0.2941	0.1111	0.2000	0.0909	0.1667	0.2105	0.0000	0.2727
<i>E. coli</i> non-O157 STEC	2007	0.0000	0.0727	0.1667	0.0256	0.1176	0.2500	0.1364	0.3333	0.2000	0.1739
<i>E. coli</i> non-O157 STEC	2008	0.0000	0.0000	0.1176	0.0417	0.0208	0.2075	0.0000	0.1250	0.2000	0.3000
<i>Listeria monocytogenes</i>	2005	1.0000	1.0000	0.9500	0.9091	1.0000	1.0000	0.7500	0.8824	0.9091	0.8000
<i>Listeria monocytogenes</i>	2006	0.8750	1.0000	1.0000	0.8824	1.0000	1.0000	1.0000	0.9474	0.7273	0.8889
<i>Listeria monocytogenes</i>	2007	1.0000	0.8889	1.0000	0.9355	0.8571	1.0000	1.0000	1.0000	0.8750	0.8571
<i>Listeria monocytogenes</i>	2008	0.8947	1.0000	0.9286	0.9048	1.0000	1.0000	1.0000	1.0000	1.0000	0.9167
<i>Salmonella</i> , non-typhoidal	2005	0.2151	0.1918	0.2857	0.3440	0.2993	0.2483	0.2712	0.2531	0.1425	0.3980
<i>Salmonella</i> , non-typhoidal	2006	0.2299	0.2087	0.2612	0.3037	0.8221	0.1986	0.2705	0.3063	0.1924	0.3729
<i>Salmonella</i> , non-typhoidal	2007	0.2153	0.1836	0.2597	0.2877	0.2973	0.2325	0.2481	0.2521	0.2050	0.3297
<i>Salmonella</i> , non-typhoidal	2008	0.2342	0.2018	0.2112	0.2797	0.3125	0.2735	0.2414	0.2430	0.2127	0.3360

<i>Salmonella</i> serotype Typhi	2005	0.7692	0.8000	0.7143	0.5000	0.8182	0.8333	0.0000		0.5000	1.0000
<i>Salmonella</i> serotype Typhi	2006	0.6875	0.6667	0.7500	1.0000	0.8750	1.0000	1.0000	1.0000	0.5000	1.0000
<i>Salmonella</i> serotype Typhi	2007	0.6250	0.6667	0.7500	0.3529	0.7500	0.6667			0.6667	1.0000
<i>Salmonella</i> serotype Typhi	2008	0.6429	1.0000	0.3333	1.0000	0.7647	1.0000	0.5000	1.0000	1.0000	1.0000
<i>Shigella</i> spp.	2005	0.1526	0.2222	0.1429	0.2496	0.2143	0.1771	0.2177	0.1667	0.1882	0.1982
<i>Shigella</i> spp.	2006	0.1391	0.1173	0.3019	0.1883	0.6042	0.1550	0.2160	0.2292	0.1915	0.2515
<i>Shigella</i> spp.	2007	0.1453	0.1429	0.2069	0.1214	0.2233	0.1838	0.1837	0.1842	0.1667	0.1753
<i>Shigella</i> spp.	2008	0.1644	0.1786	0.2105	0.1668	0.2818	0.2058	0.2414	0.2121	0.1918	0.1448
<i>Yersinia enterocolitica</i>	2005	0.2500	0.4286	0.4615	0.4074	0.6667	0.2941	0.5000	0.4500	0.2222	0.5625
<i>Yersinia enterocolitica</i>	2006	0.5556	0.4000	0.3077	0.6250	0.4000	0.1818	0.5000	0.3333	0.1667	0.5185
<i>Yersinia enterocolitica</i>	2007	0.1667	0.0000	0.1667	0.4048	0.5000	0.2105	0.5000	0.1429	0.2667	0.3077
<i>Yersinia enterocolitica</i>	2008	0.6000	0.1429	0.4286	0.3846	0.3846	0.2143	0.0000	0.2667	0.2727	0.1500

Table 3.4: Proportion of case-patients who died from CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) by pathogen, year, and FoodNet site

Pathogen	Year	FoodNet site									
		CA	CO	CT	GA	MD	MN	NM	NY	OR	TN
<i>Campylobacter</i> spp.	2005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Campylobacter</i> spp.	2006	0.0000	0.0000	0.0027	0.0046	0.0000	0.0011	0.0028	0.0000	0.0000	0.0000
<i>Campylobacter</i> spp.	2007	0.0041	0.0000	0.0026	0.0035	0.0000	0.0011	0.0000	0.0000	0.0014	0.0022
<i>Campylobacter</i> spp.	2008	0.0065	0.0000	0.0038	0.0018	0.0027	0.0011	0.0000	0.0063	0.0014	0.0021
<i>Cryptosporidium</i> spp.	2005	0.0000	0.0000	0.0000	0.0088	0.0000	0.0060	0.0000	0.0000	0.0000	0.0000
<i>Cryptosporidium</i> spp.	2006	0.0250	0.0000	0.0000	0.0093	0.0000	0.0000	0.0000	0.0000	0.0000	0.0238
<i>Cryptosporidium</i> spp.	2007	0.0000	0.0000	0.0000	0.0152	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000
<i>Cryptosporidium</i> spp.	2008	0.0000	0.0000	0.0000	0.0372	0.0000	0.0043	0.0000	0.0000	0.0000	0.0000
<i>Cyclospora cayetanensis</i>	2005	0.0000		0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
<i>Cyclospora cayetanensis</i>	2006			0.0000	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000
<i>Cyclospora cayetanensis</i>	2007	0.0000		0.0000	0.0000			0.0000	0.0000		0.0000
<i>Cyclospora cayetanensis</i>	2008			0.0000	0.0000	0.0000	0.0000	0.0000			0.0000

<i>E. coli</i> O157 STEC	2005	0.0370	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0270
<i>E. coli</i> O157 STEC	2006	0.0000	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	0.0000	0.0000
<i>E. coli</i> O157 STEC	2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
<i>E. coli</i> O157 STEC	2008	0.0000	0.0122	0.0000	0.0256	0.0000	0.0000	0.0000	0.0196	0.0179	0.0189
<i>E. coli</i> non-O157 STEC	2005	0.0000	0.0000	0.0000	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>E. coli</i> non-O157 STEC	2006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>E. coli</i> non-O157 STEC	2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>E. coli</i> non-O157 STEC	2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Listeria monocytogenes</i>	2005	0.4000	0.0000	0.1500	0.0000	0.1111	0.1333	0.0000	0.1765	0.1818	0.0000
<i>Listeria monocytogenes</i>	2006	0.0000	0.0000	0.0556	0.0588	0.0741	0.2000	0.4000	0.1579	0.3636	0.0000
<i>Listeria monocytogenes</i>	2007	0.1429	0.0000	0.3636	0.0968	0.1538	0.3333	0.2500	0.1000	0.1250	0.2857
<i>Listeria monocytogenes</i>	2008	0.1579	0.0000	0.4286	0.1429	0.1429	0.2000	0.4000	0.1875	0.2000	0.1818
<i>Salmonella</i> , non-typhoidal	2005	0.0074	0.0030	0.0055	0.0053	0.0039	0.0017	0.0130	0.0061	0.0000	0.0081
<i>Salmonella</i> , non-typhoidal	2006	0.0024	0.0028	0.0071	0.0092	0.0028	0.0014	0.0285	0.0061	0.0000	0.0026
<i>Salmonella</i> , non-typhoidal	2007	0.0141	0.0000	0.0116	0.0041	0.0024	0.0014	0.0074	0.0038	0.0032	0.0012
<i>Salmonella</i> , non-typhoidal	2008	0.0026	0.0030	0.0021	0.0050	0.0086	0.0107	0.0040	0.0000	0.0076	0.0011
<i>Salmonella</i> serotype Typhi	2005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000
<i>Salmonella</i> serotype Typhi	2006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Salmonella</i> serotype Typhi	2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000
<i>Salmonella</i> serotype Typhi	2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Shigella</i> spp.	2005	0.0000	0.0000	0.0000	0.0024	0.0103	0.0000	0.0085	0.0000	0.0000	0.0000
<i>Shigella</i> spp.	2006	0.0067	0.0056	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Shigella</i> spp.	2007	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0152	0.0000
<i>Shigella</i> spp.	2008	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Yersinia enterocolitica</i>	2005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0714
<i>Yersinia enterocolitica</i>	2006	0.1111	0.0000	0.0000	0.0870	0.0000	0.0000	0.2500	0.0833	0.0833	0.0000
<i>Yersinia enterocolitica</i>	2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Yersinia enterocolitica</i>	2008	0.1000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 3.5 Underreporting and under-diagnosis multipliers for the 25 known pathogens with surveillance data available

Pathogen	Underreporting multiplier[†] Mean (90% credible interval [CrI])	Under-diagnosis multiplier[‡] Mean (90% CrI)
<i>Bacillus cereus</i>	25.5 (8.7-52.3)	29.3 (21.8-38.5)
<i>Brucella</i> spp.	1.1 (1.0-1.2)	15.1 (10.7-21.4)
<i>Campylobacter</i> spp.	-	30.3 (23.2-39.0)
<i>Clostridium botulinum</i> , foodborne	1.1 (1.0-1.2)	2.0 (1.8-2.3)
<i>Clostridium perfringens</i>	25.5 (8.7-52.3)	29.3 (21.8-38.5)
<i>Cryptosporidium</i> spp.	-	98.6 (73.5-130.3)
<i>Cyclospora cayetanensis</i>	-	83.1 (59.1-114.5)
<i>E. coli</i> , enterotoxigenic (ETEC)	25.5 (8.7-52.3)	29.3 (21.8-38.4)
<i>E. coli</i> , Shiga toxin-producing (STEC) non-O157	-	106.8 (75.4-146.3)
<i>E. coli</i> , Shiga toxin-producing (STEC) O157	-	26.1 (16.1-41.3)
<i>Giardia intestinalis</i>	1.3 (1.1-1.5)	46.3 (36.0-59.3)
Hepatitis A	1.1 (1.0-1.2)	9.1 (6.9-11.8)
<i>Listeria monocytogenes</i>	-	2.3 (2.0-2.6)
<i>Mycobacterium bovis</i>	-	1.1 (1.0-1.1)
<i>Salmonella</i> serotype Typhi	-	13.3 (7.6-22.8)
<i>Salmonella</i> , non-typhoidal	-	29.3 (21.8-38.4)
<i>Shigella</i> spp.	-	33.3 (25.1-43.4)
<i>Staphylococcus aureus</i> , foodborne	25.5 (8.7-52.3)	29.3 (21.8-38.5)
<i>Streptococcus</i> spp., Group A, foodborne	25.5 (8.7-52.3)	29.3 (21.8-38.5)
<i>Trichinella</i> spp.	1.3 (1.1-1.5)	9.8 (5.6-16.7)
<i>Vibrio cholerae</i> , toxigenic	1.1 (1.0-1.2)	33.1 (18.4-57.5)
<i>Vibrio parahaemolyticus</i>	1.1 (1.0-1.2)	142.4 (100.1-195.1)
<i>Vibrio</i> spp., other	1.1 (1.0-1.2)	142.7 (100.4-195.2)
<i>Vibrio vulnificus</i>	1.1 (1.0-1.2)	1.7 (1.5-2.0)
<i>Yersinia enterocolitica</i>	-	122.8 (91.2-163.0)

[†]Adjustment for underreporting due to surveillance method; underreporting multiplier for passive surveillance systems (COVIS and NNDSS) derived by comparing the incidence of laboratory-confirmed illnesses for *Listeria*, non-typhoidal *Salmonella*, *Shigella*, and STEC O157 (for bacteria) and *Cryptosporidium* spp. and *Cyclospora cayetanensis* (for parasites) ascertained in FoodNet to the incidence of laboratory-confirmed illnesses for the same pathogens reportable to NNDSS; underreporting multiplier for outbreak-associated illness reported through the Foodborne Disease Outbreak Surveillance System derived by comparing the incidence of laboratory-confirmed illnesses caused by *Listeria*, non-typhoidal *Salmonella*, *Shigella*, and STEC O157 ascertained in FoodNet to the incidence of laboratory-confirmed illnesses of these bacterial infections reported to FDOSS. More detail on the data used to estimate underreporting multipliers is given in online Technical Appendix 4.

[‡] Adjustment for under-diagnosis due to variations in medical care seeking, specimen submission, laboratory testing, and test sensitivity.

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Foodborne Illness Acquired in the United States—Major Pathogens

Technical Appendix 4

Data Used to Estimate Passive and Outbreak Surveillance Underreporting Multipliers

Passive surveillance underreporting multipliers

To estimate the total number of illnesses due to the 9 (of 31) known pathogens with passive surveillance data available from the National Notifiable Disease Surveillance System (NNDSS) and the Cholera and Other *Vibrio* Illness Surveillance System (COVIS) (Box 1), we applied a passive underreporting multiplier to correct for the underreporting of cases. That is, we scaled reported counts of cases to estimated numbers had they been reported through active surveillance.

Box 1: Pathogens with passive surveillance case counts

- *Brucella* spp.
- *Clostridium botulinum*
- *Giardia intestinalis*
- Hepatitis A
- *Trichinella* spp.
- *Vibrio cholerae*, toxigenic
- *Vibrio parahaemolyticus*
- *Vibrio vulnificus*
- *Vibrio* spp., other

The approach taken was that of simple ratio estimation. We assumed that all laboratory-confirmed illnesses were enumerated by FoodNet active surveillance and applied observed ratios from pathogens in FoodNet for which we also had passive NNDSS surveillance case counts. (Box 2). That is, we computed ratios of projected total laboratory-confirmed case counts obtained through active surveillance of FoodNet pathogens to passive surveillance case counts for those pathogens in NNDSS. We then examined the distributions of these numbers. Note that FoodNet does receive counts of laboratory-confirmed illnesses for *Vibrio* spp.; however, we

chose not to use ratios of FoodNet to COVIS case counts to estimate underreporting because of the complex association of *Vibrio* spp. infections with coastal areas.

Box 2: Pathogens with both active and passive surveillance case counts

- *Cryptosporidium* spp.
- *Cyclospora cayetanensis*
- *E. coli* O157, Shiga toxin-producing (STEC) O157
- *Listeria monocytogenes*
- *Salmonella* spp.
- *Shigella* spp.

Based on these empirical distributions we extracted sets of summary features, to create a general description of pathogen-to-pathogen variability in active surveillance to passive surveillance case count ratios. Based on differences in reporting practices, we expected to treat bacterial and parasitic pathogens separately. We then used these features to inform PERT probability distributions of ratios. These PERT distributions were the source of the multipliers that were then applied to the pathogens for which we used passive surveillance data from NNDSS and COVIS to estimate total illnesses.

The observed active to passive surveillance pathogen ratios are shown in Table 1. Note that the table rows do not exactly match the classifications used for FoodNet pathogens in estimating burden of illness. This reflects features of NNDSS surveillance. FoodNet *Salmonella* data has been collapsed. FoodNet *E. coli* data has been split into two classifications: *E. coli* O157 (STEC) for 2000-2006 data and *E. coli* O157 (STEC) combined with *E. coli* non-O157 (STEC) for 2007-2008 data. The table includes four columns of summary measures applied to the individual pathogen annual ratios: mean annual ratio, group means of means for parasites and for bacteria, median annual ratio, and group mean of medians for parasites and for bacteria. The variety of summarizations is motivated by the annual data, displayed in Figure 1. The figure suggests that parasitic and bacterial pathogens should indeed be treated differently, and that is what we chose to do. Based on the data as presented in Table 1 and Figure 1, in addition to subjective inputs from authors on surveillance issues surrounding bacterial and parasitic pathogens we chose PERT distributions as follows:

Bacterial: low=0.9, modal=1.1, high=1.3

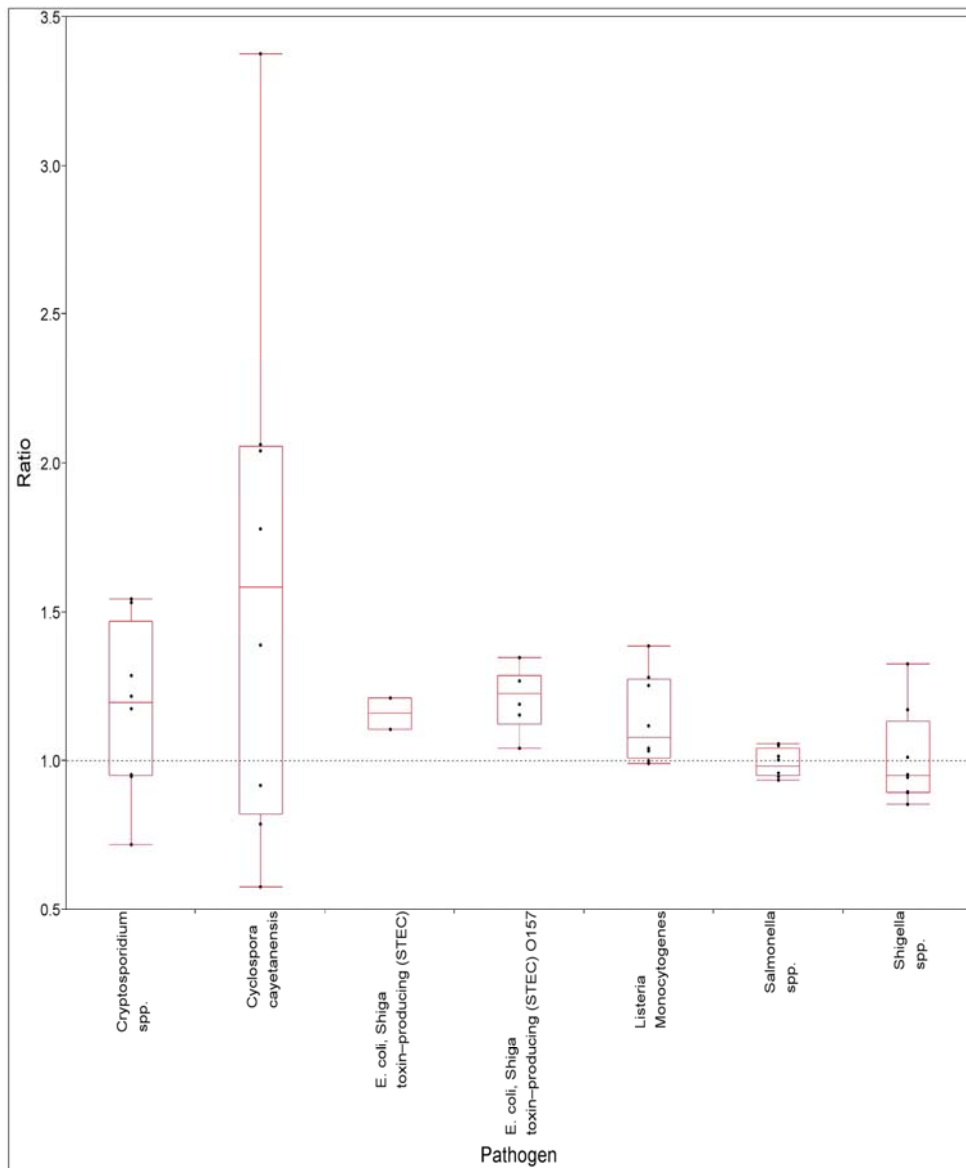
Parasitic: low=1.0, modal= 1.3, high=1.6

The PERT variance parameter was fixed at its default value of 4.

Table 1: Active and passive surveillance pathogen case counts and ratios

Pathogen	Group	Number of Years	Sum of FoodNet Projected US Illnesses	Sum of NNDSS Reported US illnesses	Mean Annual Ratio	Group Mean of Means	Median Annual Ratio	Group Mean of Medians
Cryptosporidium spp.	Parasitic	8	43,364	39,912	1.09	1.19	1.20	1.39
Cyclospora cayetanensis	Parasitic	8	1,782	1,382	1.29	1.19	1.58	1.39
E. coli (STEC)	Bacterial	2	10,736	9,279	1.16	1.10	1.16	1.08
E. coli O157 (STEC)	Bacterial	6	23,870	19,491	1.22	1.10	1.23	1.08
Listeria monocytogenes	Bacterial	8	6,837	6,070	1.13	1.10	1.08	1.08
Salmonella spp.	Bacterial	8	345,557	349,312	0.99	1.10	0.98	1.08
Shigella spp.	Bacterial	8	157,667	156,321	1.01	1.10	0.95	1.08

Figure 1: Annual active to passive surveillance ratios by pathogen. Boxplots are overlaid for visual comparison.



Outbreak surveillance underreporting multipliers

To estimate the total number of illnesses due to the 5 (of 31) pathogens with only outbreak data available from the Foodborne Disease Outbreak Surveillance System (FDOSS) (Box 3), we applied an outbreak underreporting multiplier to scale reported counts of outbreak-related cases to projected counts of national laboratory-confirmed illness.

Box 3: Pathogens with only outbreak-related case counts

- *Bacillus cereus*
- *Clostridium perfringens*
- *E. coli*, enterotoxigenic (ETEC)
- *Staphylococcus aureus*
- *Streptococcus* spp., Group A

The approach taken was again that of simple ratio estimation. We computed ratios of total laboratory-confirmed case counts in FoodNet active surveillance to outbreak-associated laboratory-confirmed case counts in FoodNet active surveillance (Box 4). In this use of FoodNet data, the outbreak-related cases are a subset of the total, obtained by exhaustive review. We used 2004-2008 data because of its completeness over the period. We then examined the distribution of these numbers.

Box 4: Pathogens with both active surveillance case counts and outbreak-related case counts

- *Campylobacter* spp.
- *Cryptosporidium* spp.
- *Cyclospora cayetanensis*
- *E. coli*, Shiga toxin-producing (STEC), O157
- *E. coli*, Shiga toxin-producing (STEC), non-O157
- *Listeria monocytogenes*
- *Salmonella*, non-typhoidal
- *Salmonella* serotype Typhi
- *Shigella* spp.
- *Vibrio* spp.
- *Yersinia enterocolitica*

Based on this empirical distribution, we extracted a set of summary features to create a general description of pathogen-to-pathogen variability in active surveillance to outbreak case count ratios. We then used those features to inform a PERT probability distribution of ratios. This PERT distribution was the source of the multipliers that were then applied to the pathogens for which we only had outbreak data. Note that in contrast to the passive surveillance multipliers we chose not to distinguish bacterial and parasitic pathogens. This was done because, while the observed parasitic ratios tended to be smaller than the bacterial ratios, we did not find an

epidemiological or surveillance argument for distinguishing them and the sample size was small. Further, the set of pathogens to which they would be applied was diverse.

The data available to us with both outbreak and laboratory-confirmed case counts was FoodNet data. We assumed that these data produced ratios that were representative of ratios that would be obtained under national surveillance in 2006. We also assumed that pathogens for which we had only outbreak data could be reasonably adjusted using a single multiplier distribution. That is, we did not attempt to estimate a specific multiplier for each of the 5 pathogens. Because of the fine granularity of the FoodNet data, we were able to consider ratios computed at multiple levels of aggregation. That is, we computed ratios of pathogen case counts at the overall level, but also at the level of year and at the level of FoodNet site. Finer aggregations produced too many cells with 0 outbreak cases to be useful. The year-level and site-level analyses produced observed ratios that were sufficiently homogeneous to suggest that our assumption that FoodNet ratios were applicable to national outbreak data (for the same pathogens) was reasonable. The extension to the 5 outbreak surveillance pathogens remains an untested assumption.

The observed FoodNet pathogen ratios are shown in Table 2. The data is strongly skewed toward higher numbers. Further, the four largest multipliers, for *Yersinia*, *Campylobacter*, *Salmonella* serotype Typhi, and *Listeria*, depend on small denominator values and/or derive from a small number of outbreaks. In light of this, we did a range of analyses, seeking a highly robust summary. We computed multipliers for the data at different levels of aggregation including state by pathogen and year by pathogen levels. We then computed medians of the resulting multipliers across states and across years. The results were consistent; there was no evidence of substantive variation in ratio distribution by state or year. From the data one might argue that any value between, say, 10 and 75, could be advocated. The overall mean, that is, the total number of active surveillance cases divided by the total number of outbreak associated cases, is 18.4. Maximum likelihood fits of PERT distributions to the complete data and various subsets and variations of the data considered in sensitivity analyses yielded means of between 30 and 60. An ad hoc median of medians analysis yielded a value of 25.6. Given the uncertainties in modeling this adjustment factor, we chose this compromise value of 25.6 as the target mean of our multiplier distribution. We then chose to seek this target with a PERT distribution parameterized using 9 of the 11 FoodNet pathogen ratios; the two extreme ratios (*Listeria*, 381.0) and

Cyclospora, 4.6) were dropped. This trimming was motivated by concerns about the basis for the values of the top 4 pathogen multipliers and that the extreme values may contain additional sampling artifacts. We used the minimum (5), maximum (237), and median (16) of the 9 values to define the minimum, mode, and maximum parameters of the PERT distribution. The remaining PERT variance parameter was chosen to equal 20, producing a PERT distribution with mean equal to 25.5, essentially achieving our target value. It is possible to use the untrimmed data to create a PERT distribution with very similar characteristics, including a mean value of ~25, but we prefer to make our down-weighting of the extreme values explicit.

Table 2: Active and outbreak surveillance pathogen case counts and ratios

Pathogen	Total lab-confirmed cases	Outbreak-related lab-confirmed cases	Ratio
<i>Yersinia enterocolitica</i>	762	2	381.0
<i>Campylobacter</i> spp.	28,878	122	236.7
<i>Salmonella</i> serotype Typhi	304	4	76.0
<i>Listeria monocytogenes</i>	651	9	72.3
<i>Vibrio</i> spp.	646	10	64.6
<i>Salmonella</i> , non-typhoidal	33,677	2,121	15.9
<i>Shigella</i> spp.	13,021	1,097	11.9
<i>E. coli</i> , Shiga toxin-producing (STEC) non-O157	963	90	10.7
<i>Cryptosporidium</i> spp.	5,120	767	6.7
<i>E. coli</i> , Shiga toxin-producing (STEC) O157	2,530	470	5.4
<i>Cyclospora cayetanensis</i>	153	33	4.6
Total	86,705	4,725	18.4