
Estimate of Illnesses from *Salmonella* Enteritidis in Eggs, United States, 2000

Carl M. Schroeder,* Alecia Larew Naugle,*
Wayne D. Schlosser,† Allan T. Hogue,‡
Frederick J. Angulo,§ Jonathon S. Rose,‡
Eric D. Ebel,¶ W. Terry Disney,# Kristin G. Holt,**
and David P. Goldman*

Results from our model suggest that eating *Salmonella enterica* serovar Enteritidis-contaminated shell eggs caused 182,060 illnesses in the United States during 2000. Uncertainty about the estimate ranged from 81,535 (5th percentile) to 276,500 illnesses (95th percentile). Our model provides but 1 approach for estimating foodborne illness and quantifying estimate uncertainty.

Foodborne salmonellae are estimated to cause ≈1.3 million illnesses, 15,000 hospitalizations, and 500 deaths per year in the United States (1). *Salmonella enterica* serovar Enteritidis is a leading cause of foodborne salmonellosis. After its emergence in the northeastern United States during the late 1970s, the *S. Enteritidis* epidemic spread throughout the country. It was detected in the Atlantic region in 1984 and the Pacific region in 1993 (2,3). Culture-confirmed *S. Enteritidis* infections peaked at ≈4/100,000 population in 1995 and declined to ≈2/100,000 in 1999 (4). Eggs and egg-containing foods are the primary vehicles of *S. Enteritidis* infection, having been implicated in 298 (80%) of the 371 known-source *S. Enteritidis* outbreaks reported to the Centers for Disease Control and Prevention (CDC) from 1985 through 1999 (4). Nevertheless, the annual number of shell egg-associated *S. Enteritidis* illnesses in the United States is unknown. One estimate suggested that 200,000 to 1 million *S. Enteritidis* illnesses occurred in the United States in 1996 (2), but it was not specific for those attributed to shell egg consumption. Using data from the Foodborne Diseases Active

Surveillance Network (FoodNet), we developed a model to estimate the number of shell egg-associated *S. Enteritidis* illnesses in the United States for 2000. The model was also designed to quantify estimate uncertainty.

The Study

The estimated number of illnesses from shell egg-associated *S. Enteritidis* in the United States for the year 2000 (Ill_{SE}) was calculated as: $Ill_{SE}=F1 \times F2 \times F3 \times F4 \times F5$ (equation 1), where

Ill_{SE} = number of *S. Enteritidis* illnesses from eating shell eggs in 2000.

F1 = number of culture-confirmed salmonellosis cases ascertained by FoodNet in 2000 = 4,330.

F2 = the proportion of culture-confirmed salmonellosis cases ascertained by FoodNet for which isolates were serotyped as *S. Enteritidis*. From the 4,330 culture-confirmed salmonellosis cases ascertained for 2000, 3,964 *Salmonella* isolates were serotyped, 585 of which were identified as *S. Enteritidis* ($585/3,964 = 0.148$).

F3 = the proportion of *S. Enteritidis* cases from eating shell eggs. In 2000, FoodNet ascertained 15 *S. Enteritidis* outbreaks in which food vehicles were identified: 12 were egg-associated ($12/15 = 0.8$). This proportion was used as a surrogate for the proportion of sporadic *S. Enteritidis* illnesses from eating shell eggs.

F4 = a multiplier to account for cases of salmonellosis that occurred in the FoodNet catchment area but were not confirmed by fecal culture, and subsequently, not ascertained by FoodNet. The value used for this multiplier was 38.6 (5).

F5 = a multiplier to extrapolate from the FoodNet catchment area to the U.S. population. For 2000, the population in the 8 FoodNet catchment sites was 30,500,000 persons, thus representing 10.8% of the U.S. population at that time (6). The multiplier was computed by taking the inverse of the proportion of the U.S. population represented by the catchment area ($1/0.108 = 9.2$).

Thus, based on equation 1 above, the Ill_{SE} point estimate was calculated as: $4,330 \times (585/3,964) \times (12/15) \times 38.6 \times (281,400,000/30,500,000) = 182,060$.

Uncertainty for the estimate of Ill_{SE} was also determined. As illustrated in equation 1, multipliers F2, F3, F4, and F5 adjusted the number of culture-confirmed salmonella illnesses ascertained by FoodNet in 2000 (F1) to estimate the number of *S. Enteritidis* illnesses due to eating shell eggs. Uncertainty associated with each multiplier contributes to the overall uncertainty associated with the estimate of Ill_{SE} . The distributions described below were incorporated into a Monte Carlo simulation (@RISK, version 4.0, Palisade Corp., Newfield, NY) of 100,000 iterations to estimate the range of potential values for Ill_{SE} (Figure).

*Food Safety and Inspection Service, Washington, DC, USA; †Food Safety and Inspection Service, College Station, Texas, USA; ‡Animal and Plant Health Inspection Service, Riverdale, Maryland, USA; §Centers for Disease Control and Prevention, Atlanta, Georgia, USA; ¶Animal and Plant Health Inspection Service, Ft. Collins, Colorado, USA; #Food Safety and Inspection Service, Fort. Collins, Colorado, USA; and **Food Safety and Inspection Service, Atlanta, Georgia, USA

F2 assumed the proportion of *Salmonella* illnesses attributable to *S. Enteritidis* ascertained by FoodNet was equal to the proportion of *Salmonella* illnesses attributable to *S. Enteritidis* throughout the United States. The β distribution (585 + 1, 3,964 – 585 + 1) was used to describe uncertainty around the F2 point value.

F3 assumed that the proportion of *S. Enteritidis* outbreaks and sporadic infections attributable to eating shell eggs was equivalent. The β distribution, (12 + 1, 15 – 12 + 1), was used to model the uncertainty around the proportion of *S. Enteritidis* cases assumed to have resulted from shell egg consumption.

F4 assumed that the impact of diarrheal illness, and the behavior of persons with diarrhea and their healthcare providers, was the same in the FoodNet catchment area as in the U.S. population. It also assumed that the proportions of case-patients who 1) sought medical attention, 2) provided a specimen for fecal culture, and 3) were confirmed as salmonellosis patients contributed equally to case ascertainment, but that these proportions differed for patients who experienced bloody diarrhea compared to those who experienced nonbloody diarrhea. A triangular distribution with a minimum value of 9.8 and a maximum value of 67.7 around the point estimate of 38.6 was specified to quantify uncertainty associated with F4.

F5 assumed that the population of the FoodNet catchment area in 2000 was representative of the U.S. population. Because this assumption was qualitative, uncertainty associated with the multiplier could not be modeled.

Conclusions

We estimated that 182,060 illnesses due to egg-associated *S. Enteritidis* occurred during 2000 (Figure). Based on previous estimates that suggested that the ratio of illnesses to hospitalizations to deaths for nontyphoidal salmonellosis is roughly 2,426 to 28 to 1 (1), our estimate extrapolates to $\approx 2,000$ hospitalizations and 70 deaths. In recognition of the fact that descriptions of the impact of illness from foodborne pathogens are inexact, our model was designed to characterize uncertainty about the estimate of illnesses resulting from eggborne *S. Enteritidis*. Ninety percent of the model iterations resulted in estimates of the number of shell egg-associated *S. Enteritidis* illnesses from 81,535 (5th percentile) to 276,500 (95th percentile) (Figure). Because the proportion of *S. Enteritidis* illnesses attributed to eggs was based on a relatively small number of outbreaks (15 outbreaks), the uncertainty about this multiplier was an important contributor to the overall uncertainty in our estimate. Angulo and Swerdlow (2) estimated that 200,000 to 1 million *S. Enteritidis* infections occurred in the United States in 1996. The lower range of our estimate in part reflects that it was computed for only those *S. Enteritidis* infections from eggs and that the rela-

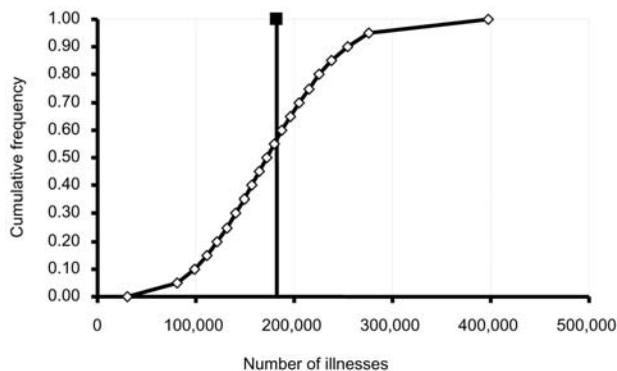


Figure. Estimated number of illnesses from *Salmonella enterica* serovar Enteritidis in shell eggs, United States, 2000. The point estimate of 182,060 illnesses is indicated by the filled box and solid vertical line. The open diamonds and attached line indicate the range of estimate uncertainty (5th percentile = 81,535 illnesses, 95th percentile = 276,500 illnesses).

tive number of *S. Enteritidis* infections reported by FoodNet was lower in 2000 than in 1996 (7).

Several assumptions were made in this study. First, all culture-confirmed salmonellosis cases in the FoodNet catchment area were assumed to have been ascertained through FoodNet, a reasonable assumption considering FoodNet is an active surveillance system. Second, the proportion of *Salmonella* isolates identified as *S. Enteritidis* in FoodNet sites was assumed to be comparable to that identified nationally. The proportion derived from FoodNet ($\approx 15\%$) was similar to that reported for 2000 through the Public Health Laboratory Information System (PHLIS) ($\approx 19\%$) (8). Third, the proportion of *S. Enteritidis* cases from shell eggs was assumed to be similar between the FoodNet catchment area and the nation. The value derived from FoodNet (80%) for 2000 was identical to that for 1985 through 1999, as reported through CDC's National *Salmonella* Surveillance System (4). Fourth, the multiplier for underascertainment was assumed to be correct. Granted, FoodNet data are limited to diagnosed illnesses, whereas most foodborne illnesses are neither diagnosed nor reported; nevertheless, the value of 38.6 used here was derived specifically for the estimation of salmonellosis cases from FoodNet data (5). Lastly, the population of the FoodNet catchment area in 2000 was assumed to be representative of the U.S. population, although FoodNet findings may not be generalizable to the nation.

Findings of this study suggest eggborne *S. Enteritidis* was an important public health problem in the United States during 2000. The findings also illustrate the potential for uncertainty in estimating the impact of foodborne illness. The model we described here provides but 1 approach for estimating foodborne illness and quantifying estimate uncertainty.

Acknowledgments

We thank Neal Golden, Regina Tan, Paul Cieslak, and Jane Harman for reviewing the manuscript before its submission and colleagues at the U.S. Food and Drug Administration's Center for Food Safety and Applied Nutrition for insightful discussions during manuscript revision.

Dr. Schroeder is a risk analyst with the U.S. Department of Agriculture. His general research interests include risk assessment and foodborne illness.

References

1. Mead PS, Slutsker L, Dietz V, McCaig LF, Bresee JS, Shapiro C, et al. Food-related illness and death in the United States. *Emerg Infect Dis.* 1999;5:607–25.
2. Angulo FJ, Swerdlow DL. *Salmonella enteritidis* infections in the United States. *J Am Vet Med Assoc.* 1998;213:1729–31.
3. Angulo FJ, Swerdlow DL. Epidemiology of human *Salmonella enterica* serovar Enteritidis infections in the United States. In: Saeed AM, Gast RK, Potter ME, Wall PG, editors. *Salmonella enterica* serovar Enteritidis in humans and animals. Ames (IA): Iowa State University Press;1999. p. 33–41.
4. Patrick ME, Adcock PM, Gomez TM, Altekruze SF, Holland BH, Tauxe RV, et al. *Salmonella* Enteritidis infections, United States, 1985–1999. *Emerg Infect Dis.* 2004;10:1–7.
5. Voetsch AC, Van Gilder TJ, Angulo FJ, Farley MM, Shallow S, Marcus R, et al. FoodNet estimate of the burden of illness caused by nontyphoidal *Salmonella* infections in the United States. *Clin Infect Dis.* 2004;38:S127–34.
6. Centers for Disease Control and Prevention. Preliminary FoodNet data on the incidence of foodborne illnesses—selected sites, United States, 2000. *MMWR Morb Mortal Wkly Rep.* 2001;50:241–6.
7. Centers for Disease Control and Prevention. Outbreaks of *Salmonella* serotype Enteritidis infection associated with eating shell eggs—United States, 1999–2001. *MMWR Morb Mortal Wkly Rep.* 2003;51:1149–52.
8. Centers for Disease Control and Prevention. *Salmonella* annual summary: 2000. Division of Bacterial and Mycotic Diseases. 2000. Available from <http://www.cdc.gov/ncidod/dbmd/phlisdata/salmtab/2000/SalmonellaAnnualSummary2000.PDF>

Address for correspondence: Carl M. Schroeder, U.S. Department of Agriculture, Food Safety and Inspection Service, Office of Public Health Science, 333 Aerospace Center, 1400 Independence Ave, SW, Washington, DC 20250–3700, USA; fax: 202-690-6414; email: carl.schroeder@fsis.usda.gov



The Ellison Medical Foundation

Senior Scholar Award in Global Infectious Disease

Request for Letters of Intent – Deadline: March 9, 2005

The Ellison Medical Foundation, established by Lawrence J. Ellison, announces the fifth year of a program to support biomedical research on parasitic and infectious diseases caused by viral, bacterial, protozoal, fungal or helminthic pathogens that are of major global public health concern but are relatively neglected in federally funded research within the U.S. Letters of intent for the Senior Scholar Award in Global Infectious Disease are due in the foundation office by **March 9, 2005**.

The intent of the Global Infectious Disease program is to focus its support by placing emphasis on:

- Innovative research that might not be funded by traditional sources, such as projects involving the application of new concepts or new technologies whose feasibility is not yet proven, projects seeking commonalities among pathogens that might yield new insights into mechanisms of disease, projects seeking to bring together diverse scientific disciplines in the study of infectious diseases, or support to allow established investigators to move into a new research area.
- Aspects of fundamental research that may significantly impact the understanding and control of infectious diseases, but have not found a home within traditional funding agencies.

Those submitting successful letters of intent will be invited to submit full applications. Evaluation is performed by a two phase process involving the Foundation's Global Infectious Disease Initial Review Group and Scientific Advisory Board. Reviewers will pay close attention to arguments as to why the proposed work is unlikely to be supported by established sources. Up to ten Senior Scholar Awards will be made in the Fall, 2005.

Eligibility: Established investigators employed by U.S. 501(c)(3) institutions, or U.S. colleges or universities, are eligible to apply. There is no limit on the number of Senior Scholar letters of intent submitted from any one institution. Whereas the Foundation only makes awards to U.S. nonprofit institutions, the Global Infectious Disease program encourages formation of research consortia between U.S. institutions and those in other disease-endemic countries, as through a subcontract mechanism, when such collaborations will benefit the proposed research. Current or past Senior Scholar Awardees are not eligible to apply.

Terms of the Award: Each award will be made for up to \$150,000 per year direct cost, with full indirect cost at the institution's NIH negotiated rate added to that, for up to four years.

Complete Application Details: For further information, see the foundation website at <http://www.ellisonfoundation.org>.

Address any questions to:

Richard L. Sprott, Ph.D.
Executive Director, The Ellison Medical Foundation
4710 Bethesda Avenue, Suite 204
Bethesda, MD 20814-5226
Phone: 301/657-1830
Fax: 301/657-1828
Email: rsprott@ellisonfoundation.org

EID

Online
www.cdc.gov/eid