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Salmonella enterica Serotype Enteritidis: Increasing Incidence of Domestically Acquired Infections

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Background. *Salmonella enterica* causes an estimated 1 million cases of domestically acquired foodborne illness in humans annually in the United States; Enteritidis (SE) is the most common serotype. Public health authorities, regulatory agencies, food producers, and food processors need accurate information about rates and changes in SE infection to implement and evaluate evidence-based control policies and practices.

Methods. We analyzed the incidence of human SE infection during 1996–2009 in the Foodborne Diseases Active Surveillance Network (FoodNet), an active, population-based surveillance system for laboratory-confirmed infections. We compared FoodNet incidence with passively collected data from complementary surveillance systems and with rates of SE isolation from processed chickens and egg products; shell eggs are not routinely tested. We also compared molecular subtyping patterns of SE isolated from humans and chickens.

Results. Since the period 1996–1999, the incidence of human SE infection in FoodNet has increased by 44%. This change is mirrored in passive national surveillance data. The greatest relative increases were in young children, older adults, and FoodNet sites in the southern United States. The proportion of patients with SE infection who reported recent international travel has decreased in recent years, whereas the proportion of chickens from which SE was isolated has increased. Similar molecular subtypes of SE are commonly isolated from humans and chickens.

Conclusions. Most SE infections in the United States are acquired from domestic sources, and the problem is growing. Chicken and eggs are likely major sources of SE. Continued close attention to surveillance data is needed to monitor the impact of recent regulatory control measures.

Salmonella enterica infection is a significant public health problem, causing an estimated 1 million domestically acquired foodborne illnesses and >350 deaths each year in the United States [1] and an estimated 93.8 million illnesses and 155 000 deaths each year worldwide [2]. *S. enterica* serotype Enteritidis (SE) is one of the most common serotypes and continues to

cause large numbers of human illnesses in the United States despite ongoing implementation of targeted control and prevention measures for >25 years [3].

Effective control of SE infection has been a moving target. An epidemic of SE illnesses associated with shell eggs began in the northeastern United States in 1978 and spread throughout the rest of the country. By 1994, SE was the most common *Salmonella* serotype causing salmonellosis, comprising 26% of all *Salmonella* isolates [4]. Voluntary farm-based interventions, use of pasteurized egg products in institutions, consumer education, and increased attention to refrigeration of eggs helped decrease rates of SE infection during the late 1990s [3–5].

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Several high-profile outbreaks during the late 2000s, including the largest SE outbreak ever reported from shell eggs in 2010 [6], have refocused national attention on food safety. National health objectives (ie, Healthy People 2020) include as a top food safety priority reducing *Salmonella* infection [7]. The Food and Drug Administration (FDA) and the US Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) have made decreasing SE illnesses a high priority performance goal and a benchmark for evaluating regulatory effectiveness [8–10]. Progress toward food safety goals for *Salmonella*, including SE, is tracked using data from the Centers for Disease Control and Prevention (CDC) Foodborne Diseases Active Surveillance Network (FoodNet) [11].

Public health authorities, regulatory agencies, food producers, and food processors need clear, accurate SE surveillance information to inform and evaluate evidence-based SE control policies and practices. To examine burden of human SE infections and understand changes over time, we analyzed FoodNet data from the period 1996–2009. We compared FoodNet SE data with passively collected data from a complementary surveillance system and with rates of SE isolation from processed chickens and egg products, 2 important sources of human SE infection. We also compared molecular subtyping patterns of SE isolated from humans with those from chickens.

METHODS

Data Sources

FoodNet

FoodNet actively collects data on laboratory-confirmed human cases of infection caused by 9 pathogens transmitted commonly through food, including *Salmonella*, in select sites around the United States. FoodNet is a collaboration of the CDC, state health departments, USDA/FSIS, and FDA. During 1996–2004, counties and states were added to the FoodNet surveillance area, which now includes the entire states of Connecticut, Georgia, Maryland, Minnesota, New Mexico, Oregon, and Tennessee and selected counties in California, Colorado, and New York. The 2011 FoodNet population comprises approximately 47 million persons, or 15% of the US population. The surveillance area has remained unchanged since 2004 and is, in general, similar demographically to the US population [12]. For each case reported, FoodNet personnel collect information on demographic characteristics (eg, age and sex), hospitalization status (within 7 days of specimen collection or if hospitalized as a result of infection), and outcome (alive or dead at hospital discharge or within 7 days of specimen collection for nonhospitalized patients). Data on recent international travel (illness onset within 7 days after return to United States or during travel for *Salmonella*) and whether

the case was associated with an outbreak have been routinely collected since 2004 [12].

Laboratory-based Enteric Diseases Surveillance

The CDC Laboratory-based Enteric Diseases Surveillance (LEDS; formerly the Public Health Laboratory Information System) passively collects information on laboratory-confirmed isolates from state public health laboratories [13]. Clinical diagnostic laboratories submit *Salmonella* isolates to state public health laboratories, which confirm the isolates as *Salmonella*, perform serotyping, and voluntarily submit a report to the CDC.

PulseNet

PulseNet is a national subtyping network for isolates for foodborne diseases surveillance [14]. State public health laboratories complete pulsed-field gel electrophoresis (PFGE) on most human *Salmonella* isolates and upload PFGE patterns to the PulseNet national database, which also serves as a central repository for PFGE data. PulseNet data are used to identify and investigate enteric diseases outbreaks.

FSIS Salmonella Verification Testing Program

The USDA/FSIS implemented a Pathogen Reduction; Hazard Analysis, and Critical Control Point Systems strategy [8] in 1996 that includes testing for *Salmonella* at US broiler chicken processing plants. Inspectors collect and submit broiler chicken carcass rinsates for a polymerase chain reaction (PCR)-based screening test for *Salmonella*, with culture confirmation for PCR-positive rinsates. The sampling strategy does not account for production volume or regional or seasonal effects. It is used to verify whether *Salmonella* performance standards are being met but not to determine prevalence of contamination or to track trends. Beginning in 2006, the testing strategy changed from random sampling to a sampling method focusing on establishments with the highest frequency of rinsates that yielded *Salmonella* and on those serotypes most frequently associated with human salmonellosis [15].

FSIS Microbiological Testing Program for Pasteurized Egg Products

Shell eggs that originate from SE-positive flocks or are at higher risk of *Salmonella* contamination for other reasons are diverted for processing into pasteurized egg products; not all shell eggs entering processing facilities are at increased risk for contamination. FSIS inspects liquid, frozen, and dried egg products and tests samples from pasteurization processes monthly with use of PCR for *Salmonella*, followed by culture for PCR-positive samples [16].

VetNet

Modeled after PulseNet, VetNet collects molecular subtyping data for isolates obtained from the FSIS *Salmonella* Verification Testing Program. The USDA Agricultural Research Service subtypes SE isolates by PFGE and uploads patterns into the VetNet database. USDA VetNet and CDC PulseNet PFGE

patterns are compared for surveillance and investigation of foodborne illness outbreaks.

Statistical Analyses

FoodNet

We included all reported human cases of SE infection during 1996–2010 in the analyses. We used a negative binomial regression model to estimate incidence of SE infection, adjusting for changes to the surveillance areas and site-to-site variation in disease rates [17]. We compared model-adjusted incidence of SE infection across all sites for each year during 2000–2009 with the mean model-adjusted incidence during 1996–1999. When the data were further stratified, the model no longer converged. Therefore, for stratified analyses, we examined crude incidence during 2004–2009, when the FoodNet catchment population was unchanged. Change in relative incidence from 2004 through 2009 was calculated from a least squares best-fit line through the plotted 2004–2009 incidence rates.

Change in incidence was examined for age groups of <1, 1–4, 5–59, and ≥ 60 years. Seasonality of (1) incidence of SE infection and (2) percentage of all reported cases of *Salmonella* infection due to SE were examined using month of specimen collection. We examined changes in the proportion of persons who reported international travel, whose infections were reported to be associated with outbreaks, and who were hospitalized or died; we report data only for years when <25% of these data were missing.

LEDS

Because of wide state-to-state variation in reporting of *Salmonella* serotypes to LEDS, a state was excluded if, in any of the years during 2000–2009, it reported serotype information for <80% of *Salmonella* isolates or it reported no SE isolates. We compared crude SE incidence during 2000–2009 with the mean crude incidence during 1996–1999.

FSIS *Salmonella* Verification Testing Program

We examined SE contamination of broiler chickens during 2000–2005, the period of random sampling. We describe yearly changes in the percentage of broiler chicken rinsates collected that yielded SE.

FSIS Microbiological Testing Program for Pasteurized Egg Products

We examined yearly percentages of samples of pasteurized egg products that yielded SE during 2000–2009.

PulseNet

Because reporting to PulseNet was limited before 2005, we examined data during 2005–2009 for yearly changes in the most common PFGE patterns in SE isolated from humans. Because SE is a clonal organism that has a limited number of different PFGE patterns, we examined changes in the 5 most commonly reported patterns by year. PFGE pattern names for

SE are reported by a numerical designation (ie, PFGE pattern JEGX01.0004 is reported as “pattern 4”).

VetNet

We described yearly changes in available PFGE patterns in SE isolated from broiler chicken rinsates. The same PFGE pattern might have different names in VetNet and PulseNet (eg, VetNet pattern Xba1.0003 corresponds to PulseNet pattern JEGX01.0004). For consistency, we report VetNet PFGE patterns by their PulseNet numerical designation (ie, VetNet pattern Xba1.0003 is reported as “pattern 4”).

Statistical analyses were performed using SAS, version 9.2 (SAS Institute). This surveillance data review was determined not to be research; thus, the project did not undergo human subjects review.

RESULTS

FoodNet

Model-adjusted annual incidence of SE infection during 2000–2003 remained similar to the 1996–1999 mean of 1.9 cases per 100 000 population (Figure 1). Incidence then steadily increased to a maximum of 2.8 cases per 100 000 population in 2008, representing a 44% increase since the period 1996–1999.

During 2004–2009, 6777 SE infections were reported. Incidences among male and female individuals were similar during this period (Table 1). Incidence was highest in the youngest age groups (≤ 4 years of age; 4.7–6.9 cases per 100 000). In the youngest and oldest age groups, the relative increase in incidence (44%–75%) from 2004 through 2009 was substantially higher than among persons in the group aged 5–59 years (25%). By FoodNet site, the mean annual incidence was highest in Maryland, followed by Connecticut and California. Relative incidence increased from 2004 through 2009 in states in the southern half of the United States (Maryland, Georgia, Tennessee, and New Mexico; range, 36%–140%) and in New York (69%); relative incidence remained generally unchanged ($\leq 20\%$ change) at other sites.

Before 2006, $\geq 25\%$ of reports were missing data on international travel; therefore, changes in international travel were examined using reports from the period 2006–2009 (15%–22% of reports were missing data on international travel). The percentage of patients with SE infection who did not report recent international travel increased steadily during 2006–2009, from 74.9% to 88.4% (Table 2). The percentage of cases reported to be sporadic (ie, not part of an outbreak) and the percentage of patients who were hospitalized or who died remained generally stable during 2004–2009.

Incidence of SE infection in FoodNet during 2004–2009 peaked during the summer months and was lowest during the

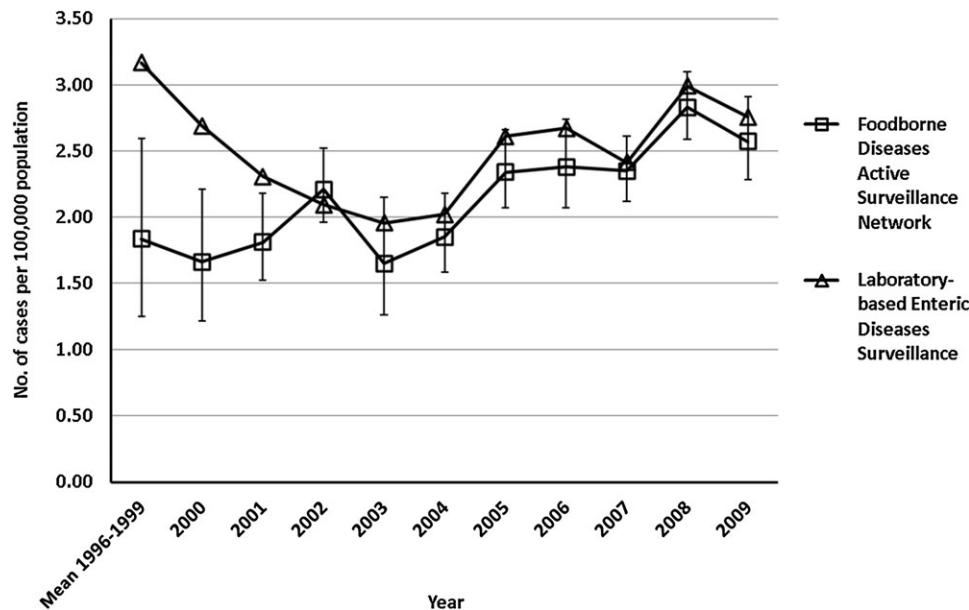


Figure 1. Model-adjusted incidence of *Salmonella* serotype Enteritidis infection by year, Foodborne Diseases Active Surveillance Network (adjusted, includes 95% confidence intervals) and Laboratory-based Enteric Diseases Surveillance (crude; excludes data from Arkansas, Colorado, District of Columbia, Florida, Louisiana, Maine, Maryland, Montana, Nebraska, Tennessee, Texas, and Wyoming because of zero counts or incomplete data), 2000–2009 compared with mean of 1996–1999 baseline.

late winter months. Conversely, the percentage of all reported *Salmonella* infections due to SE peaked during the winter months (Figure 2).

LEDS

For ≥ 1 year during 2000–2009, 11 states and the District of Columbia reported either zero isolates of SE or serotype information for $< 80\%$ of *Salmonella* isolates; these states were excluded from analysis. In the remaining 39 states, 55 221 SE isolations were reported during 2000–2009. Incidence of SE infection steadily decreased from the mean during 1996–1999 to a low in 2003. The trend then reversed, with incidence generally increasing, to a maximum in 2008 (Figure 1). The annual incidences reported through LEDS during 1996–2001 were higher than those reported through FoodNet. However, since full 10-state representation was reached in FoodNet in 2004, the annual incidence of reported SE infection has been similar in the 2 systems.

FSIS *Salmonella* Verification Testing Program and Microbiological Testing Program for Pasteurized Egg Products

During 2000–2005, the percentage of young chicken rinsates that yielded SE steadily increased, from 0.2% in 2000 to > 5 -fold higher (1.3%) in 2005 (Table 3). During 2000–2009, a mean of 0.06% of samples of pasteurized egg products tested yielded SE.

PulseNet and VetNet

In PulseNet, approximately 80% of all human isolates of SE from the period 2005–2009 had 1 of 5 dominant PFGE patterns (Table 3). Pattern 4 was the most common (43%), followed by pattern 5 (14%), and pattern 2 (12%). No trends were apparent.

In VetNet, 2 PFGE patterns predominated among SE isolates recovered during FSIS *Salmonella* broiler chicken testing during 2000–2003: pattern 4 (39%) and pattern 5 (41%) (Table 3). Together, these patterns represented 70%–88% of SE isolates each year.

DISCUSSION

Although the incidence of laboratory-confirmed SE infection decreased during the late 1990s after implementation of egg safety measures [3], it has rebounded substantially in both active and passive surveillance and in chicken carcass test results. In 2008, incidence rates in FoodNet were the highest since surveillance began in 1996. The increase in incidence of SE infection has affected many parts of the country and involves several dominant PFGE patterns. *Salmonella* is estimated to be the most common cause of domestically acquired bacterial foodborne illness in the United States [1], and SE is the most common serotype causing salmonellosis; therefore, addressing the reasons for the increase is important. Decreasing

Table 1. Number of Cases and Annual Crude Incidence per 100 000 Persons of *Salmonella* Serotype Enteritidis Infection, by Demographic Characteristics and Site, Foodborne Diseases Active Surveillance Network, 2004–2009

Characteristic	Annual Crude Incidence, no./100 000						Mean Annual Cases		Mean Annual Incidence	Change in Incidence ^a
	2004	2005	2006	2007	2008	2009	No.	(%)	No./100 000	(%)
Overall (crude)	2.0	2.4	2.4	2.4	3.0	2.7	1130	100	2.5	34
By sex										
Male	1.9	2.4	2.4	2.4	3.0	2.5	545	48	2.5	34
Female	2.0	2.4	2.5	2.3	3.0	2.8	582	52	2.4	34
By age group, years										
<1	6.1	6.4	5.6	6.1	8.3	8.6	43	4	6.9	48
1–4	4.0	4.3	4.6	3.8	6.0	5.5	115	10	4.7	44
5–59	1.8	2.4	2.4	2.3	2.8	2.3	815	72	2.3	25
≥60	1.6	1.7	1.9	1.8	2.5	2.7	154	14	2.0	75
By site										
Connecticut	3.1	3.6	3.7	3.1	3.9	3.5	121	11	3.5	12
New York	1.5	2.1	2.0	2.7	2.7	2.6	97	9	2.3	69
Maryland	3.7	4.3	4.1	4.1	5.5	4.8	247	22	4.4	36
Georgia	1.2	1.6	1.5	1.9	2.7	2.7	182	16	1.9	140
Minnesota	2.2	2.5	3.1	2.7	3.2	2.3	138	12	2.7	12
Tennessee	1.1	1.7	1.7	1.5	1.9	1.8	98	9	1.6	45
Colorado	2.8	2.2	2.4	2.2	2.9	1.7	63	6	2.4	–20
New Mexico	0.8	0.8	1.4	1.0	1.8	1.4	24	2	1.2	87
Oregon	1.6	2.0	2.1	1.3	2.1	1.6	66	6	1.8	–8
California	2.4	3.8	2.9	2.8	2.2	3.1	94	8	2.9	–5

A total of 6777 cases of *Salmonella* serotype Enteritidis infection were reported.

^a Calculated from least squares best-fit line through plotted 2004–2009 incidence data.

the number of SE infections will be necessary to meet the Healthy People national objective of decreasing the incidence of *Salmonella* infection by 25% by 2020 [7].

The rebound in incidence of SE infection is likely to have been a result of several factors; one important risk factor is eating chicken. In a FoodNet case-control study conducted during 2002–2003, eating chicken outside the home accounted for a higher percentage (36%) of domestically acquired

SE infection than any other exposure studied [20], including eating undercooked eggs inside the home (31%). Per capita broiler chicken consumption in the United States has increased steadily from the early 1980s (approximately 32 pounds) through the late 2000s (65–70 pounds) [21]. In our study, the increase in the percentage of chicken rinsates contaminated with SE mirrors increases in incidence of human infection, providing ecological evidence of a possible relationship between chicken contamination with SE and human infection. PFGE subtyping results also support this link. Although SE isolates were taken from somewhat different periods, pattern 4 represented approximately 40% of both human and chicken isolates. In addition, patterns 4 and 5 were the 2 most common patterns from human and chicken isolates. Because SE isolates have few distinct PFGE patterns (the top 2 patterns represented 80% of chicken and approximately 60% of human isolates in these data), the pattern similarities do not provide conclusive evidence of a connection but do indicate that a connection is plausible.

FSIS has implemented several new measures to decrease *Salmonella* contamination of broiler chickens. In 2006, FSIS launched an initiative to reduce *Salmonella* contamination

Table 2. International Travel, Outbreak Association, and Outcomes Among Persons With *Salmonella* Serotype Enteritidis Infection, Foodborne Diseases Active Surveillance Network, 2004–2009

Characteristic	Annual Percentage of Cases						Mean, %
	2004	2005	2006	2007	2008	2009	
No international travel ^a	...	...	74.9	76.7	84.9	88.4	81.2
Not outbreak related	95.1	90.0	93.5	95.5	94.3	96.8	94.2
Hospitalized	25.5	25.4	29.5	24.4	26.8	28.9	26.7
Died	1.0	0.5	0.4	0.4	0.8	0.5	0.6

^a International travel: illness date of onset within 7 days of return to United States or during travel.

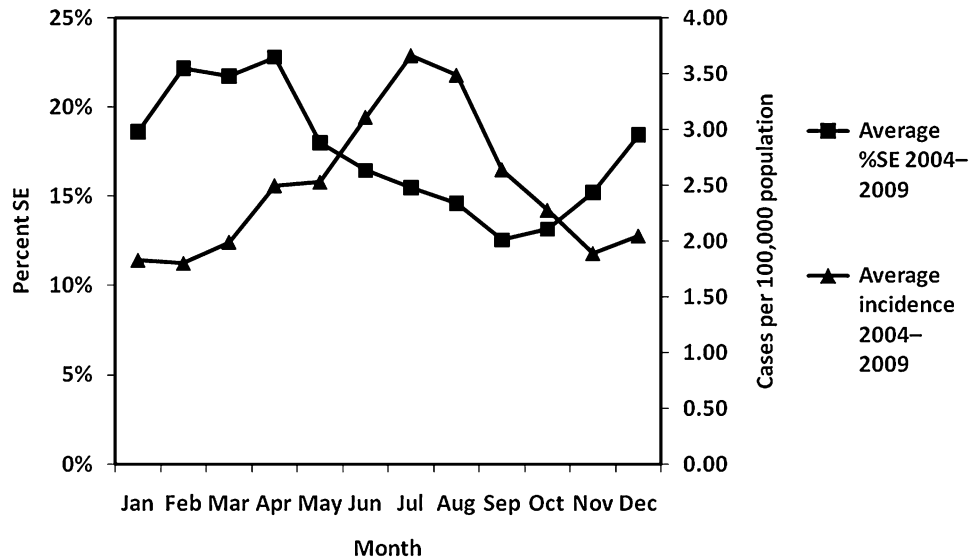


Figure 2. Mean monthly incidence of *Salmonella* serotype Enteritidis infection and percentage of all reported *Salmonella* infections that were due to serotype Enteritidis, Foodborne Diseases Active Surveillance Network, 2004–2009.

of poultry products and other meats, focusing on testing young chickens from establishments that had increasing percentages of contaminated samples [8, 15]. In a 2007–2008 FSIS baseline survey of young broilers that estimated product volume-adjusted pathogen prevalence, 8.1% of all chicken rinsates yielded *Salmonella* by PCR screening and culture; 0.4% of all rinsates yielded SE [22]. In May 2011, FSIS published a tightened performance standard for broilers for its *Salmonella* Verification Testing Program of 7.5% positivity of collected chicken carcass rinsate sets for *Salmonella* at individual slaughter establishments [9].

Although multiple interventions to improve shell egg safety likely contributed to the decrease in incidence of human SE infection during the late 1990s [3], shell eggs continue to cause illness. During 2006–2007, shell eggs accounted for 8 outbreaks of SE infection, resulting in close to 300 illnesses [23, 24]. The largest SE outbreak due to shell eggs, which caused an estimated 1900 illnesses, occurred in 2010 [6]. Shell eggs are not routinely tested; therefore, the prevalence of SE contamination is not known. Models have estimated SE contamination of US-produced shell eggs as 1 in 20 000, or 0.005% [25]. The 0.06% positivity of pasteurized egg product samples cannot be directly compared with model-based estimates, because it reflects the entire egg breaking, pooling, pasteurization, and packaging process and facility sanitation and postprocessing contamination. FSIS requires pasteurized egg products to be tested and found negative for *Salmonella* before distribution into commerce.

In July 2010, the FDA implemented the Egg Rule [26], which requires that large producers of shell eggs implement specific

measures to prevent SE from contaminating eggs on the farm, prevent SE growth during storage and transportation, maintain records documenting compliance, and register with the FDA. The FDA began conducting inspections of egg producers, including environmental testing for SE and evaluation of SE prevention plans, practices, and records. Shell eggs are tested if environmental samples test positive for SE but are only diverted for pasteurization if egg tests yield SE. Before 2010, shell eggs were not required to be tested for pathogens. Finding SE in environmental samples, such as layer manure, is associated with egg contamination [27], and US layer flocks have a high prevalence of environmental SE (7%–10% of flocks) [28]. SE-infected flocks only produce SE-infected eggs intermittently, and challenges exist in detecting SE in eggs; with the required shell egg sampling scheme, there is an approximately 95% probability that a positive egg will be detected from a flock that is producing SE-contaminated eggs.

Both incidence of SE infection and relative increases in incidence were highest among persons in the youngest and oldest age groups by 2009. Although apparent differences in incidence among age groups might occur because of detection bias (ie, ill persons at the extremes of age might be more likely to have stool cultured), detection bias cannot explain the differences in the relative increase over time among age groups [29]. Lower infectious dose thresholds in these age groups might help explain these differences. Uniform increases in exposure to SE across all ages would increase likelihood of illness most in persons with the lowest thresholds, which are more likely in those at the extremes of age. Situations with uniformly increased exposure to pathogens, such as large-scale municipal

Table 3. *Salmonella* Serotype Enteritidis Testing Results From Broiler Chickens, Egg Products, and Humans, US Department of Agriculture/Food Safety and Inspection Service and PulseNet, 2000–2009 [18, 19]

Source/Type	Year										Total
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Broiler chicken rinsates											
No. SE positive/ no. tested (%)	23/10 057 (0.2)	17/8955 (0.2)	33/9183 (0.4)	29/6468 (0.5)	58/7072 (0.8)	120/9592 (1.3)	...	...	...	...	280/51 327 (0.5)
Top PFGE patterns,^a no. (%)											
5	5 (22)	10 (63)	13 (42)	12 (43)	...	...	...	...	...	...	40 (41)
4	11 (48)	4 (25)	14 (45)	9 (32)	...	...	...	...	...	...	38 (39)
34	1 (4)	0 (0)	1 (3)	3 (11)	...	...	...	...	...	...	5 (5)
30	0 (0)	0 (0)	2 (6)	0 (0)	...	...	...	...	...	...	2 (2)
All others	6 (26)	2 (13)	1 (3)	4 (14)	...	...	...	...	...	...	13 (13)
Egg product samples											
No. SE positive/ no. tested (%)	0/1761 (0.00)	2/1656 (0.12)	0/1647 (0.00)	1/1560 (0.06)	1/1558 (0.06)	1/1610 (0.06)	2/1502 (0.13)	0/1421 (0.00)	1/1506 (0.07)	1/1441 (0.07)	9/15 661 (0.06)
Human isolates											
Top PFGE patterns, no. (%)											
4	...	...	...	...	...	1922 (38)	2071 (42)	2285 (43)	2731 (44)	3003 (47)	12 012 (43)
5	...	...	...	...	...	918 (18)	703 (14)	696 (13)	759 (12)	853 (13)	4238 (14)
2	...	...	...	...	...	579 (11)	847 (17)	861 (16)	658 (11)	530 (8)	3475 (12)
21	...	...	...	...	...	601 (12)	262 (5)	282 (5)	460 (7)	504 (8)	2109 (8)
34	...	...	...	...	...	123 (2)	181 (4)	261 (5)	321 (5)	284 (4)	1170 (4)
All others	...	...	...	...	...	934 (18)	905 (18)	969 (18)	1292 (21)	1176 (19)	5276 (19)

Abbreviations: PFGE, pulsed-field gel electrophoresis; SE, *Salmonella* serotype Enteritidis.

^a Pattern names provided are the equivalent PulseNet numerical designations (ie, JEGX01.0004 is pattern 4) of the matching VetNet patterns.

water contamination with *Salmonella*, have resulted in the highest attack rates in the youngest age groups [30]. Exposure to antibiotics, which can predispose to *Salmonella* infection through suppression of normal gut flora and can be more frequent in young individuals, might contribute to the difference in illness threshold [31]. In addition, the protective acidity of the stomach against infection is lower in infants [32] and, in older individuals, might be lowered through the increased use of antacids [33].

Similar to a prior FoodNet report [5], we found substantial regional differences in incidence of SE infection. Particularly large relative increases in incidence occurred at sites in the southern United States, and a northeastern state had the highest mean annual incidence in FoodNet. Targeted studies of regional factors, such as egg or chicken suppliers, state egg quality assurance programs, and consumer and food handler educational initiatives, might help clarify reasons for the regional incidence variability. Regional differences also help to explain why FoodNet reported lower SE incidence than LEDS before 2002; FoodNet continued to add reporting counties from states with a high SE incidence, such as Maryland and Georgia, through 2001. Because 22% of states were excluded from LEDS data because of limited reporting, 2 of which have some of the largest populations in the United States and more than half of which are in the southern United States, LEDS incidence rates should be interpreted with caution and could be underestimated. SE infections showed less seasonal variability by month than *Salmonella* infections as a group (Figure 2), which suggests that exposures might not be as seasonally variable as they are for other serotypes. Although our data do not address the causes of this summer blunting, they are consistent with the pattern expected if exposure occurs primarily through foods consumed commonly throughout the year, such as chicken and eggs.

Enteritidis is the most commonly reported serotype among travel-associated nontyphoidal *Salmonella* infections in the United States [34], and decreasing domestic sources of SE will not affect the approximately 1 in 5 SE infections that are acquired abroad. However, despite increases in international travel for US residents during the 2000s, which peaked during 2006–2008 [35], the percentage of persons with SE infection who reported no recent international travel increased consistently during 2006–2009. In addition to the increasing importance of domestically acquired SE infection, this implies that the rates of increase of domestically acquired SE infection are even higher than the overall numbers indicate. Although imports of chilled or frozen chicken have increased exponentially since the late 1990s, imports (including live chickens) represent <1% of all chicken estimated to be consumed in the United States [36]. Imports of eggs have remained stable at <0.1% of all eggs estimated to be consumed in the United

States [21, 36]. Together, these data indicate that the sources of most SE infection are domestic and that the problem of domestically acquired SE infection is increasing.

Antimicrobial resistance of human SE isolates is highest to nalidixic acid and ampicillin. SE resistance to nalidixic acid increased from 1.6% during 1996–1999 to 4.2% during 2000–2004 and 5.6% during 2005–2009, whereas resistance to ampicillin decreased from 13.9% during 1996–1999 to 6.0% during 2000–2004 and 3.4% during 2005–2009 [37, 38]. Nalidixic acid resistance has been correlated with reduced susceptibility to ciprofloxacin, a first-line antimicrobial agent often used to treat severe *Salmonella* infection [38].

The rebound in incidence of domestically acquired SE infection, particularly in the southern part of the United States, is a growing problem that is disproportionately affecting the youngest and oldest populations. Eggs and broiler chickens are the main food sources of SE illness. Reviewing egg and poultry outbreak data and continuing to develop methods to attribute illnesses to foods can help clarify their relative contributions to the burden of SE. The testing of shell eggs under the 2010 FDA Final Egg Rule [26] is an important step forward for SE control. It will also improve tracking of the contribution of shell eggs to human SE illness. The success of efforts by industry in collaboration with public health authorities in Denmark and the United Kingdom, which have included improved biosecurity, enhanced testing, and, in the United Kingdom, poultry vaccination, shows that multifaceted, preharvest, flock-based approaches such as the FDA Final Egg Rule can lead to substantial reductions in human SE infection [39, 40]. Ultimately, surveillance data on human SE infection will reflect, in part, the impact of the FDA Final Egg Rule. Because broiler chickens are a major food source of human SE infection, similar multifaceted preharvest approaches might also be needed for chickens to supplement the tighter processor-level standards now being implemented by the FSIS.

Notes

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