SUPPLEMENT ARTICLE

Chicken Consumption Is a Newly Identified Risk Factor for Sporadic *Salmonella enterica* Serotype Enteritidis Infections in the United States: A Case-Control Study in FoodNet Sites

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The sources of sporadic *Salmonella enterica* serotype Enteritidis (SE) infections in the United States are unclear. To determine risk factors for sporadic SE infection, we conducted a population-based case-control study in 5 Foodborne Disease Active Surveillance Network surveillance areas. During the 12-month study, 396 cases of SE infection were ascertained. Among the 182 case patients and 345 controls, SE infection was univariately associated with international travel (matched odds ratio [MOR], 61; 95% confidence interval [CI], 8–447), eating undercooked eggs (MOR, 2.2; 95%CI, 1–5), and eating chicken prepared outside of the home (MOR, 2.2; 95% CI, 1.3–3.4). Multivariate analysis revealed that eating chicken outside of the home remained the only significant risk factor for illness (MOR, 2.0; 95% CI, 1.1–3.6). Chicken consumption has not previously been identified in the United States as a risk factor for SE infection. Measures to prevent SE infections include educating consumers and food handlers about food safety and interventions to decrease contamination of eggs and poultry.

Salmonella organisms infect an estimated 1.4 million people annually in the United States, resulting in ~16,000 hospitalizations and >500 deaths [1]. The economic impact of salmonellosis in the United States is considerable, costing $0.5 to $2.3 billion per year [2]. Over the past 15 years, the proportion of infections caused by 1 serotype, *Salmonella enterica* serotype Enteritidis (SE), has increased substantially [3, 4]. In 1976, SE accounted for 5% of reported *Salmonella* isolates, whereas in 1996, SE was the most commonly reported *Salmonella* serotype in the United States, accounting for 25% of *Salmonella* infections [5, 6].

Most epidemiologic information about SE infections in the United States comes from outbreak investigations [3]. Shell eggs are the most common vehicle of infection in reported outbreaks of SE infection [6–10]. During 1985–1998, a total of 360 outbreaks of SE infection investigated by state and local health departments and reported to the Centers for Disease Control and Prevention (CDC) had sufficient epidemiologic or microbiologic evidence to implicate a specific food vehicle.

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Egg consumption was associated with 279 (82%) of those outbreaks [6]. However, most cases of SE infection are sporadic, rather than associated with outbreaks [1]. In the 4 reported case-control studies of sporadic SE infections in the United States conducted during 1989–1997, risk factors were similar to those identified through outbreak investigations [11–14]. Consumption of eggs was associated with sporadic SE infection in studies from New York (1989) [11], Minnesota (1993) [12], Los Angeles (1994) [13], and Wisconsin (1997) [14]. However, multistate, population-based studies have not been conducted.

SE phage types (PTs) that have been most commonly associated with outbreaks in the United States have been SE PTs 8, 13a, and 13 [15]. However, the epidemiology of SE infections in the United States has been complicated by the recent emergence and spread of SE PT4. First reported in Europe in the 1980s, SE PT4 quickly became established in European poultry flocks. In countries where SE PT4 has emerged, it rapidly replaced other PTs and resulted in at least a 5-fold increase in the rate of SE isolates recovered from humans [4, 5, 16]. In the United Kingdom, SE PT4 has caused an ongoing epidemic of both outbreak and sporadic illnesses, spreading from layer flocks to broilers [17–19]. Although eggs remain a substantial source of infection, meat from broiler chickens has increasingly been recognized as a source of outbreaks and sporadic cases of SE PT4 infection in the United Kingdom [19, 20]. The first recognized outbreak of SE PT4 infection in the United States occurred in a Texas restaurant in 1993 and was associated with egg rolls that had been dipped in batter prepared from pooled eggs [21]. In 1994, SE PT4 emerged in Los Angeles County, California, resulting in a 5-fold increase in SE infections over the previous year [13]. Most of the infections were sporadic, with the consumption of undercooked eggs identified as a risk factor for illness [13, 22]. SE PT4 emerged in Utah and Hawaii during the late 1990s, resulting in a sharp increase in the number of SE isolates reported from these states [6, 23]. SE PT4 has also been reported in Nevada and Arizona [5, 6], heightening concerns about possible subsequent increases in SE infections in those states.

The Foodborne Diseases Active Surveillance Network (FoodNet) is a collaborative project of the CDC, 9 participating health departments, the US Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS), and the US Food and Drug Administration (FDA). The purpose of FoodNet is to better elucidate the epidemiology of foodborne diseases in the United States through active surveillance for foodborne diseases and related epidemiologic studies, including population based case-control studies of certain foodborne organisms [24, 25]. In 1996, FoodNet began a case-control study of SE infections in the following 5 FoodNet surveillance areas (also known as "FoodNet sites"): Minnesota, Oregon, and selected counties in California, Connecticut, and Georgia. The main objectives of this study were to determine the risk factors and clinical features of sporadic SE infection. In addition, we examined differences in PTs among patients with culture-confirmed SE infection residing in the 5 population-based sites, and we sought to describe variations in SE isolation rates between sites.

PATIENTS AND METHODS

Active surveillance. In 1996, the FoodNet catchment area consisted of Minnesota, Oregon, and selected counties in California (Alameda and San Francisco), Connecticut (Hartford and New Haven), and Georgia (Cobb, Clayton, Douglas, Dekalb, Fulton, Gwinnett, Rockdale, and Newton). The FoodNet surveillance area covered an estimated population of 14,281,096 (5.39% of the US population). Surveillance personnel within each site contacted each of the 263 laboratories serving the catchment areas either weekly or monthly depending on the size of the laboratory. All *Salmonella* isolates that were isolated by clinical laboratories from the residents of the catchment areas were forwarded to the State Public Health Laboratory for confirmation and serotyping and then to the CDC for phage typing. The CDC Foodborne Diseases Laboratory Section used the phage typing methods described by Hickman-Brenner et al. [15].

Case-control study. From 1 May 1996 through 30 April 1997 for California, Connecticut, and Minnesota, and from 1 August 1996 through 31 July 1997 for Georgia and Oregon, FoodNet surveillance ascertained all culture-confirmed cases of *Salmonella* in the catchment area. All patients infected with SE were considered to be eligible for the case-control study, with the exception of the Minnesota site, where 1 of every 2 SE-infected patients were considered to be eligible.

FoodNet personnel attempted to interview all eligible patients. Patients were not interviewed if they did not reside within the catchment area, were not reachable (e.g., did not have a home telephone), did not speak English, or were otherwise unable to answer questions. Patients were also not interviewed if their illness was associated with an investigated outbreak in which the vehicle of transmission was clearly identified. Interviewed patients were not included in the study if they did not report having had diarrhea, were unable to give an estimated date of illness onset, if the specimen collection date was $\geqslant$10 days after the onset of diarrhea, or if the onset of illness occurred $\leqslant$28 days after another culture-confirmed case was ascertained within the same household.

Attempts were made to identify 2 age-matched controls for each interviewed case patient who met the criteria for inclusion. Controls were eligible for inclusion if they resided in the population catchment area, spoke English, and had neither diarrhea nor a household member with a culture-confirmed *Salmonella*

illness in the 28 days before onset of illness for the case patient. Controls were selected from households with the same telephone exchange as the case patients and belonged to the same age-specific stratum as the case patient (i.e., 1–5 years of age; 6–11 years; 12–17 years; 18–39 years; 40–59 years; and ⩾60 years). Failure to identify and interview at least 1 eligible control subject within 7 days of the case patient interview resulted in the exclusion of the case patient from the study.

Within 21 days of the time at which the specimen that yielded *Salmonella* was obtained, a standardized questionnaire was administered to both case patients and controls and recorded demographic data, clinical course, preexisting illness, diet, travel, diet, and food-handling techniques during the 5 days before illness onset in the case patient, as well as antimicrobial use in the 4 weeks preceding illness onset. Questions about eggs included the way in which eggs were prepared (i.e., fried, boiled, poached, or scrambled) and where they were prepared (i.e., inside or outside the home). Respondents were considered to have consumed "homemade foods containing raw eggs" if they reported eating homemade cookie dough, cake batter, egg nog, ice cream, or Hollandaise sauce. "Commercially-prepared foods" referred to foods prepared in dine-in restaurants, cafeterias, fast-food establishments, and delicatessens.

Appropriate informed consent was obtained from all participants. If a case patient or control was <12 years of age, the questionnaire was administered to an adult member of the household. If a case patient or control was 12–18 years of age, permission from a parent or guardian was obtained before the questionnaire was administered. This study was conducted in accordance with guidelines for human research specified by the US Department of Health and Human Services.

Data analysis. Data entry was conducted either at CDC or at the individual FoodNet site using EpiInfo software, version 6.04d (CDC), and analysis was conducted using SAS, version 8.1 (SAS Institute). To determine risk factors for domestically acquired sporadic SE infections, a subanalysis was conducted using case patients and their matched controls who did not report travel outside the United States in the 5 days preceding illness onset.

Differences in proportions were evaluated using the χ^2 test. Differences in median values were assessed using the Wilcoxon rank sum test. Conditional logistic regression was conducted using PROC PHREG (SAS, version 8.1; SAS Institute) to assess food exposures associated with SE infection. In modeling disease odds using numeric predictors (e.g., the number of meals consumed at home), we routinely transformed observed values to median ranks. For example, a respondent was classified as either consuming more or less than the median number of meals in the home. This simplified model assumptions and provided for a more robust assessment.

Variables significantly associated with infection at a P value <.2 by univariate analysis and variables known a priori to be associated with SE infections were included in a multivariate conditional model. Various model selection strategies were pursued, including automatic forward, backward, and best subset selection based on F-test and χ^2 score criteria, as well as manual strategies based on examining changes in the regression parameter vector and model fit criteria. For this set of models, possible interaction with matching factors and with model component variables was examined. We used the method published by Bruzzi et al. [26] for calculating attributable risk. Ninety-five percent CIs were computed for model-adjusted exposure-specific attributable fractions using a jackknife procedure outlined by Kahn et al. [27].

RESULTS

Active surveillance. During the 12-month study period, 404 cases of SE were ascertained, representing 19% of the total number of *Salmonella* infections reported from FoodNet sites. The incidence of culture-confirmed SE in the FoodNet catchment area was 2.8 cases per 100,000 population but varied by site, ranging from 0.9 cases per 100,000 in Georgia to 9.0 cases per 100,000 in Connecticut (table 1). Of those for whom hospitalization and outcome data were collected (400 and 391 patients, respectively), 59 patients (15%) were hospitalized and 1 patient (0.3%) died. After omitting those patients who were excluded by the selection process exercised in Minnesota, 341 were eligible for the case-control study.

Case-control study. Of the 341 patients eligible for the study, 302 (89%) were interviewed. The primary reasons for not being interviewed included being unreachable (52%), having outbreak-associated illness (13%), and being unable to be interviewed within 21 days of sample collection (15%). Of the 302 interviewed patients, 255 (84%) met the inclusion criteria for the study. The primary reasons for not meeting the inclusion criteria were inability to recall the date of illness onset (38%) and no reported diarrhea (28%). Of the 255 interviewed pa-

Table 1. Incidence of culture-confirmed *Salmonella enterica* serotype Enteritidis (SE) infection, by Foodborne Disease Active Surveillance Network (FoodNet) site, 1996–1997.

FoodNet site	No. of persons covered	No. of cases of SE infection	Incidence[a]
California	2,063,454	61	2.96
Connecticut	1,626,366	146	8.98
Georgia	2,729,783	24	0.88
Minnesota	4,657,758	126	2.71
Oregon	3,203,735	47	1.47
Total	14,281,096	404	2.83

[a] Per 100,000 population.

Table 2. *Salmonella enterica* serotype Enteritidis phage types recovered in the Foodborne Disease Active Surveillance Network (FoodNet) case-control study—United States, 1996–1997.

		Phage data				
		Type				
FoodNet site	No. recovered	4	8	13a	Other	NA
California	33	14	12	1	6	0
Connecticut	76	3	10	45	18	0
Georgia	9	1	1	4	2	1
Minnesota	43	12	9	11	10	1
Oregon	21	10	4	1	5	1
Total	182	40	36	62	41	3

NOTE. NA, not available.

tients who met the inclusion criteria, ⩾1 control was interviewed for 182 case patients (71%). A total of 163 case patients were each matched to 2 controls and 19 were matched to 1 control, for a total study enrollment of 182 case patients and 345 controls.

Enrolled case patients did not differ significantly from unenrolled patients with regard to age, sex, and the number of days hospitalized. Enrolled case patients were from California (33 patients [18%]), Connecticut (76 [42%]), Georgia (9 [5%]), Minnesota (43 [24%]), and Oregon (21 [12%]). A total of 62 patients (35%) had infection caused by SE PT13a; 40 (22%) were infected with SE PT4; 36 (20%) were infected with SE PT8; and 41 (23%) were infected with other PTs. Data regarding PT were missing for 3 case patients (2%) (table 2).

The median age of enrolled case patients was 31 years (range, 1–87 years). The racial/ethnic distribution of the case patients was as follows: 76% of the case patients were white; 9% were African American; 9% were Hispanic; and 1% were Asian. Case patients and controls did not differ significantly on the basis of age; however, controls were slightly more likely to be female than were case patients (63% and 56%, respectively).

The most frequently reported symptoms besides diarrhea were abdominal cramps and fever (table 3). Among case patients, 22% reported having had >20 stools per 24-h period. The median illness duration was 7 days (range, 3–20 days). Hospitalization was reported by 14% of the case patients; the median duration of hospital stay in this group was 4 days. Use of antidiarrheal agents and antimicrobial medications was common; 65% of case patients reported taking an antimicrobial medication as a result of their illness, and 73% used an antidiarrheal agent. Fluoroquinolones were the most commonly prescribed class of antibiotics; 62% of case patients who took an antibiotic for their illness reported taking a fluoroquinolone.

In univariate analysis, a history of international travel was highly associated with illness; 32 (18%) of 182 case patients, compared with 1 (0.2%) of 345 controls, reported having traveled internationally in the 5 days preceding illness onset (matched OR [MOR], 61; 95% CI, 8–447). The most commonly reported travel destinations were Mexico (47%) and western Europe (28%).

To determine risk factors for domestically acquired SE infection, data on the 150 case patients and the associated 283 controls who reported that they did not travel internationally in the 5 days preceding illness onset were analyzed. In univariate analysis, case patients were more likely than controls to have a reported an underlying medical condition (e.g., chronic gastrointestinal illness, cancer, or HIV infection and/or AIDS) (MOR, 1.7; 95% CI, 1.1–3.0). The location in which a food item was prepared was strongly associated with illness; the risk of illness increased with a decrease in the reported number of home-prepared meals consumed (MOR, 2.5; 95% CI, 1.6–3.9).

Overall, egg consumption appeared to be protective against SE infection (MOR, 0.4; 95% CI, 0.3–0.7). However, when the risk of egg consumption was evaluated on the basis of the location of preparation, case patients were approximately twice as likely as controls to have eaten undercooked eggs prepared outside of the home (MOR, 2.2; 95% CI, 1.0–5.0). Although the consumption of any egg prepared outside of the home was not significant (MOR, 1.4; 95% CI, 0.8–2.3), consumption of any egg prepared inside the home remained strongly protective (MOR, 0.3; 95% CI, 0.2–0.5). Increased risk of SE infection was also associated with eating chicken prepared outside of the home (MOR, 2.2; 95% CI, 1.4–3.4), whereas consumption of chicken prepared inside the home was strongly protective (MOR, 0.4; 95% CI, 0.3–0.6). The same phenomenon was observed when the analysis was restricted to the consumption of undercooked eggs and hamburger. No association was observed

Table 3. Clinical characteristics of patients infected with *Salmonella enterica* serotype Enteritidis, Foodborne Disease Active Surveillance Network case-control study—United States, 1996–1997.

Characteristic	*n/N* (%) of patients
Diarrhea	182/182 (100)
Abdominal cramps	162/182 (91)
Fever	157/182 (89)
Vomiting	87/182 (48)
Bloody stool	78/182 (45)
Hospitalized	9/182 (6)
Received antimicrobials	116/182 (65)
Fluoroquinolone	62/100 (62)
Sulfa drug	14/100 (14)
Cephalosporin	5/100 (5)
Treated with antidiarrheal agent	131/182 (73)

NOTE. Data are no. of patients with characteristic/no. of patients for whom data were available (%).

Table 4. Univariate analysis of factors associated with domestically acquired *Salmonella enterica* serotype Enteritidis infection, Foodborne Disease Active Surveillance Network case-control study—United States, 1996–1997.

Exposure	Study group, *n/N* (%)		Matched OR (95% CI)
	Patients	Controls	
Fewer home-prepared meals	83/148 (56)	105/281 (37)	2.5 (1.6–3.9)
Any egg	88/147 (60)	202/265 (76)	0.4 (0.3–0.7)
Prepared outside of the home	32/147 (22)	47/275 (17)	1.4 (0.8–2.3)
Prepared outside of the home, undercooked only	13/143 (9)	11/269 (4)	2.2 (1.0–5.0)
Prepared at home	52/145 (36)	162/271 (60)	0.3 (0.2–0.5)
Prepared at home, undercooked only	10/141 (7)	41/265 (16)	0.4 (0.2–0.9)
In homemade food, raw or undercooked	19/146 (13)	51/267 (19)	0.6 (0.3–1.1)
Any chicken	112/139 (81)	218/273 (80)	1.1 (0.6–1.9)
Prepared outside the home	68/139 (49)	78/266 (29)	2.2 (1.4–3.4)
Prepared at home	65/137 (47)	187/272 (69)	0.4 (0.3–0.6)
Any hamburger	52/141 (37)	149/268 (56)	0.4 (0.3–0.6)
Prepared outside the home	39/140 (28)	70/245 (29)	0.9 (0.6–1.6)
Prepared at home	18/139 (13)	83/245 (34)	0.2 (0.1–0.4)
Fresh fruit[a]	75/139 (53)	211/270 (78)	0.3 (0.2–0.5)
Underlying medical condition	32/150 (21)	40/283 (14)	1.7 (1.1–3.0)
Household member with diarrhea	21/148 (14)	38/266 (14)	1.0 (0.5–1.7)
Recent use of antibiotics	19/150 (13)	25/279 (9)	1.4 (0.7–2.6)
Recent use of antacids	24/144 (17)	48/280 (17)	1.0 (0.5–1.7)
Farm exposure (live or visit)	11/150 (7)	12/282 (4)	2.0 (0.8–4.7)
Live cattle exposure	7/150 (5)	5/282 (2)	2.8 (0.9–8.8)
Live poultry exposure	4/150 (3)	8/282 (3)	1.0 (0.3–3.3)
Live reptile exposure	14/150 (9)	27/283 (10)	0.9 (0.4–1.9)

NOTE. Data are no. of patients who were exposed/no. of respondents (%), unless otherwise indicated.

[a] Includes cantaloupe, honeydew melon, watermelon, strawberries, grapes, and pineapple.

between domestically acquired infection and having a household member with diarrhea, prior use of antibiotics or antacids; living on a farm, or exposure to live poultry, cattle, or reptiles (table 4).

The final multivariate model consisted of the following 3 factors: a median-ranked variable for number of home-prepared meals consumed (MOR, 2.4; 95% CI, 1.5–3.8), a median-ranked variable for diet diversity (computed as the number of different food items consumed during the exposure period) (MOR, 4.0; 95% CI, 2.4–6.7), and consumption of chicken prepared outside the home (MOR, 2.8; 95% CI, 1.8–4.4) (table 5).

When all cases (both domestically and internationally acquired) were considered, 17% (95% CI, 12%–23%) of SE infections could be attributed to international travel and 35% (95% CI, 22%–47%) to eating chicken outside of the home. Of all domestically acquired SE infections, 28% (95% CI, 13%–43%) could be attributed to eating chicken outside of the home.

Phage-type results. Case patients infected with SE PT4 were more likely to have traveled internationally than persons infected with other PTs; 14 (35%) of 40 case patients with illness caused by SE PT4 in our study had traveled, compared with 18 case patients (13%) infected with any of the other PTs (OR, 4.9; 95% CI, 2–12). The number of SE PT4 infections associated with international travel varied according to site. In California, 2 (14%) of 14 case patients infected with SE PT4 infections had traveled abroad in the 5 days before illness onset; by contrast, 2 (67%) of 3 case patients infected with SE PT4 in Connecticut, 6 (50%) of 12 case patients infected with SE PT4 in Minnesota, and 4 (40%) of 10 case patients infected with SE PT 4 in Oregon had traveled internationally. The single case of SE PT4 infection reported in Georgia was not associated with international travel. For those who reported having traveled internationally, the most commonly reported destination among those with SE PT4 infection was western Europe (57% of respondents). The second most commonly reported destination was Mexico (33% of respondents).

Of the 13 patients who consumed undercooked eggs prepared outside the home, 5 (38%) were infected with SE PT8, 5 (38%) with SE PT4, and 3 with SE PT13a (23%). Among the 90 case patients who reported having consumed chicken prepared outside of the home in the 5 days prior to illness

Table 5. Multivariate analysis of factors in the 5 days before onset of illness due to domestically acquired *Salmonella enterica* serotype Enteritidis infection, Foodborne Disease Active Surveillance Network case-control study—United States, 1996–1997.

Exposure	Matched OR (95% CI)	*P*
Chicken prepared outside the home	2.8 (1.8–4.4)	<.0001
Fewer number of meals prepared at home	2.4 (1.5–3.8)	.0005
Lower diet diversity	4.0 (2.4–6.7)	<.0001

onset, 33 (37%) were infected with PT13a, 24 (27%) with PT4, 14 (16%) with PT8, and 19 (22%) with other PTs.

DISCUSSION

This represents the largest and most geographically diverse study to date of sporadic SE infection in the United States. Our study demonstrated that a history of international travel and consumption of commercially prepared foods (in particular, chicken) were significant risk factors for sporadic SE infection.

The most common destination among international travelers with SE infections in our study was Mexico. Previous studies have calculated attack rates of diarrhea of 25%–50% among travelers to Mexico [28, 29]. Although enterotoxigenic *Escherichia coli* is the most frequently isolated organism from diarrheal stools in these studies, *Salmonella* and *Shigella* organisms are also common [28–30]. The source of these infections is unknown. However, because international travelers tend to eat at a variety of commercial establishments, their risk of exposure to SE may be amplified. Persons intending to travel to developing countries should be educated about the importance of careful selection of food and beverages (i.e.,"boil it, peel it, cook it, or forget it") for preventing travelers' diarrhea [30].

Chicken has not previously been reported as a cause of sporadic cases of SE nor as a frequent cause of SE outbreaks in the United States. However, endemic infection of broiler chickens with SE and consequential human illness has been described in other countries [31, 32]. Chicken is a particularly pertinent risk factor in countries where broiler flocks have been infected with SE PT4. In retail surveys from the United Kingdom,SE PT4 was isolated from 61 (21%) of 292 frozen or chilled chickens sampled in 1990, compared with none of 100 chickens tested in 1979 [33]. The number of infections with SE PT4 among humans increased in the United Kingdomas the proportion of infections with the organism among chickens increased [17, 18, 34, 35]. Ready-to-eat chicken has been implicated as a risk factor for SE PT4 illness in at least 1 case-control study in England [19]. Similarly, a 1995 study from Thailand reported that 17 (74%) of 23 SE isolates from retail chicken samples were PT4; SE PT4 is the predominant PT isolated from infected humans in Thailand [36].

By contrast, in our study, SE PT13a was the predominant PT isolated from case patients with domestically acquired infections who reported eating chicken prepared outside the home, perhaps because SE PT4 has yet to become established in broiler flocks in the United States. Once SE PT4 infects a broiler flock, it appears to become the predominant strain, to the exclusion of other PTs [18]. Although studies have confirmed the presence of SE on broiler chickens in the United States, phage typing of those isolates has not been done. In 1998, large slaughter plants and plants producing raw ground products became subject to *Salmonella* testing by the USDA. From January 1998 through January 1999, 2.4% of 573 broiler isolates from these large plants yielded SE [37]. Although the extent of SE contamination and the variety of PTs to be found in US broiler chickens are unknown, these studies support our finding that chicken is a potential source of SE infections in the United States.

A relatively small proportion of SE infections in our study could be attributed to international travel and to eating chicken prepared outside of the home (17% and 27%, respectively), indicating that other exposures not clearly elucidated by this study must also be risk factors for SE infection. The inability to implicate eggs as an independent risk factor for sporadic SE infection in this study may be an artifact of our study design, specifically, the use of a 5-day exposure period for a commonly consumed food and the exclusion of cases associated with outbreaks of infection. Sixty percent of case patients and 76% of controls reported having eaten eggs during this 5-day period. A recent study of sporadic SE infections in Denmark had similar findings at 5 days, but 25% of case patients and 16% of controls had eaten eggs in the day before onset of illness, a strongly significant association [38]. Furthermore, eating eggs prepared outside the home appears to be riskier than consuming eggs prepared in the home. Although the consumption of undercooked eggs prepared outside the home was not significantly associated with illness in multivariate analysis, eggs are a known vehicle of SE outbreaks [6–10]. Therefore, they should not be discounted as a source of sporadic infections. Restaurant-prepared dishes containing undercooked eggs are likely to be more risky than similar dishes prepared at home, because the former may involve pooling of large numbers of eggs, increasing the odds that a contaminated egg would be involved [6–10, 23]. In a study of sporadic SE infections in Utah, case patients were much more likely to eat at restaurants that used >2000 eggs per week and pooled more eggs than their matched controls, presumably because of the increased likelihood of encountering an infected egg [23]. Because undercooked eggs may be an unrecognized ingredient in many dishes, our results are likely to underestimate the true risk of SE attributable to eggs.

In the final multivariate analysis, the risk of illness increased with a decrease in the reported number of home-prepared meals consumed. This measure may, in fact, be considered to be a proxy for eating a larger number of commercially prepared meals. Prior case-control studies of sporadic SE infections in the United States have reported an association between eating in restaurants and illness [12–14, 23]. Outbreaks of SE are also frequently traced to food served at restaurants. During 1985–1991, a total of 224 (59%) of 380 outbreaks of SE reported to CDC occurred in restaurants or other commercial food settings [7]. As in the Utah study, this may represent cross-contamination of a variety of foods with *Salmonella* organisms present initially in eggs or poultry. Such cross-contamination is difficult to assess by case-control methodology because it is inapparent to the patrons. Other studies in this supplement also highlight the association between foodborne infections and eating outside of the home.

In univariate analysis, consuming any of several fruit items (e.g., strawberry, grapes, cantaloupe, honeydew melon, and watermelon) was more common among controls than case patients. We used a dietary diversity index to examine whether this was an effect specific to a single food or food group, or perhaps reflective of a difference in overall eating behavior. The multivariate analysis suggests the latter is more likely, as these apparent protective effects were not independent of dietary diversity. The effect of dietary diversity on gut flora, host resistance, and ingested pathogens is unknown, as is the potential association between diversity and a greater degree of sophistication in food handling; both explanations merit further examination.

Among all of the food exposures considered in this study, only eating chicken that had been prepared outside the home was associated with SE infection in both univariate and multivariate analysis. Similarly, only "ready-to-eat" or "take-out" chicken has been associated with illness in case-control studies in Europe [19, 39]. To our knowledge, the reason for this association with only eating chicken prepared outside the home has not been investigated. However, *Salmonella* can readily be transferred from raw chicken to cutting boards, plates, and hands [40, 41]; therefore, it is possible that the risk for cross-contamination and other foodhandling errors are compounded by various factors in a commercial kitchen (e.g., greater food volume, complex menus, and undertrained food handlers). In a study of restaurant-associated outbreaks of foodborne disease in Washington State, poultry was the most commonly implicated vehicle [42]. The most frequent contributing factors in this series were improper heating, cooling, cooking, holding, or storage of food [42].

In December 1999, the President's Council on Food Safety announced the Egg Safety Action Plan, which called for a 50% reduction in egg-associated SE illnesses by 2005 and made the reduction of SE infections a national priority [43]. Measures to control SE infection must be multidisciplinary and should involve the collaboration of partners, including local, state, and federal governments and the egg and poultry industry.

Control of SE infection will require efforts at the farm level. Quality assurance programs (QAPs) call for rigorous on-farm control procedures and microbiologic testing to reduce SE contamination of eggs and may have resulted in decreases in human SE infections in regions where the QAPs have been implemented [10, 22]. Likewise, if some broiler flocks are identified as being contaminated with SE, similar QAPs may need to be implemented, especially if SE PT4 is detected, in addition to enhanced slaughter hygiene.

Educational efforts should focus on the proper handling of egg and poultry in food service establishments and any other facilities (e.g., nursing homes and hospitals) that serve a large volume of food. Preventive measures to decrease the risk of illness in these settings include using pasteurized eggs in dishes that require pooled eggs and using irradiated chicken. Consumers must also receive education on safe foodhandling practices. For uncooked foods that are subsequently prepared at home, such as eggs and poultry, some of the responsibility of insuring food safety rests with the consumer. Yet, in a national survey conducted in 1992, one-third of respondents who prepared meals reported having used unsafe food hygiene practices, such as not washing hands or not taking precautions to prevent cross-contamination from raw meat [44]. Guidelines for safe foodhandling practices are readily available, and although many consumers have indicated knowledge of these guidelines, this has not consistently been translated into practice [44, 45].

The rates of isolation of SE that were observed in the 5 FoodNet sites were consistent with the geographic patterns that have been seen in the United States over the past decade. The increase in SE isolation rates in the United States has largely resulted from increases found in the Northeast region, presumably due to an increased proportion of SE-contaminated eggs from infected poultry layer flocks [3, 8]. In our study, the Northeast site (i.e., Connecticut) had the highest isolation rate of 8.4 cases per 100,000 population. A sharp increase in the number of SE isolates has been reported from California over the past few years, likely resulting from the emergence of PT4 in southern California [13, 22]. A recent study confirmed the presence of SE PT 4 among apparently healthy hens in a commercial layer flock in southern California [46]. In our study, the California site, which is mainly limited to northern California, had the second highest isolation rate of SE at 3.0 cases per 100,000 population.

Finally, 65% of the case patients in our study were treated with an antimicrobial agent. Of these, 62% were treated with a fluoroquinolone. These data suggest that clinicians were pre-

scribing empirical antimicrobial therapy before the availability of culture results or were attempting to treat salmonellosis with antibiotics. However, gastroenteritis caused by *Salmonella* is generally self-limited; antimicrobial therapy does not decrease the duration of symptoms and may increase the risk of complications [47]. Guidelines for the management of foodborne infections, including diagnosis on the basis of stool culture results and treatment with antimicrobial agents, were published recently [48]. Efforts to educate physicians on appropriate antibiotic use must continue to be promoted.

Consumption of chicken has not previously been associated with SE infection in the United States, although it is a commonly implicated risk factor in Europe. Further studies are needed to determine the extent that SE has been introduced into broiler flocks in the United States and the PTs that are involved. Measures to prevent SE infections must continue to address the farm-to-table continuum and include a combination of consumer and commercial food handler education.

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