Limitations to Successful Investigation and Reporting of Foodborne Outbreaks: An Analysis of Foodborne Disease Outbreaks in FoodNet Catchment Areas, 1998–1999

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To better understand factors associated with confirming the etiologic organism and identifying the food vehicle responsible for foodborne-disease outbreaks, we examined data from outbreaks reported in 1998 and 1999 through active surveillance by Foodborne Disease Active Surveillance Network (FoodNet) surveillance areas in 7 states. In 71% of these outbreaks, no confirmed etiology was identified, and in 46%, no suspected food vehicle was identified. Outbreaks involving ⩾10 cases were significantly more likely to have their etiology identified than were smaller outbreaks. In two-thirds of outbreaks in which an etiology was not confirmed, no stool specimens were collected for laboratory testing; in 55% of these outbreaks, neither clinical specimens nor food samples were tested. If the etiology of and factors contributing to foodborne-disease outbreaks are to be understood, adequate resources must be available to allow specimens to be collected and tested and epidemiologic investigations to be conducted appropriately.

Foodborne diseases cause an estimated 76 million illnesses and 5000 deaths in the United States each year; 82% of these illnesses are due to unknown agents [1]. Only a small proportion of the total number of foodborne infections are included in reported foodborne-disease outbreaks. From 1993–1997, a mean of 550 foodborne-disease outbreaks were reported in the United States annually, involving an average of 31 people each [2]. Although outbreaks provide a good opportunity to understand the epidemiology of foodborne illness, 68% of foodborne-disease outbreaks reported to the Centers for Disease Control and Prevention (CDC) have an unknown etiology [2]. There are numerous likely limitations to successful outbreak investigations. These may include delayed reporting, limited resources and competing priorities in health departments, limited collection or testing of specimens, ill persons who do not seek health care, and lack of cooperation from clinicians and laboratories.

Substantial national attention has recently focused on the quality and timeliness of national compilations of reported foodborne-disease outbreaks [3,4]. We therefore reviewed recent foodborne-disease outbreaks reported through the Foodborne Diseases Active Surveillance Network (FoodNet), a collaborative project among the CDC, the US Food and Drug Administration, the US Department of Agriculture, and the state health departments of FoodNet sureveillance areas

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(also known as "FoodNet sites"), which closely monitor foodborne disease in participating states. We examined these outbreaks to better understand factors associated with outbreak investigations that led to confirmation of the etiologic organism and identification of a food vehicle.

METHODS

We conducted this study in accordance with guidelines for human research as specified by the US Department of Health and Human Services. We analyzed data on foodborne-disease outbreaks (FBDOs) that were reported to FoodNet, the principal foodborne-disease surveillance component of the Emerging Infections Program of the CDC. Foodborne disease outbreaks were defined as the occurrence of ⩾2 cases of a similar illness resulting from the ingestion of a common food [2] and reported by a state health department as an FBDO. However, the reporting criteria of state health departments and local health officials varied by region and over time. Some reported clusters of unrelated persons complaining of illness, and others reported only thoroughly investigated outbreaks. Outbreaks occurring in 1998 or 1999 in counties under active FoodNet surveillance in both years were included in this analysis. Sites under active surveillance during this period had a total population of 20.7 million in 1998 and consisted of the states of Connecticut, Minnesota, and Oregon, and selected counties in California (Alameda and San Francisco), Georgia (Barrow, Bartow, Carroll, Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Newton, Paulding, Pickens, Rockdale, Spalding, and Walton), Maryland (Anne Arundel, Baltimore, Carroll, Harford, and Howard) and New York (Genesee, Livingston, Monroe, Ontario, Orleans, Wayne, and Yates).

Data collected included information on the number of cases, the etiologic agent, and implicated foods. Data were also collected on factors contributing to reported outbreaks. Codes for the contributing factors included 15 for "contamination factors" (such as "handling by an infected person or carrier of pathogen"), 12 for "proliferation/amplification factors" (such as "slow cooling" or "insufficient acidification"), and 5 for "survival factors" (such as "insufficient time and/or temperature during reheating").

To investigate possible factors affecting successful identification of an etiologic agent, FoodNet staff conducted a retrospective survey at each site in 2000. With this survey, they collected supplemental data on outbreaks that had occurred in 1999 in the FoodNet surveillance areas and gathered information on the number and types of specimens obtained, the methods of epidemiologic investigation, and the laboratory tests performed on the specimens. We performed statistical analyses on this data using χ^2 and Fisher's exact test and EpiInfo software, version 6.04c (CDC).

RESULTS

During 1998–1999, a total of 336 FBDOs involving a total of 6076 cases were reported in the surveillance area. The median number of cases per outbreak was 8 (mean cases, 18; range, 2–300 cases). The overall rate of reported FBDOs among all FoodNet sites during this period was 7.2 FBDOs per million population per year; for FBDOs with ⩾10 cases, the overall rate was 3.2 FBDOs per million per year. The rate of reported FBDOs varied substantially from year to year and among sites (figure 1). Of 336 reported outbreaks, 99 (29%) involved only 2 or 3 cases, and 88 (89%) of these small outbreaks were reported by a single state (Maryland).

Of the 336 reported FBDOs, 237 (71%) had no identified etiologic organism, 32 (10%) were due to *Salmonella,* 31 (9%) to Norwalk-like viruses (NLVs), 7 (2%) to *Escherichia coli* (5 enterohemorrhagic *E. coli* and 2 enterotoxigenic *E. coli*), 6 (2%) to *Shigella,* 6 (2%) to scombroid poisoning, 4 (1%) to *Clostridium perfringens,* and 13 (4%) to other etiologies (figure 2).

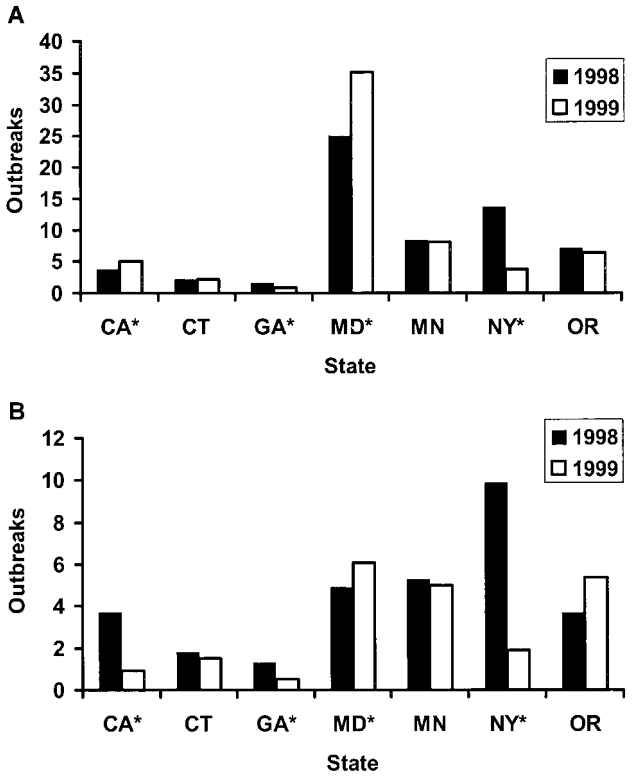

Figure 1. Annual rate of reported outbreaks of foodborne disease in FoodNet sites, 1998–1999, including all foodborne disease outbreaks *(A)* and only foodborne disease outbreaks involving ⩾10 cases *(B).* *States in which only selected counties participate in FoodNet. Outbreaks, outbreaks of foodborne disease per million population.

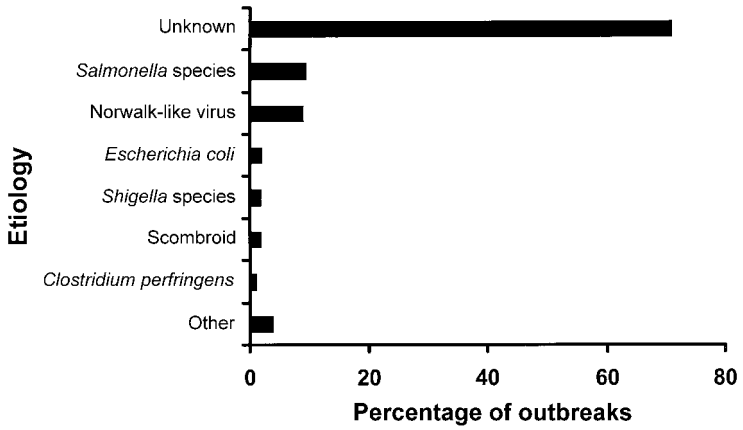

Figure 2. Confirmed etiologies of foodborne disease outbreaks reported in FoodNet sites, 1998–1999

Ten or more cases were involved in 151 (45%) of the reported outbreaks. Outbreaks involving ⩾10 cases were significantly more likely to have had an etiology identified than were outbreaks involving <10 cases (51 [37%] of 151 and 43 [23%] of 185, respectively; $P < .01$).

A food vehicle was identified in 182 (54%) of the 336 outbreaks. Of these, 58 (32%) reportedly were implicated on the basis of laboratory evidence and 51 (28%) on the basis of epidemiologic evidence. For the remaining outbreaks in which a food vehicle was identified, we lacked sufficient information to determine precisely how it was implicated. A wide variety of descriptors were used to describe the food vehicles implicated in transmission, and no single type of food item predominated.

At least 222 (66%) of the outbreaks were associated with restaurants, and an additional 30 (9%) were associated with catered events. Only 25 (7%) of the outbreaks were identified as being associated with private homes or gatherings. Insufficient descriptive information was available to determine precisely the setting of many outbreaks or the types of restaurants involved.

The 336 reported outbreaks involved a total of 6076 ill persons. Fifty FBDOs caused by bacterial pathogens that were included in routine FoodNet surveillance resulted in 381 reported culture-confirmed illnesses. In 1998, these FoodNet sites reported 9187 laboratory-confirmed cases of bacterial foodborne illness, and in 1999, they reported 8098 cases, including sporadic and outbreak-associated cases.

In 30 (9%) of the outbreaks, a food service worker was noted as the source of contamination. In 44 (13%) of the outbreaks, ⩾1 "contamination factor" was identified as a contributing factor in the outbreak. The most commonly noted contributing factors were "handling by an infected person or carrier of pathogen" (21 of 44 outbreaks) and "inadequate cleaning … leads to contamination of vehicle" (12 of 44 outbreaks). In 38 (11%) of the outbreaks, a contributing "proliferation/amplification" factor was identified, the most common of which was "allowing foods to remain at room or warm outdoor temperature for several hours" (18 of 38 outbreaks).

The retrospective survey was conducted on 115 (65%) of 177 outbreaks reported in 1999. Of these, 41 (36%) had a laboratory-confirmed etiology. Outbreaks with a confirmed etiology involved a median of 12 cases (mean cases, 26; range, 2–187 cases); outbreaks without a confirmed etiology had a median of 10 cases (mean cases, 15; range, 2–87 cases). Ten (24%) of 41 outbreaks investigated only by a local or county health department had their etiology identified, compared with 34 (46%) of 74 outbreaks in which a state health department or the CDC assisted in the investigation ($P = .03$).

Specimens of stool or implicated food were obtained for analysis in all 41 of the outbreaks with a confirmed etiology, with a median of 7 specimens per outbreak. Of the 74 outbreaks in which an etiology was not identified, no stool specimens were collected for 50 (68%), and neither clinical specimens nor food samples were tested for 41 (55%) (table 1). In outbreaks for which no etiology was confirmed but for which specimens were tested, a median of 3 specimens were collected (range, 1–10 specimens). Stool specimens were collected for 24 outbreaks in which an etiology was not confirmed. In 18 (75%) of these 24 outbreaks, the stool specimens were tested for *Salmonella* species; in 18 (75%), they were tested for *Shigella* species; in 17 (71%), they were tested for *Campylobacter* species; in 15 (63%), they were tested for NLVs; in 13 (54%), they were tested for *E. coli* O157:H7; in 11 (46%), they were tested for *Yersinia* species; in 10 (42%), they were tested for *C. perfringens;* and in 8 (33%), they were tested for *Bacillus cereus.* In 5 (21%) of these outbreaks, available specimens were tested for all of the pathogens listed; in 12 (50%) of the outbreaks, they were tested for at least *Salmonella, Shigella,* and *Campylobacter* species and *E. coli* O157:H7. No specimens were tested for *Vibrio* or *Listeria* species in these outbreaks.

Table 1. Data from a retrospective supplementary survey of outbreaks of foodborne disease occurring in 7 FoodNet sites, 1999

Variable	Etiology confirmed	No etiology confirmed
Outbreaks		
All	41 (100)	74 (100)
In which either stool or food specimens were collected for analysis	41 (100)	33 (45)
In which stool specimens were collected for analysis	38 (93)	24 (32)
Investigated by local or county health departments only	10 (24)	34 (46)
Investigated by a state health department or the CDC	31 (76)	40 (54)
Median no. of cases per outbreak	12	10

NOTE. Data are no. (%) of outbreaks, unless otherwise indicated. CDC, Centers for Disease Control and Prevention.

Not surprisingly, outbreaks in which ⩾1 stool specimen was collected were significantly more likely to have their etiology identified than outbreaks in which no stool specimens were collected (61% vs. 6%, respectively; $P < .001$). Outbreaks in which most stool specimens were collected within 3 days after illness onset were not more likely to have their etiology identified than were outbreaks in which most stool specimens were collected 1 week or more after illness onset (11 [19%] of 59 vs. 27 [53%] of 51, respectively).

DISCUSSION

In 71% of foodborne outbreaks reported in 1998 and 1999 at sites where an active surveillance system for foodborne disease existed, no etiologic agent was identified. These findings are similar to national results reported for 1993–1997 [2]. Although investigations of larger outbreaks were somewhat more successful in determining an etiologic agent, no etiology was identified in 63% of outbreaks involving ⩾10 cases. Nevertheless, thorough investigation and timely reporting of outbreaks is important. Useful information can be gathered even from outbreaks in which an etiology is not confirmed, such as data on the number of ill persons, the time and setting in which the outbreak occurred, and possible vehicles and potential environmental factors contributing to the outbreak.

The rates of reported foodborne outbreaks varied substantially from year to year and among FoodNet sites. This variation most likely reflects the fact that the CDC case definition for a foodborne outbreak is broad and does not exclude very small clusters of illness that may not undergo a thorough epidemiologic investigation [2]. Because the incidence of sporadic acute gastroenteritis in the general population is substantial, the fact that 2 people who shared a common meal subsequently experienced diarrhea does not ensure that they had the same illness or that an outbreak occurred. The reporting of outbreaks involving only 2 or 3 cases was particularly variable and may be highly dependent on the interpretation, resources, and priorities of persons responsible for investigating and reporting outbreaks in each state. Larger outbreaks appear to have been reported more consistently and were more likely to be investigated thoroughly. For this reason, it is useful to analyze larger outbreaks (for example, those with ⩾10 cases) separately when investigating the epidemiology of foodborne outbreaks.

A variety of factors may influence whether investigators are successful in identifying the microbial etiology of a foodborne outbreak. In more than two-thirds of outbreaks of unknown etiology, no stool specimens were collected. Furthermore, in investigations in which stool specimens were collected but an etiology was not identified, the specimens were often not tested for common causes of foodborne illness, including *Salmonella* species and NLVs. Stool specimens collected during outbreaks might be tested in public health laboratories for specifically requested pathogens but not necessarily for a comprehensive panel of pathogens. Stool specimens collected during the investigation of an outbreak may be handled differently than specimens routinely collected by health care providers and sent to clinical or commercial laboratories. Although many outbreak etiologies are confirmed by testing of stool specimens, most common causes of foodborne disease outbreaks can also be confirmed by isolation of the organism from epidemiologically implicated food, and testing of food samples is also an important aspect of foodborne disease outbreak investigation.

If attempts to identify the etiologies of foodborne outbreaks are to be successful, specimens must be obtained and tested appropriately. For this to occur, health officials must have sufficient resources to obtain an adequate number of specimens and deliver them to laboratories capable of testing for the appropriate pathogens, including common foodborne viruses. Evaluation of efficient specimen-collection and transport mechanisms for public health purposes may be useful. It is unclear why the etiologies of outbreaks in which specimens were collected promptly were not identified more often than those of outbreaks in which specimens were collected 1 week or more after disease onset. This could reflect a tendency to investigate

belatedly-reported outbreaks more often if they have certain characteristics that make successful identification of their etiology more likely.

Salmonella species was the most commonly identified etiology in outbreaks reported from FoodNet sites in 1998 and 1999, as it was nationally from 1993 through 1997 [2]. NLVs were the second most commonly identified pathogen in our study, identified in 9% of outbreaks. Although NLVs were estimated to cause 41% of foodborne outbreaks in Minnesota from 1981 through 1998 [5] and have been implicated in numerous outbreak reports in recent years [6], they were the identified etiology in only 0.3% of nationally reported outbreaks in 1993 through 1997 [2]. In contrast, using RT-PCR in a 1996–1997 study of 90 outbreaks in 33 states in which bacterial agents had been ruled out or specimens were referred to the CDC because of clinical suspicion of NLVs, investigators detected NLVs in specimens from 96% of the outbreaks [7]. This variation in the proportion of outbreaks attributed to NLVs reflects differences in the availability of NLV diagnostic capacities and in the effectiveness of screening for likely etiologies on the basis of symptom profiles. It is likely that the increase in recognition of NLVs as the etiology of outbreaks in our study reflects the increase in the availability of diagnostic PCR in state health department laboratories. Testing for NLVs was performed in one-half of the outbreaks in which stool specimens were obtained but no etiology was identified. This suggests that many undiagnosed outbreaks may be due to other or unknown agents. Further advances in confirming the etiologies of outbreaks will rely on increasing the frequency of stool specimen collection and increasing access to thorough diagnostic testing.

We found that outbreaks investigated only by local or county health departments were less likely to have their etiology identified than outbreaks investigated by state or federal agencies. This may, however, reflect a bias of larger agencies to participate in the investigation of larger outbreaks, in which the probability of identifying the cause is likely greater no matter who is investigating. Nonetheless, the relative success of investigations led by state and federal agencies reinforces the importance of ensuring adequate resources for investigating and responding to outbreaks at all levels of the public health system.

The results of our study suggest that patients with culture-confirmed illnesses associated with reported FBDOs account for a small proportion (<3%) of all cases of infection with culture-confirmed enteric pathogens reported to the FoodNet active surveillance program. Outbreak investigations continue to contribute substantially to our understanding of the epidemiology of foodborne illness, but it is important to understand that illnesses unrelated to recognized outbreaks may have very different epidemiologic features.

Most of the outbreaks reported in our study were associated with restaurants, although this may represent disproportionate reporting of restaurant-associated illnesses. Studies have shown that, contrary to popular opinion, 80% of inadequately cooked hamburgers were prepared in the home [8]. In the United Kingdom and The Netherlands, a large majority of outbreaks caused by *Salmonella* and *Campylobacter* infections involve only members of a single household, and in Spain, nearly 50% of foodborne infections were reported to originate in the home [9]. Alternatively, our finding may reflect a true increased risk to restaurant patrons. Additional FoodNet studies are being planned to examine this question.

Only a small proportion of the outbreak reports we examined included any information on food preparation or handling practices that might have contributed to the outbreak. Identifying specific contributing factors and the underlying antecedent causes leading to these outbreaks is important to developing practical and effective methods of intervention to prevent outbreaks of foodborne infection. To improve the usefulness of outbreak reporting, health officials must better identify and report contributing and antecedent factors.

Because our study was based on data from outbreaks reported in areas with intensive surveillance for foodborne illness, our results may not reflect what occurs in other areas of the country, where intensive investigation and reporting of outbreaks are less likely. The rate of reported outbreaks from FoodNet sites was higher than national rates in previous years [2], yet it is of interest that the percentage of outbreaks without a confirmed etiology in the FoodNet areas was consistent with national figures. Thus, the lessons learned from examining outbreaks within FoodNet may be useful elsewhere as well.

Despite substantial limitations in the current systems for reporting FBDOs, the investigation of foodborne outbreaks provides an important opportunity to better understand the epidemiology of foodborne illness and develop preventive interventions. The CDC, other federal partners, and FoodNet sites are participating in several ongoing efforts to address the current limitations to successfully investigating and reporting outbreaks. The CDC's Emerging Infections Program and Expanded Laboratory Capacity programs are helping to improve the capacity of many state health department laboratories to promptly and reliably identify NLVs and other common etiologies of foodborne illness, and to characterize pathogens by PFGE.

Laboratories in 6 of the 9 states involved in FoodNet in 2001 are currently able to test specimens for NLVs. Nationwide, 5 additional state health department laboratories and 1 county health department laboratory also have the capacity to test for NLVs. The CDC recently established the Outbreak Response and Surveillance Unit within its Foodborne and Diarrheal Diseases Branch to improve the uniformity, completeness, and timeliness of outbreak reporting. A new Web site, established by this unit, provides important tools for investigating a food-

borne outbreak, as well as ready access to foodborne-outbreak data (available at http://www.cdc.gov/ncidod/dbmd/outbreak). Other projects are under way to evaluate improved collection of stool specimens during outbreak investigations using delivered, self-contained specimen collection kits. A new program is also being instituted with the support of the US Food and Drug Administration, the Food Safety Inspection Service, the National Center for Environmental Health, and FoodNet to establish an "Environmental Health Specialist Network" (also known as "EHS-Net") that will work to identify important contributing factors and assess other issues related to environmental investigations during outbreaks. These changes will ultimately help improve foodborne-disease outbreak investigations and further elucidate the epidemiology of foodborne disease in the United States.

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