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International foodborne outbreak of *Shigella sonnei* infection in airline passengers

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SUMMARY

During 22–24 August 2004, an outbreak of *Shigella sonnei* infection affected air travellers who departed from Hawaii. Forty-seven passengers with culture-confirmed shigellosis and 116 probable cases who travelled on 12 flights dispersed to Japan, Australia, 22 US states, and American Samoa. All flights were served by one caterer. Pulsed-field gel electrophoresis of all 29 *S. sonnei* isolates yielded patterns that matched within one band. Food histories and menu reviews identified raw carrot served onboard as the likely vehicle of infection. Attack rates for diarrhoea on three surveyed flights with confirmed cases were 54% (110/204), 32% (20/63), and 12% (8/67). A total of 2700 meals were served on flights with confirmed cases; using attack rates observed on surveyed flights, we estimated that 300–1500 passengers were infected. This outbreak illustrates the risk of rapid, global spread of illness from a point-source at a major airline hub.

INTRODUCTION

Air travel offers a rapid mode of transportation for pathogens as well as passengers. Outbreaks resulting from exposures during air travel are particularly difficult to separate from illnesses attributable to preflight exposure [1]. Moreover, in most instances the incubation period after an in-flight exposure exceeds the flight time, so that illness occurs after passengers have dispersed. If their destinations are in different public health jurisdictions, identification of an epidemiological link between cases is especially challenging [2].

As *Shigella sonnei* has an infectious dose as low as 10 individual organisms, it is easily spread by the faecal–oral route. The incubation period is 12–96 h [3].

On 2 September 2004, the Ministry of Health of Japan contacted the Hawaii Department of Health (HDOH) regarding seven airline passengers who had left Honolulu and developed *S. sonnei* infection in Japan. We investigated this cluster to determine the source and scope of the illnesses and to identify control measures.

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The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention.

METHODS

Outbreak identification

The seven ill passengers in Japan left Honolulu on 23 or 24 August 2004 on four flights operated by Airline A. HDOH staff recognized a possible link between the cases in Japan and two other recent reports of *S. sonnei* infection: one in a passenger who travelled on 22 August from Honolulu to Minneapolis on Airline A (reported by the Minnesota Department of Health) and another in a passenger who travelled on 23 August from Honolulu to Sydney, Australia on Airline B and whose illness was diagnosed on return to Hawaii.

To identify additional infections, US state and local public health authorities were quickly notified through *Epi-X* [4], a secure electronic communication network established by the Centers for Disease Control and Prevention (CDC), requesting that persons with *S. sonnei* infection be questioned regarding a history of recent air travel from Hawaii. Public health authorities in Australia were also alerted. Laboratory-based case-finding efforts in the United States were conducted through PulseNet [5], a laboratory network that includes a database of pulsed-field gel electrophoresis (PFGE) patterns of *S. sonnei* and other bacterial pathogens.

Inquiries with the affected airlines revealed that they used the same airport caterer, located at Honolulu International Airport; a roster of all flights departing during 22–24 August 2004 served by this caterer was compiled.

Case definitions

A confirmed case was defined as illness in a passenger who departed Honolulu by air on 22–24 August 2004, and who had *S. sonnei* stool culture-positive diarrhoea within 7 days afterwards. A probable case was defined as diarrhoea during the 7 days after departure from Honolulu in a passenger who was on a flight on which at least one confirmed case had been identified; stool specimens from persons with probable illness either were not tested or yielded no pathogens. Diarrhoea was defined as three or more loose stools within a 24-h period.

Passenger surveys

To determine flight- and exposure-specific attack rates, passenger manifests were obtained for five domestic flights which left Honolulu between 22–24 August and were served by a single caterer. They were operated by different airlines (Airlines A, B, C, D, and E). A flight with one or more passengers with confirmed *S. sonnei* infection was defined as an affected flight; a control flight was one with no identified *S. sonnei* infections among passengers. For the flight on Airline A, the first affected domestic flight identified, all passengers who could be contacted were interviewed. Computer-generated random samples of passengers were surveyed for each of the four remaining flights (i.e. affected flights operated by Airlines B and C, and control flights operated by Airlines D and E). During September–October 2004, all surveyed passengers were interviewed by telephone using a standardized questionnaire that included menu items specific to their flight. Information was also obtained on other food and beverages consumed at the airport or during the flight, travel history, history of illness, and ill family members or travelling companions.

Laboratory investigation

Stool samples from ill persons and from employees of the implicated caterer were cultured. All available *S. sonnei* isolates were subtyped by PFGE using restriction endonucleases *Xba*I according to published methods [6]. PFGE patterns were compared with BioNumerics software (Applied Maths Inc., Austin, TX, USA) by using the Dice coefficient and 1% band-matching criteria. Patterns with no noticeable differences were considered indistinguishable. When possible, antimicrobial resistance patterns were assessed for cultured shigellas.

Environmental investigation

HDOH staff made several visits to the caterer's premises to observe food preparation. Detailed menus for meals served during the outbreak period were reviewed. Catering staff work schedules and illness logs for the month preceding the outbreak were examined. Employees were interviewed in private using a standardized questionnaire regarding history of illness, travel, visitors, and ill contacts.

Statistical analyses

Univariate analyses of the survey data were conducted to examine potential associations between exposure

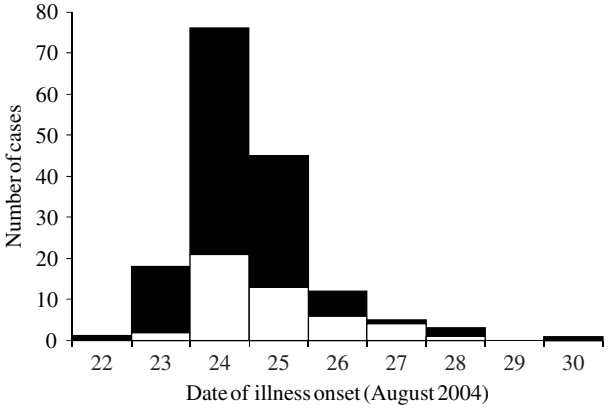

Fig. Confirmed (□, $n=47$) and probable (■, $n=114$) cases of *Shigella sonnei* infection by date of illness onset in aircraft passengers who departed Honolulu, Hawaii, 22–24 August 2004 (exact illness onset date for two of the 116 probable cases was missing).

and illness by using Epi-Info™ version 6.04b (CDC, Atlanta, GA, USA).

RESULTS

Passenger surveys

Case-finding and passenger surveys identified 47 confirmed and 116 probable cases. Affected passengers (i.e. patients) had dispersed to 22 US states, 11 Japanese cities, two Australian cities, and American Samoa. The patients had travelled on 12 different flights, operated by three airlines (Airlines A, B, and C). All left Honolulu on 22–24 August 2004. Only two (4%) of the 47 passengers with confirmed illness and none of 116 with probable illness had travelled in first class.

Patients with confirmed and probable illness ranged in age from 1 to 72 years (median 35 years); 43% were male. Surveyed passengers who were on affected flights and denied diarrhoeal illness ranged in age from 3 to 89 years (median 32 years); 55% were male.

Illness onsets peaked on 24 August 2004 (Fig.). The median onset from the implicated in-flight exposure was 2 days for both confirmed and probable cases, with ranges of 1–4 days for confirmed cases and 1–8 days for probable cases. About 90% of illness onsets occurred within 3 days of departure from Honolulu.

The median duration of diarrhoea and the median maximum number of stools per 24-h period were similar for the surveyed 21 confirmed and 116 probable cases (Table 1). However, confirmed cases usually had more severe illness, with substantially higher rates of reported fever, chills, blood in stool, and abdominal cramping. Nine (7%) patients (seven confirmed and two probable cases) were hospitalized.

Attack rates for diarrhoea ranged from 12% to 54% on the three affected flights and from 3% to 4% on the control flights (Table 2). Several food items served onboard the surveyed affected flights were associated with illness in passengers (Table 3). On the Airline A flight, consumption of the salad and the chicken entrée were each significantly associated with diarrhoeal illness, with risk ratios (RR) of 4·2 [95% confidence interval (CI) 1·9–9·5] and 1·5 (95% CI 1·2–2·1), respectively. On the Airline C flight, the salad (RR undefined, 95% CI 2·6–∞) and a lemon bar cookie (RR 3·1, 95% CI 1·3–7·4) were each significantly associated with diarrhoea. The Airline A chicken entrée was served only on Airline A, and the lemon bar was served only on Airline C. On the Airline B flight, no food items were statistically associated with diarrhoea; consumption of salad had a RR of 3·5 (95% CI 0·5–26·6). No food items were associated with diarrhoea on the two control flights.

Cold salads were common to all of the affected flights, but the composition of the salad varied between airlines and flight class of service. Menu reviews and food histories established that raw carrot was the only economy-class salad ingredient common to all 12 affected flights. In addition, the two passengers with confirmed infections who had travelled in first class on Airline B were also served salad containing raw carrot. The menu review indicated that raw carrot was not served on either of the control flights.

Laboratory investigation

Forty-seven ill passengers had documented stool cultures positive for *S. sonnei*. These cultures were processed at different laboratories across the United States and in Japan. PFGE patterns of all 29 (62%) *S. sonnei* isolates evaluated matched within one band. Only 12 (26%) of the 47 isolates had available antimicrobial susceptibility data: 11 of these were resistant to streptomycin, sulfisoxazole, tetracycline, and trimethoprim/sulfamethoxazole, although one isolate was resistant only to streptomycin. All isolates were susceptible to ampicillin and ciprofloxacin. Azithromycin susceptibility was not tested.

All 56 catering employees identified as having been involved with food preparation for affected flights submitted stool samples within 37 days of the

Table 1. *Characteristics of illness among confirmed and probable cases of* Shigella sonnei *infection among surveyed passengers who travelled on three aircraft departing Honolulu, Hawaii, during 22–24 August 2004*

Illness characteristic	Confirmed cases ($n=21$)	Probable cases ($n=116$)	OR (95% CI)
Median incubation period, days (range)	2 (1–4)	2 (1–8)	—
Median days of diarrhoea (range)	7 (4–14)	6 (1–18)	—
Median maximum number of stools/24 h (range)	12 (4–40)	10 (3–100)	—
Fever (%)	21/21 (100%)	67/113* (59%)	—
Mean maximum temperaturec (range)	39·4 °C (37·2–40·5 °C)	38·9 °C (37·8–42·2 °C)†	3·3–∞ (undefined)
Blood in stool (%)	10/21 (48%)	19/108* (18%)	4·3 (1·4–13·0)
Saw doctor (%)	21/21 (100%)	35/116 (30%)	11·0–∞ (undefined)
Provided stool sample (%)	21/21 (100%)	10/110* (9%)	41·3–∞ (undefined)
Hospitalized (%)	7/21 (33%)	2/114* (2%)	28·0 (4·5–222·3)
Received medication from doctor (%)	20/21 (95%)	33/114* (29%)	49·1 (6·4–1039·1)

OR, Odds ratio; CI, confidence interval.
* Denominator is <116.
† The maximum temperature of 42·2 °C reported by one passenger is clinically improbable.

Table 2. *Survey response rates and* Shigella sonnei *attack rates in surveyed passengers*

Airline	Confirmed case(s) on board (yes/no)	Destination of flight	Date of flight	No. of passengers on flight	No. of passengers selected for interview	No. of respondents (% of those selected)	No. reporting diarrhoea	Attack rate (%)
A	Yes	Minneapolis	22 Aug.	267	267	204 (76)	110	54
B	Yes	Seattle	22 Aug.	263	85	67 (79)	8	12
C	Yes	Burbank	23 Aug.	113	80	63 (79)	20	32
D	No	Atlanta	22 Aug.	270	91	64 (70)	2	3
E	No	San Francisco	22 Aug.	348	99	73 (74)	3	4

Table 3. *Risk for diarrhoeal illness associated with food items on surveyed affected flights* (*known cases*)

		Ate food item		Did not eat food item		
Airline	Item	Ill/total	Attack rate (%)	Ill/total	Attack rate (%)	Risk ratio (95% CI)
A	Chicken	73/112	65	35/83	42	1·5 (1·2–2·1)
	Salad	104/164	63	5/33	15	4·2 (1·9–9·5)
	Lemon bar	n.a.				
B	Chicken	2/25	8	5/35	14	0·6 (0·1–2·7)
	Salad	7/42	17	1/21	5	3·5 (0·5–26·6)
	Lemon bar	n.a.				
C	Chicken	9/24	38	9/27	33	1·1 (0·5–2·4)
	Salad	20/41	49	0/14	0	2·6–∞ (undefined)
	Lemon bar	15/27	55	5/28	18	3·1 (1·3–7·4)

OR, Odds ratio; CI, confidence interval; n.a., not applicable (i.e. not served on flight).

outbreak. These samples were cultured at the Hawaii State Laboratory; all were negative for *Shigella*. At the time the outbreak was recognized, no food items prepared for flights that had departed Honolulu during 22–24 August 2004 were available for culture.

Environmental investigation

Site visits to the caterer revealed many food hygiene deficiencies. Prepared vegetables were stored in clear plastic bins in a walk-in refrigerator. According to the caterer's usual procedure, each bin was to be labelled with the date of preparation and used within 2 days. However, during inspections, bins were noted to be unlabelled and consequently not removed systematically and chronologically. The temperature of the walk-in refrigerator was 4·4 °C, but one bin of shredded carrots registered >10 °C.

Improper glove use was also noted. Employees removed the shredded carrots and other raw vegetables from the bins with gloved hands. However, they were also observed to touch carts or door handles with gloved hands before touching the vegetables. Moreover, a chlorine vegetable sanitizer, intended to add a measured amount of chlorine to create a 50-ppm rinse for all raw vegetables, was malfunctioning and dispensed an inadequate amount of chlorine.

A review of US Food and Drug Administration reports regarding this caterer revealed that multiple food-handling deficiencies had been documented at the most recent inspection before the outbreak. Employees were noted to have touched unsanitized surfaces with gloved hands before touching food and to have made contact with the inside of plastic ice bags with bare hands. Gravy and rice were held at a temperature >10 °C for 8 h after preparation.

Review of the catering employees' schedules failed to identify a single employee involved in food preparation for all or even most of the affected flights. Although staff who prepared food for economy-class flights sometimes helped with economy-class food for other flights not on their work schedules, no overlap existed between employees who prepared food for economy and first class – indeed, meal preparation for each class was kept entirely separate (e.g. carrots for first-class meals were cut by hand, not shredded on the machine used for economy-class meals).

Sixty-two catering employees were interviewed individually. They ranged in age from 21 to 62 years (median 46 years), and 90% were female. None reported diarrhoeal illness before the outbreak, recent out-of-state travel, ill persons in their household, ill visitors, or knowledge of other ill employees. A review of the caterer's ill-employee log for August 2004 showed that 24 employees had 'called in sick'. When interviewed, only one ill employee reported diarrhoeal illness with onset on 30 August, 6 days after the outbreak period. He was not a food handler.

A traceback of the carrots showed that the caterer's Hawaii-based produce distributor had received shipments of carrots from a Salinas, California, vendor on 15 August (50-lb bags, $n=274$) and 19 August (50-lb bags, $n=640$).

Community-associated *S. sonnei* in Hawaii

During 2004 only seven *S. sonnei* infections had been identified in Hawaii before this outbreak, the most recent with illness onset in July, and only three infections during the remainder of the year. All ten *S. sonnei* isolates had PFGE patterns different from that of the outbreak strain.

DISCUSSION

This outbreak illustrates how rapid, global dissemination of foodborne pathogens can occur through contaminated in-flight meals and the resultant difficulties in recognition and investigation. Within days, travellers to two foreign countries, a US territory, and nearly half of US states were affected; many others were probably not identified.

Many foodborne pathogens are considered potential biological terrorism agents because they are fairly easy to obtain, and a limited point-source contamination can infect a substantial number of persons. One *Shigella* species, *Shigella dysenteriae*, is recognized as a Class B biological terrorism agent [7]. *S. sonnei* produces milder symptoms, but spreads as easily and as quickly. Ingestion of <10 *Shigella* organisms can produce illness. Given an incubation period of 12–96 h, airline passengers who consume food contaminated with *Shigella* on a flight are likely to become ill after air travel has ended.

The extent of this outbreak might have been greater than identified, because not all affected persons will have been examined by a physician, or might not have been tested by stool culture or reported to public health officials [8]. Resource constraints did not permit us to survey all affected flights. However, given that 2700 meals had been served on the 12 affected flights and that attack rates of diarrhoea obtained from surveyed flights ranged from 12% to 54%, we estimate that 300–1500 passengers were potentially infected in this outbreak. This estimate may be conservative, because passengers on flights other than the 12 we identified might also have been exposed to

in-flight meals contaminated with *Shigella*. During the 3-day outbreak period, the caterer prepared 11 555 meals containing the most likely vehicle, raw carrot.

Multiple lines of evidence suggest that raw carrot was the vehicle of *S. sonnei* transmission in this outbreak. A cold salad containing raw carrot was common to all affected flights and was significantly associated with diarrhoeal illness on two of the surveyed flights. Only eight passengers on the third flight (Airline B) reported diarrhoeal illness, which limited our ability to identify any statistically significant associations. Raw carrot was the only ingredient used in the economy-class salads served on all affected flights. Moreover, the only two identified first-class passengers with illness had consumed meals containing raw carrot. Although two other food items, a lemon bar dessert and a frozen chicken entrée, were also statistically associated with illness, these were commercial products that were minimally handled at the catering facility, and each had been served on only one of the three affected flights surveyed. These items are therefore less plausible vehicles for *Shigella* than a raw vegetable, which has been often implicated in previous outbreaks of *S. sonnei* dysentery [9–12]. Finally, raw carrot was not served on either of the two control flights, and the rate of diarrhoeal illness on these flights (3% and 4%) was consistent with an expected baseline rate of illness [13].

Food-handling deficiencies documented by inspections of the caterer may have contributed to *Shigella* contamination by an infected food handler – asymptomatic *Shigella* infections are known to occur [3]. Nevertheless, we did not identify a single employee's schedule that could account for exposures on all affected flights, and none of the employees prepared food for both economy- and first-class meals. In addition, disease surveillance in Hawaii failed to identify circulation of the outbreak strain of *Shigella* (i.e. a possible source of infection for local catering staff), and employees universally denied having travelled or hosted recent visitors from out of state.

The carrots were therefore probably contaminated with *Shigella* before arrival at the catering facility, and not effectively decontaminated subsequently. The 3-day duration of the outbreak was consistent with the length of time needed for the caterer to use about one 50-lb bag of whole carrots. Faecal contamination of whole carrots before preparation could explain illness in both economy- and first-class passengers whose meals were prepared in physically separate locations by different employees. Extensive contamination of carrot lots was unlikely given that >900 bags of carrots had been shipped from the same California distributor to establishments throughout Hawaii during the week before the outbreak, and not a single *S. sonnei* infection with a related PFGE pattern was identified in the local population. We noted that contamination of an isolated bag of raw carrots with another enteric pathogen, *Salmonella*, was recently documented in Canada [14].

Limitations of our study include potential recall bias by passengers in identifying foods or beverages consumed before or during their flights, the delay in the collection of stool specimens from employees, and the absence of implicated food from the affected flights for laboratory testing. In addition, some of the 'probable cases' might have been caused by other conditions. However, the consistent, short incubation observed and the severity of diarrhoeal illness reported by persons travelling on flights where co-passengers had confirmed *S. sonnei* infection suggests that the majority of 'probable cases' were correctly classified.

This investigation highlights the benefits of vigorous, real-time collaboration between international public health agencies and state and federal agencies. The *Epi-X* communication network enabled us to initiate comprehensive case-finding measures through local public health professionals in a timely manner. The PulseNet PFGE database allowed for the rapid and effective identification of possible outbreak-associated infections nationwide and the exclusion of unrelated *S. sonnei* infections.

Although we do not suspect that this outbreak was the result of an intentional act, food security professionals should note the rapid, worldwide dissemination of a foodborne pathogen from catered airline meals documented during this investigation. Our experience demonstrates that international and domestic public health and laboratory partnerships are critical for addressing disease threats effectively, regardless of origin. Such collaborations should be maintained and enhanced, as recommended by the Institute of Medicine and CDC [15, 16]. Finally, clinicians who treat patients with travellers' diarrhoea should consider including airline meals as possible sources of infection; they should communicate with their local public health agency regarding potential in-flight exposures among those patients who present shortly after a journey.

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DECLARATION OF INTEREST

None.

REFERENCES

1. **Al-Abri SS, Beeching NJ, Nye FJ.** Traveller's diarrhoea. *Lancet* 2005; **5**: 349–360.
2. **Olsen SJ, *et al.*** Transmission of the severe acute respiratory syndrome on aircraft. *New England Journal of Medicine* 2003; **349**: 2416–2422.
3. **Heymann DL (ed).** *Control of Communicable Diseases Manual*, 18th edn. Washington, DC: American Public Health Association; 2004, pp. 487–491.
4. **Centers for Disease Control and Prevention (CDC).** Learn more about Epi-X (http://www.cdc.gov/epix/). Atlanta, GA: CDC, 2006. Accessed 31 July 2006.
5. **Centers for Disease Control and Prevention (CDC).** PulseNet (http://www.cdc.gov/pulsenet/). Atlanta, GA: CDC, 2006. Accessed 31 July 2006.
6. **Ribot EM, *et al.*** Standardization of pulsed-field gel electrophoresis protocols for the subtyping of *Escherichia coli* O157:H7, *Salmonella*, and *Shigella* for PulseNet. *Foodborne Pathogens and Disease* 2006; **3**: 59–67.
7. **Centers for Disease Control and Prevention (CDC).** Emergency preparedness & response: bioterrorism agents/diseases (http://www.bt.cdc.gov/agent/agentlistcategory.asp). Atlanta, GA: CDC, 2006. Accessed 31 July 2006.
8. **Hedberg CW, *et al.*** An international foodborne outbreak of shigellosis associated with a commercial airline. *Journal of the American Medical Association* 1992; **268**: 3208–3212.
9. **Blanton EM, Mintz ED, Lynch MF.** Foodborne outbreaks of shigellosis in the United States, 1998–2004. In: *Proceedings of the 5th International Conference on Emerging Infectious Diseases*. Atlanta, GA, 19–22 March 2006.
10. **Naimi TS, *et al.*** Concurrent outbreaks of *Shigella sonnei* and enterotoxigenic *Escherichia coli* infections associated with parsley: implications for surveillance and control of foodborne illness. *Journal of Food Protection* 2003; **66**: 535–541.
11. **Kapperud G, *et al.*** Outbreak of *Shigella sonnei* infection traced to imported iceberg lettuce. *Journal of Clinical Microbiology* 1995; **33**: 609–614.
12. **Centers for Disease Control and Prevention.** Outbreaks of *Shigella sonnei* infection associated with eating fresh parsley – United States and Canada, July–August 1998. *Morbidity and Mortality Weekly Report* 1999; **48**: 285–289.
13. **Effler PV, *et al.*** Dengue fever, Hawaii, 2001–2002. *Emerging Infectious Diseases* 2005; **11**: 742–749.
14. **Food Safety Network.** Grimmway classic cut and peeled baby carrots, 1-pound bag recall (http://foodsafetynetwork.ca/fsnet/2006/6-2006/fsnet_june_23-2.htm#story0). Accessed 22 June 2006.
15. **Centers for Disease Control and Prevention, National Center for Infectious Diseases.** Addressing emerging infectious disease threats: a prevention strategy for the United States. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, 1994, pp. 1–42.
16. **Smolinski MS, Hamburg MA, Lederberg J (eds).** *Microbial Threats to Health: Emergence, Detection, and Response*. Washington, DC: The National Academies Press, 2003, pp. 149–226.