SUPPLEMENT ARTICLE

Characteristics of Foodborne Disease Outbreak Investigations Conducted by Foodborne Diseases Active Surveillance Network (FoodNet) Sites, 2003–2008

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Background. A mean of ≥1000 foodborne disease outbreaks (FBDOs) causing ≥20 000 illnesses are reported to the Centers for Disease Control and Prevention (CDC) annually. We evaluated characteristics of successful outbreak investigations (ie, those that identified an etiologic agent or food vehicle) in the Foodborne Diseases Active Surveillance Network (FoodNet).

Methods. FBDOs were defined as the occurrence of ≥2 cases of a similar illness resulting from ingestion of a common food. FBDOs reported to CDC Foodborne Disease Outbreak Surveillance System during 2003–2008 with FoodNet supplemental data available were included in the analyses.

Results. Data regarding 1200 FBDOs were available. An etiologic agent was confirmed in 715 (60%); a food vehicle was identified in 387 (32%). At least 4 fecal specimens were collected in 425 of 639 outbreaks (67%) with a confirmed etiologic agent and 48 of 232 (21%) without a confirmed etiologic agent (odds ratio [OR], 7.6; 95% confidence interval [CI], 5.3–10.9). A food vehicle was identified in 314 (47%) of 671 outbreaks investigated using a case-control or cohort study, compared with only 73 (14%) of 529 outbreaks investigated by using other methods (OR, 5.5; 95% CI, 4.1–7.3). At least 1 barrier affecting the success of the investigation was reported for 655 outbreaks, including too few patients (n = 172; 26%), too few stool specimens (n = 167; 25%), and too few control subjects (n = 152; 23%).

Conclusions. Etiologic agent and vehicle are frequently undetermined in FBDOs. Greater emphasis on fecal specimen collection and overcoming barriers to pursuing analytic epidemiologic studies can improve ascertainment of these factors.

A mean of ≥1000 foodborne disease outbreaks (FBDOs) causing ≥20 000 illnesses are reported annually to the Centers for Disease Control and Prevention (CDC) Foodborne Disease Outbreak Surveillance System (FDOSS) [1]. Outbreak surveillance is necessary for understanding the epidemiology of foodborne diseases. Successful outbreak investigations can reveal causes of illness, vehicles of transmission, and settings of exposure [2]. However, a food vehicle is undetermined in the majority of FBDOs, and an etiologic agent is often not identified [3].

Most FBDOs are investigated by local and state health department personnel and reported to FDOSS. Although the findings of individual outbreak investigations are frequently reported in the scientific literature, analyses of investigation characteristics using systematic data collected for a sizeable number of outbreaks are rare. To supplement national FDOSS surveillance, enhanced surveillance for FBDOs is conducted in 10 sites that participate in the Foodborne Diseases Active Surveillance Network (FoodNet) [4, 5]. FoodNet is a collaborative program among 10 state health departments, the CDC, the US Department

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of Agriculture Food Safety and Inspection Service (USDA-FSIS), and the Food and Drug Administration (FDA). FoodNet collects data intended to provide insight into characteristics of the outbreak investigations. To better understand barriers to successful outbreak investigations and focus improvement efforts, we reviewed multiple years of FDOSS and supplemental data collected by FoodNet.

METHODS

Data regarding FBDOs reported during 2003–2008 in the FoodNet catchment area were analyzed. During 2003–2008, the FoodNet catchment area included Connecticut, Georgia, Maryland, Minnesota, Oregon, and Tennessee and selected counties in California, Colorado, and New York; New Mexico joined FoodNet in 2004. In 2008, the FoodNet catchment area included 46 million persons (15% of the US population).

For each outbreak included in the analysis, we combined data available from FDOSS and FoodNet. During 2003–2008, FDOSS data were collected using the CDC Electronic Foodborne Outbreak System form 52.13, Investigation of a Foodborne Outbreak. For each outbreak, available data included the number of illnesses, earliest illness onset date, exposure location, investigation methods, implicated foods, etiologic agent, and location where food was prepared and eaten [6]. FoodNet provided supplemental data concerning outbreak recognition and reporting, investigation design, specimen testing, and barriers impeding the investigation by using 3 slightly different data collection forms during the periods 2003–2005, 2006–2007, and 2008. Therefore, denominators for certain data fields varied. Outbreaks missing either FDOSS or FoodNet data or those with multistate exposures were excluded from analysis.

An FBDO was defined as the occurrence of ≥2 cases of a similar illness resulting from the ingestion of a common food. Illness onset date in the earliest case patient was used to assign the month and year of the outbreak. An outbreak was classified as having an implicated food vehicle when ≥1 food was suspected as a result of statistical evidence from epidemiologic investigation or laboratory evidence. CDC criteria were used to define a confirmed etiologic agent [7]. An FBDO investigation was deemed to be successful when a food vehicle was identified and an etiologic agent was confirmed. A categorical variable for outbreak size was created by using quartiles of the number of illnesses. Federal agency involvement included the CDC, USDA-FSIS, or FDA. State agency involvement included state health departments, FoodNet groups, or state agriculture departments.

Statistical analyses were performed by using SAS software, version 9.1 (SAS Institute), or Excel software, version 97-2003 (Microsoft). Unless otherwise specified, odds ratios (ORs) were adjusted for size of the outbreak using the number of associated illnesses as a continuous variable in SAS multivariate logistic regression models. The CDC classified this work as public health surveillance, and therefore it was not subject to institutional review board review.

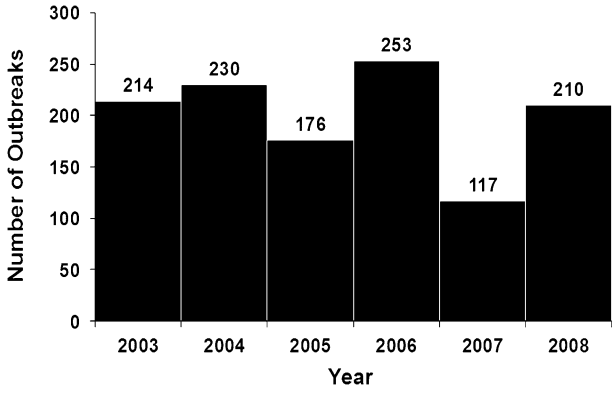

Figure 1. Number of foodborne disease outbreaks by year, FoodNet, 2003–2008.

RESULTS

Data for 1200 FBDOs occurring in FoodNet sites during 2003–2008 were included in the analysis. A mean of 200 FBDOs were reported annually (range, 117–253) (Figure 1). The mean annual rate was 4.5 FBDOs/1 million population (Table 1). Site-specific rates ranged from 1.1 to 8.9 FBDOs/1 million population. Variability in the frequency of FBDO investigation characteristics was observed among sites, including in the proportions of investigations in which ≥1 fecal specimen was collected, an analytic study was conducted, an etiologic agent was confirmed, or a food vehicle was identified (Table 1). Few FBDO investigations were successful in confirming an etiologic agent and identifying a food vehicle (262 of 1200; 22%). Therefore, we describe characteristics associated with each separately.

Confirming an Etiologic Agent

A confirmed etiologic agent was reported for 715 (60%) of the 1200 outbreaks. Among these, a food vehicle was also identified for 262 (37%). Outbreaks with a confirmed bacterial etiologic agent (n = 253) most frequently occurred during late spring and summer. In contrast, outbreaks with a confirmed viral etiologic agent (n = 426) most frequently occurred during late fall and winter (Figure 2). The seasonal distribution of the 485 outbreaks lacking a confirmed etiologic agent closely mirrors that of confirmed viral outbreaks.

The number of illnesses caused per outbreak was available for 1111 outbreaks (18 593 cases; mean, 17 cases; range, 2–273 cases); among these, 673 outbreaks also had a confirmed

Table 1. Number of Foodborne Disease Outbreaks and Investigation Characteristics, by State, FoodNet, 2003–2008

State	Outbreaks Reported, No. (n = 1200)	Mean Annual Rate, Outbreaks/ 1 Million Population[a]	Outbreaks, No. (%)				
			≥1 Fecal Specimen Collected	Analytic Study Conducted	Confirmed Etiologic Agent	Food Vehicle Identified	Confirmed Etiologic Agent and Food Vehicle Identified
California[b]	45	2.3	22 (49)	16 (36)	20 (44)	8 (18)	3 (7)
Colorado[b]	113	6.9	70 (62)	67 (59)	58 (51)	27 (24)	18 (16)
Connecticut	71	3.4	69 (97)	53 (75)	56 (79)	36 (51)	28 (39)
Georgia	151	2.6	100 (66)	50 (33)	73 (48)	34 (23)	25 (17)
Maryland	155	4.6	88 (57)	62 (40)	60 (39)	46 (30)	24 (15)
Minnesota	279	8.9	232 (83)	211 (76)	195 (70)	140 (50)	97 (35)
New Mexico[c]	11	1.1	9 (82)	3 (27)	9 (82)	3 (27)	2 (18)
New York[b]	77	3.0	50 (65)	42 (55)	46 (60)	33 (43)	19 (25)
Oregon	185	8.2	147 (79)	112 (61)	124 (67)	42 (23)	34 (18)
Tennessee	113	3.0	92 (81)	55 (49)	74 (65)	18 (16)	12 (11)
Mean	120	4.4	… (73)	… (56)	… (60)	… (32)	… (20)

[a] Census Bureau population estimate on 1 July 2008, used for rate calculation.

[b] Data collected in selected counties.

[c] Data collected in 2004–2008.

etiologic agent. Among 227 outbreaks with a confirmed bacterial etiologic agent and data regarding the number of reported illnesses, the mean was 18 illnesses (median, 9 illnesses; range, 2–212 illnesses). Among 413 outbreaks with a confirmed viral etiologic agent, the mean was 23 illnesses (median, 14 illnesses; range, 2–297 illnesses). Among 438 outbreaks without a confirmed etiologic agent, the mean was 11 illnesses (median, 7 illnesses; range, 2–137 illnesses). The proportion of outbreak investigations successful in confirming an etiologic agent increased as the number of illnesses increased (Figure 3).

Data regarding the number of fecal specimens submitted was available for 639 of 715 outbreaks (89%) with a confirmed etiologic agent and 232 of 485 (48%) without a confirmed etiologic agent. At least 4 fecal specimens were collected in 425 of 639 outbreaks (67%) with a confirmed etiologic agent and 48 of 232 (21%) without one (adjusted OR, 7.2; 95% confidence interval [CI], 4.9–10.6). The odds of confirming an etiologic agent did not further improve with the collection of >4 fecal specimens. The proportion of outbreaks with a confirmed etiologic agent remained high when the median number of days from onset of diarrhea or vomiting to collection of fecal specimens was 0–3 days (70%), 4–7 days (78%), or 8–14 days (69%).

A higher proportion of outbreaks with a federal or state agency substantively involved in the investigation had a confirmed etiologic agent (532 of 750; 71%), compared with

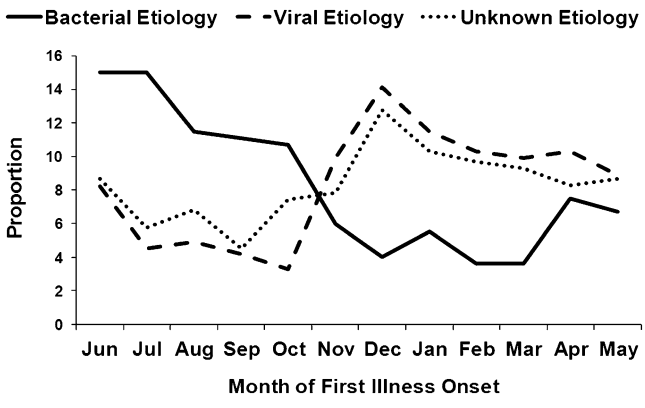

Figure 2. Proportion of foodborne disease outbreaks by month and confirmed etiologic agent, FoodNet, 2003–2008.

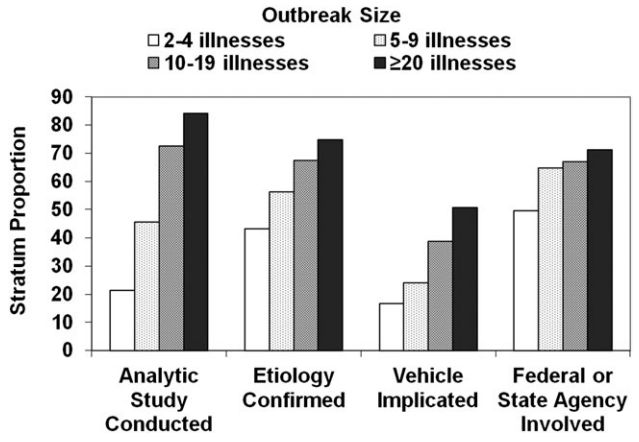

Figure 3. Outbreak characteristics by size, FoodNet, 2003–2008.

Table 2. Source of Initial Foodborne Disease Outbreak Recognition by Confirmed Etiologic Agent, FoodNet, 2003–2008

Source	Outbreaks, No. (%)		
	All (n = 1168)	Bacterial Etiologic Agent (n = 246)	Viral Etiologic Agent (n = 418)
Private citizen	870 (74)	80 (33)	363 (87)
Reportable disease surveillance	89 (8)	75 (30)	11 (3)
Medical professional report	125 (11)	43 (17)	34 (8)
Pulsed field gel electrophoresis match	33 (3)	33 (13)	0 (0)
Syndromic surveillance	3 (<1)	3 (1)	0 (0)
Other	48 (4)	12 (5)	10 (2)

investigations involving only local health departments (175 of 435; 40%; adjusted OR, 3.4; 95% CI, 2.6–4.4). Among the 650 outbreaks with a confirmed etiologic agent and data regarding where the pathogen was first identified, 471 (72%) were by public health laboratories, 173 (27%) by clinical laboratories, and 6 (1%) by the CDC. In the majority of bacterial outbreaks (156 of 237; 66%), the etiologic agent was first identified by clinical laboratories. The vast majority of viral outbreaks (390 of 402; 97%) were first confirmed by local or state public health laboratories.

Implicating a Food Vehicle

A food vehicle was implicated in 387 of the 1200 outbreaks (32%). Among these, an etiologic agent was also confirmed for 262 (68%). The proportion of outbreaks with an implicated food vehicle increased as the number of cases increased (Figure 3). A food vehicle was implicated in approximately half of outbreaks (314 of 671; 47%) investigated by using a case-control or cohort study, but the success rate decrease to approximately 1 in 7 (73 of 529; 14%) when these methods were not used (adjusted OR, 4.9; 95% CI, 3.6–6.7). A higher proportion of outbreaks with a federal or state agency substantively involved in the investigation had a food vehicle implicated (293 of 750; 39%), compared with investigations involving only local health departments (89 of 435; 20%; adjusted OR, 2.4; 95% CI, 1.8–3.2). However, the effect of agency involvement on identifying a food vehicle was modified by the type of study conducted. Among 253 FBDOs with a confirmed bacterial etiologic agent, only 91 investigations (36%) included food specimen testing. After adjusting for outbreak size, the odds of identifying a food vehicle was 4.9 times as likely when food specimens were tested (95% CI, 2.8–8.5), compared with investigation that did not include food specimen testing.

Other Characteristics

Food vehicle contamination occurred before final preparation or serving in 33 outbreaks (26%) and at the time of preparation or serving in 96 of 129 outbreaks (74%) for which these data were available. Among 1088 outbreaks in which food was prepared in a single location, the most common sites were a restaurant or delicatessen (n = 697; 64%), private home (116; 11%), or caterer (n = 72; 7%). Of 184 outbreaks with data regarding where the contaminated food was served, 158 (86%) were served in a single establishment or at a single event (eg, restaurant, wedding, party, or conference).

Among 1168 outbreaks with data available regarding how the outbreak was initially recognized by public health authorities, the majority (74%) were reported by private citizens (Table 2). Among viral outbreaks, 363 of 418 (87%) were first reported by private citizens. In contrast, only one-third of bacterial outbreaks (80 of 246; 33%) were first identified in this manner. Bacterial outbreaks were often recognized by routine health department foodborne disease surveillance (75 of 246; 30%), health care provider reporting (43 of 246; 17%), and molecular subtyping of isolates (33 of 246; 13%).

Data regarding agencies substantively involved in the investigation were available for 1185 outbreaks (99%); 435 investigations (37%) were conducted solely by local health departments, 556 (47%) were conducted by local health departments with participation by state agencies, and 54 (5%) involved local, state, and federal partners. Local health departments were not involved in 140 outbreak investigations (12%). The proportion of investigations with involvement from state or federal agencies increased as the number of reported cases per outbreak increased (Figure 3). The proportion of outbreaks investigated by using a case-control or cohort study design (eg, analytic study) also increased as the number of reported cases increased (Figure 3).

In 655 of 1200 outbreaks, ≥1 barrier affecting the success of the investigation was reported, including too few cases (172; 26%), lack of cooperation from cases (159; 24%), paucity of stool specimens (167; 25%), too few controls available (152; 23%), or inability to identify good controls (68; 10%). Investigations were also affected by delayed notification of local health departments (116; 18%).

DISCUSSION

Our findings document investigation characteristics associated with successfully identifying the etiologic agent and

food vehicle and inform several assumptions regarding FBDOs. FBDO investigations are most often successful when ≥4 stool specimens are obtained and analytic studies are conducted, although barriers to using these tools exist. FBDOs lacking multistate exposure are usually associated with food contaminated during preparation and served at a single restaurant and they are mainly recognized and investigated by local and state public health agencies.

During the 6-year reporting period, substantial fluctuation occurred in the number of FBDOs reported annually. This might reflect true changes in the incidence of disease (eg, introduction of new norovirus strains) or surveillance artifacts (eg, changes in laboratory practices). The seasonality of FDBOs demonstrates the difference in trends between bacterial and viral etiologic agents and supports the thought that most outbreaks with unconfirmed etiologic agents are caused by viral agents.

Substantial variability in the site-specific rates and characteristics of FBDO investigations was observed. This variability might be attributable to state-based differences in resources for active outbreak surveillance, investigation and reporting, commitment to FBDO investigation amid competing priorities, interpretation of the FBDO case definition, or changes in public health capacity or personnel. Analyses of site-specific data regarding these complex concerns are needed to complement the findings of this study.

We identified multiple characteristics associated with successfully confirming an outbreak etiologic agent that provide insights into improving investigative methods. Collection of ≥4 fecal specimens markedly improved rates of confirming an etiologic agent and as experimental studies have reported [8], there is value in collecting fecal specimens a week or more after symptom onset. The use of stool collection kits delivered to patients can improve the frequency of specimen collection and confirmation of etiologic agent in FBDOs [9]. In addition to hand delivery, health departments should consider establishing convenient pick-up and drop-off locations or use other methods for delivery and return (eg, mail or courier) to increase the frequency of fecal specimen collection and testing.

Building capacity to attribute foodborne diseases to the food vehicle responsible for illness is an important goal of the CDC, USDA-FSIS, and FDA [10]. We found that the odds of successfully identifying a food vehicle were substantially increased among FBDO investigations that included an analytic study (case-control or cohort study). Among FBDOs with a confirmed bacterial etiologic agent, we found a strong association between identifying a food vehicle and food specimen testing. Food specimens were collected in 36% of bacterial FDBO investigations. Investigators are encouraged to collect appropriate food specimens for microbiologic analyses more frequently, particularly when a bacterial agent is suspected. Food specimens are usually not helpful in identifying a food vehicle when a viral agent is suspected, because there are no standard methods for the identification of viruses in food. Therefore, food vehicles must be identified using statistical evidence gathered during case-control and cohort studies of FBDOs with a viral or unknown etiologic agent.

We determined that clinical laboratories identified the etiologic agent in approximately two-thirds of bacterial FBDOs and that local or state public health laboratories typically identified viral etiologic agents. These results are not surprising because the majority of clinical laboratories lack capacity to identify viral agents (eg, norovirus) in fecal specimens. State public health laboratories can detect bacterial or viral pathogens in fecal specimens but frequently only do so at the request of public health agencies as part of an outbreak investigation. The frequency and rapidity of outbreak detection can be improved if clinicians increase the frequency of fecal specimen collection from patients presenting with gastrointestinal illness [11] and promptly notify public health agencies when clusters are suspected.

Certain observations remind us that FBDOs are mainly recognized and handled locally. Despite attention given to use of molecular subtyping methods and complex surveillance systems (eg, syndromic surveillance) for detecting outbreaks nationally, the overwhelming majority of viral outbreaks and approximately one-third of bacterial outbreaks in this study were first reported by private citizens. Therefore, methods to systematically receive and review complaints from members of the general public are paramount to recognizing and responding to FBDOs. Routine health department surveillance detected approximately 30% of bacterial outbreaks, emphasizing the benefits of a strong public health infrastructure at the state and local level. Molecular subtyping methods are invaluable for detecting bacterial outbreaks with multistate exposures that require a coordinated multiagency investigational approach. Multistate outbreak investigations often help identify new food vehicles of transmission or new factors contributing to foodborne illness. However, among all outbreaks reported nationally, only 1% are attributed to multistate exposures and these cause only 5% of outbreak-associated illnesses [1].

In this study of 1200 FBDOs lacking multistate exposures, the majority were attributed to exposures outside the home and frequently caused by food contaminated at the time of preparation or serving. Approximately one-quarter of outbreaks were attributed to contamination that occurred before final preparation or serving (eg, produce contaminated before arrival at a restaurant). National programs to protect the food supply from farm to fork are vital for reducing the overall burden of foodborne illness and should emphasize safe food preparation by restaurant workers.

Epidemiologists reported difficulty recruiting patients and control subjects and obtaining fecal specimens as the barriers most frequently affecting outbreak investigations. Additional training in conducting epidemiologic studies and development of new methods for identifying and contacting patients and control subjects might help overcome these barriers. Free Internet tools can be useful for obtaining published telephone numbers, but creative methods for contacting cell phone–only users are needed (eg, social networking sites or fee-for-use cell phone directories). Credit card receipts and shopper loyalty card records can help identify patrons and assist in completing food histories. Internet-based questionnaires can increase participation in epidemiologic studies and reduce the burden of data collection on state and local health departments [12].

FDOSS and FoodNet data collected and submitted to the CDC might have been incomplete or imprecise. Data collection instruments were developed with consensus from state and federal stakeholders and definition of terms, instructions for completion, or ongoing training were informally provided to data collectors. All questions were not asked in all years during 2003–2008 and the interpretation of questions or definitions might have changed with time. Often, final data are not reported to the CDC by staff directly involved in the outbreak investigation. Our findings are likely to be biased toward larger outbreaks, because outbreaks with a limited number of illnesses are less likely to be recognized, reported, and investigated. FoodNet sites are funded to conduct active surveillance for foodborne disease; therefore, these findings might not be generalizable to other US populations under surveillance. For example, the proportion of outbreaks with a laboratory confirmed etiologic agent was higher in our study (60%) than reported nationally (45%) [3], demonstrating that barriers to successful investigations are probably even more substantial in other states.

To elucidate such critical components as the etiologic agent, food vehicle, and setting of foodborne illnesses, public health agencies must improve their responses to FBDOs. Prompt detection can be improved through implementation of systems to receive and review complaints from the public and increased participation from clinicians. Improved fecal specimen collection methods and analytic epidemiologic study execution can improve identification of etiologic agent and food vehicle, respectively. Timely detection and successful FBDO investigations can further define the epidemiology of foodborne diseases and facilitate implementation of measures to prevent and control future outbreaks.

Notes

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