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Review

Outbreaks Where Food Workers Have Been Implicated in the Spread of Foodborne Disease. Part 3. Factors Contributing to Outbreaks and Description of Outbreak Categories

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ABSTRACT

In this article, the third in a series of several reviewing the role of food workers in 816 foodborne outbreaks, factors contributing to outbreaks and descriptions of different categories of worker involvement are discussed. All the outbreaks had worker involvement of some kind, and the majority of food workers were infected. The most frequently reported factor associated with the involvement of the infected worker was bare hand contact with the food followed by failure to properly wash hands, inadequate cleaning of processing or preparation equipment or utensils, cross-contamination of ready-to-eat foods by contaminated raw ingredients, and (for bacterial pathogens) temperature abuse. Many of the workers were asymptomatic shedders or had infected family members and/or used improper hygienic practices. Outbreaks were sorted into categories based on how many workers were implicated, the origin of the infective agent (outbreak setting or off site), the degree of certainty that the worker(s) were the cause or were victims, whether or not the workers denied illness, the ability of the agent to grow in the food, whether only the workers and not the patrons were ill, and whether patrons were more responsible for their illnesses than were the workers. The most frequent scenarios were (i) a single worker causing an outbreak by directly infecting patrons; (ii) an infected worker fecally contaminating foods that were then temperature abused, leading to an outbreak; and (iii) multiple workers linked to an outbreak but with no clear initiating source. Multi-ingredient foods with limited descriptions were most frequently implicated and usually were served in restaurants or hotels, at schools, and at catered events. Identified contaminated ready-to-eat foods included produce, baked goods, beverages, and meat and poultry items. In some situations, it was not clear whether some of the workers were the cause or the victims of the outbreak. However, in other situations there may have been an underestimation of the role of the worker. For instance, workers sometimes denied infection or illness for a variety of reasons, but subsequent investigation provided evidence of infection.

This article is the third in a series of several reviewing the role of food workers in foodborne outbreaks. Members of the Committee on Control of Foodborne Illnesses of the International Association for Food Protection analyzed 816 foodborne disease outbreaks with 80,682 cases where food workers were implicated as the source of the contamination. Most of the outbreaks were from the United States, Canada, Europe, Australia, and a few other countries. Outbreaks were caused by 14 agents, primarily norovirus or probable norovirus, *Salmonella,* hepatitis A virus (HAV), *Staphylococcus aureus, Shigella, Streptococcus,* and parasites. Multiple foods and multi-ingredient foods were identified most frequently with outbreaks perhaps because of more frequent hand contact during preparation and serving. Some of the outbreaks were very large, and 11 outbreaks included more than 1,000 cases. In five of the outbreaks, more than 100 affected individuals were hospitalized, but in general, hospitalization and death rates were low (3.4 and 0.12%, respectively). Outbreaks were associated most frequently with restaurants, followed by catered functions, meals prepared in the home for special events such as parties, schools, hotels, hospitals, church social events, camps, and the workplace. Meals served on cruise ships, airplanes, and trains have also caused outbreaks where workers were responsible for the food contamination and sometimes for the further spread of the contamination when the agent was highly infectious, e.g., norovirus. The reports often did not contain enough information to be certain that the workers were the sole cause of the outbreaks; there is always some degree of uncertainty when analyzing such data. However, the 816 outbreaks we studied revealed some similar trends: workers were asymptomatic and excreted the pathogen unknowingly while working or continued to prepare food when it was obvious to them and sometimes others that they were ill and could be contaminating food. In this study,

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TABLE 1. *Number of outbreaks associated with identified food worker errors*

Pathogenic agent	Food worker error factors[a]:																		
	P1	P2	P3	P4	P6	P12	C6	C7	C9	C10	C11	C12	C13	C15	S1	S2	S3	S4	S5
Norovirus										105	1	232	6	32					
Probable norovirus										42		64	1						
HAV										32		83	1	10					
Rotavirus										4		12	1						
Unknown viral										25	1	54	2	10					
Salmonella (nontyphoidal)	4	8	21	4	10	1	5	3	15	40		129	6	6	13	3	1	2	1
Salmonella Typhi										7		21		3					
Staphylococcus aureus	7	3	15	2	4				1	27		53	1	1					
Shigella spp.	1		4							7		32	2	4	1				
Streptococcus groups A and G		3	5	1						7		17		1					
Vibrio cholerae	2		1							2		11		1	1	1			
Yersinia enterocolitica										4		7							
Campylobacter jejuni	1		1						1	2		5		1					
ETEC O157:H7 and O6:H16[b]									1			3							
Giardia lamblia/intestinalis										6		9		3					
Cryptosporidium spp.										1		3							
Cyclospora cayetanensis												11	1						
Unknown		1								14		21		1					
Total	15	16	48	7	14	1	5	3	18	325	2	767	21	73	15	4	1	2	1

[a] P1, allowing foods to remain at room or warm outdoor temperature for several hours (e.g., during preparation or holding for service); P2, slow cooling (e.g., deep containers or large roasts); P3, inadequate cold-holding temperatures (e.g., refrigerator inadequate or not working, iced holding inadequate); P4, preparing foods a half-day or more before service (e.g., banquet preparation a day in advance); P6, insufficient time and/or temperature during hot holding (e.g., malfunctioning equipment, too large a mass of food); P12, other situations that promote or allow microbial growth or toxin production; C6, raw products or ingredients contaminated by pathogens from animals or the environment (e.g., *Salmonella* Enteritidis in eggs, Norwalk virus [norovirus] in shellfish, *Escherichia coli* O157:H7 in sprouts); C7, ingestion of contaminated raw product (e.g., raw shellfish, produce, eggs); C9, cross-contamination from raw ingredients of animal origin; C10, bare-hand contact by handler or worker or preparer (e.g., with RTE foods); C11, glove-hand contact by handler or worker or preparer (e.g., with RTE foods); C12, food handling by an infected person or carrier of pathogen; C13, inadequate cleaning of processing or preparation equipment or utensils (e.g., cutting boards) leading to contamination of food; C15, failure to properly wash hands when necessary; S1, insufficient time and temperature during initial cooking or heat processing (e.g., roasted meats or poultry, canning of foods, pasteurization); S2, insufficient time and/or temperature during reheating (e.g., of sauces or roasts); S3, inadequate acidification (e.g., mayonnaise, canned tomatoes); S4, insufficient thawing followed by insufficient cooking (e.g., frozen turkey); S5, other process failures that permit the pathogenic agent to survive.

[b] ETEC, enterotoxigenic *E. coli*.

we analyzed the outbreaks for trends that could be important for developing appropriate control measures to reduce the likelihood of worker errors and outbreaks.

MATERIALS AND METHODS

The database of 816 outbreaks where food workers have been implicated, the criteria used for collecting and collating these data, and the preliminary analyses have been described previously *(10, 31).* The factors contributing to outbreaks are important for both determining the cause and developing effective controls. The factors in the outbreaks where workers are implicated are mainly associated with contamination, i.e., how the agent got onto or into the food vehicle. All of the 816 outbreaks chosen for the study involved infected food workers or occasionally infected patrons or guests who handled food. The various factors contributing to these outbreaks have been previously described *(10)* and were based on definitions listed in investigative reports published by the Centers for Disease Control and Prevention *(2)* or were assigned descriptions by the authors. Examination of these factors and the narratives of the investigation reports implicating workers revealed that food workers are implicated in outbreaks in several different ways. A decision was made to rank the various factors contributing to outbreaks and sort the outbreaks by categories.

RESULTS AND DISCUSSION

Factors contributing to outbreaks. Food workers were involved in some way with all the outbreaks in this study, and the most frequently reported food worker error factors were handling of food by a person either actively infected by or carrying a pathogen (factor C12, 767 outbreaks), bare-hand contact with food by workers (C10, 325 outbreaks), failure to properly wash hands when necessary (C15, 73 outbreaks), inadequate cleaning of processing or preparation equipment or utensils, leading to contamination of the food (C13, 21 outbreaks), and cross-contamination of ready-to-eat (RTE) foods from raw ingredients of animal origin (C9, 18 outbreaks) (Table 1). Less common factors

were contamination of raw products or raw ingredients by pathogens from animals or environment (C6, 5 outbreaks), ingestion of contaminated raw products (C7, 3 outbreaks), and gloved-hand contact between workers and RTE foods (C11, 2 outbreaks). Of the bacterial proliferation factors, the most frequently reported were inadequate cold-holding temperatures (P3, 48 outbreaks), allowing foods to remain at room or warm outdoor temperatures for several hours (P1, 15 outbreaks), slow cooling (P2, 16 outbreaks), insufficient time and/or temperature during hot holding (P6, 14 outbreaks), and preparing foods a half-day or more before serving (P4, 7 outbreaks). The most important survival factors for pathogens were insufficient time and/or temperature during cooking or heat processing (S1, 15 outbreaks) or during reheating (S2, 4 outbreaks), and insufficient thawing, followed by insufficient cooking (S4, 2 outbreaks). The pathogen associated with most of these factors (contamination, proliferation, survival) was *Salmonella* (Table 1). Survival factors apparently are less important for other bacteria, viruses, and parasites, as can be inferred from the data in Table 1, but the assignment of these factors is dependent on the quality of the investigation. Incomplete records in some investigations may have resulted in omission of some critical factors, and in other situations assumptions may result in listing factors where proof is lacking. These problems typically occur at the local level where most investigations occur, but national reporting systems may also produce different results, as was demonstrated in a report from the World Health Organization *(26).* This study of foodborne disease surveillance systems in the 30 Organization for Economic Cooperation and Development (OECD) countries revealed that only 11 of those countries surveyed listed any factors contributing to outbreaks and not all of these factors were the same. The only factor recorded by all countries was time and temperature abuse. The next most frequent factors were infected workers (seven countries), improper food storage (six countries), and cross-contamination (six countries). The percentage of outbreaks involving infected food workers as reported by the OECD countries was 0 to 11.4% (median, 3.7%), which was lower than that for outbreaks associated with time and temperature abuse (12.4 to 53.8%), improper food storage (0 to 27.9%), and cross-contamination (0 to 24.6%). The United Kingdom, with the longest history of investigating outbreaks among these 11 nations, consistently listed outbreaks with the highest percentage of recorded contributory factors. In the 2005 report on outbreaks for New Zealand *(25),* time and temperature abuses, particularly improper cooling and storage of food, were the most frequent factors recorded (>40%), followed by cross-contamination (38.1%), and infected food workers (4.9%). The order is the same as that reported by the OECD, but the percentage of outbreaks associated with these factors is higher, perhaps indicating a more detailed investigation. These studies all indicate that infected workers are a major source of illness in many (at least 4 to 5%) of the outbreaks.

A specific survey of risky food handling practices conducted in the United States revealed the importance of food worker practices and hygiene in the retail industry *(9).* About 8% of the U.S. population over the age of 15 (equivalent to almost 24 million people) is employed in food preparation or serving operations, and many of these workers report risky food-handling practices. Of this group, one-quarter did not always wash their hands (23% or 4.4 million) and one-third did not always change their gloves between touching raw meat or poultry and touching RTE food (33% or 6.3 million). More than half did not wear gloves at all when touching RTE food (60% or 11.4 million) or did not use a thermometer consistently for checking the doneness of cooked food (53% or 10.1 million) *(9).* These unsafe food handling procedures are used by millions of employees each year in the United States alone. Even more of a concern was the 4.7% of workers (about 900,000 nationally) who continued working while they were ill with diarrhea or vomiting.

In another study of 137 food workers in Wales, Clayton et al. *(3)* found that although these workers were aware of appropriate food safety actions they identified barriers that made it difficult for them to be carried out effectively. These barriers were lack of time, staff, and resources. Although the workers thought their food operations were low risk for causing illness or they had low levels of control in the operation they were employed in, each worker produced high-risk foods (foods that support the multiplication of pathogenic bacteria without a subsequent kill step). These observations probably apply to many other situations and countries.

We know that workers have intentionally or inadvertently been responsible for errors that have led to contaminated food, and these errors were compounded to cause outbreaks. Worker infection alone may not have caused gastroenteritis in patrons of a food-service operation, but when worker illness is combined with lack of hand washing, cross-contamination, and poor storage conditions, these risky practices have caused many outbreaks in multiple settings.

Asymptomatic food workers were implicated more frequently (232 outbreaks) than were symptomatic workers (154 outbreaks) in the 816 outbreaks, which helps explain the difficulty in detecting and stopping an outbreak by excluding ill food workers. More details on the specific pathogens associated with factors contributing to outbreaks are given in Table 1. Most of the infective agents were viral, but bacteria (mainly *Salmonella*) and parasites (mainly *Giardia*) were also involved. Ill family members or children who were ill or needed diapering just before a worker handled food were factors in 2.4 and 4.7% of outbreaks, respectively. Worker errors associated with family members ill with highly infectious agents such as norovirus, HAV, *Shigella,* and *Giardia* were the most frequently noted, indicating that inadequate hand washing or wearing the same clothes may allow contamination of food, resulting in patron infections in food-service establishments. Eight outbreaks were associated with international travel, two with drug use, and three with homosexual behavior; these low numbers suggest that travel and high-risk life styles may not always be significant enough factors to record during investigations. Various failures in hygienic practices con-

TABLE 2. *Outbreaks and cases by category*

Category	No. of outbreaks	No. of cases	No. of cases per outbreak		
			Mean	Median	Range
1. Single food worker who causes an outbreak	238	21,067	88.5	26.5	2–3,353
2. Single food worker who infects other workers, who in turn infect consumers or patrons					
2a. Same establishment	29	1,423	49.1	37	2–139
2b. Separate location	3	194	64.7	62	21–111
3. Food worker contaminates food, and the bacteria grow to high enough levels to cause illness after temperature abuse					
3a. Fecal contaminants	171	12,867	75.2	24	2–1,931
3b. Skin, nose, throat secretions	70	10,093	144.2	35	2–4,000
4. Multiple food workers					
4a. Unequivocally the cause	41	5,722	139.6	15	2–2,700
4b. Linked but no clear initiating source	162	10,696	66.0	24	2–3,175
5. Infected food worker but uncertain whether they are victims or cause	13	8,783	675.6	102	14–6,350
6. Food contaminated by offsite workers and delivered to the location where the outbreak occurred	40	8,306	207.7	58	3–1,465
7. Patrons are probable source of outbreak	15	635	42.3	30.0	6–262
8. Workers implicated epidemiologically and likely infected but deny illness	34	896	26.4	17	2–91
Total	816	80,682	98.9	27	2–6,350

tributed to outbreaks; of these failures, inadequate hand washing facilities, poor hand washing, and bare-hand contact with food were the most frequent. Long, dirty, or artificial nails were implicated in three outbreaks. High concentrations of pathogens were sometimes delivered to food preparation areas by pathogen-containing body secretions, such as vomitus (norovirus), open cuts and sores (*Staphylococcus aureus*), and sneezes (*Streptococcus pyogenes*).

Categorization of outbreaks. Outbreaks were sorted into different categories based on: how many workers were implicated, the origin of the infective agent (at the outbreak setting or offsite), the degree of certainty that the workers were the cause or the victims, whether the workers denied illness, the ability of the agent to grow in the food, whether only the workers and not the patrons were ill, and whether patrons were more responsible for their illnesses than were the workers (Table 2). Of the 816 reviewed outbreaks, all but 33 (4%) of the reports implicated one or more infected food workers. However, in a few outbreaks, patrons in a restaurant were much more likely to have been the source of the infections than were the workers. Laboratory confirmation of a pathogen causing the outbreak occurred in 357 (43.7%) of the outbreaks. In 110 of these, the workers were symptomatic, and in 143 the workers were asymptomatic. Although epidemiological evidence implicated a worker, stool sample testing did not identify an infected worker in 24 outbreaks, and in 85 outbreak reports there was not enough information to make a determination one way or the other. Epidemiological evidence was available in only 459 (56.2%) of the reports, e.g., the Kaplan criteria *(13)* for norovirus identification. Of these 459 outbreaks, symptomatic or asymptomatic workers were identified in 52 and 71, respectively, but 322 reports did not contain sufficient information to make a determination, and in 9 reports no infected worker was identified.

The infective period for an individual following ingestion of a pathogen depends on the organism, i.e., norovirus is thought to be shed within a short period before and after the illness stage, whereas HAV has an incubation period of 15 to 50 days and is maximally infective during the latter half of the incubation period. A review of the outbreak reports revealed that it is often difficult for investigators to obtain accurate information during the outbreak investigation because (i) persons involved are no longer accessible for interview, (ii) there is poor communication during the interview due to language difficulties, (iii) poor questioning by investigators fails to elicit the appropriate information, (iv) the workers give false information so they will not incriminate themselves, or (v) the interval between the time of the outbreak and the beginning of the investigation is too long.

The specific outbreaks were separated by category to reflect the different scenarios in which food workers were implicated in an outbreak (Fig. 1). A complete breakdown of all 816 outbreaks by the eight categories is given in Table 2. The highest number of outbreaks occurred in category 1 (238 outbreaks, 29%) followed by categories 3a (171, 21%) and 4b (162, 20%). The highest number of cases followed the same order: categories 1 (21,067 cases, 26%), 3a (12,867, 16%), and 4b (10,696, 13%). The median number of cases per outbreak ranged from 15 to 102 across all categories. It might be assumed that for most outbreaks where there was worker transmission, a single individual was the sole cause of the outbreak. However, although this was the most frequent scenario (category 1), there were several other possible situations. In 32 outbreaks, one work-

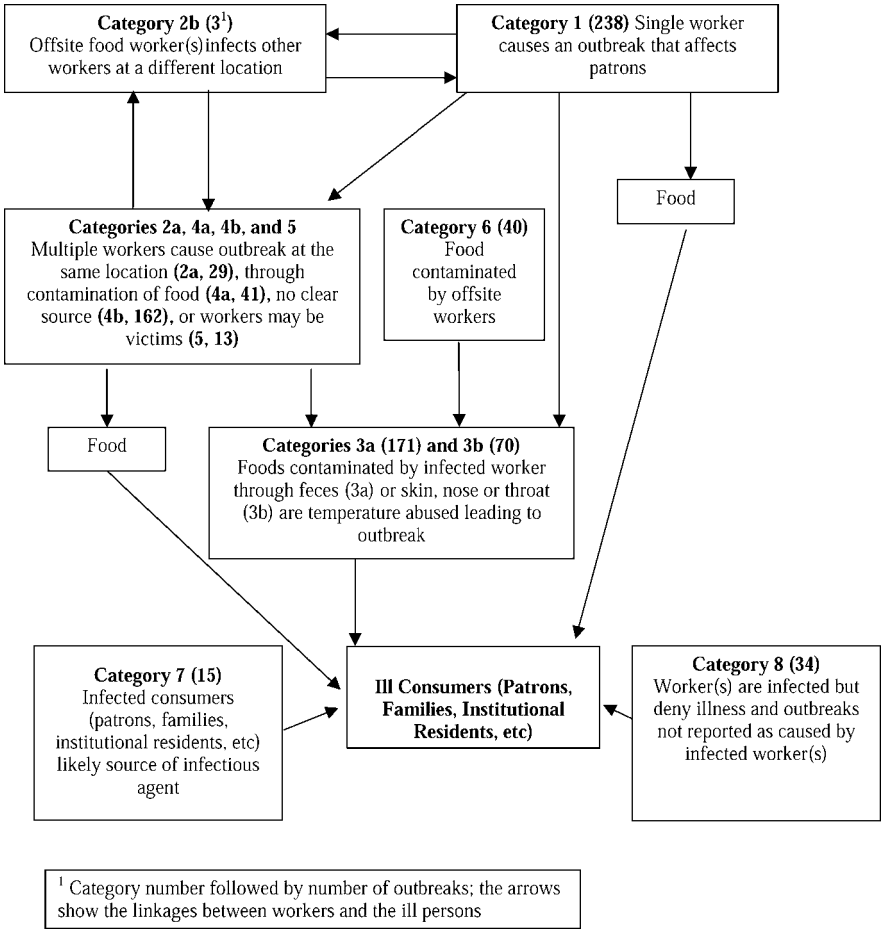

FIGURE 1. *Categories of outbreaks where workers have been implicated.*

er infected other colleagues (up to 142 in one outbreak) who in turn infected patrons (category 2), or there were multiple workers with apparently no index case, although one infected worker probably initiated the infection process (category 4a). In other situations, one or more workers contaminated food, which was stored under conditions that allowed bacterial growth and resulted in an outbreak (category 3). Food was contaminated by workers through the fecal-oral route (3a) or though nasopharyngeal excretions or skin lesions (3b). In a few outbreaks, one or more workers became infected through touching or eating food, usually a raw food of animal origin such as turkey; here, the food was the source of the agent but further spread was achieved via worker mishandling (category 5). The infection source could be offsite (i.e., remote from the setting where the outbreak infections were acquired) such as imported produce contaminated by harvesters on the farm or by workers during preparation for shipment; reported details are rarely sufficient to determine the exact route of contamination (category 6). Workers could be linked to an outbreak with no clear initiating source (category 4b), or they may be as much victims as sources of infection (category 5). Occasionally, individuals being served, particularly patrons at a social function or buffet, may infect each other (category 7).

Category 8 (outbreaks in which workers are implicated epidemiologically and probably are infected but deny illness) was considered appropriate to include in the review because there was strong evidence that such situations occur. This category would apply when (i) there is a solid epidemiologic link to a specific food or multiple foods, (ii) the foods are RTE and handled in such a way by the food worker(s) that contamination could easily occur due to bare-hand contact or inadequate hand washing practices or both, and (iii) no other plausible explanation for transmission of the agent is discovered during the investigation. Category 8 applies mainly to outbreaks caused by norovirus and suspect norovirus agents. There are many reasons why a food worker might deny illness.

(i) The workers are embarrassed that they were the likely cause of an outbreak and do not want to admit their illness because of potential job termination, pay reduction, or receiving an admonition.

(ii) The workers had mild symptoms of illness but are unsure whether they could have caused others to become ill and so respond negatively when asked if they were ill.

(iii) The workers were exposed to ill children or family members, but investigators failed to ask about these facts.

(iv) Cultural issues or lack of ability to understand questions in English make it less likely that workers will admit to having been ill.

(v) Workers were ill but became asymptomatic and returned to work apparently well (although they may have been infectious) and failed to understand that they could still infect others.

(vi) The workers were not ill but had been exposed to an ill person, became infected but not symptomatic, and transmitted the pathogen to others.

(vii) Owners or managers, afraid of litigation, loss of revenue due to negative publicity of improper operations, or increased insurance costs, attempted to conceal the outbreak by threatening workers with dismissal if they admitted illness.

(viii) The food establishment has a policy of excluding ill workers, but the owners do not want to admit that this policy is not enforced.

(ix) The manager believes that a worker is faking illness to avoid work and threatens the worker with termination if he or she fails to work as directed.

(x) The manager is unaware of worker illnesses when questioned by investigators and so responds negatively even though a worker or workers were ill.

(xi) The owners, managers, or workers distrust government sufficiently that they are noncooperative with the investigators.

Based on these factors, the number of worker-initiated infections is probably much higher than has been documented in investigations.

Category 1: single food worker who is infected and causes an outbreak though contamination of food or food contact surfaces. These outbreaks represent the most typical scenario in which one worker becomes infected and transmits the agent to patrons at a food-service facility. In the first example below, no agent was isolated from the employee or the ill children, and diagnosis was based on the epidemiological aspects of the investigation alone. In the second example, HAV was isolated from the worker, but he was only mildly affected and did not feel he needed to be off work. In the third outbreak, a baker's wife was the index case and was presumably infected by her husband, but no other worker was diagnosed with the virus.

Category 1: example 1. In 2000, 37 students at a Minnesota college developed gastrointestinal symptoms from 25 April to 1 May; the majority were ill on the 26 and 27 April. Illness was associated with consumption of any items from the cold salad bar of the dining service at the college cafeteria on 25 through 27 April. The index case involved an employee who reported developing vomiting and diarrhea on 23 April after exposure to children with the same symptoms on 22 April. This person called in sick on 24 April, but symptoms resolved later that day. The employee then returned to work on 25 April and worked the remainder of the week in the salad bar section and had extensive bare-hand contact with salad items during preparation and stocking of the salad bar with lettuce, salad toppings, and cut fruit. Additional cases with onset after the weekend of 29 and 30 April were likely due to secondary spread of the viral infection within dormitories and other campus settings. The Minnesota Department of Health diagnosed the agent as viral based on the epidemiological information available, but no specific agent was isolated. A call-in log of sick employees was useful to determine dates that food workers were ill and to ascertain which worker was responsible for initiating the outbreak *(19).*

Category 1: example 2. An outbreak of HAV infection that lasted longer than 3 months and affected over 50 people was traced to bread distributed by a small family business in England in 1989 *(32).* The index case was that of a bakery worker; she and her husband owned and ran the shop, which sold bread, sandwiches, and rolls supplied by a caterer. They also provided these products for a number of local functions. The husband, who was the source of the outbreak, was infective 6 weeks after his wife was ill. He had mild hepatitis symptoms but continued to work handling the bread, rolls, and sandwiches. He covered cuts and painful skin lesions on his hands with adhesive dressings in accordance with health and hygiene recommendations. However, because of the dressings he was unable to wash his hands thoroughly even though they were visibly soiled, and he did not wear gloves, which allowed viral particles on his hands to contact food during preparation. He is assumed to have contaminated the bread and sandwiches while wrapping them for sale. There were 68 hepatitis notifications in local villages; 43 were confirmed by laboratory testing and 7 were secondary household contacts. Further spread of hepatitis within the community was prevented by testing asymptomatic food workers for immunoglobulin (Ig) M and IgG anti-HAV antibody to detect subclinical cases. Those asymptomatic food workers who were not immune were given prophylactic treatment with intramuscular injections of normal human immunoglobulin (500 mg). None of these workers developed symptoms, and all continued to work normally.

Category 1: example 3. In 1990, a food worker in the cafeteria of a large Connecticut insurance company building was infected with *Giardia lamblia* and used her bare hands while slicing raw vegetables. This practice resulted in 27 cases of giardiasis, 18 of which were confirmed by laboratory tests from October through December *(23).* Of 19 cafeteria employees tested, this worker was the only one that tested positive for *Giardia.* She had used gloves for most food preparation activities but not for salad bar items. The outbreak lasted more than 5 weeks, but only two cases were still active in the last 6 weeks, indicating the worker may have excreted fewer cysts as time progressed. *Giardia* contamination has been linked to RTE items such as salmon, noodles, fruit salad, and sandwiches. The investigators noted that the outbreak was probably only detected because the affected individuals were insurance company employees whose medical care was administered by a single health-management team.

Category 2a: single food worker who infects other workers (victims) who in turn infect consumers or patrons in the same establishment. These outbreaks are the second most common category of worker-associated outbreaks and tend to be extended in time, because the workers start excreting the agent as they become infected one after another. In the following examples, relatively few workers were infected (two to four), but in the third outbreak cases

occurred over a 31-day period, indicating the long excretion period for HAV-infected persons.

Category 2a: example 1. In Los Angeles County, California, in August 2000, an increase in *Salmonella* Thompson infections was noted, with most affected individuals having eaten at a restaurant chain before the illnesses developed *(14).* A case-control study implicated burgers eaten by 23 individuals at the fast food restaurants. Hamburger buns also were served at a catered luncheon and at three other restaurants from which cases of *Salmonella* Thompson infection were reported (an additional 15 cases). The earliest onset of illness occurred in a burger bun packer at a bakery supplying buns for the chain, but she had not eaten at the restaurant chain. This full-time employee was responsible for removing freshly baked bread and buns from the cooling rack, feeding them through an automatic slicer, then packaging them for distribution. She did not wear gloves and handled every individual bread item (notably hamburger buns) at least twice with her bare hands. She worked from the day of illness onset on 13 July until she required overnight hospitalization on 17 July. She resumed work after hospital discharge on 18 July and continued working until termination of employment on 23 July. Although stool specimens were taken during her hospitalization, the results were not reported until 31 July, 2 weeks after onset of her illness. The patient's brother, also employed at the bakery, became ill on 17 July, and he continued to work while ill until he was removed from work on 3 August. Presumably, either his ill sister infected him through contact or he consumed the contaminated buns. He was mainly responsible for mixing the dough but did some rotation of duties that would allow contamination of bread items. The bakery did not offer any formal training on safe food handling practices. Furthermore, although many of the employees spoke only Spanish, the procedure manuals were written in English.

Category 2a: example 2. An outbreak of norovirus infections occurred among residents of a senior citizen apartment complex in Minnesota in 2000 *(19).* A local caterer delivered and served a meal to the complex while the outbreak was occurring. This same catering company provided food for a wedding reception held at a ballroom 2 days later. Of the 350 people attending the reception, 30 were ill. Incubation periods ranged from 7 to 142 h (median of 33 h), and the illnesses lasted from 4 to 109 h (median of 46 h). A catering employee and her husband reported vomiting a few days before the reception. This ill employee shared responsibility for preparing food for the wedding reception with another employee who also reported not feeling well on the day of the reception but nevertheless served hot and cold food items. Two additional employees and a household member of the second ill employee developed vomiting and diarrhea the same time as did the guests. Green beans were identified as the most likely vehicle. DNA sequencing results indicated that the caterer serving the meal at the apartment complex may have been exposed to the norovirus there and subsequently transmitted the virus to guests at the wedding reception. However, the first ill employee may have been the index case although this was not proven because of uncertainty concerning the transmission routes from the index case worker to other employees and then to the wedding guests.

Category 2a: example 3. During April and May 1986, a large foodborne outbreak of HAV infection occurred over 31 days among 97 patrons and six employees of a floating restaurant in Florida *(17).* Green salad, some pantry items, and mixed bar drinks were the vehicles of transmission. Two of the six infected employees worked in the pantry, but only one was symptomatic. These two prepared many cold items and shredded lettuce by hand, and they appeared to have sequentially infected patrons over many days. The ill pantry worker did not report his illness, and he was fired for poor hygiene (he never washed his hands at work and dipped his fingers into dressing to taste) before his illness was recognized. He was also homosexual and may have become infected by a partner. While ill, he began living with another pantry worker, and a non–food-related HAV case resulted. This outbreak suggests that HAV infection among employees may allow for transmission to patrons for prolonged periods of time.

Category 2b: single food worker who infects other workers (victims) who in turn infect consumers or patrons at a separate location. This scenario is less common or at least less frequently recorded because it requires a thorough investigation to identify the association between illnesses at two locations. A series of HAV infections affected 40 students at a university, 11 employees of two restaurants, and 11 other residents in Arizona in October through December 1973 *(16).* Two distinct epidemic waves occurred, and the investigation implicated two local restaurants as the sources of infection, one for each epidemic wave. The index case was that of a worker who prepared food at both restaurants, thus linking the two outbreaks. The first restaurant featured mainly Mexican and American foods and was patronized almost exclusively by students. There the index case worker was a kitchen helper who prepared and served salads. Cases began among students from 29 October to 25 November. The infected worker continued to work there until he was diagnosed with hepatitis A on 26 October and was responsible for causing illness in six of the employees and for infecting two others who were asymptomatic. The index case worker at the second restaurant, which served the general community but also was popular with students, added garnish such as tomatoes and lettuce to hamburgers or spaghetti. He was ill on 16 November and was infected through patronizing the first restaurant on a regular basis. Customer cases associated with this restaurant were documented from 3 to 16 December. An additional five employees showed hepatitis A symptoms. This is an example of a common-source outbreak with two distinct epidemic waves related to two separate eating establishments but with one worker responsible for both.

Category 3a: a food worker(s) who contaminates food with fecal bacterial pathogens, and temperature

abuse of that food allows bacterial growth to numbers high enough to cause illness. There are many examples of outbreaks caused by pathogens growing in food to levels sufficient to cause illness but not so many examples in which the worker is responsible for directly contaminating the food. In category 3a, the pathogens are enteric in origin and are transmitted to food through improper hand washing.

Category 3a: example 1. *Salmonella* Brandenburg was responsible for illness among 232 passengers, 27 cabin staff members, and 31 aircrew members on 45 flights originating in Paris and destined for many parts of the world, including the United States, Canada, the Caribbean, Egypt, Senegal, Japan, Venezuela, Brazil, Russia, and eight other European countries in April 1976 *(33).* The illnesses occurred from 6 through 11 April, but an alert was triggered only when an aircrew on a 9 April flight became concerned. However, meals continued to be prepared and served until 11 April, likely resulting in many more cases than the 290 finally reported to the authorities. The organism was isolated from a variety of cold foods, primarily fish (stuffed bass, stuffed fillet of sole, dory, and trout in aspic), lobster mayonnaise, sweetbreads, stewed beef, and petits fours. Of the 200 employees tested from the Parisian catering firm, only the person who had prepared the cold dishes provided a stool sample that was positive for *Salmonella* Brandenburg. Unfortunately, this employee was not identified during the regular inspection and testing of the establishment, although the surveillance program recorded 14 suspensions of staff due to infections over the previous 2 years.

Category 3a: example 2. In July 1981 in New York, various campers and staff suffered gastroenteritis and five were hospitalized for appendicitis before yersiniosis was recognized as the cause *(24, 27). Yersinia enterocolitica* O:8 was isolated from 37 persons, including the head cook and kitchen staff. Dissolved powdered milk and a milk dispenser were contaminated with the same strain, and investigators concluded that transmission occurred when the food workers cleaned and tried to repair a broken spigot in the leaking dispenser. The same strain also was isolated from chow mein, which was epidemiologically linked to the cases with the milk. It was assumed the *Yersinia* had an opportunity to grow in the milk and chow mein during the warm summer conditions and that one or more of the workers were the initiators of the infection. The head cook was asymptomatic but shed *Yersinia* at a high rate during 5 weeks of observation. He was the only person directly involved in the preparation of the milk and chow mein. Although other food workers had mild gastroenteritis, they did not restrict themselves from working in the kitchen. *Y. enterocolitica* would have grown well in the reconstituted milk that was held for 24 h under cool conditions before serving.

Category 3b: a food worker(s) who contaminates food with bacterial pathogens from the skin, nose, or throat, and temperature abuse of that food allows bacterial growth to numbers high enough to cause illness. In category 3b, the pathogen transfer is from resident populations of *S. aureus* or *Streptococcus* in the nose or throat or through skin lesions infected by *S. aureus.* When the nasopharynx is colonized or infected (pharyngitis), coughing and sneezing can transfer large numbers of organisms to food or food preparation surfaces. Streptococcal and staphylococcal outbreaks appeared more frequently in past decades than they have in the last 20 years. This decrease in infections may indicate fewer carriers because of antibiotic treatment or better refrigeration of RTE food, limiting growth of these bacteria.

Category 3b: example 1. In 1979, an outbreak of pharyngitis occurred at a convention in Florida, where 72 of 231 conventioneers were ill. *Streptococcus* group G was isolated from 10 of 16 persons with pharyngitis and 1 of 41 persons who did not have the symptoms *(28).* Group G is much less frequently implicated in foodborne disease than is group A, and strains usually belong to *Streptococcus dysgalactiae* subspecies *equisimilis* rather than *S. pyogenes,* which comprises group A. Illness was associated with chicken salad served at a convention luncheon, and affected persons included waiters and cooks. The cook developed pharyngitis the day after she prepared the chicken salad ingredients. The chicken was cooked and then refrigerated overnight in a deep container, which slowed its rate of cooling, and the meat was broken up for the salad the next day. The total aerobic count of the served salad exceeded 10^8 CFU/g. Although this cook did not become symptomatic until after the luncheon was served, she probably was excreting the pathogen while preparing the chicken and the salad. The *Streptococcus* undoubtedly grew during overnight storage, and the worker further contaminated the salad during preparation. Contamination likely occurred through sneezing or touching food with hands soiled with nasal secretions. There is no indication that she wore gloves or washed her hands frequently.

Category 3b: example 2. In 1977, many staphylococcal intoxications in Ontario and Quebec were caused by lots of Swiss-type cheese that were contaminated with *S. aureus.* Samples of 59 lots of the recalled cheese contained <25 to 10^8 CFU/g, with most wheels between 10^4 and 10^5 CFU/g *(30).* Enterotoxin B was found in 73% of the samples at levels up to 3.8 μg/100 g. A plant worker initially contaminated the starter culture for the cheese and then back-slopped the remains of the contents for future starter cultures, resulting in poor acid production and high levels of *S. aureus* on many occasions. The same strain was isolated from the worker and the cheese. Because the cheese was available only to potential purchasers because it was a new product, most of the 15 ill persons were in the wholesale or retail trade. If the cheese had been sold to customers in Ontario and Quebec, as was the intention, many other persons would have been affected.

Category 4a: multiple food workers who unequivocally cause the outbreak. Typically, a worker initiates the infection in a kitchen or food preparation area, and the spread of the infection is facilitated by the close working environment, multiple handling of food ingredients, and

possibly snacking or tasting food for flavor. Norovirus in particular can spread rapidly from person to person. In the following examples, two employees denied illness; so the outbreaks could also be classified under category 10. In the second example, some of the food was prepared at a home where there was a sick family member.

Category 4a: example 1. In 2000, a catered meal prepared in Ohio and distributed to 52 car dealerships nationwide as a reward for high car sales was responsible for multiple gastroenteritis outbreaks in 13 states, resulting in at least 333 cases *(1).* Illness occurred in car dealership employees and their family members who attended the banquet. Consumption of any of four side salads produced by one caterer was strongly associated with illness. Pasta was boiled, drained, cooled and placed in large plastic bins, other ingredients were added, and food workers mixed the salad by immersing their ungloved arms up to the elbow. Although the catering company employees denied any history of illness in the preceding week, 2 of 15 employees had elevated IgA antibody titers to norovirus, indicative of possible recent infection. This caterer had been cited by health inspectors for multiple sanitary code violations and was temporarily closed pending sanitary improvements. It seems highly likely that these two employees were infected and contaminated the salad during its preparation.

Category 4a: example 2. A catering company in New South Wales prepared 21 meals for 14 events held between 13 and 15 October 2003. Seventy-three persons who consumed one of the catered meals became ill; norovirus was identified in three stool samples submitted during the investigation. Three people were involved with food handling and preparation on 12 through 15 October and another person helped deliver meals to the events *(29).* One food worker reported becoming ill with diarrhea and vomiting around midday on 15 October. Although the other two food workers denied a history of illness in either the week of the outbreak or before, it was otherwise reported that these two had been ill with diarrhea and vomiting in the 2 days before the outbreak. It also was reported that a family member of one of these food workers had been sick with diarrhea and vomiting on 10 October, and the implicated food (dessert bars [sweet slices]) had been prepared in the home of this food worker rather than at the catering premises. Food items such as fruit slices and sandwiches are easily contaminated during preparation and handling. The caterers reported using a hand gel before handling food but did not use gloves for food preparation. On inspection, hand washing facilities were inadequate, and it was reported that soap and hand towels were not routinely provided.

Category 4a: example 3. From December 1988 to January 1989, an extended outbreak of yersiniosis occurred in Atlanta, Ga. *(15),* involving 14 infants and a 10-year-old boy. Most cases developed soon after Thanksgiving, Christmas, and New Years when chitterlings were served. Women, who were also caregivers for the infants, prepared the chitterlings by boiling the intestines of pigs after they were cleaned of any remaining feces, a process that required about 5 h. The infants had no direct contact with the raw chitterlings during that time, but some pig intestinal fecal material contaminated the preparers, their hands, or the kitchen surfaces in the different homes. *Y. enterocolitica* O:3 was isolated from the patients and unopened chitterling boxes, but the asymptomatic caregivers were not tested. The 10-year-old boy touched a chitterling and did not wash his hands. It was assumed that the infants were infected via the caregivers as they cared for the children at the same time as preparing the chitterlings. The caregivers probably did ingest some of the pathogen and may have been colonized without developing an infection.

Category 4b: single or multiple workers who are linked to an outbreak, but there is no clear initiating source. Many outbreaks have been placed in this category, which includes outbreaks in which no clear initiating source was identified. Most likely, one worker was infected and in turn infected the others, but there is no evidence of where the infection originated.

Category 4b: example 1. In July 1992, 46 patrons at 21 restaurants in Michigan and 1 restaurant in Ohio were infected with *Shigella flexneri* through consumption of preprepared salads made at a central commissary *(5).* During the same time period, 15 infected workers had diarrheal illness, and all but one had eaten in the cafeteria where tossed salad was served daily. Four of these ill employees had worked in the preparation of the salad during the outbreak period. The salad was made of lettuce, cabbage, and carrots that were chopped and mixed with bare hands. The mixture was bagged by machine, and employees added or subtracted from the bags to meet the weight standard. The local health department noted extensive direct handling of the salads by employees. The stool samples from two of the four ill employees did not culture *Shigella.* More than one worker was likely responsible for the contamination, but the investigation failed to identify the actual infected employees, either because the employees did not admit or remember working in salad preparation during July or they were asymptomatic.

Category 4b: example 2. There were 63 cases of norovirus infections that were traced to three consecutive banquets at a New Jersey restaurant in 1979 *(11)*; green salad was implicated. A few employees were ill before the outbreak occurred, and the one worker that prepared the lettuce was ill at the beginning of the outbreak. None of the personnel wore gloves, and the lettuce was prepared in an unsanitary way.

Category 5: food workers become infected, but it is uncertain whether they are victims or cause of outbreak. Outbreaks in this category may occur more frequently than has been recorded because of the difficulty in determining whether the worker is the victim or the cause. Infected workers may appear to be an obvious source of infection during an investigation. However, when onset times for the different cases are known, workers may be exonerated because they were ill at the same time or after most of the other affected individuals.

Category 5: example 1. In 2003, there were 23 cases of salmonellosis in a Minnesota restaurant associated with consumption of French toast made with eggs produced from hens in a flock contaminated with *Salmonella* Enteritidis *(21).* Seven food workers were also infected, and four had symptoms while working. The cases were linked to exposures from 26 October to 15 November; the first food worker experienced symptoms beginning on 2 November. It is probable that some of the cases occurred because the infected workers contaminated the French toast or other ingredients at the restaurant in addition to the initial contamination from one or more infected eggs. Many of the incubation periods were very long (median of 81 h in all cases), suggesting a low infective dose.

Category 5: example 2. Following a buffet served in a ward in a Welsh hospital in 1996, 80 of 460 staff and patients suffered from a suspected norovirus infection. Foods associated with illness included ham, coleslaw, bread rolls, and cheese and pineapple on sticks *(7).* Some of the food was prepared in the hospital kitchen and some was prepared in the ward. Hospital kitchen staff preparing the buffet did not report illnesses before they served the food. Two food items were delivered to a neighboring hospital, and no indication of associated illness was reported. Other food items, including the pineapple sticks, were prepared in the ward by staff and patients. It is uncertain who handled the different foods, and it was concluded that one or more persons contaminated the food during preparation or during the party when people served themselves. The investigation was hampered by a low response rate for the food consumption questionnaire, and there may have been a reporting bias. However, if one or more norovirus excretors touched the food items, it is not unreasonable that several foods would be implicated. This outbreak illustrates where food preparers (in the ward) became infected and how food workers may be both the cause and victims of the infection.

Category 6: food contaminated by offsite workers, delivered to the location where the outbreak occurs, and provided directly to consumers or patrons. In several outbreaks, contaminated food items, mainly produce, were imported from one country to another or from an area distant from the outbreak location but within the same country. It is often difficult to determine the precise source of the contamination because of difficulty collecting data from different jurisdictions far apart. A human source is necessary for contamination by some pathogens such as *Shigella* and viruses; contamination can come directly from feces on hands or equipment or indirectly via sewage in a water supply. For most other pathogens, e.g., *Escherichia coli* O157:H7, *Salmonella,* or *Yersinia,* an animal source is also possible. For category 6 outbreaks, the role of the food worker in the contamination event frequently is unclear.

Category 6: example 1. In Denmark from June to September 2005, six point-source outbreaks of norovirus infection occurred and were linked to frozen raspberries imported from Poland *(6).* All the outbreaks were in institutions or commercial catering settings. A cold dessert dish prepared from frozen raspberries that had not been heated had been served 1 day before the start of each outbreak. In the first five outbreaks, frozen raspberry pieces had been used, which could be traced to the same large batch imported to Denmark from Poland in the spring of 2005. In the last outbreak in September, the frozen raspberries had been supplied by a different Polish producer to a different Danish importer and made into a traditional Danish dessert of buttermilk, fromage frais, sugar, vanilla, and raspberries. With a total of 1,143 cases, these raspberries caused the largest number of foodborne infections attributable to a single vehicle in Denmark in many years. Delay in the implementation of a recall following the first large outbreak involving 450 patients of a hospital allowed the second large outbreak to occur among clients of a meals-on-wheels service in early June. In this outbreak, an estimated 400 mainly elderly people were affected, and at least 23 were hospitalized. Three different types of norovirus were found in the six outbreaks. Because the Polish frozen raspberries were exported to several European countries, outbreaks due to these products would be expected beyond Denmark, but none were reported. One outbreak of norovirus infection in France in March involved imported frozen raspberries that may have come from the same Polish source, but the country of origin was not stated *(4).* Norovirus contamination may have occurred at the farm from fecally contaminated irrigation water, during harvesting from infected farm workers, and/or during processing and freezing from infected workers at the company. The final hypothesis was that several independent contamination events took place, explaining the heterogeneous distribution of norovirus strains in the Danish shipments. Infected workers engaged in the harvesting or processing of raspberries in Poland were a likely but not a proven source.

Category 6: example 2. In August and September 2004, a large outbreak of HAV infection occurred involving tourists at a specific hotel in the Egyptian resort city of Hurghada *(8).* A total of 351 cases were reported and affected guests from nine European countries, although most guests were German. There were 20 secondary cases. The investigation strongly implicated the juices served at the breakfast buffet as the vehicle of infection. Guests who developed HAV infection after their vacation were 2.6 times more likely to have ingested orange juice than were healthy controls. Although the juice was consumed by 60% of the controls, virus concentrations probably fluctuated within the juice over a 4-week period, resulting in varying degrees of exposure. None of the hotel staff in Egypt was positive for IgM anti-HAV antibodies, making it unlikely that an infected employee was the source. The Egyptian Ministry of Health and Population focused its investigation on the hotel's suppliers. Independent of the case-control study results, the juice supplier came under suspicion. At the site of production, hygiene problems were identified, and the juice was not pasteurized. Although an infected worker at the juice production company was the most likely source, none of the company staff was IgM positive, but staff mem-

bers often changed and were not available for testing. A large proportion of German tourists in the hotel were not immunized against HAV, although immunization is explicitly recommended in international and national guidelines for travelers to Egypt and other HAV-endemic areas. Some of the infected travelers reported that the physicians consulted for pretravel advice had considered HAV vaccination unnecessary for this type of travel and destination.

Category 7: individuals being served, rather than workers, are the probable source of the infectious agent. This category is rare in commercial food settings but more frequent where people prepare food and bring it to a social event, such as a birthday party or potluck supper, and where there are no trained food workers to supervise the occasion. The two examples are of outbreaks where food was served in a setting of extensive patron contact with food and with each other. In the second example, some guests at a wedding reception had been vomiting when the food was being placed in the buffet line, and the virus had spread to the wedding party and other guests not in direct contact with the affected individuals or the food.

Category 7: example 1. Three successive norovirus outbreaks occurred in May 1998, May 1999, and June 1999 in a Mediterranean-style restaurant in Melbourne, Australia *(18).* Food was typically placed on platters, and patrons ate with their fingers while moving among the tables. Different norovirus strains were isolated from the cases in the three outbreaks, indicating that there was no reservoir of the virus but that contamination of the food was recurring. In the first two outbreaks, one or two patrons had so-called incubation periods of a few hours between eating and onset. More likely, these individuals were incubating the viral infections as they were eating and were sufficiently contagious to contaminate the food they touched. In the third outbreak, a food worker may have been carrying the norovirus. The sharing of food from a common platter by eating with fingers would allow easy spread of any viral particles. This investigation shows how easily norovirus can be transmitted in settings where many people are in close contact and there are opportunities for many people to touch and eat the food. The same situation sometimes may occur on cruise ships, on which many norovirus illnesses have been reported.

Category 7: example 2. A norovirus outbreak in 2004 occurred at a wedding reception attended by 200 guests in Minnesota *(22).* Three guests developed gastroenteritis in the week before the wedding, and several guests had ill family members. The guests ate buffet style, but the head table had plated meals, none of which were significantly associated with illness. During the buffet service there were multiple episodes of vomiting by guests. The caterers were interviewed and reported no illness in themselves or family members. A food worker who worked the buffet line began vomiting 2 days after the wedding reception and was considered a victim rather than a source. Guests who ate the buffet had an elevated risk of illness ($P = 0.06$, close to significant), but those at the head table also were exposed. Norovirus was identified in nine stool specimens. This outbreak was almost certainly spread by ill guests who vomited during the reception, indicating the very infectious nature of the virus.

Category 8: workers are implicated epidemiologically as the source and are probably infected but deny illness. Although this category should not exist, it appears to be a reality. When workers deny illness, it is not easy to identify them as the source of an outbreak. Workers are hesitant to report illness because of fears of job loss and forced time off work without pay. However, the illness may be mild, and workers could believe the symptoms are not associated with contagious infections. Several outbreaks assigned to other categories also had workers who denied illness. All of the examples below occurred in Minnesota.

Category 8: example 1. In December 2000, a number of patrons suffered from norovirus gastroenteritis after a Christmas party at a restaurant *(19).* Any dessert was implicated statistically as the cause of the outbreak. Two secondary cases occurred in family members. Seven of eight stool samples from patrons and four of five stool samples from the food workers were positive for norovirus. The food workers denied illness before the party. They ate leftovers and became sick at the same time as the patrons. It is not clear whether the workers became infected only after eating leftovers; however, the cause of the outbreak was definitely linked to restaurant workers preparing the desserts, and at least one worker must have transmitted the virus to the food.

Category 8: example 2. On 16 May 2002, 18 cases of norovirus infection were associated with consumption of Mexican food at a restaurant *(20).* One food worker did not indicate he was ill, but he reported having a child at home who was ill with vomiting and diarrhea on 13 May, and the worker had been in the restaurant kitchen on 12 May. Stool samples from the child and from four patrons were positive for the same molecular strain of norovirus. Thus, it is likely that the worker was infected by the child, although the worker may not have been symptomatic on 12 May.

Category 8: example 3. During November and December 2004, 43 initial cases of salmonellosis were associated with consumption of gravy in a restaurant *(22).* Six additional cases were also associated with the same restaurant but not with the gravy. Three of 21 employees tested positive for *Salmonella* Newport but denied illness. It was hypothesized that the cases among restaurant patrons resulted from a contamination event that occurred when employees prepared raw turkeys for a catered lunch; kitchen surfaces may have become cross-contaminated. *Salmonella* shed by at least three infected workers contributed to contamination of kitchen surfaces and food items, resulting in 49 cases (26 were confirmed by laboratory tests).

Category 8: example 4. A group of six relatives who ate at a restaurant in 2004 reported gastrointestinal illness *(22).* The relatives had not shared a common event except the meal at the restaurant, and no other patrons of the res-

TABLE 3. *Number of outbreaks by category and setting where the food was provided*

Setting	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Food-service facilities												
Restaurant	106	13	1	58	4	21	83	4	12	2	20	324
Hotel	5	4		5	3	3	6		3	2	1	32
Cafeteria	4			3	4	1						12
Private club and resort	1	1			1		3	1		1		8
Subtotal	116	18	1	66	12	25	92	5	15	5	21	376
Mobile or temporary services												
Church social event	8			2	3	1	4				1	19
Fair or festival				1								1
Mobile food service					1							1
Meals-on-wheels									1			1
Temporary food service							1					1
Vending machine					1							1
Subtotal	8	0	0	3	5	1	5	0	1	0	1	24
Catered events												
Conference or other function	28	5		20	9	5	22	1	4	1	9	104
Workplace	4			3	1		2		3			13
Wedding	2			2					1	4		9
Subtotal	34	5	0	25	10	5	24	1	8	5	9	126
Health care institutions												
Hospital	4	1		8	1	1	4	1	1			21
Other institution	3			3	5				1			12
Nursing home	3	1		2	1		1		2			10
Subtotal	10	2	0	13	7	1	5	1	4	0	0	43
Schools												
School	12	2	2	9	9	3	5		2	1		45
Daycare facility	2			1			1					4
Subtotal	14	2	2	10	9	3	6	0	2	1	0	49
Camps and Armed Forces												
Camp	5			7	3		4					19
Military base	5				2		1		1			9
Refugee camp				1								1
Subtotal	10	0	0	8	5	0	5	0	1	0	0	29
Prisons and jails				2	2							4
Community events												
Native American Indian reservation				2	1							3
Closed community									1			1
Rainbow gathering								1				1
Music festival							1					1
Subtotal	0	0	0	2	1	0	1	1	1	0	0	6
Home-related activities												
Special event at home	21	1		23	10	3	9	2	4	4	1	78
Picnic	2			1			1				1	5
Subtotal	23	1	0	24	10	3	10	2	4	4	2	83
Commercial travel												
Airplane	1			6	4		1					12
Cruise ship							1	3				4
Train		1		1		1						3
Subtotal	1	1	0	7	4	1	2	3	0	0	0	19
Retail food outlets												
Supermarket	4			3	1		2				1	11
Butcher shop				1								1
Subtotal	4	0	0	4	1	0	2	0	0	0	1	12

TABLE 3. *Continued*

Setting	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Processing plants												
Bakery	7			3	3	2	2		1			18
Processing plant	1			1	1				3			6
Subtotal	8	0	0	4	4	2	2	0	4	0	0	24
Unknown location	10			3			8					21
Total	238	29	3	171	70	41	162	13	40	15	34	816

taurant reported illness. The stool specimen of one of the six affected individuals was positive for norovirus. None of the workers were apparently ill; however, stool specimens were not collected. The manager translated the questions during the investigation because most of the staff spoke Spanish; he also interviewed the server of the complainant's party, who was no longer an employee. The investigation team concluded that because of limited and potentially biased information from the restaurant staff, time constraints, and the limited number of patrons available to be contacted by county staff, the outbreak could not be adequately characterized even though the likely source of the norovirus was one or more employees.

Difficulty in assigning categories. The following examples from Minnesota illustrate the difficulties in determining the source of infection of some outbreaks and to which categories the outbreaks should be assigned *(19).*

Difficulty in assigning categories: example 1. In April 2000, 12 of 18 individuals who attended a birthday party at a restaurant and movie theater exhibited gastrointestinal symptoms that met the Kaplan criteria for epidemiologically confirmed norovirus. However, pathogens were not isolated from two stool specimens obtained. All food items served at the birthday party were commercially prepared and served to the party's tables in the movie theater. No food workers at the restaurant reported illness within 7 days of the event. However, the hostess of the party reported that her two children (ages 5 and 8) were ill with vomiting and diarrhea less than 2 days before the birthday party. Both children and their parents attended the party, and the parents assisted in the service of foods and beverages to the children. The cheese pizza was served family style, with children often helping themselves, and the pizza was statistically linked to illness. It seems likely that the hostess or the ill child was the source of this foodborne outbreak. The hostess had more opportunities than did the others to infect two-thirds of those attending by contaminating the food served. This outbreak most likely belongs in category 1 but also could be placed in category 4b.

Difficulty in assigning categories: example 2. In June 2000, four different groups experienced gastrointestinal symptoms after eating meals catered by one establishment over 2 days. Turkey focaccia sandwiches, lemon bars, and cantaloupe were all strongly associated with illness. Five of five stool samples were positive for norovirus group IV, which is very rare in the United States and had not been found previously in Minnesota. All food workers denied illness before the event. However, one food worker was ill 1 day after the event and reported a child that was ill with gastrointestinal symptoms during the week before the outbreak. Focaccia sandwiches were prepared with extensive bare-hand contact. The food worker with direct contact with a sick child was the most likely source of the norovirus infections, provided he or she was ill before all the others that were affected. This outbreak could be assigned to category 2a provided the implicated worker was ill before the others (both patrons and workers).

Difficulty in assigning categories: example 3. In October 2000, an outbreak of gastroenteritis occurred in two unrelated groups of eight persons who ate egg dishes and pancakes at the same restaurant at the same time. Twelve of the 16 patrons interviewed met the case definition of illness. Eleven of these 12 reported diarrhea, 9 reported vomiting, and 8 reported fever, but none reported bloody stools; 5 visited a healthcare provider. Incubation periods ranged from 26 to 55 h (median of 37 h). Duration of illness ranged from 7 to 53 h (median of 32 h). Specimens from four patrons tested positive for norovirus but negative for *Salmonella, Shigella, Campylobacter,* and *E. coli* O157:H7. None of the 26 employees who worked 15 October reported illness. Stool samples from restaurant employees were negative for norovirus, but three samples were positive for *Salmonella* Thompson and had an indistinguishable pulsed-field gel electrophoresis pattern. These employees were excluded from the restaurant until an additional two consecutive stool samples were negative for *Salmonella.* All 30 environmental swabs were negative for bacterial pathogens. Plates were garnished with RTE food items (shredded cheese, melon, etc.) using bare hands that could have introduced a pathogen(s). It was concluded that the outbreak was caused by a calicivirus (norovirus), and no specific food was identified as the vehicle. The three employees who were positive for *Salmonella* Thompson appeared to be infected without evidence of transmission to patrons, at least in the limited number of patrons tested. All the workers denied illness but may have been asymptomatic excretors of *Salmonella,* and one worker probably was a short-term carrier of norovirus, although this carriage could not be demonstrated. There were opportunities for transmission

TABLE 4. *Number of cases by category and setting where the food was provided*

Setting	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Food-service facilities												
Restaurant	5,096	556	21	3,773	176	689	3,479	119	2,489	105	435	16,938
Hotel	727	130		194	454	554	927		539	36	64	3,625
Cafeteria	369			207	116	71						763
Private club and resort	1,136	45			67		169	102		25		1,544
Subtotal	7,328	731	21	4,174	813	1,314	4,575	221	3,028	166	499	22,870
Mobile or temporary services												
Church social event	309			52	4,136	20	224				62	4,803
Fair or festival				85								85
Mobile food service					42							42
Meals-on-wheels									400			400
Temporary food service							34					34
Vending machine				3								3
Subtotal	309			137	4,181	20	258		400		62	5,367
Catered events												
Conference or other function	1,144	355		1,190	1,050	458	547	1,012	2,070	34	281	8,141
Workplace	61			488	20		158		582			1,309
Wedding	82			72					54	129		337
Subtotal	1,287	355		1,750	1,070	458	705	1,012	2,706	163	281	9,787
Health care institutions												
Hospital	274	26		505	20	80	304	80	450			1,739
Other institution	165			107	759				96			1,127
Nursing home	159	73		118	69		150		500			1,069
Subtotal	598	99		730	848	80	454	80	1,046			3,935
Schools												
School	4,231	224	173	334	489	1,016	306		128	262		7,163
Daycare facility	209			16			34					259
Subtotal	4,440	224	173	350	489	1,016	340		128	262		7,422
Camps and Armed Forces												
Camp	464			581	101		270					1,416
Military base	463				1,261		9		37			1,770
Refugee camp				1,931								1,931
Subtotal	927			2,512	1,362		279		37			5,117
Prisons and jails				360	397							757
Community events												
Native American Indian reservation				32	121							153
Closed community									48			48
Rainbow gathering								6,350				6,350
Music festival							3,175					3,175
Subtotal				32	121		3,175	6,350	48			9,726
Home-related activities												
Special event at home	844	12		482	158	36	136	323	134	44	10	2,179
Picnic	31			24			56				33	144
Subtotal	875	12		506	158	36	192	323	134	44	43	2,323
Commercial travel												
Airplane	290			1,793	488		253					2,824
Cruise ship							19	797				816
Train		2		107		56						165
Subtotal	290	2		1,900	488	56	272	797				3,805
Retail food outlets												
Supermarket	80			108	3		6				11	208
Butcher shop				59								59
Subtotal	80			167	3		6				11	267

TABLE 4. *Continued*

Setting	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Processing plants												
Bakery	4,321			102	148	2,742	291		9			7,613
Processing plant	132			50	15				770			967
Subtotal	4,453			152	163	2,742	291		779			8,580
Unknown location	480			97			149					726
Total	21,067	1,423	194	12,867	10,093	5,722	10,696	8,783	8,306	635	896	80,682

of pathogens through bare-hand contact. This outbreak could be placed in categories 4b, 5, or 10.

Difficulty in assigning categories: example 4. Eighteen people that attended a birthday party in October 2000 were interviewed, and nine met the case definition. Most people ate multiple foods, but none of these foods were statistically linked to illness. The wife of the person who served hot dogs was ill with gastrointestinal symptoms but did not attend the party; the server became ill 2 h after the party. A 6-year-old child at the party had gastroenteritis 4 h before the party. Based on the symptoms and distribution of incubation periods, this gastroenteritis outbreak probably was viral in origin. Transmission of illness could have occurred through the hot dog server with the 2-h incubation, but person-to-person transmission could not be ruled out because of the presence of a symptomatic child. This outbreak is similar to the first one listed in this section with a potentially infected server and/or child. This outbreak would best fit in category 1, but because of the uncertainty it could also be assigned to category 4b.

Other ways to separate outbreaks. Outbreak categories can be further broken down by setting (Tables 3 and

TABLE 5. *Number of outbreaks by categories and etiological agents*

Etiological agent	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Viral												
Norovirus	112	15	1			33	55	5	11	12	30	274
Hepatitis A virus	54	8	2			3	6	1	9	1		84
Probable norovirus	25						39					64
Unknown virus	15	4				3	30	1	1	2	1	57
Rotavirus	8	1					3					12
Total viral	214	28	3	0	0	39	133	7	21	15	31	491
Bacterial												
Salmonella (nontyphoidal)	1			126				2			1	130
Salmonella Typhi	1			19					1			21
Staphylococcus aureus					53							53
Shigella spp.	12			3			7	3	7		1	33
Streptococcus pyogenes groups A and C					17							17
Vibrio cholerae				9			1		1			11
Yersinia enterocolitica				6		1						7
Campylobacter jejuni				5								5
ETEC O157:H7 and O6:H16[a]				3								3
Total bacterial	14	0	0	171	70	1	8	5	9	0	2	280
Parasitic												
Cyclospora cayetanensis								1	10			11
Giardia lamblia/intestinalis	6	1				1	1					9
Cryptosporidium spp.	3											3
Total parasitic	9	1	0	0	0	1	1	1	10	0	0	23
Unknown	1	0	0	0	0	0	20	0	0	0	1	22
Total	238	29	3	171	70	41	162	13	40	15	34	816

[a] ETEC, enterotoxigenic *E. coli*.

TABLE 6. *Number of cases by categories and etiological agents*

Etiological agent	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Viral												
Norovirus	13,472	603	111			5,625	3,396	533	2,228	334	779	27,081
Hepatitis A virus	2,352	523	83			43	302	102	1,379	262		5,046
Probable norovirus	773						1,312					2,085
Unknown virus	582	139				12	935	378	37	39	26	2,148
Rotavirus	674	85					659					1,418
Total viral	17,853	1,350	194	0	0	5,680	6,604	1,013	3,644	635	805	37,778
Bacterial												
Salmonella (nontyphoidal)	290			8,717				80			49	9,136
Salmonella Typhi	132			608					17			757
Staphylococcus aureus					6,423							6,423
Shigella spp.	2,417			295			3,623	6,678	2,261		2	15,276
Streptococcus groups A and G					3,670							3,670
Vibrio cholerae				2,387			9		3			2,399
Yersinia enterocolitica				517		15						532
Campylobacter jejuni				238								238
ETEC O157:H7 and O6:H16[a]				105								105
Total bacterial	2,839	0	0	12,867	10,093	15	3,632	6,758	2,281	0	51	38,536
Parasitic												
Cyclospora cayetanensis								1,012	2,381			3,393
Giardia lamblia	181	73				27	21					302
Cryptosporidium spp.	157											157
Total parasitic	338	73	0	0	0	27	21	1,012	2,381	0	0	3,852
Unknown	37						439				40	516
Total	21,067	1,423	194	12,867	10,093	5,722	10,696	8,783	8,306	635	896	80,682

[a] ETEC, enterotoxigenic *E. coli*.

4), agent (Tables 5 and 6), and food (Tables 7 and 8). Norovirus and probable norovirus were the dominant agents associated with categories 1, 2a, 4a, 4b, 5, 6, 7, and 8 (Table 5). HAV was more often associated with categories 1, 2a, 2b, 4a, 4b, and 6. The relatively few outbreaks caused by parasites were mostly in categories 1 and 6. The outbreaks in which temperature abuse allowed pathogen growth are by definition restricted to categories 3a and 3b. However, within category 3a, *Salmonella* (145 outbreaks) was most frequent followed by *Vibrio cholerae* (9 outbreaks), *Yersinia* (6 outbreaks), *Campylobacter* (5 outbreaks), *Shigella* (3 outbreaks), and *E. coli* (2 O157:H7 outbreaks and 1 O6:H16 outbreak). Within category 3b, *S. aureus* was identified more often (53 outbreaks) than was *Streptococcus* (17 outbreaks) (Table 5). Pathogens such as *E. coli* and *Campylobacter* with a history of low infective doses were not involved to any great extent with outbreaks where workers were implicated. In category 6, apart from norovirus, both

TABLE 7. *Number of outbreaks by category and food group*

Food group	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Meat	8			16	7	1	4					36
Poultry	4	1		17	7		1				1	31
Eggs	1			7	10			2				20
Dairy	5			2	2		1					10
Seafood	6			12	3		1		3		1	26
Baked goods	15	1		4	4	3	7					34
Produce	24	2		8	3	5	13	2	29	2	7	95
Beverages	10	3		3		1	4	1	1	1	1	25
Multiple ingredients	145	21	3	83	32	28	112	7	6	11	23	471
Other	20	1		19	2	3	19	1	1	1	1	68
Total	238	29	3	171	70	41	162	13	40	15	34	816

TABLE 8. *Number of cases by category and food group*

Food group	Categories: 1	2a	2b	3a	3b	4a	4b	5	6	7	8	Total
Meat	1,573			1,167	276	15	96					3,127
Poultry	69	67		681	275		15				49	1,156
Eggs	7			244	1,643			80				1,974
Dairy	4,200			53	27		41					4,321
Seafood	398			239	1,563		2		83		8	2,293
Baked goods	1,336	12		149	148	2,757	480					4,882
Produce	2,079	101		3,254	122	463	357	1,229	6,978	295	143	15,021
Beverages	321	121		152		20	351	202	351	6	4	1,528
Multiple ingredients	10,472	1,102	194	5,542	5,858	2,375	5,529	7,247	846	303	690	40,158
Other	612	20		1,386	181	92	3,825	25	48	31	2	6,222
Total	21,067	1,423	194	12,867	10,093	5,722	10,696	8,783	8,306	635	896	80,682

Shigella and *Cyclospora* were the main agents; *Cyclospora* was associated with several outbreaks in which raspberries imported to Canada and the United States were contaminated with the parasite. Apart from the multi-ingredient foods, which were the dominant food group in most of the outbreak categories, produce was associated with the largest number of outbreaks (24) in any category, and most of these outbreaks were in category 1 (Table 7). There were relatively few outbreaks (97, 11.9%) associated with meat, poultry, dairy, and eggs, and these outbreaks tended to be in categories 1, 3a, or 3b (categories 3a and 3b are associated with conditions that promote bacterial growth). Outbreaks linked to beverages and baked goods (10 and 15 outbreaks, respectively) were most frequently in category 1. Apart from multi-ingredient foods, the foods associated with the most cases by category were produce in category 6 (6,978 cases), dairy products in category 1 (4,200 cases), produce in category 3a (3,254 cases), and breads and baked goods in category 4a (2,757 cases) (Table 8). Outbreaks originated in many settings, but in general there was no one outbreak category associated with a particular setting, e.g., restaurant, category 1 (106 outbreaks) and category 4b (83 outbreaks) (Table 3). Food workers in every category of outbreak were associated with restaurants and catered conferences or other functions. Only one category was missing from home-associated outbreaks, and two categories were missing from outbreaks in hotels and schools. Outbreaks following catered wedding meals were mainly linked to the categories 1 and 3a, a finding quite different from that for other catered events. The settings with the largest number of cases were the Rainbow Community gathering in category 5 (6,350 cases), restaurants in category 1 (5,096 cases), bakeries in category 1 (4,321), schools in category 1 (4,231), restaurants in category 4b (3,479), and a music festival community event in category 4b (3,175) (Table 4). The numbers associated with the community events illustrate that when a large group is exposed to a pathogen, many cases may result.

CONCLUSION

This article provides more details implicating food workers in 816 outbreaks than did the previous two articles in this series on food worker–associated outbreaks. Factors contributing to outbreaks are not always documented in reports, but when they are they are an invaluable resource. These factors help identify the most common and the unusual situations that result in contamination of food and the environment. The most frequently reported failure associated with infected workers was bare-hand contact with the food and/or improper washing of the hands. In numerous instances, investigators attributed the failure to properly wash hands to the lack of adequate hand hygiene supplies or facilities. In other situations, workers became contaminated by caring for an ill family member or by changing diapers of ill babies before going to work. Although fingernails were implicated in relatively few outbreaks, long or artificial nails that were difficult to clean after visiting the washroom were reported. Vomitus, sneezes, and open cuts and sores can deliver large quantities of pathogens into the food or the preparation environment.

Did the workers understand what the consequences of these actions could be, or did they deliberately commit these acts because of the inconvenience of taking sanitary precautions? The former situation is partially remedied by education and continual training. The latter situation may reflect improperly designed or maintained facilities, time constraints, negative attitudes towards management, or general antisocial behavior. In one outbreak, antisocial behavior was exhibited by a worker on an army base who deliberately urinated into the food *(12).* Asymptomatic workers were more likely to be associated with an outbreak than were workers who were frankly ill, particularly when the outbreak was associated with a virus. Because there often are no outward indications that a virus carrier is infective, no particular care can be taken by either the worker or management to restrict food handling and preparation practices, and infection cases can occur over an extended period of time. Only regular worker stool and blood screening could detect the asymptomatic or carrier state, and this approach is impractical in an industry with a highly mobile work force. Food establishment managers or employees may deny illness for a variety of reasons, making both investigation and implementation of control strategies more difficult. These issues highlight the need to insist that workers use good sanitary practices, including thorough hand washing and drying.

In this article, eight different categories of outbreaks in which food workers have been implicated are described. This categorization may be artificial and probably is incomplete. For instance, in several outbreaks more than one category could be assigned, and perhaps this approach should be considered in future investigations. How should the relatively few deliberate contamination events be categorized? They could be placed in a separate category, but at present they are included in the existing categories 1 through 8. Figure 1 shows both data on the different categories and possible linkages between them. An outbreak may start through an infection from a local or offsite source (categories 1 and 2b), which may or may not result in more workers being infected (categories 2a, 4a, 4b, and 5). These workers most likely contaminate food that may under certain circumstances allow growth of the pathogens (categories 3a and 3b), or food already contaminated may be brought into a facility (category 6). Those who ingest this food (or contact fomites from infected workers) then become ill. A few cases may result directly from other ill persons who are eating at the same time (category 7). Category 8 is a very uncertain one, because outbreaks in this group could fit into many of the other categories if the workers were to admit to being ill. This use of this category highlights the issue of worker denial.

Even though this attempt to categorize outbreaks is somewhat speculative and incomplete, it allows analysis of different scenarios of worker infection and food contamination by agent, food group, and setting, and these analyses can provide important information that help regulators and researchers develop appropriate and effective control mechanisms.

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