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Salmonella Outbreaks in Restaurants in Minnesota, 1995 through 2003: Evaluation of the Role of Infected Foodworkers

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ABSTRACT

The 23 restaurant-associated salmonellosis outbreaks that occurred in Minnesota from 1995 through 2003 were reviewed to characterize the role of infected foodworkers. The median duration of the outbreaks was 21 days (range, 1 to 517 days). The median number of culture-confirmed patron cases per outbreak was seven (range, 1 to 36 cases). The median incubation for patron cases ranged from 9 h to 5.9 days. A specific food vehicle was implicated in four outbreaks and suspected in five. *Salmonella* of the same serotype and pulsed-field gel electrophoresis subtype as that found in patrons was recovered from foodworkers in 19 outbreaks. Overall, 12% (129 of 1,033) of foodworkers tested positive for *Salmonella.* Sixty-four (53%) of 121 *Salmonella*-positive foodworkers reported not having had a recent gastrointestinal illness. Overall, the median duration of *Salmonella* shedding was 16 days. Among foodworkers who reported gastrointestinal illness, the median shedding duration was 30 days as compared with 3 days for asymptomatic foodworkers. Positive environmental samples were recovered in 4 (33%) of 12 outbreaks. No specific food vehicle was identified in any outbreaks associated with *Salmonella*-positive environmental samples. The median duration of outbreaks with positive environmental samples (187 days) was significantly longer than the median duration of outbreaks with negative environmental results (26 days, $P = 0.03$). A higher proportion of *Salmonella*-positive foodworkers (22 versus 8%) was identified in outbreaks with positive environmental samples. *Salmonella* outbreaks in restaurants are frequently prolonged yet produce a small number of confirmed patron cases. Prolonged outbreak durations suggest a persistent reservoir of contamination. Infected foodworkers likely serve as an important source for *Salmonella* transmission. Therefore, assessment of foodworker infection is essential for controlling restaurant outbreaks.

Nontyphoidal salmonellae are important foodborne pathogens that cause an estimated 1.4 million illnesses and more than 15,000 hospitalizations in the United States each year *(41).* From 1993 to 1997, *Salmonella enterica* was the most common foodborne outbreak etiology reported to the Centers for Disease Control and Prevention, accounting for 357 outbreaks; 137 (38%) of those outbreaks occurred in commercial food establishments (restaurants, delicatessens or cafeterias) *(36).*

Salmonella can be shed in the stool of infected persons for weeks after infection. A literature review conducted 20 years ago revealed that 50% of persons with *Salmonella* infections stopped shedding the organism by 5 weeks, and 90% of adults were culture negative 9 weeks after infection *(8).* In a study in Sweden, the median duration of shedding was 35 days in symptomatic infected travelers and 38 days in asymptomatic infected travelers *(24).*

The infectious dose of nontyphoidal *Salmonella* for humans is generally described as 10^2 to 10^3 organisms *(6, 34).* However, doses of 10 to 20 organisms *(12, 25)* and even fewer than 10 organisms *(11, 13, 16, 18, 21)* have caused illness. Several outbreak investigations have provided evidence of an inverse relationship between dose and incubation of illness, with low doses resulting in longer incubation periods *(15, 17, 31, 32).* Attack rates are also dependent on dose, with low doses resulting in lower attack rates *(15, 21).*

The number of *Salmonella* organisms shed in the stool decreases over time; however, one study revealed counts higher than 10^3 (range, 5×10^4 to 4×10^6) organisms per gram of feces in 5 of 10 specimens from persons tested 20 to 25 days after illness and counts higher than 10^2 (range, 10^2 to 2×10^5) organisms per gram of feces in 5 of 7 specimens from persons tested 27 to 33 days after initial diagnosis *(38).* In the same study, fingertip contamination after defecation was demonstrated. Handwashing was sufficient to remove the contamination from the fingertips of eight of nine study participants. The stool of the participant whose hands remained contaminated after handwashing had a *Salmonella* count of 6×10^3 organisms per gram of feces 15 days after illness *(38).* In an earlier study in which fingers were artificially inoculated with *Salmonella,* the pathogen was recovered after a 15-s handwashing bout at 10 min postinoculation *(37).*

The low infectious dose, prolonged shedding, and contamination of fingertips support the possibility that infected foodworkers can contaminate food and transmit *Salmonel-*

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la. However, the magnitude of the role of infected foodworkers in *Salmonella* outbreaks in commercial food establishments is uncertain. There is a prevalent paradigm that the contribution of foodworker *Salmonella* infection in transmission to patrons is negligible *(8, 12)*; however, this paradigm is based on a decades-old interpretation of available data. Since that time, numerous outbreak investigations have clearly implicated foodworkers or suggested foodworker transmission of *Salmonella (7, 14, 15, 19, 23, 26, 30).*

To further characterize the potential role of infected foodworkers in transmission of *Salmonella* to patrons during restaurant outbreaks, we evaluated all salmonellosis outbreaks in restaurants in Minnesota from 1995 through 2003, including the shedding of *Salmonella* in the stools of infected foodworkers associated with those outbreaks.

MATERIALS AND METHODS

Outbreak investigation records and summary reports of all confirmed foodborne salmonellosis outbreaks in restaurants in Minnesota from 1995 through 2003 were reviewed. An outbreak was defined as two or more cases of salmonellosis associated with the same *Salmonella* serotype and pulsed-field gel electrophoresis (PFGE) subtype with a common exposure, regardless of whether the cases involved patrons or foodworkers. The number of infected patrons identified for each outbreak was determined. The duration of an outbreak was defined as the number of days with documented transmission to patrons. Incubation time was calculated as the number of hours between the reported meal date and time and the date and time of illness onset for confirmed patron cases and in some outbreaks suspected patron cases. If meal time or onset time was not available, incubation time was calculated in days.

All employees of the outbreak restaurants regardless of specific duties (foodworkers) were required to submit stool specimens for *Salmonella* testing. Stool samples from foodworkers associated with 19 outbreaks were sent to the Minnesota Department of Health Public Health Laboratory (MDH PHL) for testing, and samples from three outbreaks were tested by the City of Minneapolis Public Health Laboratory as part of the investigation. *Salmonella* isolates from specimens tested at the City of Minneapolis were sent to the MDH PHL for confirmation and serotyping. *Salmonella* isolates from outbreak cases detected through routine surveillance were serotyped at the MDH PHL and subtyped by PFGE using previously described standardized methods *(5). Salmonella* isolates from some or all foodworkers in each outbreak also were subtyped by PFGE. Environmental samples collected by public health staff involved in the investigation were tested at the City of Minneapolis in two outbreaks and at the MDH PHL in six outbreaks. Environmental isolates were serotyped and subtyped by PFGE at the MDH PHL. In four outbreaks, environmental sampling was conducted by private commercial laboratories hired by the implicated restaurant. Isolates from three of these outbreaks were confirmed, serotyped, and subtyped by PFGE at the MDH PHL. Isolates from the fourth outbreak were not forwarded to the MDH PHL.

For most outbreak investigations, two consecutive negative *Salmonella* cultures collected at least 24 h apart were required of each foodworker; only one negative culture was required during three outbreak investigations. All foodworkers who tested positive for *Salmonella* were required to continue to submit stool samples until two or more consecutive specimens collected at least 24 h apart tested negative for *Salmonella.* Attempts were made to interview all foodworkers about their history of gastrointestinal symptoms (including specific symptoms and date of illness onset) and job responsibilities using a standard questionnaire at the time of the investigation. A foodworker was classified as having a history of gastrointestinal illness when any compatible symptoms were reported within 1 month of the earliest known meal date associated with a salmonellosis case or during the investigation, even when symptoms were mild (e.g., any nausea, any cramps, or any diarrhea) or could have been explained by a chronic condition.

The total number of foodworkers interviewed and tested for each outbreak was ascertained. Laboratory records of foodworkers who tested positive for *Salmonella* were reviewed to document the dates of specimen collection of the first positive, last positive, first negative, and second negative specimens. If specimen collection date was unavailable, date of specimen receipt at the PHL was used as a proxy for the specimen collection date. Interview records were reviewed to ascertain whether the foodworker reported a history of gastrointestinal illness symptoms and to ascertain the date of symptom onset.

Duration of *Salmonella* shedding in the stool was defined as the number of days from symptom onset until the collection date of the last positive stool specimen. For reportedly asymptomatic foodworkers and foodworkers who did not recall the onset date, shedding was calculated from the collection date of the first positive specimen to the collection date of the last positive specimen. Shedding in foodworkers who stopped submitting stool samples before they had any negative results was calculated using the date of the last positive sample submitted. To more directly compare symptomatic and asymptomatic infections, shedding was also calculated in symptomatic foodworkers from the collection date of the first positive specimen after the start of the investigation to the collection date of the last positive specimen. The Wilcoxon two-sample test was used to compare the median durations of *Salmonella* shedding in the stool of symptomatic and asymptomatic foodworkers and to compare the median duration of outbreaks in restaurants with *Salmonella*-positive and -negative environmental sample results.

Descriptive and summary statistics were generated using SAS 9.1 and SAS Enterprise Guide 2.0 (SAS Institute, Cary, N.C.).

RESULTS

Outbreak and restaurant characteristics. From 1995 through 2003, 39 confirmed foodborne outbreaks of *Salmonella* infection were identified in Minnesota. Of these, 23 outbreaks occurred in restaurants (range, one to four per year). *Salmonella enterica* serotypes associated with restaurant outbreaks included Typhimurium (seven outbreaks), Heidelberg (five), Enteritidis (four), Braenderup (three), Newport (three), and Montevideo (one) (Table 1). Two restaurants had two outbreaks each (Table 1; outbreaks 10 and 22 and outbreaks 11 and 21). A single restaurant chain accounted for five outbreaks (nos. 6, 7, 8, 12, and 17) in different locations. Eighteen of the 23 restaurants were table service restaurants (outbreaks 1, 3, 4, 6 through 14, 16, 17, and 20 through 23), 3 were buffets (outbreaks 2, 18, and 19), 1 was a cafeteria-style restaurant (outbreak 5), and one was a nonchain soup, salad, and sandwich restaurant (outbreak 15). Eleven of the 23 outbreaks occurred in restaurants that serve breakfast all day (outbreaks 1, 6, 7, 8,

TABLE 1. *Descriptive data for outbreaks of salmonellosis in restaurants in Minnesota, 1995 through 2003*

Outbreak no.	*Salmonella* serotype	Vehicle	Outbreak dates	Positive environmental samples	Outbreak duration (days)[a]	No. of confirmed infected patrons	Incubation time[b]		
							Median (days)	Shortest (h)	Longest (days)
1	Typhimurium	Unknown	May 95–Aug 95	No	92	33	3.0	24.0	13.0
2	Typhimurium	Unknown	Jul 95–Aug 95	None taken	20	8	2.8	24.0	4.0
3	Typhimurium	Salad	Aug 95–Sept 95	None taken	21	9	2.0	9.0	8.9
4	Typhimurium	Unknown	Jan 96–Jun 96	None taken	167	5	1.0	24.0	8.0
5	Newport	Chicken pasta salad suspected	Jul 97–Dec 97	No	147	20	2.5	24.0	11.0
6	Braenderup	Unknown	July 97–Oct 97	Yes	99	4	1.9	12.0	10.8
7	Braenderup	Unknown	Oct 97–Jul 98	Yes	274	3	4.5	48.0	7.0
8	Braenderup	Unknown	Oct 97–Mar 99	Yes	517	7	5.9	23.0	7.4
9	Heidelberg	Unknown	Jun 98	None taken	1	1	3.6		
10	Heidelberg	Unknown	May 99	No	4	3	1.2	8.0	2.0
11	Montevideo	Unknown	Jun 99	No	1	1	10.0		
12	Heidelberg	Unknown	Jun 99–Jul 99	Yes	53	25	1.5	11.0	8.0
13	Typhimurium	Unknown	Aug 99	No	1	3	5.0		
14	Heidelberg	Meatloaf or eggs suspected	Apr 00–Jun 00	No	37	5	0.4	1.5	4.3
15	Typhimurium	Ground turkey suspected	Apr 00–May 00	None taken	5	4	5.0	96.0	6.0
16	Enteritidis	Eggs suspected	Sep 00	No	25	10	0.9	8.0	5.9
17	Enteritidis	Eggs	Jun 01–Jul 01	No	27	12	2.3	1.0	3.3
18	Newport	Unknown	Aug 01	None taken	11	9	2.0	24.0	6.0
19	Enteritidis	Chicken suspected	Apr 02	None taken	4	2	3.5	72.0	4.0
20	Newport	Unknown	Jul 02	None taken	7	5	2.3	13.0	7.7
21	Typhimurium	Unknown	Nov 02	None taken	14	14	3.4	37.0	11.9
22	Heidelberg	Eggs or pancakes	Sep 03	None taken	25	36	3.8	12.0	11.0
23	Enteritidis	French toast or eggs	Oct 03–Nov 03	None taken	21	20	3.4	19.0	7.3

[a] Documented length of transmission to patrons.
[b] Confirmed and probable case information may have been included in the calculations of incubation time.

10, 12, 14, 16, 17, 21, and 23), and 2 outbreaks occurred at a restaurant with an extensive breakfast menu (outbreaks 11 and 21). Six outbreaks occurred in restaurants serving ethnic foods: Chinese (outbreaks 2, 18, and 19), Italian (outbreaks 5 and 9), and Indian (outbreak 13).

The median duration of the restaurant outbreaks was 21 days, ranging from 1 day in outbreaks where only one patron case was identified to 517 days. Transmission to patrons occurred for more than 10 days in 70% of the restaurant outbreaks, for more than 1 month in 35%, and for more than 3 months in 21%. The two outbreaks with only one patron case were investigated when surveillance revealed culture-confirmed infections with the same serotype and PFGE subtype of *Salmonella* in a patron and a foodworker. Additional infected foodworkers were subsequently identified in the investigations of those outbreaks.

A vehicle was statistically implicated in four (17%) of the outbreaks (Table 1). In five additional outbreaks (22%), a vehicle was suspected but not statistically confirmed. During the study time period, there were 16 foodborne outbreaks of salmonellosis in settings in Minnesota other than a restaurant. In 14 (88%) of those outbreaks, a specific vehicle was implicated. Of those 16 outbreaks, 11 occurred at events (e.g., wedding receptions, banquets, and graduation or other parties) or in institutional settings; for these 11 outbreaks, a vehicle was identified in 10 (91%). The remaining five outbreaks were associated with commercial food products consumed in a variety of settings; for these outbreaks, a vehicle was confirmed in four and was strongly suspected in one.

Patron cases. The median number of culture-confirmed patron cases identified per restaurant outbreak was 7 (range, 1 to 36) (Table 1). With the exception of the two outbreaks (nos. 9 and 11) in which a single infected patron was identified and two other outbreaks (nos. 5 and 15), *Salmonella* isolates recovered from all patrons were indistinguishable by PFGE. In one outbreak (no. 5), two subtypes (different by six bands) of *Salmonella* Newport were isolated from patrons. In another outbreak (no. 15), two subtypes of *Salmonella* Typhimurium that differed by nine bands were isolated from patron cases.

The median incubation time for patrons for each outbreak ranged from 9 h to 5.9 days (excluding outbreaks 9, 11, and 13, in which incubation time was known for only one person). The range of incubations was also recorded for each outbreak. The shortest documented incubation was 1.5 h, and the longest was 13 days.

Foodworker illness and shedding of *Salmonella* in stools. In 22 of the 23 restaurant outbreaks, foodworkers

TABLE 2. *Number of foodworkers tested and number for whom an illness history was obtained in restaurant-associated outbreaks of salmonellosis in Minnesota, 1995 through 2003*

Outbreak no.[a]	Total no. of foodworkers tested	No. (%) of foodworkers with *Salmonella*:				
		With outbreak serotype	With any serotype	For whom symptom status was obtained	With history of gastrointestinal illness	Reportedly asymptomatic
1	60	13 (22)	13 (22)	12 (92)	7 (58)	5 (42)
2	14	1 (7)	1 (7)	0		
3	63	16 (25)	16 (25)	15 (94)	10 (67)	5 (33)
4	31	3 (10)	5 (16)	4 (80)	1 (25)	3 (75)
5	237	4 (2)	4 (2)	4 (100)	1 (25)	3 (75)
6	68	3 (4)	3 (4)	3 (100)	0	3 (100)
7	0					
8	41	10 (24)	10 (24)	8 (80)	1 (13)	7 (88)
9	117	2 (2)	3 (3)	1 (33)	1 (100)	0
10	12	2 (17)	2 (17)	2 (100)	1 (50)	1 (50)
11	39	9 (23)	9 (23)	9 (100)	5 (56)	4 (44)
12	74	26 (35)	27 (36)	27 (100)	11 (41)	16 (59)
13	7	0	0			
14	12	3 (25)	3 (25)	3 (100)	0	3 (100)
15	14	2 (14)	2 (14)	2 (100)	2 (100)	0
16	25	2 (8)	2 (8)	2 (100)	0	2 (100)
17	72	2 (3)	3 (4)	3 (100)	2 (67)	1 (33)
18	17	0	0			
19	10	0	0			
20	24	5 (21)	5 (21)	5 (100)	4 (80)	1 (20)
21	44	10 (23)	10 (23)	10 (100)	6 (60)	4 (40)
22	23	4 (17)	4 (17)	4 (100)	1 (25)	3 (75)
23	29	7 (24)	7 (24)	7 (100)	4 (57)	3 (43)
Total	1,033	124 (12)	129 (12)	121 (94)	57 (47)	64 (53)

[a] See Table 1.

were interviewed about their history of gastrointestinal illness and submitted stool specimens for *Salmonella* testing as part of the investigation. In 18 of 22 outbreaks, all foodworkers were required to submit stool samples until two consecutive specimens collected at least 24 h apart tested negative for *Salmonella.* In three outbreaks (nos. 9, 14, and 20), all foodworkers were required to submit one stool sample, but those whose samples were positive for *Salmonella* were required to continue submitting specimens until two consecutive specimens tested negative for *Salmonella.* In one of those three outbreaks (no. 20), workers who reported a history of gastrointestinal illness were also required to submit two stool samples for testing, even if the first was negative for *Salmonella.* In one outbreak (no. 1), all workers were required to submit specimens until three consecutive specimens were negative.

Salmonella-positive foodworkers were identified in 19 (83%) of 22 outbreaks. *Salmonella* of the same serotype as the patron isolates was recovered from foodworker specimens in all 19 outbreaks. Of 1,033 foodworkers tested overall, 129 (12%) submitted at least one stool sample that was positive for *Salmonella.* One hundred twenty-four of the 129 foodworkers were positive for the outbreak serotype (Table 2). For eight foodworkers in 4 of 17 outbreaks (nos. 1, 12, 16, and 21) the first specimen was negative for *Salmonella* but the second, which was collected 1 to 7 days later, was positive. Four foodworkers stopped submitting stool samples before any of their specimens tested negative. Thirty-five (7%) of 499 foodworkers tested in 14 outbreaks reported a history of recent gastrointestinal symptoms but two consecutive stools samples were negative for *Salmonella.*

Salmonella of the same PFGE subtype as the patron isolates was isolated from foodworker stool samples in all outbreaks with *Salmonella*-positive foodworkers. In addition, *Salmonella* Newport of a subtype that differed by more than 10 bands was recovered from one foodworker in one outbreak (no. 5), and two different subtypes of *Salmonella* Typhimurium (the outbreak subtype and a subtype that was nine bands different) were recovered from a stool sample of one *Salmonella*-positive foodworker in another outbreak (no. 15). Two different subtypes of *Salmonella* Heidelberg (the outbreak subtype and a subtype that was one band different) were recovered from the stool of one foodworker in one outbreak (no. 12). *Salmonella* subtypes that differed by only one band from the patron isolates were recovered from one foodworker in two additional outbreaks (nos. 11 and 20).

Illness history was obtained for 121 of the 129 foodworkers that tested positive for *Salmonella,* and 64 (53%) of these 121 foodworkers reported not having a history of recent gastrointestinal illness symptoms.

The proportion of *Salmonella*-positive foodworkers ranged from 0 to 36% per outbreak (median, 16%). Among

TABLE 3. *Median shedding period for* Salmonella *serotypes in stool samples of foodworkers in restaurant-associated salmonellosis outbreaks in Minnesota, 1995 through 2003*

Salmonella serotype	No. of workers	Median (range) shedding period (days)[a]
All	129	16 (1, 280)
Typhimurium	45	17 (1, 280)
Heidelberg	37	5 (1, 127)
Braenderup	13	3 (1, 74)
Enteritidis	12	25 (1, 114)
Newport	10	23 (5, 58)
Montevideo	9	27 (1, 87)
Oranienberg	1	1
Somatic C2	1	17
Unknown	1	1

[a] Shedding period was calculated from the date of illness onset in symptomatic foodworkers and from the collection date of the first positive sample for asymptomatic foodworkers.

those who tested positive and for whom an illness history was obtained, the proportion that reported no history of recent gastrointestinal illness ranged from 0 to 100% per outbreak (median, 44%) (Table 2).

The median duration of shedding regardless of illness history ($n = 129$) was 16 days (range, 1 to 280 days), and this value varied by serotype. Among serotypes associated with multiple cases, the median duration of shedding ranged from 3 days for *Salmonella* Braenderup to 27 days for *Salmonella* Montevideo (Table 3).

Among *Salmonella*-positive foodworkers who reported gastrointestinal illness ($n = 57$), the median duration of shedding was 30 days (range, 2 to 280 days) (Fig. 1A). Among asymptomatic foodworkers ($n = 64$), the median duration of shedding was 3 days (range, 3 to 97 days) (Fig. 1B). To more directly compare shedding in the two groups, the shedding period was recalculated in symptomatic foodworkers from the collection date of the first *Salmonella*-positive specimen after the start of the investigation to the collection date of the last *Salmonella*-positive specimen for both groups. The median duration of shedding from the first positive specimen was 13 days among symptomatic foodworkers and 3 days among asymptomatic foodworkers ($P = 0.004$).

The date of illness onset was available for at least one foodworker in 15 of the 19 outbreaks with positive foodworkers (Table 2). In 13 of these 15 outbreaks (nos. 1, 3, 4, 5, 8, 9, 11, 12, 15, 17, 18, 21, and 23), foodworkers reported illness onset before at least one patron's illness onset. In four outbreaks (nos. 9, 11, 15, and 21), at least one foodworker reported illness onset before the onset of the earliest patron illness. In 8 of 15 outbreaks (nos. 2, 5, 8, 9, 12, 15, 21, and 23), at least one foodworker had illness onset before the median patron illness onset point. In six outbreaks (nos. 5, 9, 12, 15, 21, and 23), the median foodworker illness onset date was before the median patron illness onset date.

Environmental sampling. Environmental sampling was conducted in 12 outbreak restaurants, and positive environmental samples were recovered in 4 (33%) of these restaurants. In three outbreaks, *Salmonella* of the outbreak serotype and PFGE subtype was recovered from (i) a cold holding area behind the cook's line and a cutting board (outbreak 6), (ii) egg grill grease traps, cake grill grease traps, and cutting boards (outbreaks 7 and 8), (iii) grill stands (outbreak 8), and (iv) the dishwasher area and employee break room (outbreak 7). In one outbreak, *Salmonella* was recovered from a grill grease trap and the side surface of a water cooler (outbreak 12), but isolates were not serotyped or subtyped by PFGE.

A vehicle was not identified in any of the outbreaks with *Salmonella*-positive environmental samples; in these outbreaks, the median duration of transmission was 187 days, and 22% of the workers tested positive for *Salmonella.* Conversely, a specific vehicle was implicated or suspected in four (50%) of the eight outbreaks in which *Salmonella* was not recovered from the environment; in these outbreaks, duration of transmission was shorter (median, 26 days; $P = 0.03$), and only 8% of the workers tested positive for *Salmonella* (Table 4).

Previously unrecognized outbreak. During the review of surveillance cases, a previously unrecognized *Salmonella* Enteritidis outbreak associated with a single restaurant in 1997 was identified. The six cases were caused by *Salmonella* Enteritidis with an indistinguishable PFGE pattern. The four infected patrons and two infected foodworkers from the restaurant were interviewed as part of routine surveillance. Their illness onset dates and patron meal dates ranged from June through September 1997.

DISCUSSION

The results of this study indicate that salmonellosis outbreaks in restaurants are usually not simple point source events caused by ingestion of one particular contaminated food item; rather, they are complex events that may last for several weeks or months. Despite the long duration, in many outbreaks only a small number of patron cases were identified. Nine of the outbreaks in the study period included 5 or fewer culture-confirmed patron cases, and fewer than 10 cases were identified in four of the five outbreaks with the longest duration. The identified cases likely represented only a small proportion of those who actually become ill. An estimated 38.6 salmonellosis cases occur for each culture-confirmed case *(41)*. Therefore, even a few confirmed cases can signal a much larger problem.

The importance of infected foodworkers as a source of contamination in these outbreaks is supported by several observations. First, a specific food vehicle was statistically implicated or suspected in a low proportion of the restaurant outbreaks (39%), which suggests that the specific food items or food handling errors were not the primary causes for these outbreaks.

Second, foodworkers infected with *Salmonella* were identified in the majority (83%) of the outbreak investigations. Overall, 12% of the foodworkers tested positive for

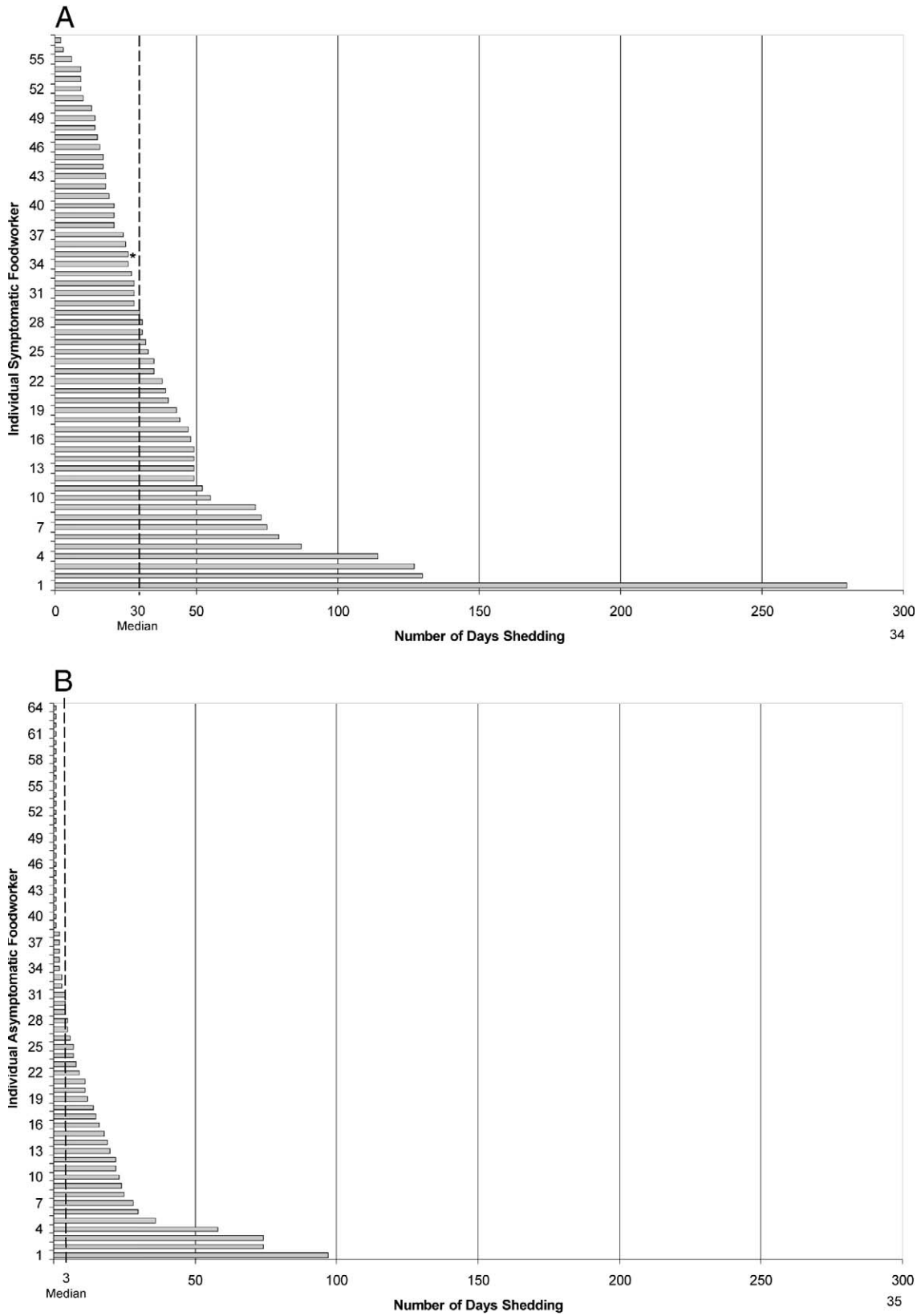

FIGURE 1. *Shedding in (A) symptomatic (*n = *57) and (B) asymptomatic (*n = *64) foodworkers tested during restaurant-associated outbreaks of salmonellosis in Minnesota, 1995 through 2003. * When infected individual did not recall the date of onset, shedding was calculated as the time between collection of the first* Salmonella*-positive stool sample and collection of the last positive specimen.*

TABLE 4. *Characteristics of restaurant-associated outbreaks of salmonellosis in Minnesota, 1995 through 2003, separated by results of environmental sampling*

Salmonella status of environmental samples	No. of outbreaks	No. (%) of outbreaks in which a vehicle was identified	No. (%) of *Salmonella*-positive foodworkers	Median duration of outbreaks (days)[a]
Positive	4	0	40/183 (22)	186
Negative	8	4 (50)	35/464 (8)	26

[a] Documented period of transmission to patrons.

Salmonella. Among these employees, half reported no history of recent gastrointestinal illness. Infected foodworkers who reported a history of illness shed *Salmonella* in the stool for a median of 1 month. Even though it is impossible to ascertain when asymptomatic persons became infected, the duration of shedding differed significantly in symptomatic and asymptomatic infected workers when shedding was compared based on the start of testing. Because these data were collected during outbreak investigations, it is not known how many of the *Salmonella*-positive foodworkers sought antibiotic treatment as a result of testing during the investigation. Foodworkers with a history of gastrointestinal illness may have preferentially sought treatment after finding out that they were infected with *Salmonella,* and because antibiotic treatment may prolong the duration of shedding *(2, 33, 35, 42),* these foodworkers shed *Salmonella* in the stool for longer than did their asymptomatic peers. Alternatively, some of the foodworkers that tested negative after antibiotic treatment that was not disclosed to the outbreak investigators may have continued to shed the pathogen because their infection was not truly eradicated and their negative status was only temporary *(10).*

Third, illness incubation in many patrons was longer than the 12 h to 3 days *(3, 4)* believed to be characteristic of *Salmonella* infections. In 43% of the outbreaks, the median incubation period was longer than 3 days. The long incubation periods and relatively small number of cases identified in these outbreaks suggest that the infectious dose was low, as would be expected if infected foodworkers were an important source of contamination in restaurants. A restaurant-associated outbreak of *Salmonella* Typhimurium infection in Denmark in 2003 that was traced to an asymptomatic infected foodworker had the same pattern of long incubation period and low infection rate *(15).* Long incubation and low infection rates were also attributed to low levels of contamination of dessert buns in an outbreak of *Salmonella* Enteritidis infection among school children in Japan in 2001 *(31).*

Although handwashing should be sufficient to remove *Salmonella* contamination from fingers, most people, even those in professions where hand hygiene is critical, do not adequately wash their hands *(1, 9, 40).* Thus, infected foodworkers likely act as a reservoir of *Salmonella* and contaminate foods at high enough levels to transmit illness to some patrons.

The prolonged outbreak durations documented in this study indicate either continual reintroduction of contaminated food or a persistent reservoir of contamination. Both the persistence of the outbreak strains identified by PFGE and the difficulty in implicating a specific vehicle strongly suggest that a reservoir of contamination within the restaurant is more likely than reintroduction of a single contaminated food over time. Infected foodworkers, environmental contamination, or both could serve as sources of contamination of different foods with a low inoculum of *Salmonella* over a period of weeks to months. In these investigations, *Salmonella* was recovered from food contact areas such as cutting boards and grill grease traps and from areas that did not come into direct contact with foods, such as an employee break room and a water cooler. These findings suggest that foodworkers' hands can contaminate surfaces. In contrast with the high proportion of outbreaks in which infected foodworkers were identified, in only 33% of the outbreaks evaluated for environmental contamination was *Salmonella* recovered from the environment.

Eating outside the home has consistently been a risk factor for sporadic *Salmonella* infections. A case-control study of salmonellosis conducted in 1996 and 1997 revealed that eating eggs outside the home was a risk factor for *Salmonella* Heidelberg infections *(20)* and that eating runny eggs outside the home and eating chicken outside the home were risk factors for *Salmonella* Enteritidis infections *(27).* More than half of the outbreaks in the present study occurred in restaurants that serve breakfast all day or have extensive breakfast menus and therefore use a large number of eggs. Therefore, eggs were considered the likely vehicle through which *Salmonella* entered the restaurant in many of our outbreaks, with subsequent transmission to patrons facilitated by infected foodworkers and environmental contamination. Outbreaks with low infection rates and long duration may represent the midpoint in a continuum ranging from transmission to a single patron resulting in a sporadic case of illness to the easily identified outbreak with a large number of cases in a short period of time *(22, 28, 29, 39).* Without use of real-time PFGE subtyping in conjunction with routine interviewing of all affected individuals, many of these outbreaks would have escaped detection. Our identification of a previously undetected outbreak during the review of records for this study illustrates that outbreaks with few cases over a prolonged period of time are easy to miss, even when real-time PFGE is used in conjunction with interviews.

Outbreaks of *Salmonella* infection in restaurants are complex events involving multiple factors that can be evaluated using a systems-based approach to correlate outbreak presentations with food safety system failures: (i) consumption of undercooked foods of animal origin (FAO) can be a direct source of illness for patrons; (ii) uncooked FAO can be a source for cross-contamination of ready-to-eat (RTE) foods; (iii) FAO can contaminate the environment, leading to sporadic or persistent contamination of RTE foods over time; (iv) foodworkers can become infected through contact with FAO or with environments contaminated by FAO or by consumption of contaminated foods; (v) infected foodworkers can contaminate the environment,

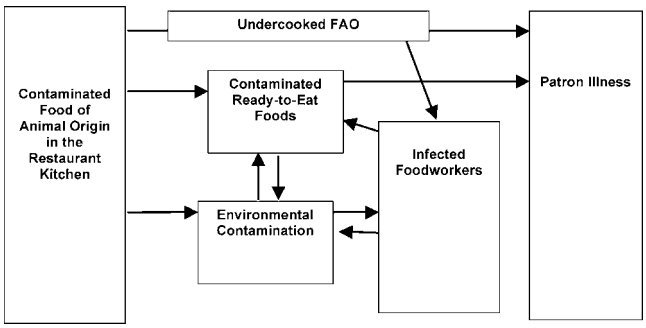

FIGURE 2. *Outbreaks of salmonellosis in restaurants are complex events with multiple pathways leading to transmission to patrons.*

which in turn can result in contamination of RTE foods; and (vi) RTE foods can become contaminated when prepared by infected foodworkers (Fig. 2). The complexity of these potential food safety system failures makes it difficult to ascertain the original source of the organism (food versus foodworker).

Regardless of the initial source of the outbreak, our results demonstrate that foodworkers frequently serve as reservoirs for *Salmonella* and contribute to transmission to patrons. Thus, assessment of foodworker infection by obtaining an illness history and testing stool samples and exclusion of infected foodworkers from the food establishment are essential for controlling restaurant-associated outbreaks of salmonellosis.

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