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Review

Outbreaks Where Food Workers Have Been Implicated in the Spread of Foodborne Disease. Part 1. Description of the Problem, Methods, and Agents Involved

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ABSTRACT

Food workers in many settings have been responsible for foodborne disease outbreaks for decades, and there is no indication that this is diminishing. The Committee on Control of Foodborne Illnesses of the International Association for Food Protection was tasked with collecting and evaluating any data on worker-associated outbreaks. A total of 816 reports with 80,682 cases were collected from events that occurred from 1927 until the first quarter of 2006. Most of the outbreaks reviewed were from the United States, Canada, Europe, and Australia, with relatively few from other parts of the world, indicating the skewed set of data because of availability in the literature or personal contact. Outbreaks were caused by 14 agents: norovirus or probable norovirus (338), *Salmonella enterica* (151), hepatitis A virus (84), *Staphylococcus aureus* (53), *Shigella* spp. (33), *Streptococcus* Lancefield groups A and G (17), and parasites *Cyclospora, Giardia,* and *Cryptosporidium* (23). Streptococcal, staphylococcal, and typhoid outbreaks seem to be diminishing over time; hepatitis A virus remains static, whereas norovirus and maybe nontyphoidal *Salmonella* are increasing. Multiple foods and multi-ingredient foods were identified most frequently with outbreaks, perhaps because of more frequent hand contact during preparation and serving.

The Centers for Disease Control and Prevention (CDC) estimates there are up to 76 million cases of foodborne illness each year in the United States *(31),* and some other countries report similarly large numbers. The contribution of the infected food worker (whether symptomatic or not) to these cases has been difficult to establish. Bryan *(4)* noted that in 18% of 766 outbreaks occurring between 1961 and 1982, a colonized food worker had touched the implicated food. However, the infected food worker was documented as responsible for only 7% of the salmonellosis outbreaks in England and Wales over a 10-year period *(42).* More recently, the CDC estimated that 20% of foodborne illnesses caused by bacterial agents are a result of transmission from the infected worker *(51),* which is similar to the earlier percentage of outbreaks determined by Bryan *(4).* In many outbreaks, it was unclear whether the workers were the cause or the victims of the infections *(12, 14).* This is partly because the outbreaks are not thoroughly enough investigated and partly because the disease transmission patterns are complex. More specifically, investigations are often hampered because (i) there is too long a delay between the outbreak event and the start of the investigation, with the likelihood that the persons involved in the outbreak are no longer available for further questioning or have forgotten the details; (ii) the information is limited because of language difficulties or poor employee communication skills; or (iii) there is ineffective questioning by the investigators *(26, 39, 53).*

Many of the outbreaks reported in the literature where the contribution of the food worker to the case numbers was investigated were decades old; there appears to be less interest today in reporting details. This could be because it is assumed that we know all there is to understand about worker involvement, and there are fewer resources assigned to make complete investigations, especially for small outbreaks. However, because outbreaks involving food workers still continue today, there is a need for a more comprehensive assessment of the role they play in disease transmission. For instance, in the Lansing, Michigan, area, there were three large outbreaks involving restaurants in the spring of 2006 in which food workers were known or suspected to have been the cause of approximately 800 norovirus infections *(18, 43).*

A review on the involvement of the ill or asymptomatic food worker in foodborne illness outbreaks was initiated as a project of the Committee on Control of Foodborne Illnesses of the International Association for Food Protection

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(IAFP). The Committee on Control of Foodborne Illnesses decided that the database should include outbreak data from homes, restaurants, institutions, processing plants, and farms from both the United States and other countries. However, it was recognized that the review was far from a complete analysis of all the available information, and this article should be considered an initial report. The goal of the study was to develop an understanding of the dynamics of transmission of infectious agents to and from the food worker in a variety of settings. The Committee on Control of Foodborne Illnesses approached the task with the premise that all foodborne illness is fundamentally preventable and that by influencing human behavior, there will be fewer opportunities for the spread of infectious disease agents and, thus, human infections.

This article is the first of a series of several that review the role of food workers in foodborne outbreaks. It contains the rationale for reviewing the data, the methodology used, and a summary of the general results. The remaining articles will categorize the outbreaks by worker involvement, risk factors, and means of prevention.

METHODS

Review of existing literature and criteria used. Outbreak data available from 1927 to the present were obtained in which food workers were reported to have been instrumental or at least contributory to an outbreak. An outbreak was defined as two or more persons infected or intoxicated after consuming a food that had been linked epidemiologically or microbiologically to the ill persons. Water and ice used in beverages are included as food. Secondary cases arising from contact with any of those who became ill because of contaminated food or contact with an infected food worker were noted and excluded in the listed case numbers. The term food worker is used in this context to describe individuals who harvest, process, prepare, and serve food. By definition, the task of food handlers is more limited to preparation and serving duties, but both worker and handler are often used interchangeably in investigative reports and in the literature. Thus, we use food worker to describe both worker and handler in this study.

Criteria for selection of outbreaks. The data used in assessing the role of the food worker in outbreaks were derived from a variety of published and unpublished sources. These articles were identified through searches of whole text abstracts and outbreak summaries documented by MEDLINE with key words or phrases pertaining to foodborne illness in various segments of the food industry, including restaurants, delicatessens, hospitals, catering establishments, cruise ships, airplanes, trains, camps, cafeterias, and homes, and were as follows: food preparer, food handler, food worker, ill worker, ill employee, asymptomatic carrier, infected employee, excreter, kitchen help, family transmission, household illness, household transmission, outbreak, hand contamination, and cross-contamination. In addition, searches were made by specific disease, e.g., salmonellosis, linked with worker, handler, staff, and food service. Food-associated key words were seafood, poultry, bakery goods, cheese and dairy, produce, salads, sandwiches, meat, hors d'oeuvres, and ready-to-eat (RTE) food. We also requested and obtained outbreak data over a multiyear period from the states of Michigan (2000 to 2003), Minnesota (1999 to 2004), New York (1985 to 2000), and Washington (1990 to 2003). Because one of us (C.A.B.) was employed by the Washington Department of Health and was involved with foodborne disease investigations during this time frame, much additional information came from personal communication. Data from individual states were received in the form of line listings through the respective state Departments of Health and, for Michigan, also from the Department of Agriculture. Line listings were also obtained from annual reports of foodborne and waterborne disease outbreaks published by Health Canada (1976 to 1996). Line listings are summaries of narrative reports of outbreaks in a tabular format, typically expressed in a few lines of text, with information, when available, on etiological agent, date of onset, location, food mishandling location, food vehicle, number of persons ill and number exposed, incubation period, duration, symptoms, laboratory data, factors contributing to the outbreak, and other relevant data.

Most of these outbreaks showed a factor such as handling by an infected person or carrier of a pathogen. However, a few selected outbreaks were included where strong epidemiological data suggested that food workers were the likely source of the pathogen, but all food workers denied illness, or else the patrons themselves, rather than the food workers, were identified as the likely source of the pathogen. These line listings may or may not have been accompanied by more detailed information through separate reports or appendices; however, these were rarely available to the reviewers. All these sources were reviewed by the authors, and selections were made on the basis of the completeness and relevance of the information. Even so, it was recognized that the role of the worker in some reports was much more clearly stated than in others. References and other comments were obtained from existing reviews *(19, 32, 46)*.

Criteria for selection of factors contributing to the outbreaks. The authors searched the available information from the outbreaks selected for review, whether contained in a peer-reviewed publication, line listing, or narrative, for any pertinent factors that contributed to the occurrence of the outbreaks. These were written in English or translated from another language. The data could be evaluated only as presented. So, undoubtedly, some data were missed or not included in some of the reviewed accounts. One key aspect of outbreak investigation is the identification of factors contributing to outbreaks. CDC form 52.13 (Revised 11-2004), "Investigation of a Foodborne Outbreak," was the basis for the majority of the factors used in this study *(11)*. The factors identified in the form are based on earlier research done by Bryan and others on factors related to foodborne outbreaks *(5, 6, 52)* and are coded C, P, and S. Factors identified with a "C" are contamination factors, while those with a "P" refer to factors that allow proliferation or amplification of bacterial pathogens. An "S" designates factors that allow pathogens to survive in the food. In addition, another factor was used from the Washington State Health Department coded as C-15, "failure to properly wash hands when necessary." C-15 included some of the following types of observations: food workers' hands were not washed after using the toilet; running water was not available for hand washing; no soap or towels were used; or food workers failed to wash their hands after contaminating events occurred (e.g., handling raw meat). Factors reported as linked to an outbreak should have occurred near the time of that outbreak. If the factors were observed either earlier or later (e.g., during routine inspections), they would not be reported, although sometimes it is not possible to tell exactly when observations were made regarding factors in the reports. Frequently, during the investigation of viral or parasitic outbreaks, P factors related to temperature abuse or conducive to bacterial growth were excluded, because viruses or parasites do not grow in foods, even though they were

TABLE 1. *Number of outbreaks and cases involving food workers by decade*

Decade	No. of outbreaks	No. of cases
1920s	1	138
1930s	0	0
1940s	1	18
1950s	1	600
1960s	10	1,958
1970s	73	5,791
1980s	191	31,413
1990s	306	24,736
2000–2006[a]	233	16,028
Total	816	80,682

[a] Very few outbreaks were utilized for this study in 2006, because reports had not yet been written up.

TABLE 2. *Pathogens identified in outbreaks and cases involving food workers*

Agents	No. of outbreaks (%)	No. of cases (%)
Viral	491 (60.2)	37,778 (46.8)
Norovirus	274 (33.6)	27,081 (33.6)
Hepatitis A virus	84 (10.3)	5,046 (6.3)
Viral/probable norovirus	64 (7.8)	2,085 (2.6)
Unknown viral	57 (7.0)	2,148 (2.7)
Rotavirus	12 (1.5)	1,418 (1.8)
Bacterial	280 (34.3)	38,536 (47.8)
Salmonella (nontyphoidal)	130 (15.9)	9,136 (11.3)
Salmonella Typhi	21 (2.6)	757 (0.9)
Staphylococcus aureus	53 (6.5)	6,423 (8.0)
Shigella spp.	33 (4.0)	15,276 (18.9)
Streptococcus groups A and G	17 (2.1)	3,670 (4.5)
Vibrio cholerae	11 (1.3)	2,399 (3.0)
Yersinia enterocolitica	7 (0.9)	532 (0.7)
Campylobacter jejuni	5 (0.6)	238 (0.3)
Escherichia coli O157:H7 and O6:H16 enterotoxigenic *E. coli*	3 (0.4)	105 (0.1)
Parasitic	23 (2.8)	3,852 (4.8)
Cyclospora cayetanensis	11 (1.3)	3,393 (4.2)
Giardia lamblia/intestinalis	9 (1.1)	302 (0.4)
Cryptosporidium spp.	3 (0.4)	157 (0.2)
Unknown	22 (2.7)	516 (0.6)
Total	816 (100.0)	80,682 (100.0)

noted in the investigative reports. These same factors, however, were included in reviewed outbreaks of bacterial etiology.

Factors listed in the outbreak reports involving food workers were as follows:

(i) **C-6** Raw products and ingredients contaminated by pathogens from animals or the environment (e.g., *Salmonella* Enteritidis in egg, Norwalk [norovirus] in shellfish, *Escherichia coli* in sprouts);

(ii) **C-7** Ingestion of contaminated raw product (e.g., raw shellfish, produce, eggs);

(iii) **C-9** Cross-contamination from raw ingredients of animal origin;

(iv) **C-10** Bare-hand contact by handler, worker, or preparer (e.g., with RTE foods);

(v) **C-11** Glove-hand contact by handler, worker, or preparer (e.g., with RTE foods);

(vi) **C-12** Handling by an infected person or carrier of pathogen;

(vii) **C-13** Inadequate cleaning of processing, preparation equipment, or utensils leading to contamination of vehicle (e.g., cutting boards);

(viii) **C-15** Failure to properly wash hands when necessary;

(ix) **P-1** Allowing foods to remain at room or warm outdoor temperature for several hours (e.g., during preparation or holding for service);

(x) **P-2** Slow cooling (e.g., deep containers or large roasts);

(xi) **P-3** Inadequate cold-holding temperatures (e.g., refrigerator inadequate or not working, iced holding inadequate);

(xii) **P-4** Preparing foods a half day or more before service (e.g., banquet preparation a day in advance);

(xiii) **P-6** Insufficient time and temperature during hot holding (e.g., malfunctioning equipment, too large a mass of food);

(xiv) **S-1** Insufficient time and temperature during initial cooking and heat processing (e.g., roasted meats and poultry, canned foods, pasteurization);

(xv) **S-4** Insufficient thawing followed by insufficient cooking (e.g., frozen turkey).

Criteria for pathogen identification. Some of the outbreaks listed were determined only on epidemiological grounds, while others were determined on the basis of laboratory analyses, together with some epidemiology. Analytical methods are rarely mentioned, except in peer-reviewed publications. However, it is assumed that state and national laboratories use standard methods that are developed through an approved process and are approximately equivalent. Most of the methods will not have changed much during the past few decades except for the introduction of PCR technology. However, because most agencies are required to isolate a pathogen, standard enrichment (where necessary) and selective media were still used for picking colonies, with subsequent identification by biochemical tests and serology, even if PCR was used for screening samples. One major exception for change over time is noroviruses. It has long been recognized that enteric viruses, especially those in the Norwalk-like group, are an important cause of morbidity and probably responsible for many foodborne outbreaks. Mead et al. *(31)* believed that 40% of norovirus infections in the United States are foodborne, whereas Adak et al. *(1)* reckoned that only 10.7% were transmitted through food in the United Kingdom. Diagnosis was mainly on epidemiological characteristics, and Kaplan et al. *(24)* developed criteria to identify norovirus outbreaks in a standard way. The criteria consist of four points: (i) vomiting in more than 50% of the affected individuals, (ii) mean or median incubation period of 24 to 48 h, (iii) mean or median duration of illness of 12 to 60 h, and (iv) no bacterial pathogen isolated from stool culture. Recently, Turcios et al. *(50)* evaluated these criteria confirming their utility, and when all components are assessed during an investigation, the criteria provide a 99% specificity rate. These criteria have proved useful over the years; for instance, a large number of the Washington Department of Health outbreaks listed in this report were confirmed epidemiologically as norovirus by the Kaplan criteria. The second advance was laboratory confirmation of Norwalk and Norwalk-like viruses and their consolidation into one group—the noroviruses. During the 1980s and first half of

TABLE 3. *Pathogens identified in outbreaks involving food workers by decade*

	1920s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	Total
Viral agents									
Norovirus[a]					4	60	87	122	273
Hepatitis A virus				3	10	26	31	14	84
Viral/probable norovirus						3	56	6	65
Viral (unknown species)						3	19	35	57
Rotavirus						9	1	2	12
Bacterial agents									
Salmonella (nontyphoidal)					23	32	46	29	130
Salmonella Typhi		1		4	3	8	4	1	21
Staphylococcus aureus					23	13	11	6	53
Shigella spp.				1	2	11	14	5	33
Streptococcus group A	1		1	2	3	7	3		17
Vibrio cholerae					1	7	3		11
Yersinia enterocolitica[a]					3	3	1		7
Campylobacter jejuni[b]						2	2	1	5
Escherichia coli O157:H7 and other Shiga toxin-producing *E. coli*[b]						1	2		3
Parasitic agents									
Cyclospora cayetanensis[c]							7	4	11
Giardia lamblia/intestinalis					1	4	2	2	9
Cryptosporidium spp.[b]							3		3
Unknown						2	14	6	22
Total	1	1	1	10	73	191	306	233	816

[a,b,c] Emerging foodborne pathogens first identified in the 1970s, 1980s, and 1990s, respectively.

the 1990s, norovirus outbreaks were seldom confirmed in the laboratory because of complicated serologic or direct electron microscope examinations, which only a very few laboratories attempted to do. This changed during the past decade with the advent and widespread use of reverse transcriptase–PCR tests *(37)*; this is the main reason for a dramatic increase in outbreaks confirmed as caused by noroviruses in the past few years.

RESULTS

Epidemiological data. A total of 816 outbreaks were selected out of the many reviewed that had some evidence of food worker involvement, and these were summarized in line listings that were somewhat different from the state or Canadian reports, excluding such data as symptoms. Lines contain the following information on each of the outbreaks: implicated food vehicle, etiological agent, setting where the food was prepared, all reported cases and whether these were epidemiologically or laboratory confirmed, factors that contributed to the outbreak (for those in the United States, the CDC factors are listed; see above), number of ill workers, a short narrative of the outbreak, and the scientific reference. The complete line that lists all 816 outbreaks with the appropriate references reviewed in this and the following two articles is available on the IAFP website. Because the study describes outbreaks in which food workers were implicated, the main risk factor was the CDC-assigned category C-12, but this applied only to outbreaks in the United States, although similar factors were reported for outbreaks in other countries. The 816 outbreaks with 80,682 cases occurred between 1927 and 2006. The number of outbreaks involving workers increased to a maximum in the 1990s. In the 1920s, 1940s, and 1950s, only one outbreak was documented per decade (Table 1). In the succeeding decades, the numbers were as follows: 1960s, 10; 1970s, 73; 1980s, 191; 1990s, 306; and for the first 6 years in the 2000s, 233, which has the potential to be the highest number of any decade, assuming the same proportion is reported during the next 4 years ($233 \times 10/6 = 388$). Thus, this trend is ever increasing and should give concern to managers of food operations and local health authorities. Before the 1960s, the number of outbreaks reported was

TABLE 4. *Geographic distribution of outbreaks involving food workers*

Geographic region	No. (%) of outbreaks	No. (%) of cases
United States	647 (79.3)	54,888 (68.0)
Canada	62 (7.6)	3,320 (4.1)
Europe	63 (7.7)	7,694 (9.5)
Australia/Asia	27 (3.3)	4,680 (5.8)
Middle East	3 (0.4)	400 (0.5)
Latin America/Caribbean	6 (0.7)	5,408 (6.7)
Africa	4 (0.5)	2,394 (3.0)
Unknown	2 (0.2)	55 (0.1)
Multiple countries	2 (0.2)	1,843 (2.3)
Total	816 (100)	80,682 (100)

TABLE 5A. *Food categories and viral agents associated with outbreaks where food workers were implicated*

Food category	No. (%)			
	Norovirus		Probable norovirus	
	Outbreaks	Cases	Outbreaks	Cases
Meats	8 (2.9)	441 (1.7)		
Poultry	1 (0.4)	67 (0.2)	1 (1.6)	15 (0.7)
Eggs			1 (1.6)	7 (0.3)
Dairy	4 (1.5)	4,048 (14.9)		
Seafood	3 (1.1)	31 (0.1)	1 (1.6)	53 (2.5)
Breads and bakery	12 (4.4)	4,037 (14.9)	3 (4.7)	169 (8.1)
Produce	44 (16.1)	3,856 (14.2)	2 (3.1)	57 (2.7)
Beverages	8 (2.9)	353 (1.3)	5 (7.8)	291 (14.0)
Multi-ingredient foods	175 (63.9)	13,554 (50.0)	47 (73.4)	1,411 (67.7)
Other	19 (6.9)	694 (2.6)	4 (6.3)	82 (3.9)
Total	274 (100)	27,081 (100)	64 (100)	2,085 (100)

low, likely because of the lack of resources for implementing surveillance systems, the lack of interest by public health authorities, or both. However, we also recognize that since the 1970s, there has been a dramatic increase in the number of restaurant outlets in most developed countries and, today, throughout the world. This is especially true of the fast food chains, both in variety and quantity. We record 324 restaurant outbreaks, of which at least 10 were fast food, in which food workers were implicated.

Agents involved in the outbreaks where food workers were implicated. Fourteen (14) different genera of viruses, bacteria, and parasites representing many species were identified as the etiologic agents in the 816 outbreaks (Table 2). Viruses caused 491 (60.2%) outbreaks; of these, 274 were norovirus (previously called Norwalk, Norwalk-like viruses, and small round structured viruses) (27,081 cases); 64 were probable norovirus (2,085 cases); 84 were hepatitis A virus (HAV) (5,046 cases); 12 were rotavirus (1,418 cases); and 57 were unidentified viruses causing gastrointestinal illness (2,148 cases). Noroviruses and probable noroviruses accounted for 338 outbreaks (41.4% of the total) and 29,166 cases (36.1% of the total). These represent the largest group of outbreaks and cases caused by one agent or group of similar agents, and most of these were recorded in the past two decades (Table 3). However, it is recognized that norovirus probably caused many outbreaks in previous years when the methodology was not available to detect the virus, and thus, there is no record of these. In addition, opportunities for rapid transmission through close contact of individuals in fast food chains and cruise ships have increased lately. Rotavirus is not considered a significant foodborne agent, although it is a frequent cause of morbidity in children from nonfood sources; Mead et al. *(31)* stated that only 1% of outbreaks are attributable to transmission through food for a total of 39,000 cases for the whole of the United States. Yet, in our survey, this type of virus was the identified agent in 12 foodborne disease outbreaks with 1,418 cases.

Bacteria were responsible for 280 outbreaks, the majority being attributed to *Salmonella* (151 outbreaks and 9,893 cases), *Staphylococcus aureus* (53 outbreaks and 6,423 cases), *Shigella* (33 outbreaks and 15,276 cases), and *Streptococcus* (17 outbreaks and 3,670 cases). All but one of the streptococcal outbreaks were caused by Lancefield

TABLE 5B. *Food categories and bacterial agents associated with outbreaks where food workers were implicated*

Food category	No. (%)							
	Salmonella		*Staphylococcus aureus*		*Shigella* spp.		*Streptococcus* spp.	
	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
Meats	12 (7.9)	1,043 (10.6)	7 (13.2)	276 (4.3)	2 (6.0)	1,161 (7.6)		
Poultry	18 (11.9)	730 (7.4)	6 (11.3)	203 (3.2)	2 (6.1)	37 (0.2)	1 (5.9)	72 (2.0)
Eggs	8 (5.3)	243 (2.5)	6 (11.3)	535 (8.3)			4 (23.5)	1,108 (30.2)
Dairy	1 (0.7)	132 (1.3)	2 (3.8)	27 (0.4)				
Seafood	11 (7.3)	413 (4.2)			2 (6.1)	64 (0.4)	3 (17.6)	1,563 (42.6)
Breads and bakery	4 (2.6)	149 (1.5)	4 (7.5)	148 (2.3)	1 (3.0)	12 (0.1)		
Produce	7 (4.6)	1,263 (12.8)	3 (5.7)	122 (1.9)	7 (21.2)	2,715 (17.8)		
Beverages	3 (2.0)	152 (1.5)						
Multi-ingredient	71 (47.0)	4,544 (45.9)	24 (45.3)	4,966 (77.3)	14 (42.4)	8,012 (52.4)	8 (47.1)	892 (24.3)
Other	16 (10.6)	1,224 (12.4)	1 (1.9)	146 (2.3)	5 (15.2)	3,275 (21.4)	1 (5.9)	35 (1.0)
Total	151 (100)	9,893 (100)	53 (100)	6,423 (100)	33 (100)	15,276 (100)	17 (100)	3,670 (100)

TABLE 5A. *Extended*

No. (%)					
Hepatitis A virus		Rotavirus		Unknown viral	
Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
				2 (3.6)	77 (3.5)
				1 (1.8)	17 (0.8)
1 (1.2)	61 (1.2)				
2 (2.4)	22 (0.4)			1 (1.8)	2 (0.1)
7 (8.3)	305 (6.0)	1 (8.3)	41 (2.9)	1 (1.8)	10 (0.5)
10 (11.9)	1,368 (27.1)	1 (8.3)	3 (0.2)	3 (5.3)	48 (2.2)
7 (8.3)	577 (11.4)			2 (3.5)	155 (7.2)
49 (58.3)	2,453 (48.6)	10 (83.3)	1,374 (96.9)	38 (66.7)	1,524 (70.9)
8 (9.5)	260 (5.2)			9 (15.8)	315 (14.7)
84 (100)	5,046 (100)	12 (100)	1,418 (100)		2,148 (100)

group A; the other was caused by group G. Outbreaks involving *Salmonella* also seem to be on the rise in recent decades. Because the methodology has not changed substantially for detection of this pathogen for at least two decades, this probably represents a real increase. Typhoid fever outbreaks linked to food workers, however, seem to have peaked in the 1980s. A similar trend occurred for outbreaks associated with *S. aureus* and *Streptococcus* group A, with peaks in the 1970s and 1980s, respectively (Table 3). A temporal change has occurred because the growth conditions for both *S. aureus* and streptococci have been made less favorable through better temperature control of RTE foods, even though the nasopharynx carriage rate for toxigenic *S. aureus* and group A *Streptococcus* has probably not changed over the years *(2, 54)*. Another possibility is that these two pathogens are not searched for as assiduously as in previous years because of a lack of resources and the perception they cause mild illness. Because group A streptococci infect with easily recognizable symptoms, the first reason is the most likely scenario. A streptococcal outbreak was the first chronologically documented outbreak in this report involving food workers in 1927 *(44)*.

Outbreaks caused by parasites included *Cyclospora cayetanensis* (11), *Giardia lamblia/intestinalis* (9), and *Cryptosporidium* (3), with *Cyclospora* having by far the largest number of cases (3,393) primarily because of a number of raspberry-associated outbreaks in both Canada and the United States. The *Cryptosporidium* was not always typed to species but was probably *parvum* or *hominis* (previously *C. parvum* genotype 1).

Secondary spread. It is often not easy to distinguish between a secondary case and a primary case with a longer incubation period in a general outbreak setting. However, only 8.8% of cases were documented as secondary in a study of 936 households with infectious gastroenteritis *(38)* and 15% in a large waterborne norovirus outbreak of schoolchildren *(21)*. Immunoglobulin is given to all possibly exposed persons if an infection in a food service setting is identified, because outbreaks of HAV typically have more secondary cases than do other agents. In one outbreak, the secondary case rate was 45%, but not all primary cases may have been identified *(7)*.

In the reports we reviewed, secondary cases from foodborne outbreaks were rare. However, it is possible many of these were not noted in the investigative reports. Secondary

TABLE 5B. *Extended*

No. (%)							
Vibrio cholerae		*Yersinia enterocolitica*		*Campylobacter* spp.		*Escherichia coli*	
Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
2 (18.2)	83 (3.5)	1 (14.3)	15 (2.8)			1 (33.3)	16 (15.2)
				1 (20.0)	81 (34.0)		
		2 (28.6)	53 (10.0)				
1 (9.1)	37 (1.5)			1 (20.0)	79 (33.2)		
1 (9.1)	1,931 (80.5)					1 (33.3)	77 (73.3)
5 (45.5)	243 (10.1)	2 (28.6)	398 (74.8)	3 (60.0)	78 (32.8)	1 (33.3)	12 (11.4)
2 (18.2)	105 (4.4)	2 (28.6)	66 (12.4)				
11 (100)	2,399 (100)	7 (100)	532 (100)	5 (100)	238 (100)	3 (100)	105 (100)

TABLE 5C. *Food categories and parasitic agents associated with outbreaks where food workers were implicated*

Food category	No. (%)			
	Cyclospora cayetanensis		*Giardia lamblia/intestinalis*	
	Outbreaks	Cases	Outbreaks	Cases
Meats				
Poultry				
Eggs				
Dairy				
Seafood			1 (11.1)	29 (9.6)
Breads and bakery				
Produce	10 (90.9)	3,359 (99.0)	3 (33.3)	58 (19.2)
Beverages				
Multi-ingredient foods	1 (9.1)	34 (1.0)	4 (44.4)	195 (64.6)
Other			1 (11.1)	20 (6.6)
Total	11 (100)	3,393 (100)	9 (100)	302 (100)

[a] Unknown agent = most of these are probably viral in origin.

cases were documented in only 8 of the 816 outbreaks (three HAV, three norovirus, one *Streptococcus* group A, and one *Vibrio cholerae*), and the numbers were not usually noted. Secondary spread mostly occurred in confined units, such as schools with the children and their parents, families on a military base, or sexual partners. During a hotel outbreak, norovirus-infected kitchen workers spread the virus to other staff members remote from the kitchen, either by direct contact or by aerosol transmission *(35)*. In a Micronesian cholera outbreak, the pathogen spread from families to families, although food preparation was the originating source *(22)*; similarly, cholera was rapidly transferred throughout a refugee camp after initial food and water contamination *(47)*. Homosexual contact between HAV-infected food workers and their partners allowed the infection to spread in two outbreaks *(27)*.

Distribution of outbreaks involving food workers by geographic region and mode of transport. In this review, most of the outbreaks were reported from the United States (647), followed by Europe (63), Canada (62), and Australia and Asia (27). Relatively few episodes from other parts of the world were reported as outbreaks, indicating the skewed set of data used because of availability in the literature or through personal contact (Table 4).

There were 42 outbreaks (8,568 cases) where the foods responsible for illness were obtained from an off-site location. The mean and median numbers of these cases were 209.0 and 62, respectively. Sixteen outbreaks occurred where food, primarily produce, was harvested and shipped from another country. For the United States, the countries of origin were Mexico (basil *(30)*, green onions *(10)*, parsley *(34)*, and strawberries *(23)*); Guatemala (raspberries *(20)* and mamey *(25)*); Thailand (coconut milk *(8)*); and India (shrimp *(16)*). Parsley contaminated by both O6:H16 enterotoxigenic *E. coli (34)* and *Shigella sonnei* originated from Mexico *(9)*. Raspberries contaminated with norovirus from Poland caused several outbreaks—six in Denmark and one in France *(17)*. In addition, contaminated lettuce *(15)*, strawberries *(36)*, and oysters *(41)* produced in one part of the United States affected people in another part. In most of these outbreaks, unfortunately, the actual source of the infection, including worker transmission, was not proven but only likely or possible. However, in a Scottish HAV outbreak from frozen raspberries, one raspberry picker was identified as the source of the illness because he carried the same HAV strain as the infected persons *(40)*. Canned mushrooms from China containing staphylococcal enterotoxin caused a number of illnesses in the United States *(29)*. Workers, shedding *S. aureus* from the skin or nasopharynx, likely handled the mushrooms that were stored in brine at room temperature before canning. This allowed pathogen growth and production of a heat-stable toxin that was not inactivated by the canning process.

In 10 additional outbreaks, foreign travel to Central America or Eastern Asia by food workers was cited as the source or possible source of *Shigella* spp. (three), *Salmonella* Typhi (four), *Salmonella* Paratyphi (one), *Salmonella* Enteritidis (one), and HAV (one) infections. Illnesses on cruise ships and airlines were reported by several countries and are described in detail in a section on Commercial Travel in Todd et al. *(49)*.

Foods involved in outbreaks where food workers were implicated. The food vehicle categories identified in food worker–associated outbreaks are shown in Table 5A through 5C. Reports identified "multiple foods" in 245 outbreaks, i.e., two or more foods listed in the report, but the investigation was unable to determine which ones were sufficiently contaminated to cause the illnesses. Multi-ingredient foods were noted most frequently (471), perhaps because of more intensive handling during preparation, which may have increased the chance for contamination. Outbreaks associated with multi-ingredient foods included 106 with various salads: lettuce and leafy green salads (71), potato salad (21), pasta salad (7), coleslaw (4), antipasto salad (2), and Caesar salad (1). The sandwiches implicated in 82 outbreaks were typically not described in detail and therefore have unspecified ingredients. Several outbreaks listed Mexican (nine) and Chinese (two) food, pasta (four),

TABLE 5C. *Extended*

No. (%)					
Cryptosporidium spp.		Unknown agent[a]		Total for categories	
Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
		1 (4.5)	15 (2.9)	36 (4.4)	3,127 (3.9)
1 (33.3)	15 (9.6)			31 (3.8)	1,156 (1.4)
				20 (2.5)	1,974 (2.4)
				10 (1.2)	4,321 (5.4)
				26 (3.2)	2,293 (2.8)
		1 (4.5)	11 (2.1)	34 (4.2)	4,882 (6.1)
2 (66.6)	142 (90.4)	1 (4.5)	22 (4.3)	95 (11.6)	15,021 (18.6)
				25 (3.1)	1,528 (1.9)
		19 (86.4)	468 (90.7)	471 (57.7)	40,158 (49.8)
				68 (8.3)	6,222 (7.7)
3 (100)	157 (100)	22 (100)	516 (100)	816 (100)	80,682 (100)

pizza (four), soup (three), rice (three), dip (one), and stuffing (one) but without further description. RTE products that have been extensively handled may be contaminated and were occasionally involved in outbreaks; these included hors d'oeuvres, cold snacks with sauces, and glazes (five outbreaks).

Low water activity does not allow bacterial growth in most baked goods or cake frosting, but there were a surprising number of outbreaks, some very large, associated with icing or frosting on cakes and glazed pastries (10 norovirus, 3 HAV, 3 *Salmonella,* 2 *S. aureus,* and 1 rotavirus outbreak). Direct contact between contaminated hands or arms and the ingredients was enough to transfer the agents to the product in sufficient quantity to cause illness. Examples of these are as follows: (i) 414 people became ill with norovirus infection after eating pastries served in a Winnipeg hotel *(45)*; (ii) 68 persons became infected with HAV, which was associated with eating buns and pickles handled by a worker in a Chattanooga fast food restaurant who was an intravenous drug user *(33)*; and (iii) 12 persons became infected with HAV that originated from an infected cook who contaminated cream while preparing pastries in a Glasgow restaurant *(13).*

The outbreaks that involved bacterial pathogens typically were associated with potentially hazardous foods that allowed growth, such as *Salmonella* (47 multiple foods; 34 meat, fish, and poultry; 16 salads; and 9 sandwiches) and *S. aureus* (13 meat and poultry, 6 sandwiches, and 5 egg and custard dishes). *Streptococcus pyogenes* was implicated in 17 outbreaks, of which 6 involved salads and 4 involved egg dishes. *Campylobacter* was implicated as the causative agent in three salad incidents and one each for custard and multiple foods. Parsley, hamburger, and Mexican food were the vehicles for three separate *E. coli* outbreaks. There were seven *Yersinia enterocolitica* outbreaks, three of which had unusual food sources: tofu *(48),* chitterlings *(28),* and chocolate milk *(3).*

The outbreak reports and publications from which we selected the 816 outbreaks associated with the food worker were of variable quality, utility, or both. Either the role of the food worker was not a major thrust of the article, and thus, there were limited data, or it was difficult to extract the relevant information regarding the role of the food worker in the cause or spread of the outbreak. For instance, some reports received extensive coverage in the media, while others were restricted to internal health department reports or state line listings, and only about one third (32.8%) were in peer-reviewed scientific publications. Large numbers of workers may be employed at any one establishment but are employed in shifts, employed on a part-time basis, or assigned to a specific job on a periodic basis. These groups of workers are sometimes difficult to identify and observe for symptoms during an outbreak investigation, and key index cases may be missed.

Detailed information on outbreak episodes involving homes, camping trips, or small restaurants is probably underrepresented in this study. In some cases, the worker may have been a victim of the infection rather than the cause, becoming ill at the same time as the customers or later. In other situations, the worker blatantly disregarded normal hygienic practices, which may have been a result of individual preferences or the accepted way of doing business in the establishment. The 816 outbreaks we studied showed concerns that have been previously documented: workers are asymptomatic and excrete the pathogen unknowingly while working, or they continue to prepare food when it is obvious to them, and sometimes others, that they are ill and maybe contaminating food. This seems to be in contrast to the 1988 World Health Organization study conducted by an international working group, which concluded that asymptomatic carriers of nontyphoidal *Salmonella, Shigella, V. cholerae,* and enteric viruses pose only minimal risks as long as good hygiene is practiced *(55).* All the line listings we collated are available on the IAFP website. The next stage of this project will be to examine the burden of the outbreaks in more depth to identify responsible factors more specifically.

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