Deaths Associated With Bacterial Pathogens Transmitted Commonly Through Food: Foodborne Diseases Active Surveillance Network (FoodNet), 1996–2005

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Background. Foodborne diseases are typically mild and self-limiting but can cause severe illness and death. We describe the epidemiology of deaths associated with bacterial pathogens using data from the Foodborne Diseases Active Surveillance Network (FoodNet) in the United States.

Methods. We analyzed FoodNet data from 1996–2005 to determine the numbers and rates of deaths occurring within 7-days of laboratory-confirmation.

Results. During 1996–2005, FoodNet ascertained 121,536 cases of laboratory-confirmed bacterial infections, including 552 (.5%) deaths, of which 215 (39%) and 168 (30%) were among persons infected with Salmonella and Listeria, respectively. The highest age-specific average annual population mortality rates were in older adults (≥65 years) for all pathogens except Shigella, for which the highest age-specific average annual population mortality rate was in children <5 years (.2/1 million population). Overall, most deaths (58%; 318) occurred in persons ≥65 years old. Listeria had the highest case fatality rate overall (16.9%), followed by Vibrio (5.8%), Shiga toxin–producing Escherichia coli O157 (0.8%), Salmonella (0.5%), Campylobacter (0.1%), and Shigella (0.1%).

Conclusions. Salmonella and Listeria remain the leading causes of death in the United States due to bacterial pathogens transmitted commonly through food. Most such deaths occurred in persons ≥65 years old, indicating that this age group could benefit from effective food safety interventions.

Foodborne diseases are an important public health problem in the United States, resulting in an estimated 48 million illnesses annually [1, 2]. Although most are mild and self-limiting, more serious illness does occur, resulting in an estimated 128,000 hospitalizations and 3000 deaths. Serious illness leading to death can occur in patients who develop neurologic, hepatic, and renal syndromes, those who become bacteremic, or have complications from surgery. Young children, older persons, and persons with immunocompromising conditions are often more vulnerable and at a higher risk of complications. Additionally, foodborne infections may exacerbate life-threatening illnesses in persons with preexisting medical conditions. Though uncommon, deaths account for most of the costs, including medical care, associated with foodborne infections [3, 4]. Moreover, these deaths may be preventable. To better
understand the burden and epidemiology of deaths from foodborne diseases in the United States, we analyzed 10 years (1996–2005) of population-based active surveillance data from the Foodborne Diseases Active Surveillance Network (FoodNet).

METHODS

FoodNet is an ongoing collaborative surveillance activity of the Centers for Disease Control and Prevention (CDC), the US Department of Agriculture-Food Safety and Inspection Service, the US Food and Drug Administration, and state health departments participating in the CDC's Emerging Infections Program. When established in 1996, FoodNet comprised 5 surveillance areas (Minnesota, Oregon, and selected counties in California, Connecticut, and Georgia). Since then, the FoodNet surveillance area has expanded to include the populations of the entire states of Connecticut, Georgia, Maryland, Minnesota, New Mexico, Oregon, and Tennessee and selected counties in California, Colorado, and New York. From 1996 to 2005, the surveillance population increased from 14.2 million persons (5% of the US population) to 44.9 million persons (15% of the US population).

Since 1996, FoodNet has conducted active, population-based surveillance for laboratory-confirmed infections due to 7 bacterial foodborne pathogens transmitted commonly through food: Campylobacter, Listeria monocytogenes, Salmonella, Shigella, Shiga toxin–producing Escherichia coli (STEC) O157, Vibrio, and Yersinia [5]. To ascertain cases, each surveillance area has established reporting procedures with all clinical laboratories serving the FoodNet surveillance area. A FoodNet case is defined as an instance of laboratory-confirmed Campylobacter, STEC, L. monocytogenes, Salmonella, Shigella, Vibrio, or Yersinia (non-pelit) from a resident of the FoodNet catchment area during a given time period (eg, calendar year). Laboratory-confirmed cases of infection in residents in the FoodNet catchment area are reported at least monthly, and FoodNet personnel routinely contact the clinical laboratories to ensure complete case ascertainment. Data are collected on the case patient's age, sex, county of residence, specimen source (eg, stool, blood), hospitalization status, and outcome (ie, alive or dead). Infections are considered invasive if the pathogen was isolated from blood or another normally sterile site; if both invasive and noninvasive isolates are obtained, the invasive isolate takes precedence for FoodNet reporting. FoodNet surveillance includes reports of pregnant women who develop Listeria infection, as well as infants in whom culture yields Listeria. For this analysis, Listeria infection cases included only isolates from a normally sterile site or placental or fetal tissue. Data were collected as part of public health surveillance activities as determined by the CDC and institutional review boards from participating sites.

In FoodNet, infection-related hospitalization is defined as overnight admission to the hospital within 7 days of the specimen collection date. Patient outcome (alive or dead), determined by interviews with patients, family members, or healthcare professionals or by medical chart review, is recorded at 7 days after specimen collection or, for case patients who are hospitalized, at hospital discharge, whichever is later. For this analysis, we assumed that patients with an unknown outcome were alive [6]. We conducted a sensitivity analysis to assess the impact of this assumption by excluding cases with unknown patient outcome and comparing the results.

The case fatality rate (CFR) was calculated by dividing the number of deaths by the number of laboratory-confirmed cases of infection and multiplying by 100. We determined the number of deaths and CFR for each pathogen and compared CFRs by pathogen for infections in which the pathogen was isolated from a normally sterile site (eg, blood, cerebrospinal fluid, bone) with infections isolated from a nonsterile site (eg, stool or urine) [7]. We also compared CFRs by age group (0–4, 5–64, and ≥65 years old) and examined trends overall and by age group. Annual population mortality rates (annual number of deaths/1 million population) by pathogen and age group were averaged over the 10-year period using US census data for the population of the surveillance area. Data were analyzed using SAS software (version 9.1).

RESULTS

From 1996 to 2005, FoodNet identified 121,536 laboratory-confirmed cases of infection with Campylobacter, L. monocytogenes, Salmonella, Shigella, STEC O157, Vibrio, or Yersinia. A total of 552 deaths (5% of cases) were recorded during the 10-year period. Most deaths (n = 492; 89%) were among hospitalized patients, and, although sterile-site infections accounted for only 4% (n = 4789) of all laboratory-confirmed bacterial infections, 61% of deaths (n = 336) occurred in persons in whom the pathogen was cultured from a normally sterile site. The CFR for infections in which the pathogen was isolated from a normally sterile site was 7.0%, compared with 0.2% for pathogens isolated from a nonsterile site, usually stool (relative risk, 37.15; 95% confidence interval, 31.43–43.92) (Table 1).

Most cases of infection were due to Campylobacter or Salmonella; however, the proportion of case patients with Salmonella infection who died was 4 times higher than that among those with Campylobacter infection (Table 1). Overall, the largest numbers of deaths occurred among patients infected with Salmonella (39% of deaths) or L. monocytogenes (30% of deaths). L. monocytogenes and Vibrio, pathogens causing low-incidence infections, had the highest CFRs (16.9% and 5.8%, respectively). Among infections in which the pathogen was isolated from a normally sterile site, Salmonella and Listeria caused most cases and deaths, and Vibrio and Listeria had the highest CFRs (35.3% and 16.9%, respectively). Nonsterile site infections for Campylobacter, Salmonella, Shigella, STEC O157,
Vibrio, or Yersinia had relatively low CFRs; the highest was .8% for STEC O157 infections. Overall, most deaths occurred in persons 65 years of age (318 of 552; 58%) (Table 2). The highest age-specific average annual population mortality rates were seen in older adults (65 years) for infection with each pathogen, except Shigella infection, in which the highest average annual population mortality rate was in children 0–4 years of age (.17/1 million population). In this age group, the highest average annual population mortality rate was for STEC O157 infection (.67/1 million population), followed by Listeria and Salmonella. Listeria had the highest CFR across all age groups. The second-highest CFR was STEC O157 among children 0–4 years old and Vibrio among persons 5 years old.

Sixty-one pregnant women were identified with laboratory-confirmed listeriosis. No deaths were reported among them; however, of 47 women with a known fetal outcome, 24 (51%) had an abortion or stillbirth. Overall, among the 121,536 reported cases, 19,788 (16%) had an unknown outcome. When these cases were excluded from the analyses, results did not change substantially. In particular, the ranking of CFRs did not change overall or within subgroups.

**DISCUSSION**

We examined deaths among persons with laboratory-confirmed bacterial infections transmitted commonly through food, using

### Table 1. Laboratory-Confirmed Infections and Deaths, Case Fatality Rate (CFR), and Average Annual Population Mortality Rate (AAPMR) by Pathogen for All Infections and Sterile and Nonsterile Site Isolates

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>All laboratory-confirmed infections</th>
<th>Sterile site isolates*</th>
<th>Nonsterile site isolates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases, no. (%)</td>
<td>Deaths, no. (%)</td>
<td>CFR, %</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>46,354 (38)</td>
<td>52 (9)</td>
<td>.1</td>
</tr>
<tr>
<td>Salmonella</td>
<td>45,970 (38)</td>
<td>215 (39)</td>
<td>.5</td>
</tr>
<tr>
<td>Shigella</td>
<td>21,048 (17)</td>
<td>22 (4)</td>
<td>.1</td>
</tr>
<tr>
<td>STEC O157</td>
<td>4829 (4)</td>
<td>40 (7)</td>
<td>.8</td>
</tr>
<tr>
<td>Yersinia</td>
<td>1576 (1)</td>
<td>11 (2)</td>
<td>.7</td>
</tr>
<tr>
<td>Listeria</td>
<td>997 (21)</td>
<td>168 (30)</td>
<td>16.9</td>
</tr>
<tr>
<td>Vibrio</td>
<td>762 (1)</td>
<td>44 (8)</td>
<td>5.8</td>
</tr>
<tr>
<td>Total</td>
<td>121,536</td>
<td>552</td>
<td>.5</td>
</tr>
</tbody>
</table>

**NOTE.** Data from the Foodborne Diseases Active Surveillance Network (FoodNet), 1996–2005.

* Sterile site isolations were from blood or another normally sterile site (836 case reports were missing data on the specimen source).

b AAPMRs are given as deaths/1 million population.

c STEC, Shiga toxin–producing Escherichia coli.

d Listeria infections included sterile site isolates only.

### Table 2. Laboratory-Confirmed Infections and Deaths, Case Fatality Rate (CFR), and Average Annual Population Mortality Rate (AAPMR) by Pathogen and Age Group

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Age, 0–4 years</th>
<th>Age, 5–64 years</th>
<th>Age, ≥ 65 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases, no. (%)</td>
<td>Deaths, no. (%)</td>
<td>CFR, % AAPMR</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>6080 (21)</td>
<td>2 (6)</td>
<td>0.03</td>
</tr>
<tr>
<td>Salmonella</td>
<td>13,738 (49)</td>
<td>11 (31)</td>
<td>0.1</td>
</tr>
<tr>
<td>Shigella</td>
<td>6372 (23)</td>
<td>4 (11)</td>
<td>0.1</td>
</tr>
<tr>
<td>STEC O157</td>
<td>1222 (4)</td>
<td>12 (33)</td>
<td>1.0</td>
</tr>
<tr>
<td>Yersinia</td>
<td>768 (3)</td>
<td>1 (31)</td>
<td>0.04</td>
</tr>
<tr>
<td>Listeria</td>
<td>112 (0)</td>
<td>6 (17)</td>
<td>5.4</td>
</tr>
<tr>
<td>Vibrio</td>
<td>12 (0)</td>
<td>0 (0)</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>28,304</td>
<td>36</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**NOTE.** Data from the Foodborne Diseases Active Surveillance Network (FoodNet), 1996–2005. Ages were missing from 483 case reports, including 112 for Campylobacter infection, 263 for Salmonella infection, 98 for Shigella infection, 7 for Shiga toxin–producing Escherichia coli (STEC) O157 infection, and 3 for Yersinia infection; these cases included 1 death.

* AAPMRs are given as deaths/1 million population.

b Sterile site isolates only.
10 years of active surveillance data from FoodNet. Deaths occurred in all age groups; however, older adults were at highest risk. *Salmonella*, a high-incidence pathogen with a low CFR, and *L. monocytogenes*, a low-incidence pathogen with a high CFR, were the leading causes of death overall.

Persons ≥65 years of age had the highest age-specific mortality rate overall and for 6 of the 7 pathogens examined. Foodborne illness is generally more severe in older adults and more likely to result in hospitalization or death than in younger persons [8–11]. Studies suggest that the increased risk of death in older adult patients hospitalized with *Salmonella* or *Campylobacter* infection may be due to the higher prevalence of comorbidities [12]. The increased risk for severe outcomes along with the high cost of treatment indicate that this age group could benefit substantially from effective food safety interventions. In particular, residents of long-term care facilities could benefit from improved food safety, because residence in these facilities has been found to be a risk factor for foodborne illness among older adults [11, 13, 14].

Although similar numbers of laboratory-confirmed *Campylobacter* and *Salmonella* infections are reported each year in the United States, the death rate among persons with *Salmonella* infections was 4 times higher than among persons with *Campylobacter* infections. Population-based studies support the finding that illnesses are generally more severe among persons with *Salmonella* infections than among those with *Campylobacter* infection. For example, population-based studies have documented a higher proportion of positive blood cultures for *Salmonella* infections (5%–6%) [15, 16] than for *Campylobacter* infections (.4%–1.0%) [17, 18]. A population registry study in Denmark found that patients with nontyphoidal *Salmonella* infection had longer average hospital stays and >6-fold the risk of invasive illness than those with *Campylobacter* infection [19]. The fact that *Salmonella* infections are more likely to be isolated from blood or other normally sterile sites may explain the higher death rate compared with *Campylobacter* infections.

Most deaths occurred in persons with sterile site infections. However, it is possible that some of the nonsterile site deaths were misclassified. The classification of a nonsterile site isolate (ie, specimen isolated from stool) does not preclude the possibility that the infection was also present in a sterile site; that is, a patient may have had an invasive infection but may not have had the pathogen isolated from the sterile site. Deaths after specimen collection or after a hospital discharge occurring outside the 7-day window recorded in FoodNet surveillance might have been misclassified.

FoodNet staff document patient outcome at 7 days after specimen collection or, for case patients who are hospitalized, at discharge from the hospital, whichever is later. They do not, however, determine conclusively whether the patient died as a result of that infection, nor are data routinely collected on comorbidities or other factors that may have contributed to the death. It is possible, therefore, that we have overestimated the number of deaths due to these infections, particularly among older persons who are likely to have comorbid conditions. A chart review of *Salmonella* infections that occurred in FoodNet sites in 1996 found that most deaths were due, at least in part, to that infection [20]. That study also found that *Salmonella* infection was included as a cause of death on less than half of the death certificates or hospital charts of these patients, suggesting that the number of deaths due to *Salmonella* infection determined from these sources is greatly underreported [20]. We assumed that case patients with missing outcome information were alive. This decision is supported by a recent study that found that mortality information was accurate and few deaths were missed through routine FoodNet surveillance [6]. In our study, 51% of infections in pregnant women with a known fetal outcome resulted in an abortion or stillbirth. This is likely to be an underestimate, because fetal outcomes were not reported for all pregnancy-related infections; however, this is unlikely to change the CFR for listeriosis.

This study highlights the pathogens under surveillance in FoodNet that are responsible for the most deaths overall and in high-risk age groups. These data should be considered alongside other information on the incidence and severity of disease when prioritizing interventions. In particular, these data highlight the importance of reducing the burden of *Salmonella* infections in the United States. *Salmonella* is a leading cause of bacterial foodborne illness and death; however, rates of *Salmonella* infection have shown little decline over the past 10 years [21]. Efforts to reduce the burden of foodborne disease should also focus on *L. monocytogenes* and *Vibrio*, which both have very high CFRs, and STEC O157, which was responsible for a high number of deaths in children <5 years of age. Further declines in the incidence of infection with bacterial pathogens commonly transmitted through food are likely to require continued efforts of industry and government to reduce contamination of the food supply and to educate clinicians and consumers, particularly high-risk groups such as older adults, about ways to reduce the risk of foodborne infection.

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**References**