An Increase in Sporadic and Outbreak-Associated *Salmonella* Enteritidis Infections in Wisconsin: The Role of Eggs

Mary Jo Trepka, John R. Archer, Sean F. Altekruse, Mary E. Proctor, and Jeffrey P. Davis

In Wisconsin, reported *Salmonella enterica* serotype enteritidis (SE) infections during 1997 more than doubled compared with the previous 9 years. A case-control study was conducted to determine risk factors for sporadic infections, and results of outbreak investigations were reviewed. Eating raw eggs (matched odds ratio [MOR] = 14.5; 95% confidence interval [CI], 1.7–591.6), eating raw or undercooked eggs (MOR = 5.8; 95% CI, 1.3–28.0), eating any eggs (MOR = 4.2; 95% CI, 1.2–16.2), and dining at a restaurant (MOR = 4.7; 95% CI, 1.4–18.4) were associated with infection in the case-control study. For 3 of the 8 outbreaks, a probable source was identified, in each instance, foods containing eggs. Human infections decreased after eggs were diverted from implicated flocks. This epidemic demonstrates the continuing need for quality assurance on egg farms and enhanced education of consumers and commercial food preparers regarding safe handling of eggs.

Since the 1970s, the incidence of *Salmonella enterica* serotype enteritidis (SE) infections has increased in European and North and South American countries [1]. In the United States from 1972 to 1996, the proportion of *Salmonella* isolates that were SE increased from 6% to 25%, making SE the predominant *Salmonella* serotype [2]. Investigations of outbreaks [3–5] and sporadic SE infections [6–9] have most frequently identified eating raw or undercooked eggs as the principal risk factor for human illness.

From 1 May to 31 July 1997, in Wisconsin, there was an increase in both sporadic and outbreak-related SE cases reported to the Bureau of Communicable Diseases, Wisconsin Division of Public Health (DPH) staff, particularly phage type 13a (figure 1). During the same period, 5 outbreaks of SE phage type 13a infections occurred. However, 71 (72%) of the 98 reported laboratory-confirmed cases were not associated with recognized outbreaks. To determine the risk factors for sporadic infections and prevent further cases, *Salmonella* surveillance data were reviewed, a case-control study was conducted, and implicated egg-production flocks were tested. We report the findings from the surveillance data review, the case-control study of sporadic cases, and the outbreak investigations.

**Materials and Methods**

Data from the DPH *Salmonella* surveillance system were reviewed for the 10-year period 1988–1997 to determine trends in reported cases of SE infection. SE infections were included in the surveillance system if the pathogen was isolated from a clinical specimen. Outbreak classification of SE cases included in the surveillance system was reviewed for the years 1994–1997. An outbreak-associated case in the surveillance database was defined as a laboratory-confirmed illness linked to an outbreak of SE infection.

A matched case-control study was conducted to identify risk factors for sporadic SE infection. A “case” was defined as a diarrheal illness with onset after 1 August 1997, not associated with a recognized cluster, in a Wisconsin resident from whom SE was isolated from a stool or blood specimen. Cases were identified through laboratory-based surveillance by the 2 laboratories that do *Salmonella* serotyping in Wisconsin: the Wisconsin State Laboratory of Hygiene and the Bureau of Laboratories, City of Milwaukee Health Department.

Case-patients were enrolled and interviewed from 2 September to 31 October 1997, as soon as possible after case notification. Attempts were made to enroll 2 controls per case-patient. Controls were sex-, county-, and age-matched. Controls were age-matched within 2 years if the case-patient was aged <10 years, within 5

Reprints or correspondence: Dr. Jeffrey P. Davis, Chief Medical Officer and State Epidemiologist for Communicable Diseases, Division of Public Health, Wisconsin Division of Public Health, Madison, WI 53703-3044.
years if the case-patient was aged 11–24 years, and within 10 years if the case-patient was aged ≥25 years. Controls were selected by systematic digit dialing. All interviews were conducted by local and state health department staff by use of a standardized questionnaire developed after interviews with previous cases. Participants were asked about food items eaten within the 3-day period before the case-patient’s onset date of illness and usual source, transport, and preparation of eggs, beef, and poultry. Other data collected included sources of water, travel history, animal contact, social functions attended, and dining at a restaurant. If a participant was uncertain about an answer to a question, the answer was coded as “unknown” and was not used in the analysis for that question. For participants aged <14 years, a parent was interviewed. For households with >1 case-patient among persons in a household, only the case-patient with the earliest date of illness onset was included. Controls were excluded if they had abdominal cramping or a diarrheal illness within 1 week before the corresponding case-patient’s date of illness onset. Participants were excluded if they had traveled out-of-state during the 3 days preceding the case-patient’s date of illness onset. Raw eggs were defined as raw eggs alone or in mixtures such as raw cookie or cake dough or homemade Caesar salad dressing. Undercooked or raw eggs were defined as sunny-side up, over easy, or soft-boiled eggs, eggs in meringue pie or hollandaise sauce, or any eggs in the raw eggs group. Case-control data were analyzed by use of Mantel–Haenszel matched \( \chi^2 \) analysis for dichotomous variables with Epi-Info Version 6.0 (Centers for Disease Control and Prevention, Atlanta), and multivariate analysis was conducted by use of conditional logistic regression analysis with SAS Version 6.08 (Cary, NC).

Outbreak files were reviewed to summarize the SE outbreaks and implicated sources for 1988–1997. An outbreak was defined as ≥2 laboratory-confirmed SE cases in persons with a common exposure. For each case-patient enrolled in the case-control study and from at least 2 patients in each outbreak, SE isolates were sent to the Foodborne Diseases Laboratory, Centers for Disease Control and Prevention (CDC), for phage typing by the method developed by Ward et al. [10]. The isolates were also sent to the Public Health Laboratory Division, Minnesota Department of Health for pulsed-field gel electrophoresis. The CDC 1997 protocol “Standardized Molecular Subtyping of \textit{Escherichia coli} 0157 : H7 by Pulsed-Field Gel Electrophoresis (PFGE)” was followed by use of restriction enzyme \textit{XhoI}, except for the use of an initial switch time of 2.2 s, a final switch time of 37.3 s, and a run time of 22 h.

Egg traceback investigations and flock testing were conducted by staff of the Food and Drug Administration and the Wisconsin Department of Agriculture, Trade, and Consumer Protection. En-
environmental and egg samples from farms were phage typed at the National Veterinary Services Laboratory in Ames, Iowa, by use of the method developed by Ward et al. [10].

Results

Surveillance data. During 1997, a total of 395 cases of laboratory-confirmed SE infections were reported in Wisconsin, representing 39.6% of Salmonella sp. isolates that were serotyped and/or serogrouped. In addition, there were 66 (6.6%) Salmonella sp. isolates that were not sero- typed but did belong to Salmonella serogroup "D," the serogroup of SE. With 216 isolates, Salmonella Typhimurium was the second-most frequently reported serotype. During 1997, the SE isolation rate peaked at 7.6 cases per 100,000 population, 2.3× the 1988–1996 mean annual incidence rate. The 1997 SE cases were similar in severity to those reported during previous years; the proportion of 1997 case-patients hospitalized (21.4%) was similar to that of 1994–1996 case-patients (24.5%; P = .4). During 1997, a total of 110 (27.8%) cases of SE infection were outbreak-related (including 34 secondary cases, almost all associated with an infected food handler), compared with a mean of 13 (8.8%) cases per year during 1994–1996. In addition, 20 cases were associated with community clusters for which no common exposure was identified. Furthermore, during 1997, the number of cases of sporadic infection (n = 265) substantially exceeded the mean annual number of sporadic cases (n = 134) during 1994 to 1996. In October and November the number of human SE cases decreased but was still above historic baseline levels (figure 1). The number of reported SE infections returned to pre-epidemic levels in January 1998 and remained at that level throughout 1998.

Case-control study of sporadic cases. From 2 September to 31 October, 42 (40.8%) of 103 eligible case-patients were enrolled in the study; 7 case-patients were subsequently excluded because of out-of-state travel during the 3 days preceding the date of illness onset. Two controls each were interviewed for 24 case-patients, and 1 control each was interviewed for 11 case-patients. The median time between date of illness onset and interview for matched cases and controls was 18 days. Of the 35 enrolled case-patients, 19 (54.3%) were female, the median age was 38 years, and 8 (22.9%) were hospitalized. These characteristics were similar to those of unenrolled eligible case-patients. Of the 34 enrolled persons for whom SE isolates were phage typed, 19 (55.9%) patients were infected with phage type 13a; 13 (38.2%) with phage type 8; 1 (2.9%) with phage type 6; and 1 (2.9%) with phage type 6a. The PFGE analysis characterized phage types 8 and 13a as SE PFGE type 1.

Statistically significant associations with SE infection were found for eating raw eggs, eating undercooked eggs, dining at a restaurant, and eating eggs (table 1). In a conditional logistic regression including the 2 variables eating eggs and eating at a restaurant, both variables were independently associated with infection (eating eggs: matched odds ratio [MOR] = 5.2; 95% confidence interval [CI], 1.3–20.9; eating at restaurant: MOR = 7.3; 95% CI, 1.7–31.9). Findings were similar for case-patients and controls regarding usual length of time needed to transport eggs from the supermarket to the home or number of weeks that a carton of eggs was kept in the household.

Outbreak investigations. The number of outbreaks of SE infection increased from an average of ~1 outbreak per year during 1988–1995 to 3 in 1996 and 8 in 1997. For 5 (50.0%) of the 10 outbreaks during 1988–1996, a food item was implicated, and eggs or egg-containing products were the vehicles for 3 (60.0%) of these 5 outbreaks. For 3 (37.5%) of the 8 outbreaks occurring in 1997, a food item was implicated. In each instance, the implicated food contained undercooked large

Table 1. Association between sporadic infections of Salmonella enteritidis and foods and activities during 3 days preceding date of illness onset, Wisconsin, 1997.

<table>
<thead>
<tr>
<th>Food or activity</th>
<th>Exposed case-patients/total case-patients, a no. (%)</th>
<th>Exposed controls/total controls, a no. (%)</th>
<th>MOR (95% CI) b</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ate raw eggs b</td>
<td>8/32 (25.0)</td>
<td>1/57 (1.8)</td>
<td>14.5 (1.7–591.6)</td>
<td>.006</td>
</tr>
<tr>
<td>Ate raw or undercooked eggs b</td>
<td>14/31 (45.2)</td>
<td>10/54 (18.5)</td>
<td>5.8 (1.3–28.0)</td>
<td>.02</td>
</tr>
<tr>
<td>Dined at a restaurant b</td>
<td>27/33 (81.8)</td>
<td>24/54 (44.4)</td>
<td>4.7 (1.4–18.4)</td>
<td>.01</td>
</tr>
<tr>
<td>Ate eggs b</td>
<td>22/32 (68.8)</td>
<td>24/57 (42.1)</td>
<td>4.2 (1.2–16.2)</td>
<td>.02</td>
</tr>
<tr>
<td>Used private well as source of home drinking water</td>
<td>10/33 (30.3)</td>
<td>8/59 (13.6)</td>
<td>2.9 (0.7–11.2)</td>
<td>.2</td>
</tr>
<tr>
<td>Traveled out of the county b</td>
<td>10/35 (28.6)</td>
<td>11/59 (18.6)</td>
<td>1.7 (0.5–6.3)</td>
<td>.5</td>
</tr>
<tr>
<td>Exposed to pets or livestock b</td>
<td>22/35 (62.9)</td>
<td>33/59 (55.9)</td>
<td>1.6 (0.5–5.2)</td>
<td>.5</td>
</tr>
<tr>
<td>Attended a social event (e.g., party or potluck b)</td>
<td>6/35 (17.1)</td>
<td>9/59 (15.3)</td>
<td>1.2 (3–5.4)</td>
<td>1.0</td>
</tr>
<tr>
<td>Lived in a rural area</td>
<td>7/35 (20.0)</td>
<td>12/59 (20.3)</td>
<td>9 (2–34)</td>
<td>.9</td>
</tr>
<tr>
<td>Used antibiotics c</td>
<td>2/31 (5.7)</td>
<td>3/59 (5.1)</td>
<td>3 (1–9.0)</td>
<td>.9</td>
</tr>
<tr>
<td>Ever ate at a salad bar in restaurants</td>
<td>12/32 (37.5)</td>
<td>30/55 (54.5)</td>
<td>5 (2.1–12.2)</td>
<td>.1</td>
</tr>
<tr>
<td>Ate beef b</td>
<td>20/31 (64.5)</td>
<td>43/56 (76.8)</td>
<td>5 (2–19)</td>
<td>.4</td>
</tr>
<tr>
<td>Ate ice cream b</td>
<td>10/32 (31.3)</td>
<td>28/53 (52.8)</td>
<td>4 (1–1.2)</td>
<td>.1</td>
</tr>
<tr>
<td>Ate poultry b</td>
<td>13/33 (39.4)</td>
<td>34/50 (68.0)</td>
<td>3 (1–1.1)</td>
<td>.07</td>
</tr>
</tbody>
</table>

NOTE. CI, confidence interval; MOR, matched odds ratio.

a If case-patients or controls did not know, they were excluded from food- or activity-specific analysis.

b Question refers to 3 days preceding case-patient’s date of illness onset.

c Question refers to 1 week preceding case-patient’s date of illness onset.
or extra large grade A shell eggs (omelet, cake with meringue topping, eggs Benedict with hollandaise sauce; table 2). In the 8 outbreaks during 1997, a total of 90 persons met the outbreak-specific case definition for SE infection. In each of the first 7 outbreaks, the SE phage type was 13a. During November, an outbreak of SE phage type 8 infections occurred among restaurant patrons who ate eggs Benedict with hollandaise sauce. The PFGE pattern of isolates from all 1997 outbreaks was SE PFGE type 1.

Traceback investigations. Environmental sampling was undertaken of the 11 flocks used by either or both suppliers (A and C) for the 2 outbreaks in which eggs were implicated (table 2). These suppliers were also the source of eggs for 4 of the other 5 phage type 13a outbreaks in which no food item was implicated. Salmonella enteritidis was isolated from the environments of 8 (72.7%) flocks. The percentage of SE-positive environmental specimens from contaminated flocks was 3.0%–72.4%. Salmonella enteritidis phage type 13a was isolated from the environmental samples of 6 flocks, including the flock with the greatest contamination. By mid-October, eggs from flocks with environmental samples positive for SE were diverted to pasteurization.

Results of traceback investigations for the SE phage type 8 outbreak indicated that 2 egg suppliers (F and H) could have supplied the eggs used to make the eggs Benedict with hollandaise sauce (table 2). The flocks for suppliers F and H were tested in spring 1998. Salmonella enteritidis was isolated from the environments of all 8 supplier F flocks with 20%–76% of SE-positive environmental specimens taken from each flock. The SE phage types isolated included type 8 but not type 13a. Eggs from supplier F flocks were diverted in June. For 3 of the 8 flocks, eggs were tested. Salmonella enteritidis phage type 8 was isolated from egg samples of the 3 flocks. No SE was isolated from the environments of the supplier H flocks.

Discussion

During 1997, the number of sporadic and outbreak-associated SE cases, primarily SE phage type 13a, in Wisconsin more than doubled compared with the previous 9 years. Reported illnesses were similar in severity during 1997 compared with those reported during previous years, suggesting that the increase in reported SE cases was not an artifact of enhanced reporting. In the case-control study, an association between sporadic SE infections and eating eggs was found, with the strongest association for eating raw eggs, followed by eating raw or undercooked eggs. After controlling for dining at a restaurant, the association between SE infection and eating eggs persisted. Eggs or egg-containing foods were implicated in 3 of the 8 outbreaks.

After traceback and diversion of eggs from phage type 13a SE-contaminated flocks in October 1997, the number of illnesses and outbreaks decreased and returned to pre-epidemic levels by January 1998. There are no other published reports of SE-infection activity after traceback and diversion of eggs. Although a number of factors, such as cyclical variations in SE infections among poultry or better egg-handling and storage practices, may have contributed to the decline of SE infections among Wisconsin residents, the decline suggests that diversion of eggs from outbreak-associated flocks with SE-contaminated environmental samples may be effective in decreasing SE infections among humans.

The association between eggs and sporadic and outbreak-related SE cases is consistent with reports from other settings. Previous case-control studies of sporadic SE infections have found statistically significant associations between SE infections and eating eggs [5, 8] and eating raw or undercooked eggs or egg-containing dishes [6–9]. During 1985–1991 in the United States, shell eggs or foods containing shell eggs were implicated in 82% of outbreaks of SE infection in which a probable vehicle was identified [3].

As in a study of sporadic SE infections in Los Angeles County [8], a statistically significant association between sporadic SE infections and dining at a restaurant persisted after controlling for egg consumption. Restaurant staff may be particularly likely to pool large numbers of eggs, store pooled eggs, or undercook foods [11]. Poor general sanitation [12] or infected

Table 2. Outbreaks of Salmonella enteritidis (SE) infections, Wisconsin, 1997.

<table>
<thead>
<tr>
<th>Date of illness onset of first cases</th>
<th>No. cases/no. exposed</th>
<th>Place of food preparation</th>
<th>Implicated food item</th>
<th>Phage type from human isolates</th>
<th>Egg supplier</th>
<th>Phage types recovered from poultry environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 May</td>
<td>7/unknown</td>
<td>Restaurant</td>
<td>Omelet</td>
<td>13a</td>
<td>A</td>
<td>8, 13, 13a, 23</td>
</tr>
<tr>
<td>26 June</td>
<td>16/46</td>
<td>Restaurant</td>
<td>Unknown</td>
<td>13a</td>
<td>A and C, F</td>
<td></td>
</tr>
<tr>
<td>20 July</td>
<td>3/unknown</td>
<td>Restaurant</td>
<td>Unknown</td>
<td>13a</td>
<td>C</td>
<td>8, 13a</td>
</tr>
<tr>
<td>27 July</td>
<td>10/10</td>
<td>Private home</td>
<td>Cake w/ meringue topping</td>
<td>13a</td>
<td>A and C, F</td>
<td>8, 13a</td>
</tr>
<tr>
<td>31 July</td>
<td>13/15</td>
<td>Private home</td>
<td>Unknown</td>
<td>13a</td>
<td>A and C, F</td>
<td></td>
</tr>
<tr>
<td>4 August</td>
<td>3/unknown</td>
<td>Restaurant</td>
<td>Unknown</td>
<td>13a</td>
<td>A and C, F</td>
<td>8, 13a</td>
</tr>
<tr>
<td>2 September</td>
<td>11/10</td>
<td>Nursing home</td>
<td>Unknown</td>
<td>13a</td>
<td>A and C, F</td>
<td>8, 13a</td>
</tr>
<tr>
<td>23 November</td>
<td>27/200</td>
<td>Restaurant</td>
<td>Eggs Benedict w/ hollandaise sauce</td>
<td>8</td>
<td>F and H</td>
<td>2, 8, 23a</td>
</tr>
</tbody>
</table>

* Odds ratio undefined, but food item accounts for all SE cases.

b Supplier A and C flocks tested because of eggs being implicated in the May 26 and July 31 outbreaks.

c Supplier F flocks (H flocks tested negative for SE).

JID 1999;180 (October) Salmonella Enteritidis and Eggs 1217
food handlers [13] may also contribute to the association between SE infection and restaurant dining.

This study has several limitations. The delay between the date of illness onset and interview of case-patients and controls may have affected the accuracy of recall. Recall bias may have resulted from the distribution on 29 September 1997 of a press release to Wisconsin news media informing the public about the increased number of SE infections and measures to prevent infection, including thoroughly cooking eggs. However, the press release was not widely publicized despite DPH efforts. A probable source of infection was identified for only 38% of 1997 outbreaks. This is similar to the situation nationwide and may be due in part to the small size of some outbreaks, which makes it difficult to implicate a vehicle statistically [3].

The experience in Wisconsin underscores the public health challenges related to SE infections. Many persons with sporadic illness were unaware of the hazards of eating raw or undercooked eggs. This is consistent with the findings that 53% of participants of a 1992 nationwide study reported ever eating raw eggs or foods containing raw eggs [14] and that 50% of participants of a 1995–1996 multitstate survey reported eating undercooked eggs within the previous year [15]. Because SE can survive moderate cooking [16], the public needs to be educated about the importance of thoroughly cooking eggs (e.g., until the yolk is firm). In addition, restaurants are an important venue for SE outbreaks, and food sanitation violations were identified in 3 of the 5 restaurants where outbreaks occurred. Educating food handlers about proper storage, handling, and thorough cooking of eggs should be enhanced, and restaurants, hospitals, and nursing homes should use pasteurized eggs for recipes calling for pooled, raw, or inadequately cooked eggs. This is particularly important for persons at greatest risk for invasive disease (e.g., immunocompromised or elderly persons, pregnant women, and young children).

The experience in Wisconsin also suggests that investigation of SE outbreaks with traceback to flocks and diversion to pasteurization plants of shell eggs from contaminated flocks is effective in preventing future outbreaks and sporadic infections. However, egg tracebacks are not conducted for sporadic SE infections [5] and are a late response to outbreaks. Therefore, preventive measures at the farm level should be a priority of the egg-production industry. The Pennsylvania Egg Quality Assurance Program appears to have reduced SE infection in flocks [17] and may have contributed to the reduction in human SE isolation rates in the Mid-Atlantic Region, which is the market for Pennsylvania eggs [18]. In Wisconsin, state officials and the poultry industry are currently designing a similar program for Wisconsin egg producers. The 1997 Wisconsin SE epidemic demonstrates that a decade after recognition of the role of shell eggs in SE infections, eggs continue to play an important role in sporadic and outbreak-associated SE infections. Interventions to prevent SE infections should be enhanced throughout the farm-to-table continuum.

Acknowledgments

We thank the following persons for their contributions to this investigation: staff of 22 Wisconsin local health departments; Mike Barnett, Steve Steinhoff, Cindy Partridge, Mike Pederson, Jack Shere, Kathy Strelow, Kathy Manner, Cindy Koschmann, Yvonne Bellay, and Clarence Siroky of the Wisconsin Department of Agriculture, Trade, and Consumer Protection; Marjorie Hamacher and Linda Kelly of the Wisconsin State Laboratory of Hygiene; Dave Boxrud of the Public Health Laboratory Division, Minnesota Department of Health; Andrew Pelletier, Keith Robbins, Lori Hutwagner, and Mary Evans of the Centers for Disease Control and Prevention; Kathy Ferris, Susan Mangual-Ruiz, and Brenda Morningstar of the National Veterinary Services Laboratory; Cheryl Bigham, Jon Polzine, and Marilyn Balmer of the Food and Drug Administration.

References


