S U P P L E M E N T A R T I C L E

Reptiles, Amphibians, and Human *Salmonella* Infection: A Population-Based, Case-Control Study

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To estimate the burden of reptile- and amphibian-associated *Salmonella* infections, we conducted 2 case-control studies of human salmonellosis occurring during 1996–1997. The studies took place at 5 Foodborne Diseases Active Surveillance Network (FoodNet) surveillance areas: all of Minnesota and Oregon and selected counties in California, Connecticut, and Georgia. The first study included 463 patients with serogroup B or D *Salmonella* infection and 7618 population-based controls. The second study involved 38 patients with non–serogroup B or D *Salmonella* infection and 1429 controls from California only. Patients and controls were interviewed about contact with reptiles and amphibians. Reptile and amphibian contact was associated both with infection with serogroup B or D *Salmonella* (multivariable odds ratio [OR], 1.6; 95% confidence interval [CI], 1.1–2.2; $P < .009$) and with infection with non–serogroup B or D *Salmonella* (OR, 4.2; CI, 1.8–9.7; $P < .001$). The population attributable fraction for reptile or amphibian contact was 6% for all sporadic *Salmonella* infections and 11% among persons <21 years old. These data suggest that reptile and amphibian exposure is associated with ~74,000 *Salmonella* infections annually in the United States.

Approximately 1.4 million human *Salmonella* infections and an estimated 600 associated deaths occur each year in the United States [1]. Although infection with non-typhoidal *Salmonella* usually causes self-limited diarrheal illness, serious sequelae, including meningitis, sepsis, and death may occur, especially among infants, elderly persons, and immunocompromised persons [2–5]. Most infections are caused by the consumption of contaminated meat, poultry, or eggs [6, 7]. However, investigations of outbreaks [8, 9] and sporadic infections [10–12] have revealed cases of salmonellosis that occurred after direct or indirect contact with reptiles. Reptile-associated *Salmonella* infections are more likely to be associated with invasive disease [13], more commonly lead to hospitalization [14], and more frequently involve infants [15] than do other *Salmonella* infections.

Salmonellae are divided into 60 serogroups and >2300 serotypes [16]. Except for characterizing clinical aspects of a few serotypes, such as *Salmonella enterica* serotype Typhi, serogrouping and serotyping are mainly used as public health tools to recognize outbreaks and identify and control sources of infection. Salmonellae from serogroups B and D account for approximately two-thirds of all reported *Salmonella* infections and include the 2 most common serotypes, *S. enterica* serotype Enteritidis and *S. enterica* serotype Typhimurium, which together cause approximately one-half of all human infections in the United States.

Salmonellae are naturally found in the gastrointestinal tract of reptiles (e.g., lizards, snakes, and turtles) and amphibians (e.g., frogs and newts) [17–27]. Of all

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Salmonella serotypes, 40% have been cultured predominantly from reptiles and are rarely found in other animals or humans. Human infections with these serotypes frequently indicate a reptile source [14]. However, <1% of human *Salmonella* infections are caused by these "reptile-associated" serotypes [13]. Neither the extent to which reptiles are also the source of human *Salmonella* infections by more common serotypes nor the possibility that amphibians as well as reptiles can cause human salmonellosis have been examined. We therefore conducted 2 population-based, case-control studies of nontyphoidal *Salmonella* infection in the United States to investigate whether reptiles and amphibians spread serotypes commonly found in human infections (serogroup B or D *Salmonella*) as well as less common serotypes (non–serogroup B or D *Salmonella* that include "reptile-associated" serotypes). We used data collected in these studies to estimate the burden of reptile- and amphibian-associated salmonellosis in the United States.

METHODS

The Foodborne Diseases Active Surveillance Network (FoodNet). FoodNet is a collaborative effort among the Centers for Disease Control and Prevention (CDC), selected state health departments, the US Department of Agriculture, and the US Food and Drug Administration [28]. FoodNet conducts active, population-based surveillance for laboratory-confirmed illnesses caused by infection with primarily foodborne pathogens. For that surveillance, public health officials regularly contact all microbiology laboratories that test stool samples in selected sites in the country. For this study, we reviewed data from laboratories throughout Minnesota and Oregon and in specific counties in California (San Francisco and Alameda), Connecticut (Hartford and New Haven), and Georgia (Cobb, Clayton, Douglas, Dekalb, Fulton, Gwinnett, Rockdale, and Newton). All 263 laboratories that were identified as serving the catchment areas participated in the study, covering an estimated population of 14,281,096 (5.4% of the estimated US population in 1996) [29].

Case selection. 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, we identified all patients with culture-confirmed *Salmonella* infection. Patients infected with nontyphoidal serogroup B or D *Salmonella* were eligible for the main case-control study if they resided in participating catchment areas, had culture-confirmed illness, reported having diarrhea (defined as ⩾3 loose stools in a 24-h period), could remember the date of onset for their diarrhea, had diarrhea onset ⩽10 days before their stool sample was collected, spoke English, and were reachable in <16 telephone attempts. Patients were excluded if their infection had been associated with an outbreak for which a vehicle had been clearly identified by the local or state health department or if the onset of their illness was ⩽28 days after the onset of another culture-confirmed case in the same household. In Minnesota, 1 of every 2 patients with salmonellosis was considered to be potentially eligible. Within 21 days of specimen collection, we administered a standardized questionnaire to patients concerning their demographic data, the clinical course of their illness, preexisting illnesses, diet, travel history, and contact with reptiles or amphibians during the 5 days before illness onset. If the patient was <12 years of age, the questionnaire was administered to an adult member of the household. Permission from a parent or guardian was obtained prior to speaking with a case or control patient 12–18 years of age. We obtained informed consent from participants and conducted research in accordance with guidelines for human experimentation as specified by the US Department of Health and Human Services.

Patients with *Salmonella* infection due to serogroups other than B or D in the California site (Alameda and San Francisco counties) were contacted by telephone and administered the same 4 questions regarding reptile and amphibian exposure included in the questionnaire administered to patients with group B or D *Salmonella* infection. The 4 questions were as follow: (1) "In the five days before illness onset, were there any reptiles (such as snakes, turtles, iguanas, or other lizards) or any amphibians (such as frogs or salamanders) in your house?" (2) If so, "What types of reptiles or amphibians?" (3) "Did you visit a place (such as a school, pet store, or another home) where there was a reptile?" (4) "In those five days, did you touch a reptile?"

Control selection. We obtained population-based controls from the 5 sites by random-digit dialing using a sample design that results in more frequent calls to telephone bank strata with a higher probability of contacting a residential household [30]. During analysis, we accounted for differential probabilities of selection by adjusting for population characteristics of different strata. Our goal was to enroll 150 persons per month in each site. This selection method allowed us to enroll a representative selection of households in the FoodNet surveillance areas (also known as "FoodNet sites"), as well as to reliably estimate the incidence of diarrhea, associated health care–seeking practices, and population food-consumption patterns—additional interests of the study committee. We excluded non–English-speaking persons and respondents who reported having diarrhea within the 4 weeks before the interview.

Data analysis. We entered data into a computer using EpiInfo computer software, version 6.02 (CDC). We weighted data for controls using 1995 intercensal population estimates (SUDAAN, version 7.0) by their probability of selection based on household size and age- and sex-distributions within each FoodNet site. We then performed univariate and logistic regression analysis using SAS computer software, version 6.12

(SAS Institute). All risk factors associated with serogroup B or D *Salmonella* infection ($P < .05$) in univariate analysis were available for inclusion in a multivariable model. For analyses involving non–serogroup B or D *Salmonella* infections, only information on patients' age and sex was available and included in the multivariable model. Risks measured by multiple variables (e.g., reptile exposure in the home and touching a reptile) and those associated with exposure to specific types of reptiles were entered into separate multivariable models to avoid multicollinearity. To select variables for the final logistic regression model, we used a forward regression strategy, and to assess potential collinearity among covariates in the regression models, we used a matrix of Kendal's Tau correlation coefficients. Interaction was assessed by comparing -2 log likelihood values for the reduced and full models.

We calculated the population attributable fraction (PAF) for risk factors using adjusted ORs and the proportion of cases exposed to the risk factor [31]. Ninety-five percent CIs were computed for model-adjusted exposure-specific attributable fractions using variance estimators described by Greenland [32]. To assess the robustness of PAF estimates, we calculated the PAF for reptile and amphibian contact using a variety of models including and excluding demographic variables and risk factors known to be associated with *Salmonella* infection from outbreaks. These risk factors included age, sex, income, season, international travel, chronic illness, and consumption of eggs, poultry, meat, alfalfa sprouts, tomatoes, cantaloupe, and apple cider. Estimates of the annual number and percentage of reptile- and amphibian-associated cases were adjusted for the exclusion of outbreak-associated cases by subtracting the proportion of all reported cases associated with outbreaks from the estimated number of annual *Salmonella* infections and conservatively assuming that reptiles and amphibians were associated with no outbreaks. All *P* are 2-tailed.

RESULTS

Active surveillance. During the study period, 2157 cases of salmonellosis were ascertained. Serogrouping was performed on isolates from 2056 infected persons (93%); 1465 (73%) of these isolates were serogroup B or D. The incidence of culture-confirmed group B or D *Salmonella* infection in the FoodNet catchment area was 9.5 cases per 100,000 persons and varied by state, ranging from 7.2 cases per 100,000 persons in Oregon to 13.9 cases per 100,000 persons in Connecticut. Of the 1446 patients (98.7%) whose treatment information was available, 325 (22%) were hospitalized; of the 1416 (97%) with mortality data, 10 (0.7%) died. Omitting patients excluded by the selection algorithm in Minnesota, we found that 1226 patients were potential case subjects for the study.

Table 1. Association between serogroup B or D *Salmonella* infection and potential risk factors.

Potential risk factor[a]	No. of cases/total (%)	Weighted percentage of controls[b]	Univariate OR (95% CI)	Multivariate OR (95% CI)[c]	*P*	PAF, % (95% CI)[d]
Any reptile or amphibian contact[e]	43/453 (9)	5	1.8 (1.3–2.5)	1.6 (1.1–2.2)	.009	3.4 (1.0–5.1)
Reptile or amphibian in home						
All	33/460 (7)	4	2.1 (1.5–3.0)	1.6 (1.1–2.4)	.01	2.8 (0.8–4.2)
Snake	9/452 (2)	1	2.7 (1.4–5.0)	1.6 (0.8–3.2)	.2	…
Turtle	6/454 (1)	1	1.5 (0.7–3.3)	0.8 (0.4–1.8)	.6	…
Iguana	3/451 (1)	1	1.1 (0.4–3.4)	0.4 (0.1–1.4)	.1	…
Non-iguana lizard	12/453 (3)	1	5.2 (3.1–8.7)	2.7 (1.5–5.0)	.001	…
Amphibian	12/454 (3)	1	1.9 (1.1–3.3)	1.6 (0.9–2.8)	.1	…
Touched reptile	23/453 (5)	3	1.7 (1.1–2.5)	1.6 (1.0–2.4)	.04	1.8 (0.1–3.0)
Visited place with reptile	43/456 (9)	8	1.1 (0.8–1.6)	0.9 (0.7–1.3)[d]	.7	…
Chronic, non-diarrheal illness	85/441 (19)	11	1.9 (1.5–2.3)	2.5 (1.9–3.2)	<.001	11.5 (9.3–13.2)
International travel	48/462 (10)	2	7.3 (5.7–9.4)	8.4 (6.1–11.5)	<.001	9.2 (8.7–9.5)
Ate pink hamburger in restaurant	14/392 (4)	2	1.7 (1.0–2.9)	1.3 (0.8–2.3)	.3	…
Ate eggs in restaurant	109/430 (25)	17	1.6 (1.3–2.0)	1.6 (1.2–1.9)	<.001	9.1 (5.0–12.3)

[a] Demographic factors associated with increased risk for *Salmonella* infection on multivariable analysis were female sex (OR, 1.2; 95% CI, 1.0–1.5), household income <$15,000 per year (OR, 1.6; 95% CI, 1.2–2.1), age (OR, 1.25; 95% CI, 1.2–1.3, for every 10 year decrease in age), season, and site. Potential risk factors not associated ($P > .05$) with increased risk for *Salmonella* infection on univariate analysis were consuming alfalfa sprouts, tomatoes, cantaloupe, apple cider, meat, poultry, hamburger at home, pink hamburger at home, ground beef, steak, roast beef, sausage, hot dogs, turkey, chicken, eggs, eggs at home, and runny eggs at home, and having a known immunosuppressive illness. PAF, population-attributable fraction.
[b] Weighting based on 7618 population-based controls.
[c] Controlling for age, sex, site, season, income, and other risk factors included in the final model.
[d] Calculated only for major risk factors associated with illness ($P < .05$).
[e] Reptile or amphibian in home or touched reptile.

Table 2. Multivariable analysis of association between serogroup B or D *Salmonella* infection and potential risk factors among persons aged <21 years.

Potential risk factor	No. of cases/total (%)	Weighted percentage of controls[a]	OR (95% CI)	*P*	PAF, % (95% CI)[b]
Any reptile or amphibian contact[c]	33/206 (16)	9	2.4 (1.6–3.5)	<.001	9.5 (6.2–11.6)
Reptile or amphibian in home					
All	25/212 (12)	6	2.5 (1.6–3.9)	<.001	7.0 (4.3–9.1)
Amphibian	9/208 (4)	3	2.9 (1.5–5.8)	.002	…
Snake	7/206 (3)	1	3.5 (1.5–8.1)	.004	…
Non-iguana lizard	7/208 (3)	1	4.1 (1.8–9.5)	<.001	…
Iguana	2/206 (1)	1	0.4 (0.1–2.8)	.4	…
Turtle	4/208 (2)	1	1.2 (0.4–3.2)	.7	…
Touched reptile	18/206 (9)	6	2.3 (1.4–3.8)	<.001	5.3 (3.1–6.7)

NOTE. Analysis controlled for age, sex, site, season, income, chronic illness, international travel, and egg consumption. PAF, population-attributable fraction.

[a] Weighting based on 1550 population-based controls.
[b] Calculated only for major risk factors associated with illness ($P < .05$).
[c] Reptile or amphibian in home or touched reptile.

Case-control study. Of these potential case subjects, 687 (56%) were interviewed. The primary reasons for not being interviewed were not being reachable by telephone (32%), not being interviewed ⩽21 days from sample collection (26%), and being part of an outbreak (7%). Of the 687 patients who were interviewed, 463 (67%) were included in the study. The primary reasons for the 224 interviewed patients not meeting inclusion criteria were that 90 (40%) reported no diarrhea or did not remember the date of onset of diarrhea, 58 (26%) reported the onset of diarrhea >10 days before a stool sample was obtained, and 63 (28%) lived in a household with another person with a culture-confirmed case of *Salmonella* infection. Only 21 eligible patients (3%) who were contacted refused to participate. There were 7618 controls included in the study.

Using univariate analysis, we found that persons with *Salmonella* infection were more likely than controls to report having a reptile or amphibian in their home (7% vs. 4%; OR, 2.1; 95% CI, 1.5–3.0) or touching a reptile (5% vs. 3%; OR, 1.7; 95% CI, 1.1–2.5) (table 1). *Salmonella* infection was specifically associated with having a snake, non-iguana lizard, or amphibian in the home, but not with having a turtle or iguana. Illness was associated with "any reptile or amphibian contact," a combination variable of having a reptile or amphibian in the home or touching a reptile (9% vs. 5%; OR, 1.8; 95% CI, 1.3–2.5).

Table 3. Association between non–serogroup B or D *Salmonella* infection and potential risk factors among infected persons from the San Francisco Bay area.

Potential risk factor	No. of cases/total (%)	Weighted percentage of controls[a]	Multivariable OR (95% CI)	*P*	PAF, % (95% CI)[b]
Any reptile or amphibian contact[c]	7/35 (20)	4	4.2 (1.8–9.7)	<.001	15.2 (8.8–17.9)
Reptile in home					
All	6/38 (16)	3	3.9 (1.6–9.5)	.002	11.8 (6.1–14.1)
Amphibian	2/36 (6)	1	6.3 (1.5–27.2)	.01	…
Snake	0/36 (0)	1	…[d]	…	…
Non-iguana lizard	3/37 (8)	1	6.5 (1.9–21.4)	.002	…
Iguana	3/37 (8)	1	19.8 (6.0–64.9)	<.001	…
Turtle	2/37 (5)	1	3.1 (0.7–13.1)	.1	…
Touched reptile	2/32 (6)	2	3.1 (0.7–12.9)	.1	…

NOTE. Analysis controlled for age and sex. PAF, population-attributable fraction.

[a] Weighting based on 1429 population-based controls.
[b] Calculated only for major risk factors associated with illness ($P < .05$).
[c] Reptile or amphibian in home or touched reptile.
[d] Not calculable due to lack of convergence of multivariable logistic regression model.

Table 4. Recommendations for preventing transmission of *Salmonella* from reptiles and amphibians to humans.

Pet store owners, health care practitioners, and veterinarians should provide information to owners and potential purchasers of reptiles and amphibians about the risk of acquiring salmonellosis from their pets.
Persons should always wash their hands with soap and water after handling reptiles and amphibians or their cages.
Persons at increased risk for infection with serious complications from salmonellosis (e.g., children <5 years old and immunocompromised persons) should avoid contact with reptiles and amphibians.
Reptiles and amphibians should be kept out of households containing children <5 years old or immunocompromised persons; families expecting a new child should give their pet reptiles and amphibians away before the infant arrives.
Reptiles and amphibians should not be kept in child-care centers.
Reptiles and amphibians should not be allowed to roam freely throughout the house.
Reptiles and amphibians should be kept out of kitchens and other food preparation areas to prevent contamination; kitchen sinks should not be used to bathe pets or to wash their dishes, cages, or aquariums; if bathtubs are used for these purposes, they should be thoroughly cleaned afterwards.

Serogroup B or D *Salmonella* infection was also associated with international travel, having a chronic illness, eating pink hamburger in a restaurant, and eating eggs in a restaurant.

Using multivariable analysis, we found that patients with serogroup B or D *Salmonella* infection were significantly more likely than controls to be younger, to be female, and to report a household income of ⩽$15,000 per year. Reptile or amphibian contact remained significantly associated with infection, with a PAF of 3%. Age was an effect modifier of the association between *Salmonella* infection and reptile or amphibian contact; the association was strongest for persons under the age of 21 years (OR, 2.4; 95% CI, 1.6–3.5). The association was significant and of similar magnitude for persons <11 years old and those 11–20 years old. Illness among all persons < 21 years old was associated specifically with having a snake, non-iguana lizard, or amphibian in the home (table 2). The PAF for reptile or amphibian contact in this age group was 9.5% (95% CI, 6.2%–12%), the highest for any risk factor associated with illness (the next highest being 8% for having a chronic illness, 7% for eating eggs in a restaurant, and 5% for international travel).

Reptile or amphibian contact was associated with infection even when we restricted our analysis to patients infected with *S.* Enteritidis and *S.* Typhimurium (OR, 1.5; 95% CI, 1.0–2.3). However, this association was not statistically significant on multivariable analysis (OR, 1.4; 95% CI, 0.9–2.0).

***Infection with non–serogroup B or D* Salmonella.** One hundred forty-one cases of non–serogroup B or D *Salmonella* infection were reported from the San Francisco Bay area. Fifty-three (38%) of these infections were associated with an outbreak of *S. enterica* serotype Montevideo and *S. enterica* serotype Meleagridis infections caused by the consumption of contaminated alfalfa sprouts. Answers to survey questions by 38 (43%) of the remaining cases and 1429 controls indicated that persons with non–serogroup B or D *Salmonella* infection more frequently reported reptile or amphibian contact than controls did (20% vs. 4%; OR, 4.2 [95% CI, 1.8–9.7]; PAF, 15.2% [95% CI, 8.8%–17.9%]) (table 3). In addition, illness was independently associated with having an amphibian, iguana, or non-iguana lizard in the home. For patients <21 years old, the PAF for reptile or amphibian contact was 23%.

Annual incidence of reptile- and amphibian-associated cases. Data from FoodNet indicate that an estimated 1.41 million cases of *Salmonella* infection occurred in the United States during the 1-year study period [1]. This is comparable with estimates made in 1987 of between 800,000 and 3.7 million annual *Salmonella* infections [33]. Serogroup B and serogroup D *Salmonella* constituted 72% of the *Salmonella* infections reported to FoodNet. The PAF for reptile or amphibian exposure among cases with serogroup B or D *Salmonella* infection was 3%, and that for those with non–serogroup B or D *Salmonella* infection was 15%; for patients <21 years old, the PAFs for reptile and amphibian contact were 9.5% and 23%, respectively. Assuming site homogeneity, we combined these estimates based on the proportion of *Salmonella* infections that was serogroup B or D and the proportion that was non–serogroup B or D in FoodNet sites. Our analysis of these combined estimates again indicated that reptile and amphibian contact was associated with 6% of all sporadic *Salmonella* infections and 11% of sporadic *Salmonella* infections among persons <21 years of age. Of all *Salmonella* infections in the study, 88% were not associated with known outbreaks, suggesting that ~74,000 *Salmonella* infections (6% of 1.24 million non–outbreak-associated cases) may be associated with reptile and amphibian exposure in the United States annually.

DISCUSSION

During the 1996–1997 study period, we estimated that 74,000 *Salmonella* infections in the United States were associated with reptile or amphibian contact. *Salmonella* infection was independently associated with both touching a reptile and having a reptile or amphibian in the home. Previous reports have shown that direct reptile contact is not necessary for transmission of *Salmonella;* in one case series of infections with an iguana-associated serotype, only 14% of cases had direct reptile contact [15]. Other reports have also described infection from indirect contact such as visiting a babysitter who owned iguanas, cleaning an iguana's cage, sucking on pebbles from a turtle's aquarium, sharing a hospital room with a patient whose mother owned a monitor lizard, and being handled by a parent who owned black rat snakes [9, 10, 34–36].

The exact means of transmission for *Salmonella* may vary for different types of reptiles and amphibians. Lizards are frequently allowed to roam around the house, potentially contaminating objects such as rugs, table-tops, and furniture that are later touched by residents or have food prepared upon them. *Salmonella* survives well in the environment; it has been isolated from dried reptile stool in cages 6 months after removal of the reptile [37] and from aquarium water 6 weeks after removal of a turtle [34]. This survivability allows *Salmonella* to be transmitted by environmental surfaces well after a reptile has been returned to its cage. Although snakes are unlikely to be let free in the home, they are frequently handled, potentially contaminating the hands, arm, and neck of owners. Caregivers who have touched reptiles have accidentally infected infants by allowing them to suck on the caregivers' fingers [38]. Turtles and amphibians are kept in aquariums that contain water that can become contaminated with *Salmonella* and allow for growth of the organism [25, 27, 36, 39], creating enhanced opportunities for transmission. Because of the risk for indirect transmission, the CDC has developed guidelines for preventing reptile-associated salmonellosis that include recommendations to keep reptiles out of households containing young children or persons with weak immune systems and to not allow reptiles to roam freely throughout the house [15, 37, 40, 41]. We have adapted these guidelines to include amphibians (table 4).

Reptiles and amphibians have long been known to harbor *Salmonella* [17, 42, 43] and to cause human infection [44]. They are asymptomatic carriers of *Salmonella,* and reported carriage rates from point prevalence studies have been as high as 94% [45]. It is possible that all reptiles and amphibians carry *Salmonella,* and that reports of <100% carriage involve intermittent shedding and variations in the sensitivity of culturing techniques. In a small study during which iguanas were repeatedly cultured for *Salmonella,* every iguana was found to carry the organism [46]. The high rate of colonization suggests that *Salmonella* may be a natural commensal organism in the gastrointestinal tract of these animals.

From the forest, field, or pond to the home, the lives of reptiles and amphibians provide them several opportunities to become infected with *Salmonella.* Reptiles and amphibians might initially be infected before birth while in the ovary, oviduct, or cloaca, as has been reported for turtles [26, 47, 48]. In the wild, the colonization of *Salmonella* in iguanas and toads may be related to the eating of feces, which typically contaminates food and water; insects, soil, and pond water have all been shown to carry *Salmonella* [47, 49]. In the home, reptiles and amphibians might acquire *Salmonella* from being fed undercooked chicken or meat or by contact with household dust, all of which have the potential to contain *Salmonella* [50, 51]. Attempts to permanently rid reptiles of *Salmonella* infection by antibiotic treatment have been unsuccessful, suggesting that the animals readily become reinfected from their environment or sequester the infection [52, 53].

In the early 1970s, pet turtles were responsible for an estimated 18% of salmonellosis among children from 1–9 years old [54, 55]. This led first to the institution of multiple local and state restrictions on the sale of turtles and then in 1975 to a federal ban on all shipments of pet turtles with a shell length <10 cm [54]. These actions resulted in a 77% reduction in the incidence of infection with "turtle-associated" *Salmonella* serotypes among children aged 1–9 years and a near-elimination of turtle-associated salmonellosis [54]. However, recent reports have indicated that the number of cases of reptile-associated salmonellosis has been increasing [13]. Unlike the 1970s, when turtle-associated salmonellosis especially affected young children [54, 56], information from our control population indicates that pet reptiles and amphibians are currently popular with children of all ages and young adults. With an estimated PAF of 11% among persons <21 years old, the current problem of reptile- and amphibian-associated salmonellosis is comparable with the problem of turtle-associated salmonellosis 3 decades ago.

Our larger study was designed to detect whether reptile and amphibian contact was associated with serogroup B or D salmonellosis—serotypes that are frequently associated with consumption of contaminated food. Surprisingly, among persons <21 years of age, reptile and amphibian exposure had the largest PAF for infection of any of the risk factors we assessed, including those typically thought to be the cause of salmonellosis, such as eating eggs in a restaurant and travel outside the United States. In addition, the suggestion of an association between reptile and amphibian contact and infection with *S.* Typhimurium and *S.* Enteritidis is interesting, because cultures of samples from reptiles have yielded both serotypes [8, 56], and cases of *S.* Typhimurium infection associated with pet snakes have recently been reported [40].

Campaigns to reduce people's risk for salmonellosis should include efforts to prevent reptile- and amphibian-associated infections, especially among persons who are considering purchasing a reptile or amphibian, those who already own one, and families who have young children. Potential venues for education might include pet stores, physician and veterinarian offices, and schools. Educational efforts to prevent turtle-associated infections did not work well in the 1970s, perhaps because of the widespread distribution of turtles: an estimated 15 million turtles were sold or given away each year in the United States, and many turtles were obtained through sources other than pet stores [56]. Currently, most of reptiles are obtained from pet stores (CDC, unpublished data), allowing for more-focused educational campaigns. In collaboration with the Pet Industry Joint Advisory Council, the CDC has developed educational posters for pet stores, and in 1999, the Council for State and Territorial Epidemiologists issued a statement that recommended pet stores be required to educate customers about the prevention of reptile-associated salmonellosis. However, if current approaches are not successful, legal restrictions on the importation or sale of reptiles and amphibians would be warranted, as was the case prior to successful governmental restrictions on turtles in the 1970s.

This study only included cases of salmonellosis that were not associated with a known outbreak. Foodborne outbreaks of salmonellosis can be extremely large; for example, an outbreak of ice cream–related *S.* Enteritidis infections in 1994 involved an estimated 220,000 people [57]. If reptiles and amphibians were less likely than contaminated food and water to cause large outbreaks of disease, we may have overestimated the PAF associated with these pets. However, outbreaks caused by reptile-associated infections have also been reported; for example, an outbreak of *S. enterica* serotype Weltevreden infections was caused by geckos in a water tank in Hawaii [58]; an outbreak of *S.* Enteritidis infections occurred among visitors to a zoo reptile exhibit [8]; and an outbreak of *S. enterica* serotype Poona infections was associated with eating cake at a birthday party held at a house with 2 iguanas [9]. In addition, we excluded only 3% of all serogroup B or D *Salmonella* infections because they were associated with an outbreak. In our study of non–serogroup B or D infections, we excluded 38% of such infections because they were associated with a single outbreak in the San Francisco Bay area. In estimating the annual number of reptile- and amphibian-associated cases, we conservatively assumed that nationally the same percentage of non-serogoup B or D *Salmonella* cases were associated with an outbreak (and not caused by reptile or amphibian exposure), and, thus, we may have underestimated the total number of infections associated with reptile or amphibian contact.

Although we administered the questionnaire to patients within 21 days of specimen collection to minimize recall bias, respondents may have been more likely to remember some exposures, such as international travel or having contact with a reptile or amphibian, than they were to remember recently consumed food items. If this were the case, then we might have overestimated the PAF for some of these factors. In addition, fewer than one-half of all reported cases of salmonellosis in FoodNet sites participated in these studies. The major reasons for exclusion were our contacting cases >21 days after their sample collection, our inability to reach patients by telephone, and respondents not having diarrhea or not remembering the date of diarrhea onset. Although these exclusion criteria were necessary components of the studies, they may limit the generalizability of the results.

We excluded nonindex cases from the case-control study. It is unlikely that foodborne *Salmonella* infections would cause more secondary infections than reptile-or amphibian-associated infections, because the shedding of nontyphoidal *Salmonella* in a person's stool is likely to be similar across serotypes and modes of infection. Food contamination could potentially cause more nonindex cases than reptile or amphibian sources if multiple persons in a single home were exposed to the same food. This would result in an overestimation of the proportion of all infections associated with reptile and amphibian contact. However, multiple infections associated with reptile contact in the same household are also frequently reported [37, 56].

In our case-control study of non–serogroup B or D *Salmonella* infection, we did not collect case information other than the patients' age and sex, their *Salmonella* serotype, and their history of reptile and amphibian contact. The results might have changed if information were available on other potential risk factors for *Salmonella* infection. However, PAF estimates in the study of serogroup B or D *Salmonella* infection varied little when multiple potential risk factors were included in or excluded from the regression model. The study of non–serogroup B or D *Salmonella* was conducted in the San Francisco Bay area, only 1 of the 5 sites included in the larger study. The 3.3% rate of reptile exposure among controls in the San Francisco Bay area may not be representative of the other 4 sites, although it was the median value among them (range, 2.7%–5.6%). In addition, although the association between the risk of salmonellosis and having a reptile or amphibian in the home was statistically significant, the PAF of 15% was based on the exposure of only a few infected patients. Finally, the 13 million people living in the 5 FoodNet sites may not be representative of the nation, and reptile and amphibian exposure may be more or less important risk factors for salmonellosis in other parts of the country.

CONCLUSIONS

This is the first study to show an association between sporadic infection with common *Salmonella* serotypes and reptile exposure. It is also the first to show that exposure to amphibians, which have previously been reported to carry *Salmonella* organisms, is also associated with human infection. Health care practitioners and public health officials should ask specifically about reptile and amphibian exposure among persons with salmonellosis and educate all patients and the general population about how to prevent the zoonotic spread of *Salmonella* from their pets. Our findings emphasize the need for improved prevention efforts without which thousands of preventable cases of reptile- and amphibian-associated salmonellosis may continue to occur annually in the United States.

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