The Home Environment and Salmonellosis in Children

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ABSTRACT. *Objective.* **To explore the role of foods and the home environment in the development of *Salmonella* infections in infants and children.**

Methods. **Home investigations were conducted of patients younger than 4 years of age infected with *Salmonella*. Cultures were obtained from foods, persons residing in the home, animals/pets/insects, and environmental sources. Like serotypes encountered in the index patients and isolates from the home underwent typing with pulsed-field gel electrophoresis.**

Results. **Home inspections were conducted in ~66% of eligible homes on the average of 3.4 days after the confirmation of the *Salmonella* isolate. A total of 526 cultures from 50 homes were obtained from foods (120), household members (73), refrigerators (52), water (47), countertops (46), soil (42), can-openers (36), vacuum cleaners (34), animals/pets/insects (26), and others (50). Isolates with a serotype identical to those in the index patient were found in 16 homes, 3 of which included an isolate of a second serotype, and an isolate of a different serotype was recovered in 3 homes. The pulsed-field gel electrophoresis patterns of the isolates of identical serotypes from the subjects and from their environment were indistinguishable in all but 2 patients. Among isolates of the same serotype encountered in different homes, all patterns were different. The identical serotype was found in multiple locations (4), dirt surrounding front doors (4), household members (3), vacuum cleaner (1), animals/pets/insects (1), and a refrigerator shelf (1).**

Conclusions. **These data illustrate the importance of the child's environment in the development of salmonellosis. Clinicians should concentrate on educating the parents about the environmental spread of *Salmonella*. Contaminated foods in the home play a less significant role in the infection of infants and children. *Pediatrics* 1999; 103(1). URL: http://www.pediatrics.org/cgi/content/full/103/1/e1; *Salmonella, salmonellosis, children, infants, home.***

ABBREVIATIONS. PFGE, pulsed-field gel electrophoresis; DT, definitive type.

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Previous data from Arkansas have demonstrated that the case rates of nontyphoidal *Salmonella* infections for infants and children exceed those of the rest of the nation.[1] The majority of the cases are sporadic, and they occur without an identifiable source of infection,[2] although clinicians continue to emphasize contaminated foods as the major source of infection for these young patients. Recent data, however, have concluded that the role of foods must be questioned in explaining the epidemiology of salmonellosis for infants and young children.[2–4] The purpose of this study was to explore the role of the food and the home environment in the development of *Salmonella* infections in infants and children.

METHODS

Investigators were informed when a child younger than 4 years of age had *Salmonella* isolated from any specimen submitted to the clinical microbiology laboratory from the outpatient clinics/emergency department or the inpatient service at Arkansas Children's Hospital from September 1995 to October 1997. The decision to submit specimens for bacterial cultures was made at the discretion of the treating physician. Telephone or in-person contact with a parent/guardian of the child was made after positive results from cultures were found. After informed consent was obtained, demographic data were collected, and a questionnaire was administered concerning parental education and occupation; government assistance (eg, WIC participation); medical history of the patient with salmonellosis; involvement of others in the family with a similar illness; preparation and consumption of foods considered to be high risk; pet ownership and type of pet (reptile versus mammal); smoking in the household; day care attendance; and family income. When applicable, questions concerning formula preparation/consumption and breastfeeding were included. Permission then was obtained to seek cultures for *Salmonella* in the home of the patient. An attempt was made to obtain rectal swabs from all other persons residing in the home, as well as from all pets. In addition, cultures were obtained from leftover foods in the refrigerator, the refrigerator itself, water samples, countertops, soil samples, can-openers, vacuum cleaner contents, cutting boards, and other soiled areas of the home that were encountered on inspection of the house. Foods were chosen based on availability and were required to have been present from the time of the initiation of illness in the index patient. No environmental or food samples were obtained from areas outside of the immediate home environment (eg, day care facility).

All samples except water and swab samples were treated as follows. A 25-g sample was placed into a flask containing a solution of sterile lactose broth and mixed well, and the pH was adjusted to 6.8 ± .2 using sterile NaOH or HCl. The solution was incubated at 35°C for 24 hours. One loop of sample was transferred to a Hektoen enteric agar plate (Remel Laboratories, Lenexa, KS) and a selenite broth and incubated for 18 to 24 hours at 35°C. Presumptive colonies were transferred to triple sugar iron agar slants and urea broth tubes using a sterile inoculation needle, and were incubated at 35°C for 24 hours before being inspected. *Salmonella* species were confirmed and serogrouped using polyvalent sera. Samples of *Salmonella* then were sent to the Arkansas Department of Health for serotyping. Isolates that would not serotype had their serogroup verified by the Department of

Health. Like serotypes encountered in the home underwent DNA fingerprinting by a procedure described previously.[2] Fingerprints of like isolates were compared using Bio-Rad Molecular Analyst/PC fingerprinting software (Bio-Rad Laboratories, Hercules, CA). Because the isolates being compared were of the same serotype, they were considered to be genetically different if there was more than one band variation in pulsed-field gel electrophoresis (PFGE) patterns.[5]

Water samples were collected using a sterile 142-mm-diameter membrane of 0.45 μ pore size that filtered ~3 L of water. The filter then was placed into sterile lactose broth and processed as described above. All swabs obtained from environmental, human, and/or animal sources were placed into selenite broth and on Hektoen enteric agar and evaluated as described previously.

The McNemar test for matched pairs was used to compare the prevalence of diarrhea among similar groups.

This study was reviewed and approved by the Human Research Advisory Committee of the University of Arkansas for Medical Sciences.

RESULTS

During the 26 months of the study, 75 patients were eligible and 50 (66%) agreed to participate. Inspection of the homes occurred on the average of 3.4 days (range, 0–11 days) after the index patient was confirmed to have an infection attributable to *Salmonella*. Patient demographics are outlined in Table 1. Five index patients were identified as having chronic illnesses including congenital heart disease (2), sickle cell trait (2), and sickle cell disease (1). Index patients also had other medical complaints including chronic ear infections (3), allergies (3), asthma (3), reflux (3), recent pneumonia (1), and heart murmur (1). A total of 34% of the homes had other individuals with symptoms similar to those in the index patient. Seventeen index patients attended day care or mother's day out programs.

Six families raised chickens and four had a family member working in a poultry plant, three working in a restaurant with raw poultry products, and one working in a pork plant. Fifty-four percent of the families were receiving Women, Infants, and Children's Supplemental Nutrition Program assistance at the time of the index patient's illness. Eighteen of the index patients (36%) consumed only formula and baby foods and none were breastfed, and an additional 6 consumed both table foods and formula/baby foods. For the patients who used formula only, 13 used city tap water, 4 used well water, and 1 used bottled water to mix the formula, and only 7 boiled the water before mixing the formula.

TABLE 1. Patient Demographics for Infections Attributable to *Salmonella*

Patients (N = 50)	Result (%)
Sex	
Male	30 (60)
Female	20 (40)
Race	
Caucasian	29 (58)
African-American	21 (42)
Age breakdown	
<3 Mo	8 (16)
3–6 Mo	6 (12)
6–12 Mo	11 (22)
12–24 Mo	11 (22)
24–36 Mo	10 (20)
>36 Mo	4 (8)

TABLE 2. Serotypes of the *Salmonella* Isolate From the Index Patient

Serotype (N = 50)	Result (%)
S typhimurium	16 (32)
S newport	16 (32)
S javiana	3 (6)
S agona	2 (4)
S heidelberg	2 (4)
S norwich	2 (4)
Group C1	2 (4)
Others*	7 (14)

* Not able to group or serotype *S bareilly, S branderup, S arizonae, S st. paul,* group D, E1.

Salmonella typhimurium and *S newport* were the most common organisms isolated from the index patients (Table 2). Of 526 cultures obtained from various sources in the homes (Table 3), 120 were from foods (Table 4). Only foods identified in the refrigerator left over from the time of the initial patient's illness were cultured, and at least one food sample was obtained from every house visited. The 73 household members that allowed testing represented only 31% of those who were eligible. Fifty-eight percent of the homes had pets, with the most common being dogs, followed by cats, birds, and chickens. Others encountered included fish, snakes, lizards, ducks, rabbits, pigs, hamsters, guinea pigs, turtles, and cattle.

Isolates of *Salmonella* were recovered in 19 (38%) households. Thirteen of the homes had only an isolate of the same serotype as that for the index patient, whereas 3 homes had an isolate of the same serotype as that for the index patient and a second isolate of a different serotype (Table 5). Three homes had only an isolate of a different serotype. *S typhimurium* from the index case was recovered in 2 of these homes, whereas *S javiana* was recovered from a brother in 1 home and group B *Salmonella* was recovered from the dirt and rat droppings in the second. Group C1 *Salmonella* was recovered from the index case in the third home, whereas *S bareilly* was recovered from the dirt. Nine households included 13 (18%) individuals with positive results for stool cultures. Three of these individuals had diarrhea onset before that in the index patient, six had illness onset after that in the index patient, and four were asymptomatic. The age and sex of the index patients were distributed equally among those homes with other positive findings. Only 4 of these homes included an index patient who attended day care or mother day's out programs. However, in 74% of the homes with other

TABLE 3. Culture Sources in Home Evaluation (N = 526)

Foods	120	Animals/pets/insects	26*
Household members†	73	Cutting boards	17
Refrigerators	52	Kitchen tables	12
Water	47	Sink/faucet	10
Countertops	46	Kitchen floors	4
Soil samples	42	Sponge/dish rag	4
Can-openers	36	Dryer/stove/basket	3
Vacuum cleaners	34		

* Cultures obtained from dog (11), cat (4), cockroach (3), cattle (3), chicken (2), lizard (1), rat (1), rabbit (1).
† Other than the index patient.

TABLE 4. Foods Cultured for *Salmonella* in the Home Evaluation ($N = 120$)

Chicken	10	Peanut butter	3
Milk	10	Mayonnaise	3
Beef	10	Turkey	3
Cheese	9	Hot dogs	3
Sausage	6	Lettuce	3
Infant formula	6	Salad dressing	2
Dip	5	Cabbage	2
Potatoes	5	Pork chops	2
Jar baby foods	4	Gravy	2
Spaghetti	3	Bologna	2
Butter	3	Bread	2
Fruit	3	Other*	19

* Lasagna, ketchup, frito pie, greens and ham, rice, cole slaw, bell pepper, ravioli, beans, jelly, ice cream, macaroni and cheese, sour cream, sandwich spread, spinach, flour, tomato, carrots, and apple sauce.

culture-positive findings, the index patient was white. *S typhimurium* was the most common isolate recovered from index patients older than 1 year of age (38%), whereas *S newport* was the most common isolate from index patients younger than 1 year of age (38%). The PFGE patterns of the isolates from the index patient and isolates of the same serotype in the household of the index patient were indistinguishable in all but 2 cases. These patterns differ from those of isolates of the same serotype isolated from the other index patients and their households and from those of isolates of different serotypes (Table 5; Figs 1, 2). These data suggest that the index patients and isolates of the same serotype from their households are linked. This is consistent with a conclusion of intrahousehold transmission of *Salmonella*, directing attention to the possible sources of infection.

DISCUSSION

Salmonella were isolated from 38% of the homes inspected, with all but 5 homes having at least 1 isolate identical to that of the index patient in its serotype and PFGE pattern. *Salmonella typhimurium* and *S newport* were the two most common isolates recovered and are the most prominent human pathogens in our region.[1,2] *S typhimurium* was found to be more common in older children, as has been noted previously.[2] Patient demographics, socioeconomic status, and diet history did not differ from those in our previous study of this same age group of patients, but there was a higher percentage of illness in other family members at the time of illness in the index patient (34% vs 17%; $P < .001$).[2] These previous data obtained by the use of a case–control survey highlighted the complexities of identifying the source of human salmonellosis in infants and children. There were no data supporting the role of contaminated foods as a major risk factor, whereas there were data suggesting that the environment or other individuals in the environment might have a significant role in transmitting disease. The present study was conducted in an attempt to answer those questions.

Identical isolates of *Salmonella* were recovered from other inhabitants of the home, and from animals and environmental sources. Of the 120 foods sampled, however, only one piece of block cheese was demonstrated to harbor *Salmonella*. This cheese was the remainder of a larger block that had been handled repeatedly. A brother and sister of the index patient also were culture-positive in this home; thus, it is likely that the contamination of the cheese was the result of chronic handling and was not the major source of infection. An attempt was made to complete the home investigations as soon as possible to recover any leftover foods that still might be present. It is also certainly possible that all the contaminated foods could have been discarded or consumed before our arrival. This would not be supported by results of other studies that have investigated refrigerators for contaminated foods. In a recent study seeking *Listeria monocytogenes* in foods, specimens were collected at a median of 10 days (range, 3–34 days) after the onset of illness in the index patient. *L monocytogenes* was recovered from at least one food specimen in the refrigerators of 64% of these patients.[6] Likewise, *Salmonella* has been demonstrated to be recov-

TABLE 5. PFGE Patterns of Similar Household Isolates of *Salmonella*

Serotype Index Patient	PFGE Pattern Index Patient	Household Source(s)	Serotype Household Isolates	PFGE Pattern Household Isolates
S norwich	A	Vacuum cleaner	*S norwich*	A
S typhimurium	B	Mother	*S typhimurium*	B
S newport	C	Grandmother	*S newport*	C
S newport	D	Dirt	*S newport*	D
S newport	E	Dirt	*S newport*	E
S newport	F	Sister	*S newport*	F
S typhimurium	G	Dirt	*S typhimurium*	G
S newport	H	Vacuum cleaner	*S newport*	X
S newport	I	Dog stool	*S newport*	Y
S typhimurium	J	Grandfather, sister, dead calf, sick calf	*S typhimurium*	J,J,J,J
S typhimurium	K	Block cheese, brother, sister	*S typhimurium*	K,K,K
S typhimurium	L	Sister, refrigerator, vacuum cleaner	*S typhimurium*	L,L,L
S typhimurium	M	Brother, sister, sister, dirt, cockroach	*S typhimurium*	M,M,M,M,M
S newport	N	Dirt	*S newport*	N
		Vacuum cleaner	*S rubislaw*	P
S arizonae	Q	Lizards	*S arizonae*	Q
		Countertop	*S newport*	R
Group C1	S	Refrigerator	Group C1	S
		Mother	*S typhimurium*	T

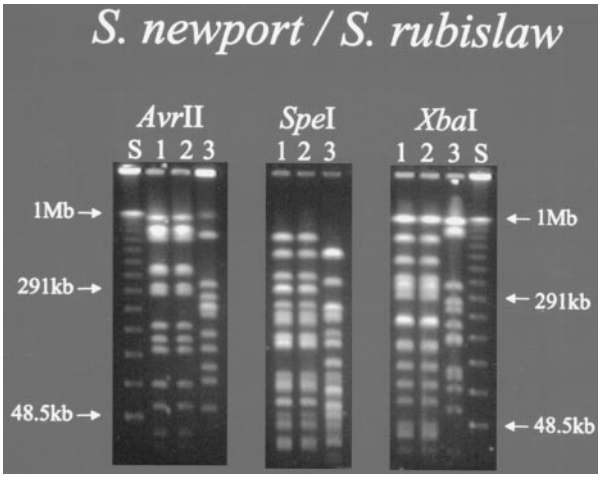

Fig 1. Restriction endonuclease analysis patterns of *S newport* recovered from a patient and a dirt sample (lanes 1 and 2) compared with *S rubislaw* recovered from the vacuum cleaner in the same household (lane 3) generated by PFGE after AvrII, SpeI, and *Xba*I digestion.

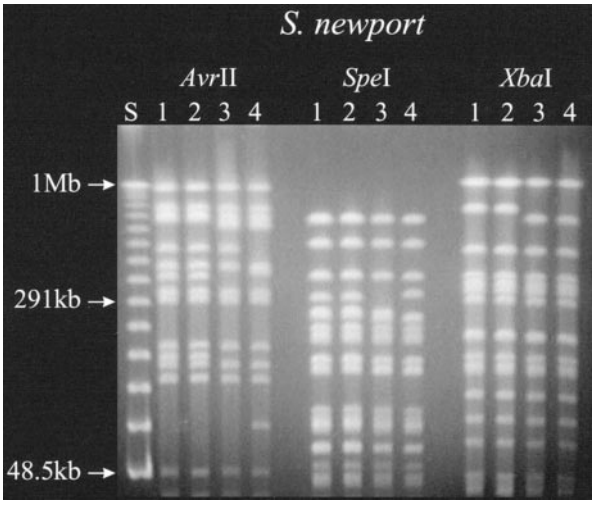

Fig 2. PFGE profiles of AvrII-, SpeI-, and *Xba*I-digested genomic DNAs from 2 *S newport* isolates from one household (lanes 1 and 2), compared with two *S newport* control isolates, randomly selected from a bigger collection (lanes 3 and 4).

ered easily from contaminated foods in investigations conducted 3 days after the foods were served.[7] In considering contaminated foods as a major risk factor for this age group of patients, approximately one third of the patients consumed only formula and jar foods very unlikely to be the source of sporadic disease. If contaminated foods in the home contributed to the development of sporadic salmonellosis in our patient group, we would have expected to recover them in greater quantities. These current data support results from previous investigations that also have failed to implicate foods in the home as a source of infection for children younger than 4 years of age.[2,3]

Nine of the homes with positive findings had individuals other than the index patient who were culture-positive for *Salmonella*, and all but two of these individuals had an isolate identical to that in the index patient (Table 5). This is consistent with results from other investigators who have found an increased number of infected persons in the families of pediatric index patients.[8–12] Results from these investigations have revealed that 19% to 45% of household contacts also were culture-positive for *Salmonella*. More importantly, 45% to 97% of the culture-positive individuals were asymptomatic. Only 18% of family contacts in the current study were culture-positive and, of these, 31% were asymptomatic. The reason for the lower involvement of family members compared with that shown in previous studies is unclear. Some of the lower results may have been attributable to the fact that only 31% of eligible family members allowed testing. A second consideration is that families are now more familiar with the intrafamilial spread of such organisms than they were in previous years, and have taken precautions to prevent its occurrence. Nevertheless, intrafamilial spread still appears to be a major risk factor in the acquisition of disease for these younger patients.

Salmonella isolates were recovered in mammals and/or reptiles and/or insects in 5 of the homes and in each case except 2, the serotype/genotype recovered was identical to that for the index patient. Two of the households had purchased cattle recently (30 head total), and each home had lost >70% of their calves to diarrhea. Both homes with these cattle had an index patient with *S typhimurium*. Recently, *S typhimurium* definitive type 104 (DT 104) has become recognized as an important isolate in humans because it tends to be multidrug-resistant, has increased morbidity and mortality, and is obtained from contact with sick farm animals, especially cattle.[13] Isolates from these two homes were sent to the Centers for Disease Control and Prevention, and one was found to be DT 104-complex (PFGE pattern J; Table 5), whereas the second was unrelated to DT 104. Two of the homes had reptiles as pets. In one, the index isolate could not be serogrouped or serotyped by the Department of Health, indicating that it was an organism encountered very rarely in human infections. The household pets were two pythons, and cultures could not be obtained from the snakes or their tank and there were no other culture-positive findings from the home. Because of the unusual nature of the isolate, it is certainly likely that this isolate came from the snake. The second household included an index child with *S arizonae*, and an organism of the identical serotype/genotype was recovered from the lizard tank. This organism is a recognized reptile-associated serotype.[14] Rats and cockroaches also have been noted to carry *Salmonella*, and are a natural method of checking for environmental contamination.[15]

Positive cultures from the environment were found in 11 homes. Although clinicians tend to focus on the areas of the home that would come into contact with contaminated food such as countertops, cutting boards, and refrigerators, these areas tend to be free of organisms.[16] In the current study, there were only two culture-positive results found from the multiple cultures of refrigerators (52), countertops (46), can-openers (36), and cutting boards (17).

Results of cultures obtained from vacuum cleaners and dirt surrounding the front door were positive more often than were results from other environmental sources. Vacuum cleaner contents are a well-localized collection of debris from all over the home and an easy place to check for environmental contamination.[17–20] They also have been found to contain *Salmonella* more commonly when there are infants in the home who are infected with these organisms.[17] Dirt from around the front doors has been postulated to have a role in environmental contamination of the homes as well.[17,19,20] Because all but 4 such isolates were identical to isolates in the index patient, this would support the hypothesis that infants and young children may come into contact with such organisms either through aerosolization or by having direct contact with contamination soil or debris.

These data continue to highlight the difficulty in attempting to find the major risk factor for the development of salmonellosis in infants and children. The data also indicate that these organisms are encountered daily by our patients and that their risk factors present themselves in many forms. For the younger patient, infected individuals, pets, and other environmental sources appear to be much more significant than contaminated foods in the home.

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