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Large *Salmonella* Enteritidis outbreak with prolonged transmission attributed to an infected food handler, Texas, 2002

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SUMMARY

In March 2002, an outbreak of *Salmonella* Enteritidis (SE) infections occurred at a convention centre in Dallas, Texas and continued for 6 weeks. We conducted epidemiological studies, obtained clinical and environmental cultures, and interviewed employees to identify risk factors for infection. From 17 March–25 April 2002, the implicated hotel kitchen catered 41 multi-day conferences attended by 9790 persons. We received 617 illness reports from residents of 46 states. Sauces or items served with sauces were implicated in three cohort studies. SE phage-type 8 was identified as the agent. Eleven food service employees, including one who prepared sauces and salsa, had stool cultures that yielded SE. Although the original source was not determined, prolonged transmission resulted in the largest food handler-associated outbreak reported to date, affecting persons from 46 US states. Transmission ended with implementation of policies to screen food handlers and exclude those whose stool cultures yielded salmonellas.

Key words: Disease outbreak, epidemiology, gastroenteritis, *Salmonella* Enteritidis.

INTRODUCTION

Salmonella outbreaks, particularly large ones in which a food handler is clearly implicated, are uncommon [1–4]. Hedberg *et al.* [1] reported a food handler-associated outbreak of *Salmonella* Enteritidis (SE) that occurred at a fast-food restaurant; a single food handler who had developed only mild gastrointestinal illness without diarrhoea 1 day before the outbreak caused 89 symptomatic SE infections. Hundy & Cameron [2] identified 28 patrons who became ill with *Salmonella* Typhimurium after eating at a Korean restaurant during a 3-day period; illness was strongly associated with consumption of mango pudding. A culture-positive food handler reported an onset of illness 2 days before the first cases; the food handler's only role was preparation of the mango pudding. Blaser *et al.* [3] reported a biphasic *S.* Typhimurium outbreak that resulted in 41 ill restaurant patrons; although multiple items were implicated, in the second phase of the outbreak a tainted salad prepared

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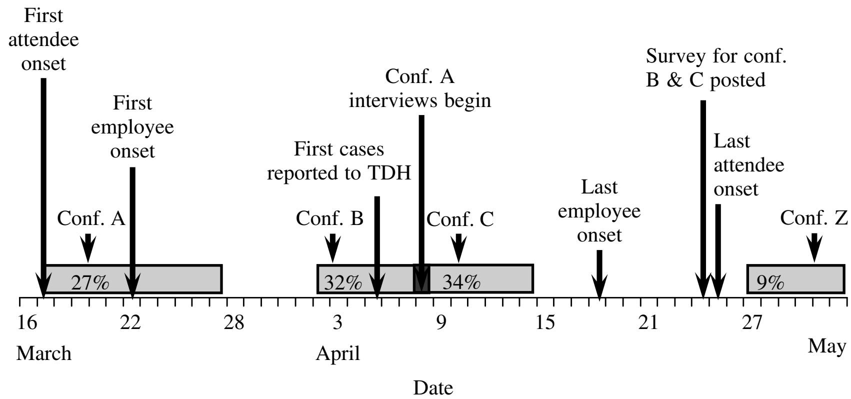

Fig. 1. Timeline of outbreak and investigation at Hotel X, March–April 2002, Dallas, Texas. Percentages given in grey bars are conference attack rates. TDH, Texas Department of Health.

by a culture-positive food handler was implicated. Khuri-Bulos *et al.* [4] reported a SE outbreak at a university hospital cafeteria; 183/619 consumers (19·3%) of a single meal became ill. Mashed potatoes were the implicated vehicle. Although none of the kitchen staff reported illness in the preceding 3 months, 11 were SE culture-positive, one of these 11 was solely responsible for preparing the mashed potatoes. The largest reported food handler-associated outbreak reported in the literature occurred at a building site canteen in Madrid in 1994 and resulted in 448 illnesses [5]. We describe a larger foodborne outbreak of *Salmonella* with prolonged transmission attributed to an asymptomatic infected food handler.

METHODS

Outbreak

On 5 April 2002, the Texas Department of Health (TDH) was notified about a cluster of diarrhoea cases due to SE in 10 persons attending a conference at a hotel and convention centre (Hotel X) in Dallas. Subsequently, other guests of Hotel X reported illness, and all had attended a conference. During the outbreak period of 17 March–25 April 2002, 41 multi-day, catered conferences were held at Hotel X with at least 9790 attendees including residents of all 50 states, several US territories, and several other countries.

Hotel X operated 1600 guest rooms and a convention centre with over 50 conference rooms. Conferences ranged from a single session where only water was served to large catered events lasting over a week with up to 4000 attendees. The hotel had nine kitchens; the largest was the banquet kitchen, the only one that prepared food for in-house conferences.

Dallas County Department of Health and Human Services led an investigation to assess the extent of the outbreak and to determine risk factors for illness.

Symptom survey

To determine the scope of the outbreak, we posted a symptom survey on a secure internet website and instructed conference sponsors and organizers to distribute information about the survey to attendees. Attendees of three conferences selected for additional epidemiological studies were excluded from the symptom survey. For this survey, illness was defined as nausea, vomiting, or diarrhoea ($\geqslant 3$ loose stools per day) in a person within 7 days of attending a catered conference at Hotel X during 17 March–25 April 2002. Figure 1 is a timeline for the investigation and indicates the dates of key events. The duration of the outbreak is defined by the onset of illness of the first and last cases reported to TDH (Fig. 1).

Cohort studies

We selected three multi-day conferences each with at least 100 attendees from the beginning, middle, and end of the outbreak period to ensure adequate power to determine risk factors for illness, and to capture changes in transmission during the outbreak. Conference A was held during 17–27 March; Conference B, 2–8 April; and Conference C, 8–14 April (Fig. 1). We developed a different questionnaire for each conference which included all food (including condiments) and beverage items prepared for conference attendees according to menus provided by the management of Hotel X. The questionnaire also inquired about meals attendees may have had outside the conference and hotel. We restricted the case definition for the risk-factor surveys to persons who reported $\geqslant 3$ loose stools in any 24-h period within 7 days after attending a conference at Hotel X during 17 March–25 April 2002.

The study of Conference A was conducted first. Beginning on 8 April, we interviewed by telephone attendees who were identified from a conference participant roster as Texas residents and therefore could be contacted without delay since they lived in the jurisdiction of the TDH. Studies of Conferences B and C began on or about 24 April. For attendees of Conferences B and C, we posted questionnaires on a secure internet website and provided instructions for completing the survey to conference sponsors and organizers for distribution to attendees. These questionnaires were programmed such that respondents could not proceed through the questionnaire without providing a response. 'Don't know' was included as an option, but was rarely used. Questionnaires were left on a secure server for 2 weeks. We cross-referenced the names of respondents with the attendee rosters to ensure attendance at the conference.

Follow-up survey

To confirm that outbreak had ended, we emailed a follow-up survey for attendees of Conference Z (27 April 27–2 May) that began 2 days after onset of illness of the last conference attendee to report a diarrhoeal illness to TDH. We used a similar case definition as that used in the symptom survey, changing only the exposure period.

Environmental investigation

The hotel facility was inspected by City of Dallas Environmental and Health Services. Hotel management and kitchen staff were interviewed regarding food preparation, food handling methods, and sanitizing procedures. The food preparation areas were inspected to ensure compliance with the City of Dallas Health Code. Samples of food items implicated in previous *Salmonella* outbreak investigations [5–7] were collected on 12 April, including Caesar salad dressing, poultry, unpasteurized orange juice, and a box of shell eggs.

We administered a questionnaire in English and Spanish for the kitchen food handlers that focused on work duties, kitchen procedures, and illness. We verified self-reported illness histories from the survey with employee sick-leave records. Work schedules were only available for the period during which Conference A was held; however, during employee interviews, employees were also asked about working during the period of Conference C. Reponses were then confirmed by review of employee work schedules.

Laboratory investigation

Stool samples were cultured using standard methods at local health departments [8]. Pulsed-field gel electrophoresis (PFGE) following digestion with *Xba*I and *Bln*I restriction enzymes, and phage typing of SE isolates was conducted at state public health laboratories or at CDC using methods reported previously [9–13]. For two isolates, commercial laboratories determined antimicrobial susceptibility to ampicillin, trimethoprim–sulfamethoxazole, and ciprofloxacin using the Vitec (bioMérieux, Marcy l'Etoile, France) automated system.

Food samples and swabs of refrigeration units, sinks, and floor drains were cultured [14]. Public drinking water samples collected at Hotel X were tested for chlorine [15].

On 23 April, the hotel management required food and beverage service staff to submit a stool specimen for culture. Persons whose specimens yielded SE were not allowed to prepare food until culture of two successive stool specimens were negative.

Statistical analysis

Data from each cohort were analysed and modelled separately using SAS version 8e [16]. We calculated odds ratios (OR), and exact 95% confidence intervals (95% CI). We constructed a saturated multivariable model for each conference that included all food and beverage exposures that were significantly associated with illness in univariate analysis ($P \leqslant 0{\cdot}1$). Multivariate models were then reduced through the application of backward stepwise elimination model-building strategies with a 5% retention rule ($P \leqslant 0{\cdot}05$) to identify independently significant associations.

Table 1. *Signs, symptom, and illness characteristics of ill persons attending conferences at Hotel X during March–April 2002, Dallas, Texas*

	Symptom survey (total ill = 475)	Conference A (total ill = 47)	Conference B (total ill = 54)	Conference C (total ill = 41)	Conference Z (total ill = 8)
Attack rate (%)	37 (475/1269)	27 (47/173)	32 (54/170)	34 (41/119)	9 (8/91)
Diarrhoea (%)	91	100	98*	100	75
Bloody	n.c.	15	11	11	0
Watery	n.c.	100	98	90	75
Abdominal cramps (%)	88	81	83	90	75
Nausea (%)	72	77	78	78	50
Headache (%)	75	72	80	66	38
Fever (subjective) (%)	57	68	43	61	25
Vomiting (%)	17	36	22	29	38
Sought medical attention (%)	36†	19	28	59	13
Median incubation period, days (range)	n.c.	2·5 (1–12)	n.c.	1·5 (0·5–5)	4 (1–8)
Median duration of symptoms, days (range)	n.c.	4 (1–21)	3 (0·5–32)	4·5 (1–12)	2 (0·5–8)

n.c., Data not collected.
* One person did not indicate type of diarrhoea.
† Symptom survey question asked if person was 'ill enough to see a doctor', and not whether they had actually seen one.

RESULTS

Symptom survey

Of the 1269 attendees who returned symptom surveys, 475 (37%) reported nausea, vomiting, or diarrhoea. Diarrhoea, abdominal cramps, nausea, headache, and fever were each reported by more than 50% of those affected (Table 1) and 173 (36%) patients felt ill enough to see a doctor. No deaths were reported. Ill attendees included residents of 46 states.

Cohort studies

Of the 1463 attendees at Conference A, 173 (12%) were interviewed by telephone, and of these 47 (27%) reported an illness that met the cohort study case definition (Fig. 2). Among the 189 food and beverage items available at this multi-day conference, multivariable analysis revealed three items that were significantly associated with illness (Table 2); all were served for dinner on Thursday, 21 March. They were chicken tacos (OR 6·84, 95% CI 1·64–28·63, $P<0{\cdot}01$), (frozen, precooked) bacon bits offered as a topping on a baked potato bar (OR 6·65, 95% CI 1·16–38·57, $P=0{\cdot}04$), and (frozen, precooked) quesadillas (OR 2·89, 95% CI 1·03–8·13, $P=0{\cdot}04$). Salsa was also available as a condiment and according to banquet staff was used by attendees having the chicken tacos, potato bar, and the quesadillas. Salsa consumption was statistically significantly associated with illness in univariate analysis (14/26 who ate the salsa became ill *vs.* 16/68 who did not; OR 3·79, 95% CI 1·31–11·12, $P<0{\cdot}01$) but its association was not significant in the multivariable model. Of note salsa was also served during dinner of the previous day, 20 March.

Of the 1201 attendees of Conference B, 170 (14%) completed the web-based survey. Of these, 54 (32%) had an illness that met the case definition (Fig. 2, Table 1). Among the 198 foods included in the questionnaire, multivariable analysis revealed three items that were significantly associated with illness (Table 3): sweet-and-sour sauce served for dinner on Thursday, 4 April (OR 7·06, 95% CI 2·12–23·58, $P<0{\cdot}01$) during a meal when salsa was also served but not implicated, any drink with a lemon slice consumed Friday evening, 5 April (OR 2·79, 95% CI 1·12–6·97, $P=0{\cdot}03$), and picante sauce, a type of salsa served as a condiment at breakfast on Saturday, 6 April (OR 9·14, 95% CI 2·44–34·31, $P<0{\cdot}01$).

Of the 416 Conference C attendees, 119 (29%) completed the web-based survey. Forty-one respondents (34%) met the case definition (Fig. 2, Table 1). Of the 210 exposure variables included in the questionnaire, multivariable analysis revealed three items statistically significantly associated with illness (Table 2). All were served for lunch on Friday, 12 April: salsa (OR 4·56, 95% CI 1·01–20·58,

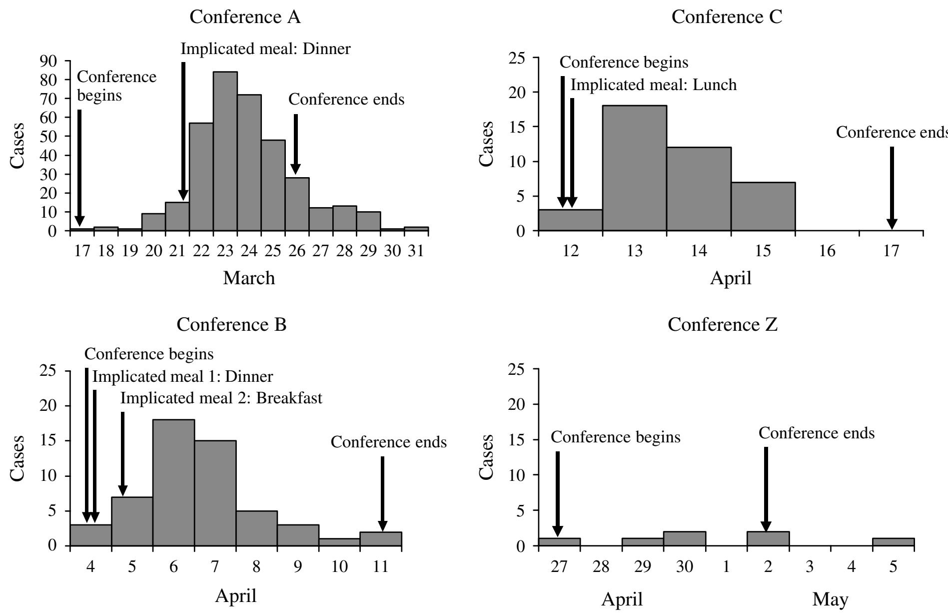

Fig. 2. Epidemic curves for Conferences A, B, C, and Z. For Conference Z one ill attendee did not report an onset date.

$P=0{\cdot}05$), chili con queso (OR 5·34, 95% CI 1·32–21·59, $P=0{\cdot}01$), and sour cream (OR 4·41, 95% CI 1·01–19·17, $P=0{\cdot}05$). The salsa and chili were both condiments for tostados, and the sour cream was a condiment for beef or chicken tacos, but attendees were free to use these condiments for any entrée.

Follow-up survey

Of 1116 attendees of Conference Z (27 April–2 May 2002), a convenience sample of 364 attendees was contacted by email, 91 (25%) of whom returned completed surveys. Eight attendees (9%) reported an illness within 1 week after arriving at the hotel (Fig. 2, Table 1), and one sought medical attention. That person provided a stool culture that tested negative, but the patient had been taking an antibiotic for 24 h before providing the specimen. We asked another attendee who was still suffering from diarrhoea to provide a stool specimen, but no enteric pathogens were isolated.

Environmental investigation

On 12 April, City of Dallas Environmental and Health Services staff inspected the banquet kitchen. Cultures of food samples, ice water, and environmental swabs (from inside the main ice machine, the cutting board used to cut vegetables, the walk-in cooler where eggs were stored, and the meat slicer in the raw vegetable preparation area of the banquet kitchen) did not yield SE. The free chlorine content of the water collected from multiple sites within Hotel X was similar to the Dallas municipal water supply.

Because salsa was implicated in two cohorts, we reviewed its preparation with a senior banquet kitchen chef. The picante sauce was prepared the same way as salsa with all the same ingredients; we, therefore, considered it salsa by another name. The salsa was freshly made daily by the same employee. The ingredients were Roma tomatoes, yellow onions, cilantro (coriander), jalapeños, garlic salt or fresh garlic, salt, and vinegar or lemon juice. Onions and jalapeños were blackened on a grill then combined with the other ingredients in a large vertical food processor for 5–10 min. The design of the food processor required that the salsa be scooped out of the bowl using a pot or other device during transfer into serving bowls. The salsa was then covered and refrigerated until needed. Unused salsa was discarded at the end of the day. The senior banquet kitchen chef also reported that when sour cream and salsa were both prepared as condiments, the chef preparing the salsa might also transfer sour cream into serving bowls.

Several ingredients in the salsa were also used in other food items. With the exception of chili con queso, which was sometimes prepared with fresh Roma tomatoes, none of these other food items was associated with illness. Because contaminated cilantro

Table 2. *Food items significantly associated with illness among persons attending conferences at Hotel X during March–April 2002, Dallas, Texas*

Cohort	Exposure	% Exposed (exposed/total)		OR*	95% CI	*P* value
		Case	Non-case			
Conference A	Quesadilla	54 (19/35)	26 (12/46)	2·89	1·03–8·13	0·04
	Bacon topping	25 (7/28)	4 (2/45)	6·65	1·16–38·57	0·04
	Chicken taco	34 (12/35)	7 (3/46)	6·84	1·64–28·63	$<0·01$
Conference B	Drink with lemon slice	78 (29/37)	57 (39/69)	2·79	1·12–6·97	0·03
	Sweet & sour sauce	66 (19/29)	33 (19/57)	7·06	2·12–23·58	$<0·01$
	Picante sauce (salsa)	76 (16/21)	26 (7/27)	9·14	2·44–34·31	$<0·01$
Conference C	Sour cream	73 (22/30)	29 (11/38)	4·41	1·01–19·17	0·05
	Salsa	88 (28/32)	41 (15/37)	4·56	1·01–20·58	0·05
	Chili con queso	70 (23/33)	24 (8/33)	5·34	1·32–21·59	0·01

OR, Odds ratio; CI, confidence interval.
* Adjusted via a conference-specific multivariable regression model, as described.

Table 3. *Public health interventions to end transmission during an outbreak of* Salmonella *Enteritidis at Hotel X during March–April, 2002, Dallas, Texas*

Date	Intervention
12 April	Banquet kitchen closed
	Prepared food items discarded
15 April	Use of only pasteurized egg products
	Service of only pasteurized orange juice
	Preparation and service of only hot food items
	Service of only bottled water and commercially packaged ice
	Food handlers to wear gloves
	Two sanitarians assigned to food preparation area 24 h a day
23 April	Food service staff screened for *Salmonella* Enteritidis

had been implicated in previous salsa-related investigations [17, 18], we examined produce purchase records. Several different shipments of cilantro and Roma tomatoes were used to prepare salsa for conference meals during the outbreak. Several other kitchens at Hotel X had received cilantro and Roma tomatoes from the same distributor and producer, sometimes on the same day, but no illnesses were associated with these other restaurants within Hotel X. The local produce distributors that supplied the hotel with cilantro and other produce indicated that other food service establishments in the Dallas area had received a portion of the same lot of cilantro, but none had reported complaints from ill patrons.

Food handler survey

There were 157 kitchen staff working in the nine hotel kitchens; of these, 136 were food handlers. Of the food handlers, 115 (85%) completed questionnaires; their median age was 41 years, and 47% were female. Notably, 51% of kitchen staff reported that they worked in more than one kitchen.

From 1 February to 15 May 2002, 14 (12%) kitchen staff reported an illness that met the cohort study case definition. Nine recalled when their symptoms began, and all illnesses occurred after illness onset of the first conference attendee identified as part of the outbreak (Fig. 1). Eight of these ill kitchen food handlers had worked in the banquet kitchen; two were cooks; two were kitchen supervisors that reported some hot food preparation activities; the remaining were stewards or food runners.

Laboratory investigation

A total of 43 attendees had stool cultures that yielded SE, including three attendees of conferences selected for cohort studies. All 21 SE isolates tested further had indistinguishable *Xba*I and *Bln*I PFGE patterns and were phage-type 8. These PFGE patterns were common in SE isolates in the United States as was the phage type at that time. Two isolates underwent antibiotic susceptibility testing and were susceptible to all drugs tested.

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Interventions

On 12 April, City of Dallas Environmental and Health Services closed the banquet kitchen and all prepared foods made in the banquet kitchen were discarded (Table 3). Any unused raw items in the banquet kitchen coolers were essentially embargoed in the banquet kitchen coolers when the banquet kitchen was closed. However, banquet kitchen staff were relocated to the main kitchen, and the food service options for conferences were limited to items considered low risk for salmonellosis (e.g. hot foods and beverages). Despite these instructions salsa preparation continued. On 15 April, City of Dallas Environmental and Health Services staff conducted 24-h monitoring of food preparation for 3 days to ensure compliance with the Dallas Health Code during all phases of food preparation. Table 3 lists the other interventions to reduce transmission during the outbreak and their date of implementation. On 19 April the banquet kitchen was reopened and meal preparation for conferences was transferred back from the main kitchen to the banquet kitchen.

Because of continuing reports of diarrhoeal illness in conference attendees, on 23 April hotel management required all food and beverage service staff ($n=704$) to have a negative stool culture before they could return to work; 687 (98%) submitted specimens. Of the 545 non-kitchen food and beverage service staff (e.g. servers, runners, etc.) who were tested, seven (1%) had stool cultures that yielded SE. Of the 157 members of eight different kitchen staffs, 142 (90%) submitted stool samples. Salmonellae were isolated from four; three were SE and one was *Salmonella* serotype Anatum. The SE isolates had PFGE patterns that were indistinguishable from the outbreak pattern and were phage-type 8. They were isolated only from stool specimens of banquet kitchen chefs. Of these three chefs, two were supervisors who did not routinely prepare food; one of these met the cohort case definition, the other denied symptoms. The remaining chef with a stool sample positive for SE was an asymptomatic sous chef, and was the only food handler of the 142 to report salsa and other sauce preparation among his duties. Review of work schedules for the period during which Conference A was held revealed that this sous chef was off on Wednesday, 20 March but worked on Thursday, 21 March and Friday, 22 March (the implicated meal for Conference A was Thursday 21 March). In addition, during employee interviews the sous chef reported working on Friday, 12 April and Saturday, 13 April (the implicated meal for conference C was on Friday 12 April). No information was available for the sous chef's work schedule during the period of Conference B; however, the implicated meals during Conference B were on Thursday, 4 April and Friday, 5 April, which were days the sous chef normally worked. Finally, unlike 51% of other kitchen staff mentioned previously, the sous chef was assigned full-time to the banquet kitchen.

DISCUSSION

This nationwide outbreak of SE gastroenteritis was the largest reported *Salmonella* outbreak propagated by a food handler. It was also among the largest SE outbreaks in the United States since the Schwan's ice cream outbreak in 1994 [19]. That investigation concluded that tanker trucks previously used to transport unpasteurized liquid eggs were not adequately disinfected before filling with ice cream premix. SE from the raw eggs contaminated 138 000 gallons of ice cream and caused an estimated 224 000 symptomatic cases [19].

Although the original source of this outbreak was not determined, it was most likely propagated by consumption of contaminated sauces prepared by an infected sous chef. This conclusion is supported by several findings. First, salsa was implicated in two cohorts and food items served with salsa were implicated in a third. Sweet-and-sour sauce was also implicated in one cohort during a meal in which salsa was not served. Second, we identified an asymptomatic carrier, the sous chef, who was also the only food handler who had salsa preparation among his duties. Third, the outbreak continued despite closure of the banquet kitchen and relocation of kitchen staff to the main kitchen. Last, the outbreak ended following screening stool samples and exclusion of all SE-infected food and beverage service staff. Although a vertical food processor of similar design to the one used in the banquet kitchen was implicated in a previous SE outbreak [20], our investigation lead to an asymptomatic sous chef who was shedding SE in his stool. Indeed, available work records and menus for Conference A indicated salsa was served during two dinners; however, this sous chef only worked the day of the implicated meal. Since the median duration of non-typhoidal *Salmonella* excretion by adults is 4 weeks, but 10% of adults still excrete salmonellae for up to 9 weeks [21], it is possible that the asymptomatic sous chef was the sole source of the outbreak. However, it is also possible that SE entered the banquet kitchen by another route and several employees were responsible for transmission.

Both the most commonly implicated vehicle and the mode of transmission in this outbreak are remarkable. The majority of outbreaks of SE have been associated with raw or undercooked eggs or cross contamination following the handling of such food [22]. This is the first reported outbreak of SE associated with salsa. Salsa has been a source of outbreaks caused by other pathogens [17, 23, 24]. Several studies of salsa collected from restaurants in the United States and Mexico have shown sufficient numbers of organisms to result in human disease [18, 25]. In most reported outbreaks associated with salsa, the salsa became tainted through use of contaminated ingredients such as cilantro [17, 23] or onions [24]. While fresh tomatoes have not been implicated in a salsa-related outbreak, they have been implicated in *Salmonella* outbreaks in the past and should also be considered as a possible vehicle in contaminating salsa [26, 27]. Once inoculated, bacteria continue to multiply adapting to the acidic environment [28, 29]. The lack of cooking during preparation of salsa compared to other sauces prepared by the asymptomatic chef probably explains why it caused the most cases.

Prevention of food handler propagation of disease requires strict attention to proper food handling and preparation [1–4]. While employees can be educated regarding the risk of disease transmission during and after a diarrhoeal illness, work policies such as lack of sick leave and risk of loss of revenue for underemployed food workers act as disincentives for employees to report and remain out of work while ill [30]. Furthermore, asymptomatic infection and prolonged shedding following a diarrhoeal illness have also resulted in outbreaks [4, 31] and are difficult to identify. Routine screening of food service staff failed to prevent a *Salmonella* outbreak in a university hospital where employees were required to submit stool cultures every 3 months, suggesting that routine screening of employees is not an effective means of prevention [4]. Indeed, shedding of enteric pathogens may be intermittent [21]. Finally, employees may also passively transfer and contaminate food items with the fingertips [32, 33]. Pether & Gilbert [34] demonstrated that *Salmonella* can persist on heavily contaminated hands despite a 15-min wash with soap and water and can survive on fingertips for at least 3 h. Nevertheless, in the setting of an ongoing outbreak, screening of food handlers directly involved with food preparation should be considered as an intervention given the possibly of asymptomatic carriage, especially when other control measures have been put in place and transmission continues [21, 31].

We confirmed the end of the outbreak by conducting a survey of attendees of Conference Z which began 48 h after the last reported illness onset. The incidence of diarrhoeal illness in Conference Z attendees in the 7 days following the conference was 9% compared to the range of 27–34% attack rates among the cohorts studied, indicating that the outbreak had ended. In a survey of the general population, 8% of a comparable age group reported an acute diarrheal illness in the 4 weeks prior to the interview [35].

In terms of methods, the use of the internet to conduct epidemiological investigations is not new [36–38]; however, this investigation was unique in that three methods to conduct surveys were used: Conference A attendees were interviewed by phone; attendees of Conferences B and C completed web-based surveys as did the symptom-survey respondents; and Conference Z attendees received the survey by email. Unfortunately the refusal rate and non-response rate for Conference A was not recorded. Response rates for the web-based survey and the email surveys were similar. This is notable in that typical response rates for emailed surveys are low [39]. Each method had its own advantage and disadvantage. Telephone interviews are labour intensive because they require interviewers to call and record responses on paper, which then have to be entered. On the other hand well-trained interviewers can minimize the number of missing responses. Moreover, telephone interviews can be completed quickly if sufficient staff is available. Finally, because it is an active method, overall response rates are typically high. Web-based surveys are less labour intensive but require extensive piloting to ensure not only that questions are appropriately worded but also that there are no problems in the survey programme. Electronic data security is also an issue. Web-based surveys have the advantage that on completion of the interview, the data are immediately available. Nonetheless, web-based surveys are a passive method and response rates may be low [36, 38]. Reminders may improve response rates [39, 40]. Emailed surveys are not very labour intensive in preparation but still require data entry. They are therefore subject to the same data-entry errors as any paper-based surveys. Like web-based surveys they require respondents to have internet access. While 88% of US households had internet access in 2008 [41], in certain subgroups, such as conference attendees, internet access is likely to be higher and therefore a reasonable option [39]. Other researchers have used variations on the above such as recorded telephone interview with success [42]. All of these methods should be considered as options when conducting an outbreak investigation. Schleyer & Forrest as well as other authors evaluated the use of electronic surveys and provided guidelines on survey preparation using these media [39, 43, 44].

This investigation was limited in several ways. First, the symptom survey and cohort studies relied on passive reporting and responses rates were low. However, these response rates are typical of outbreak investigations conducted using the internet around the same time [36, 38]. More importantly, despite the response rates the results were sufficient to achieve their goal which was to identify a vehicle. The attack rate may have been inflated since ill persons were more likely to have responded in reporting illness. We therefore did not extrapolate the attack rate to the entire cohort. Second, the time lag between exposure and interview could have resulted in poor recall of exposures. However, we had the advantage of multiple cohorts and the results of the laboratory and environmental investigations to identify a biologically plausible cause for continued transmission of the outbreak and a method to eventually end the outbreak.

A large SE outbreak occurred at a hotel convention centre in Dallas, Texas in 2002 and continued for several weeks. Food handler screening for SE infection and a policy of excluding infected workers from handling food coincided with the end of transmission. In outbreak investigations where conventional control measures fail to end transmission, screening and exclusion of infected workers from food handling should be considered as an early intervention.

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DECLARATION OF INTEREST

None.

REFERENCES

1. **Hedberg C, *et al.*** An outbreak of *Salmonella* Enteritidis infection at a fast-food restaurant: implications for foodhandler-associated transmission. *Journal of Infectious Disease* 1991; **164**: 1135–1140.
2. **Hundy R, Cameron S.** An outbreak of infections with a new *Salmonella* phage type linked to a symptomatic food handler. *Communicable Diseases Intelligence* 2002; **26**: 562–567.
3. **Blaser M, *et al.*** An outbreak of salmonellosis involving multiple vehicles. *American Journal of Epidemiology* 1981; **114**: 663–670.
4. **Khuri-Bulos N, *et al.*** Foodhandler-associated *Salmonella* outbreak in a University Hospital despite routine surveillance cultures of kitchen employees. *Infection Control and Hospital Epidemiology* 1994; **15**: 311–314.
5. **Faustini A, *et al.*** An outbreak of *Salmonella* hadar associated with food consumption at a building site canteen. *European Journal of Epidemiology* 1998; **14**: 99–106.
6. **Patrick ME, *et al.*** *Salmonella* Enteritidis infections, United States, 1985–1999. *Emerging Infectious Diseases* 2004; **10**: 1–7.
7. **Centers for Disease Control and Prevention.** Outbreak of *Salmonella* serotype Muenchen infections associated with unpasteurized orange juice – United States and Canada, June 1999. *Morbidity & Mortality Weekly Report* 1999; **48**: 582–585.
8. **Grasmick A.** Processing and interpretation of bacterial fecal cultures. In: Isenber D, ed. *Clinical Microbiology*

Procedures Handbook, vol. 1. Washington, D.C.: American Society for Microbiology, 1992.
9. **Centers for Disease Control and Prevention.** Standardized molecular subtyping of *Escherichia coli* by pulsed-field gel. Atlanta, GA: CDC, 1998.
10. **Skibsted U, *et al.*** Random amplification of polymorphic DNA, pulsed-field electrophoresis and phage-typing in the analysis of a hospital outbreak of *Salmonella* Enteritidis. *Journal of Hospital Infection* 1998; **38**: 207–216.
11. **Hickman-Brenner FW, Stubbs AD, Farmer III JJ.** Phage typing of *Salmonella* Enteritidis in the United States. *Journal of Clinical Microbiology* 1991; **29**: 2817–2833.
12. **Ward LR, De Sa J, Rowe B.** A phage-typing scheme for *Salmonella* Enteritidis. *Epidemiology & Infection* 1987; **99**: 291–294.
13. **Hickman-Brenner FW, Stubbs AD, Farmer 3rd JJ.** Phage-typing of *Salmonella* enteritidis in the United States. *Journal of Clinical Microbiology* 1991; **29**: 2817–2823.
14. **Food and Drug Administration.** *Bacteriological Analytical Manual*, 7th edn. Arlington, VA.: Association of Official Agricultural Chemists, 1992.
15. **American Public Health Association.** *Standard Methods for the Examination of Water and Wastewater*, 20th edn. Washington, D.C.: American Public Health Association, 1998.
16. **SAS Institute.** SAS/STAT User's Guide, version 8. Cary, NC: SAS Institute, Inc., 1999.
17. **Campbell JV, *et al.*** An outbreak of *Salmonella* serotype Thompson associated with fresh cilantro. *Journal of Infectious Disease* 2001; **183**: 984–987.
18. **Adachi JA, *et al.*** Enteric pathogens in Mexican sauces of popular restaurants in Guadalajara, Mexico, and Houston, Texas. *Annals of Internal Medicine* 2002; **136**: 884–887.
19. **Hennessy TW, *et al.*** A national outbreak of *Salmonella* Enteritidis infections from ice cream. *New England Journal of Medicine* 1996; **334**: 1281–1286.
20. **McQuigge M, *et al.*** Institutional outbreak of *Salmonella* gastroenteritis in Owen Sound, 1991/92. *Public Health and Epidemiology Report* (PHERO), May 1992, pp. 157–159.
21. **Buchwald DS, Blaser MJ.** A review of human Salmonellosis II. Duration of excretion following infection with nontyphi *Salmonella*. *Reviews of Infectious Diseases* 1984; **6**: 345–355.
22. **Braden CR.** *Salmonella* enterica serotype Enteritidis and eggs: a national epidemic in the United States. *Clinical Infectious Diseases* 2006; **43**: 512–517.
23. **Tsang TH, *et al.*** Large *Shigella sonnei* outbreak linked to salsa in California, 1998 (abstract P10). In: *Program and Abstracts of the 48th Annual Epidemic Intelligence Service Conference* (*Atlanta*). Atlanta: Centers for Disease Control and Prevention, 1999, p. 51.
24. **Wheeler C, *et al.*** An outbreak of Hepatitis A associated with green onions. *New England Journal of Medicine* 2005; **353**: 890–897.
25. **Estrada-Garcia T, *et al.*** Faecal contamination and enterotoxigenic *Escherichia coli* in street-vended chili sauces in Mexico and its public health relevance. *Epidemiology & Infection* 2002; **129**: 223–226.
26. **Centers for Disease Control and Prevention.** Multistate outbreaks of *Salmonella* infections associated with raw tomatoes eaten in restaurants – United States, 2005–2006. *Morbidity & Mortality Weekly Report* 2007; **56**: 909–911.
27. **Hedberg CW, *et al.*** Outbreaks of salmonellosis associated with eating uncooked tomatoes: implications for public health. *Epidemiology & Infection* 1999; **122**: 385–393.
28. **Bower CK, Daeschel MA.** Resistance responses of microorganisms in food environments. *International Journal of Food Microbiology* 1999; **50**: 33–44.
29. **Brudzinski L, Harrison MA.** Influence of incubation conditions on survival and acid tolerance response of *Escherichia coli* O157:H7 and non-O157:H7 isolates exposed to acetic acid. *Journal of Food Protection* 1998; **61**: 542–546.
30. **Kimura AC, *et al.*** A multi-state outbreak of *Salmonella* serotype Thompson infection from commercially distributed bread contaminated by an ill food handler. *Epidemiology & Infection* 2005; **133**: 823–828.
31. **Dryden MS, *et al.*** Asymptomatic food handlers as the source of nosocomial salmonellosis. *Journal of Hospital Infections* 1994; **28**: 195–208.
32. **Blaser MJ, *et al.*** An outbreak of salmonellosis involving multiple vehicles. *American Journal of Epidemiology* 1981; **114**: 663–670.
33. **Pether JVS, Scott RJD.** *Salmonella* carriers are the dangerous? A study to identify finger contamination with salmonellae by convalescent carriers. *Journal of Infection* 1982; **5**: 81–85.
34. **Pether JVS, Gilbert RJ.** The survival of *Salmonella* on finger tips and transfer of the organisms to food. *Journal of Hygiene* 1971; **69**: 673–681.
35. **Imhoff B, *et al.*** Burden of self-reported acute diarrheal illness in FoodNet surveillance areas, 1998–1999. *Clinical Infectious Diseases* 2004; **38** (Suppl.): 219–226.
36. **Kuusi M, *et al.*** Internet use and epidemiologic investigation of gastroenteritis outbreak. *Emerging Infectious Diseases* 2004; **10**: 447–450.
37. **Fox LM, *et al.*** Emergency survey methods in acute cryptosporidiosis outbreak. *Emerging Infectious Diseases* 2005; **11**: 729–731.
38. **Srikantiah P, *et al.*** Web-based investigation of multistate salmonellosis outbreak. *Emerging Infectious Diseases* 2005; **11**: 610–612.
39. **Schleyer TK, Forrest JL.** Methods for the design and administration of web-based surveys. *Journal of the American Medical Informatics Association* 2000; **7**: 416–425.
40. **Ghosh TS, *et al.*** Internet- versus telephone-based local outbreak investigations. *Emerging Infectious Diseases* 2008; **14**: 975–977.
41. **Duffy J.** 20% of U.S. has never sent e-mail. PC World. (http://www.pcworld.com/businesscenter/

article/146019/20_of_us_has_never_sent_email.html). Accessed 7 June 2008.

42. **Pryor JH, *et al.*** Rapid response to a conjunctivitis outbreak: the use of technology to leverage information. *Journal of American College Health* 2002; **50**: 267–271.
43. **Viney KA, McAnulty JM.** The evaluation of web-based data collection for enhanced surveillance of cryptosporidiosis. *NSW Public Health Bulletin* 2008; **19**: 15–19.
44. **Raat H, *et al.*** Feasibility, reliability, and validity of adolescent health status measurement by the Child Health Questionnaire Child Form (CHQ-CF): internet administration compared with the standard paper version. *Quality of Life Research* 2007; **16**: 675–685.