Foodborne Disease in Australia: The OzFoodNet Experience

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In 2000, Australia improved national surveillance of gastro-intestinal and foodborne illness by adapting the Centers for Disease Control and Prevention’s (CDC’s) FoodNet model of active surveillance. The OzFoodNet surveillance network applied concentrated effort at the national and local levels to investigate and understand foodborne disease, to describe more effectively its epidemiology, and to provide better evidence for minimizing the number of cases of foodborne illness in Australia. The Australian government funded each of Australia’s 6 states and 2 territories to employ ≥1 epidemiologist to enhance surveillance of foodborne disease, with a coordinating team based at the federal Department of Health and Ageing. OzFoodNet estimated that there are ~5.4 million cases of foodborne disease per year, costing AS1.2 billion annually. In Australia, contaminated food results in ~100 outbreaks of illness each year, with the incidence of outbreaks of illness caused by fresh produce and internationally distributed food increasing. In addition, OzFoodNet showed the value of aggregating national-level outbreak data for policy development and conducted successful multijurisdictional investigations of outbreaks; these investigations implicated a variety of foods, including alfalfa sprouts, chicken meat, eggs, peanuts, baby corn, tahini, and oysters.

Foodborne diseases are globally important because of their high incidence and the costs that they impose on society. There is a great potential for large outbreaks of foodborne illness in both developing and developed countries. More than 200 different diseases may be transmitted through contaminated food or water [1]. Most foodborne diseases result in gastroenteritis, but other nongastroenteric illnesses are common. Prevention of foodborne disease occurs through interventions aimed at the food production industry, food services, and consumers [2–5]. Health departments commonly conduct surveillance for diseases potentially transmitted by food to monitor trends and outbreaks to aid prevention efforts [4]. However, only a small proportion of cases are reported to health departments, because infections due to some pathogens are not notifiable and patients do not seek medical attention or receive a specific diagnosis for their illness [6, 7].

In Australia, there are 6 states and 2 territories, with a combined population of 20.7 million people (figure 1) [8]. State and territory health departments are responsible for surveillance of diseases potentially transmitted by food. All jurisdictions have legislation that requires physicians and laboratories to provide notification about cases of specified diseases, including those transmitted by contaminated food and water, such as Campylobacter and Salmonella infection. In the past, Australia experienced several large and serious outbreaks of foodborne disease. Examples include an outbreak of norovirus infection caused by contaminated orange juice that resulted in an estimated 25,000 cases of norovirus infection in Australia in 1991 (T. Stewart, personal communication) and an outbreak of Escherichia coli O111 infection caused by contaminated mettwurst that resulted in 23 pediatric cases of hemolytic uremic syndrome, with 1 fatality, in South Australia in 1995 [9, 10].

Historically, estimates of the burden of foodborne illness in Australia were limited and not well accepted by the food industry [11]. Regulatory agencies responsible for food safety needed more reliable estimates of the prevalence and causes of foodborne disease. Although intermittent and ad hoc summaries of outbreaks of foodborne disease were published before OzFoodNet, no national repository of systematically compiled summaries of outbreaks of foodborne disease was available [12, 13]. The major risk factors for infection due to common foodborne pathogens, such as Salmonella species, were a matter of speculation. Some diseases, such as Campylobacter infection, rarely manifest as outbreaks, and new approaches were required to understand the epidemiology of these foodborne illnesses. In addition, little information was available on the frequency...
Figure 1. Map of Australia showing states and territories. Estimated resident populations for 2006 were as follows: Australian Capital Territory, 0.3 million persons; New South Wales, 6.8 million persons; Northern Territory, 0.2 million persons; Queensland, 4.1 million persons; South Australia, 1.6 million persons; Tasmania, 0.5 million persons; and Victoria, 5.1 million persons [8].

with which foodborne diseases crossed state and territory borders and the number of outbreaks that were occurring [12]. To address these issues, the Australian Government established OzFoodNet in 2000.

OZFOODNET

After a localized pilot study in New South Wales in 1999, the OzFoodNet group of epidemiologists was established to improve surveillance, management, and prevention of foodborne diseases across the country [14]. OzFoodNet was partly modeled on the CDC’s Foodborne Diseases Active Surveillance Network (FoodNet) [3].

The aim of OzFoodNet was to (1) estimate the incidence and cost of foodborne illness in Australia; (2) investigate outbreaks of foodborne disease, particularly those crossing state and territory borders; (3) improve understanding of the epidemiology of foodborne disease by enhancing surveillance and conducting special studies of foodborne pathogens; (4) provide data essential for future risk assessments and policy interventions; and (5) train people to investigate foodborne illness. Under the program, each state and territory health department employed ≥1 OzFoodNet epidemiologist to supplement local, state-based investigation of foodborne disease and to contribute to national surveillance and applied research. The total cost of OzFoodNet is ~A$2 million annually. In 2002, the Australian government commissioned an independent review of OzFoodNet’s activities; the review team included eminent Australian epidemiologists and 2 epidemiologists from the CDC.

The review team found that OzFoodNet contributed substantially to improving the knowledge base about the burden of foodborne illness in Australia. After the review, the government changed the networks funding from a year-to-year basis to an ongoing basis [15].

To improve detection, management, and prevention of foodborne diseases, OzFoodNet worked closely with a range of organizations, including state and territory health departments, food safety regulators, public health laboratories, public health training programs, departments of agriculture, and international health agencies. OzFoodNet became a member of Australia’s peak national body for infectious disease control, the Communicable Diseases Network Australia, and sought technical input from the Public Health Laboratory Network and the National Centre for Epidemiology and Population Health [14, 16].

NETWORK COMMUNICATION

OzFoodNet relied on regular and timely communications among network members through face-to-face meetings 3 times per year, monthly teleconferences, and e-mail list servers. The main purpose of this communication was to discuss recent clusters of cases of foodborne disease, to identify increases in the number of cases of such disease that may represent a multistate outbreak, and to review progress of OzFoodNet’s applied research program.

Face-to-face meetings held in different jurisdictions on a rotating basis aided communication with other people who were investigating foodborne disease within each jurisdiction and helped epidemiologists learn more about surveillance in Australia. Regular communication has resulted in more consistent surveillance practices across Australian jurisdictions and better recognition of national trends and outbreaks.

Every 2 weeks, OzFoodNet sites prepares a cluster report of all cases of enteric diseases that is summarized nationally and sent to >100 stakeholders by e-mail. These cluster reports have been successful in documenting the scale of activity relating to investigations of outbreaks of gastroenteritis of all causes and modes of transmission and identification of multistate outbreaks [17, 18]. The collection of data on outbreaks of nonfoodborne enteric disease highlighted the significant burden caused by enteric diseases transmitted by nonfoodborne routes.

To communicate findings to stakeholders and the public health community, OzFoodNet prepares written reports on a quarterly and annual basis [19]. These reports highlight changes in the incidence of selected foodborne diseases and summarize outbreaks of foodborne disease. OzFoodNet epidemiologists actively communicate findings from research studies and outbreak investigations in journals and at conferences to ensure that study data are accessible. In the past 7 years, OzFoodNet investigators published ~50 articles in peer-reviewed journals,
and >50 articles were presented at national and international conferences. OzFoodNet also prepares short reports for industry bulletins, trade magazines, and conferences to ensure that a wider group of stakeholders are informed about foodborne diseases and how they are investigated.

**APPLIED RESEARCH**

OzFoodNet began with an ambitious work program, including enhanced surveillance of potentially foodborne diseases, collection of summary data on outbreaks of foodborne disease, a national survey on the incidence of gastroenteritis in the community, surveys of physicians and laboratories about the testing and reporting of foodborne disease, and 4 multisite case-control studies of risk factors for listeriosis, salmonellosis, Shiga toxin–producing *E. coli* infection, and campylobacteriosis. One of OzFoodNet’s primary tasks was to estimate the burden of foodborne diseases in Australia. A key part of this estimation was the National Gastroenteritis Survey (NGS), which was a telephone survey of 6047 persons in Australia over a 12-month period during 2001–2002. The NGS revealed that 17.2 million (95% CI, 14.5–19.9 million) cases of gastroenteritis occurred annually (rate, 0.92 cases per person per year; 95% CI, 0.77–1.06 cases per person per year) [20, 21]. In 2008, OzFoodNet again performed the NGS to examine whether the incidence of gastroenteritis had changed since the period 2001–2002.

To estimate the burden of foodborne gastroenteritis, data of variable quality from multiple sources were needed [22, 23]. A key principle was to account for uncertainty in the estimation process to provide a more realistic estimate for policy decisions [23]. OzFoodNet estimated that 32% (95% credible interval, 24%–40%) of cases of gastroenteritis were foodborne, equating to 5.4 million (95% credible interval, 4.0–6.9 million) cases annually [25]. OzFoodNet identified that the social burden of foodborne gastroenteritis was considerable, resulting in ~1.2 million visits to a physician, 300,000 prescriptions for antibiotics, and 2.1 million missed days of work [21]. An additional 6000 cases of foodborne nongastrointestinal illnesses occurred annually; these illnesses included listeriosis, hemolytic uremic syndrome, and toxoplasmosis [24]. Foodborne diseases cost Australia A$1.2 billion each year, primarily because of lost productivity costs when people miss days of work to recover from gastroenteritis or care for a sick family member [24]. The study examined the costs averted from successful outbreak investigations in which illness was prevented because of early identification and removal of a food vehicle from the food supply and found that the costs averted ranged from A$85,000 to A$1.3 million for individual outbreak investigations. This represented the first comprehensive study, to our knowledge, of gastroenteritis and foodborne illness in Australia.

The NGS contributed to improving logistics of case-control studies through the development of databanks as sources of information on control subjects. Survey respondents were asked whether they were willing to participate in future surveys, and if they agreed, the age and sex of all household members were recorded in a Microsoft Access database known as the control bank. The control bank was composed of data from 5123 (85%) of 6047 households surveyed in the NGS and included data on 14,021 potential control subjects [25]. OzFoodNet investigators used the database of control subjects to conduct multistate case-control studies of patients with *Campylobacter*, *Salmonella* Enteritidis, *Salmonella* Typhimurium 135, and Shiga toxin–producing *E. coli* infections during the period 2001–2006, to investigate risk factors for these diseases [26]. In addition, OzFoodNet Sites conducted a multicenter case-control study of listeriosis and several case-control studies of infections caused by locally important *Salmonella* serotypes to examine risk factors for such infections [27].

An OzFoodNet case-control study of campylobacteriosis involved ~2000 study participants and was expanded to include molecular typing of human isolates using flagellin A gene (*flaA*) typing; this provided more robust epidemiologic information on this common foodborne disease [28, 29]. Using *flaA* typing made it possible to refine the case definition for the case-control study and to identify strain-specific risk factors for infection [30]. OzFoodNet used underreported factors specific for campylobacteriosis, in addition to population-attributable risks, to estimate that ~50,500 (95% credible interval, 10,000–105,500) infections per year occurred in persons aged ≥5 years as a result of consumption of chicken meat in Australia [31, 32]. Some key findings from these studies are listed in table 1.

**SURVEILLANCE AND OUTBREAK INVESTIGATION**

OzFoodNet epidemiologists in each jurisdiction aimed to enhance the surveillance of sporadic cases of foodborne diseases and of outbreak investigations by preparing national hypothesis-generating questionnaires for various diseases and sharing information on local protocols for follow-up of cases. One example of enhanced surveillance of foodborne diseases was the systematic investigation of cases of *S. Enteritidis* infection to detect emergence of strains that may be locally acquired in Australia (figure 2). *S. Enteritidis* is not established in egg-laying flocks in Australia, and >80% of infections are acquired while people travel overseas, particularly to Asian countries [19]. Enhanced surveillance identified that *S. Enteritidis* phage type 26 was the major strain responsible for locally acquired infections in Australia and that the incidence of this phage type decreased in recent years and rarely resulted in outbreaks. *S. Enteritidis* 26 infections predominantly occurred during the summer months, and ~75% of these infections occurred in Queensland [19].

OzFoodNet greatly enhanced identification of outbreaks...
<table>
<thead>
<tr>
<th>Disease</th>
<th>No. of cases reported nationally</th>
<th>Estimated no. of annual infections$^a$ (95% credible interval)</th>
<th>Estimated percentage of foodborne diseases (95% credible interval)</th>
<th>Man food vehicles and research findings</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campylobacteriosis</td>
<td>~16,000</td>
<td>223,000 (93,800–362,800)</td>
<td>75 (67–83)</td>
<td>9.6 community cases per case reported to surveillance; infections acquired from chicken (~50,000 cases), offal (~3500 cases), and pets (~8500 cases); low levels of fluoroquinolone resistance among human isolates; molecular typing (flaA) improves risk factor identification</td>
<td>[19, 26, 30–33]</td>
</tr>
<tr>
<td>Salmonella infection</td>
<td>~8400</td>
<td>48,700 (15,000–91,300)</td>
<td>87 (81–93)</td>
<td>7.6 community cases per case reported to surveillance; Salmonella Mississippi (~75 cases annually, 80% of cases in Tasmanian residents; drinking untreated was the water main risk factor, exposure to native birds was important); Salmonella Enteritidis (~380 cases annually, ~50 cases locally acquired annually, 75% of cases occurred in Queensland residents, predominantly phage type 26, absent in commercial egg-laying flocks)</td>
<td>[19, 23, 27, 32]</td>
</tr>
<tr>
<td>Listeria infection</td>
<td>~60</td>
<td>120</td>
<td>98 (92–100)</td>
<td>Host factors were the most important predictor of disease, risky foods were commonly eaten; perinatal case-fatality rate, 25%; nonperinatal case-fatality rate, 25%</td>
<td>[19, 24]</td>
</tr>
<tr>
<td>Shiga toxin-producing Escherichia coli infection</td>
<td>~80</td>
<td>3800 (1000–33,000)</td>
<td>65 (48–82)</td>
<td>High rate in South Australia because of intensive screening of bloody stool samples (2%-4% of bloody stool samples were stx positive); predominantly serotype O157; animal exposure was an important predictor of disease</td>
<td>[19, 32, 34]</td>
</tr>
</tbody>
</table>

$^a$ Adjusted for underreporting.
through regular networking and sharing of information both nationally and internationally. This was highlighted in 2001 when Victoria experienced an outbreak of multidrug-resistant S. Typhimurium 104 infection that affected 23 persons in Melbourne’s Turkish community. The source of the outbreak remained unidentified until an OzFoodNet epidemiologist in Queensland informed the Victorian site about an article in *Eurosurveillance* about a similar Swedish outbreak in which Turkish helva was implicated [35, 36]. Further investigation identified helva as the food vehicle, and Australian food safety agencies were able to recover ~87% of a contaminated shipment of helva, potentially preventing 1185 cases in the community and saving A$1.3 million that would have been lost as a result of lost productivity and health care costs [15].

Similarly, in 2007, the source of an outbreak of multidrug-resistant *Shigella sonnei* infection in Queensland was identified as fresh baby corn imported from Thailand, after a summary report of a Danish outbreak was published in *Eurosurveillance* [37]. OzFoodNet posted rapid alerts to international bulletins on 2 other occasions that related to outbreaks of *Salmonella* Stanley infection caused by contaminated peanuts from China in 2001 and *Salmonella* Montevideo infection caused by contaminated sesame seed products from the Middle East in 2003; these alerts resulted in the detection of more cases and contaminated foods internationally [17, 38]. These outbreaks ultimately resulted in food recalls in Australia, the United Kingdom, New Zealand, and Canada [39]. Since 2001, OzFoodNet has recorded 14 outbreaks of foodborne disease associated with imported foods (table 2) [39]. In addition, OzFoodNet has acted as a national focal point for investigators in other countries who have examined Australian foods that were potentially contaminated, such as alfalfa sprout seed [43, 44].

Since 2001, OzFoodNet has coordinated ≥24 multijurisdictional investigations of outbreaks of infections due to various agents, including hepatitis A, norovirus, typhoid fever, *Salmonella*, and toxigenic *E. coli*. Twelve of these investigations resulted in identification of a food vehicle, such as rock melons, poultry, papaya, alfalfa sprouts, chicken meat, and eggs [45]. Multijurisdictional outbreak investigations are challenging for many reasons, particularly the large number of agencies involved and difficulties with robust and rapid communication [46, 47]. A key area of potential difficulty during these complex investigations was the conduct of rapid, multisite case-control studies. The use of control banks has improved the efficiency of recruitment of control subjects, and the use of Web-based data collection has also been successful [25, 45]. In addition, the use of standardized questionnaires and regular conference calls has improved multistate investigations. OzFoodNet cooperated with state, territory, and federal government agencies, in addition to other key players, such as public health labo-
<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Countries affected</th>
<th>No. of outbreaks</th>
<th>No. of Australian cases</th>
<th>Pathogen</th>
<th>Implicated food</th>
<th>Exporting country or region</th>
<th>Comments</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Europe and Australia</td>
<td>1</td>
<td>23</td>
<td><em>Salmonella Typhimurium</em> definitive type 104</td>
<td>Helva</td>
<td>Turkey</td>
<td>Multidrug-resistant <em>Salmonella</em> infection, which is rare in Australia</td>
<td>[34]</td>
</tr>
<tr>
<td>2001</td>
<td>United Kingdom, Canada, and Australia</td>
<td>1</td>
<td>55</td>
<td><em>Salmonella Stanley, Salmonella Newport</em></td>
<td>Dried peanuts</td>
<td>China</td>
<td>Isolates were fully sensitive to all antibiotics tested; sharing of PFGE images among countries showed indistinguishable isolates</td>
<td>[36]</td>
</tr>
<tr>
<td>2002–2003</td>
<td>New Zealand, United Kingdom, Canada, and other Australian states</td>
<td>2</td>
<td>58</td>
<td><em>Salmonella Montevideo, Salmonella Tennessee</em></td>
<td>Tahini</td>
<td>Egypt and Lebanon</td>
<td>Multiple brands of tahini and helva contaminated with <em>Salmonella</em> species; inquiries with manufacturing country did not identify source of contamination</td>
<td>[17]</td>
</tr>
<tr>
<td>2002–2004</td>
<td>Australia</td>
<td>6</td>
<td>338</td>
<td>Norovirus and suspected viral illness</td>
<td>Oysters</td>
<td>Japan</td>
<td>Product caused illness when consumed cooked and uncooked; in some instances, packaging warned to cook before consumption</td>
<td>[18]</td>
</tr>
<tr>
<td>2005</td>
<td>Australia</td>
<td>1</td>
<td>5</td>
<td>Ciguatoxin</td>
<td>Snapper</td>
<td>Fiji</td>
<td>Fish brought into Australia in a suitcase</td>
<td>[19]</td>
</tr>
<tr>
<td>2006</td>
<td>Australia</td>
<td>1</td>
<td>5</td>
<td>Sodium nitrate</td>
<td>Nutre powder</td>
<td>China</td>
<td>Powder added as a food “flavoring”</td>
<td>[40]</td>
</tr>
<tr>
<td>2006</td>
<td>Australia</td>
<td>1</td>
<td>3</td>
<td><em>Vibrio cholerae</em></td>
<td>White bait (Nanata)</td>
<td>Indonesia</td>
<td>Fish eaten raw during preparation of traditional Italian dish</td>
<td>[41]</td>
</tr>
<tr>
<td>2007</td>
<td>Denmark and Australia</td>
<td>1</td>
<td>55</td>
<td><em>Shigella sonnei</em> biotype g</td>
<td>Baby corn</td>
<td>Thailand</td>
<td>PFGE typing of isolates confirmed relatedness, and investigations identified a common packing plant in Thailand</td>
<td>[42]</td>
</tr>
</tbody>
</table>

**NOTE.** Adapted from Tauxe et al. [39].
ratories, to document national procedures, to investigate multijurisdictional outbreaks, and to develop guidelines to ensure that the processes are robust.

The OzFoodNet outbreak register was developed to capture reports of outbreaks of foodborne disease and to guide food safety programs and policy development. The data collection tools were based on forms used by the CDC, the Health Protection Agency in the United Kingdom, and the European regional office of the World Health Organization [48, 49]. From its inception in 2001 through 2006, OzFoodNet sites entered data on >3000 outbreaks of gastroenteritis that occurred through all transmission routes, in addition to data on other outbreaks of foodborne illness, such as listeriosis and hepatitis A. OzFoodNet sites reported that, in 690 of these outbreaks, infection was transmitted through contaminated food; the annual mean rate of outbreaks was 5.6 outbreaks per 1 million population. Three hundred three of these foodborne outbreaks affected ≥10 persons (rate, 2.5 cases per 1 million population).

These data on outbreaks have proven to be useful for public health and regulatory agencies to develop policy, to better understand how foodborne disease manifests, and to observe trends in outbreaks of foodborne disease [17, 18]. Food safety agencies regularly use summary data from the register to rank risks posed by different foods and to provide information for risk assessments (e.g., in the development of standards for the production of seafood, chicken meat, eggs, and dairy products). In 2005, OzFoodNet summarized outbreaks of norovirus infection associated with individually quick-frozen oysters; this resulted in restriction of importation of these products into Australia from certain growing areas in Japan and Korea [18, 39]. Another example is when the Australian regulatory agencies increased the frequency of testing of imported sesame seed 

The International Collaboration on Enteric Disease Burden of Illness Studies has since expanded to >30 countries; the members of the study group meet annually and discuss methodologic issues for studies, analyses of similar datasets, work on collaborative international projects, and exchange of staff members [53]. To develop surveillance capacity in the region, OzFoodNet has acted as short-term consultants and temporary advisors for the World Health Organization on issues relating to the global and regional burden of foodborne diseases [54]. In addition, OzFoodNet has had regular interaction with groups that conduct foodborne disease surveillance in other countries, particularly Europe, Canada, and in more recent years, Malaysia and other Asian countries.

Most importantly, the OzFoodNet program of work has improved Australia’s capacity for foodborne disease surveillance and control at the state, territory, and commonwealth government levels. In total, OzFoodNet staffing accounts for 18.5 full-time positions in Australia, including 3 epidemiologist positions at the national level. OzFoodNet epidemiologists have developed guidelines for investigations of outbreaks, trained key public health care workers, and successfully piloted new tools, such as Web-based data-collection systems [55, 56].

CONCLUSIONS

OzFoodNet has been successful in conducting surveillance and applying research of foodborne diseases in Australia during the past 7 years. It is important to recognize that many of these successes are the result of hard work by many different partners, including public health units, health departments, laboratories, reference laboratories, food safety agencies, collaborative networks, and departments of agriculture. There is a need to continue to build on the work of these different groups and to improve the relatedness of human-, animal-, and food-based data on infectious pathogens [57, 58]. Australia still faces many challenges to maintain robust surveillance but now has a strong basis to move forward to control diseases potentially transmitted by food that are spread locally, nationally, and internationally. The FoodNet model has proven to be useful in Australia and has allowed for the development of national intelligence on the incidence and causes of foodborne diseases [3, 59].

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