Epidemiology of bacterial toxin-mediated foodborne gastroenteritis outbreaks in Australia, 2001 to 2013

Fiona J May, Benjamin G Polkinghorne, Emily J Fearnley

Abstract

Bacterial toxin-mediated foodborne outbreaks, such as those caused by *Clostridium perfringens, Staphylococcus aureus* and *Bacillus cereus,* are an important and preventable cause of morbidity and mortality. Due to the short incubation period and duration of illness, these outbreaks are often under-reported. This is the first study to describe the epidemiology of bacterial toxin-mediated outbreaks in Australia. Using data collected between 2001 and 2013, we identify high risk groups and risk factors to inform prevention measures. Descriptive analyses of confirmed bacterial toxin-mediated outbreaks between 2001 and 2013 were undertaken using data extracted from the OzFoodNet Outbreak Register, a database of all outbreaks of gastrointestinal disease investigated by public health authorities in Australia. A total of 107 laboratory confirmed bacterial toxin-mediated outbreaks were reported between 2001 and 2013, affecting 2,219 people, including 47 hospitalisations and 13 deaths. Twelve deaths occurred in residents of aged care facilities. *Clostridium perfringens* was the most commonly reported aetiological agent (81 outbreaks, 76%). The most commonly reported food preparation settings were commercial food preparation services (51 outbreaks, 48%) and aged care facilities (42 outbreaks, 39%). Bacterial toxin outbreaks were rarely associated with food preparation in the home (2 outbreaks, 2%). In all outbreaks, the primary factor contributing to the outbreak was inadequate temperature control of the food. Public health efforts aimed at improving storage and handling practices for pre-cooked and re-heated foods, especially in commercial food preparation services and aged care facilities, could help to reduce the magnitude of bacterial toxin outbreaks. *Commun Dis Intell* 2016;40(4):E460–E469.

Keywords: foodborne illness; bacteria-mediated; gastroenteritis; *Staphylococcus aureus; Bacillus cereus, Clostridium perfringens*

Introduction

Two different types of bacterial toxins can cause gastroenteritis. Preformed toxins are produced by *Staphylococcus aureus* and *Bacillus cereus* (emetic toxin).[1,2] These toxins are formed in the food and are resistant to heat, so the risk of illness is not removed by cooking.[3,4] Onset of illness is rapid, between 30 minutes and 6 hours, and vomiting is the most commonly reported symptom.[3] *In vivo* toxins are produced by *Clostridium perfringens* and *B. cereus* (diarrhoeal toxin), and are formed in the digestive tract after food containing the bacteria is consumed. While adequately cooking food can kill the bacterial vegetative cells, both *C. perfringens* and *B. cereus* produce heat-resistant spores that can survive cooking and subsequently regerminate after cooking. Onset of illness is between 6 and 16 hours. Diarrhoea is commonly reported and vomiting is not common.[5,6] All 3 toxin-producing bacteria are ubiquitous in the environment, and *S. aureus* is a normal component of human flora.[7]

Individual cases of *S. aureus, B. cereus* and *C. perfringens* gastroenteritis are not notifiable diseases in Australia, so gastroenteritis caused by these pathogens are only reported if they are part of an outbreak, defined as two or more cases of the same illness with a common source. Gastrointestinal outbreaks are collated in the national OzFoodNet Outbreak Register.

OzFoodNet was established in 2000 by the Australian Government as a network of epidemiologists with representatives in every state and territory. OzFoodNet focuses on enhanced surveillance for foodborne illnesses.[8] The OzFoodNet Outbreak Register is a Microsoft Access database maintained by OzFoodNet Central (at the Australian Government Department of Health), and has been in use since 2001. State and territory-based OzFoodNet epidemiologists collect and provide summary data quarterly to OzFoodNet Central on all gastrointestinal outbreaks investigated in their jurisdiction. Summaries of outbreaks are published in OzFoodNet quarterly and annual reports.[9,10]

The aim of this study was to describe the epidemiology of bacterial toxin-mediated foodborne outbreaks in Australia between 2001 and 2013, and to identify high risk groups and risk factors to inform prevention measures.

Methods

Data collection

Outbreak Register data were extracted on 2 February 2015. Variables analysed included aetiology, laboratory confirmation of aetiology, food vehicle, state or territory of outbreak, year of outbreak, number of cases, number hospitalised, number of deaths, median age of cases, per cent of cases for each gender, median incubation period and duration, number of cases reporting each symptom, factors contributing to the outbreak (microbial growth and microbial survival), the setting in which food was prepared, the consumption setting and the free text remarks variable. Application of inclusion and exclusion criteria was performed in Microsoft Excel, and data cleaning and analysis was performed in StataSE 13 (Stata Corp, College Station, TX, USA). Missing data, nonsensical data and answers of 'unknown' were treated as unknown responses. Completeness for all variables was defined as useable data, i.e. values other than missing or unknown.

Case definitions

All confirmed bacterial toxin outbreaks included in this analysis were laboratory confirmed according to simplified Centers for Disease Control and Prevention (CDC) guidelines for bacterial toxin outbreaks.[11] Outbreaks were classified as laboratory confirmed if the aetiological agent was isolated or enterotoxin was detected in clinical specimens from 2 or more cases, or at least 10^5 organisms were isolated per gram of epidemiologically implicated food.[11] Confirmed bacterial toxin-mediated foodborne or suspected foodborne outbreaks with onset between 2001 and 2013 were included. Five aetiology categories were created for analysis:

1. '*Bacillus cereus*' – *B. cereus* was listed as the sole aetiology.
2. '*Clostridium perfringens*' – *C. perfringens* was listed as the sole aetiology.
3. '*Staphylococcus aureus*' – *S. aureus* was listed as the sole aetiology.
4. 'Preformed toxin' – both *S. aureus* and *B. cereus* were listed as the confirmed aetiology.
5. '*In vivo* toxin' – both *C. perfringens* and *B. cereus* were listed as the confirmed aetiology.

For further attribution of outbreaks caused by *B. cereus*, the following criteria based on the known characteristics of *B. cereus* illness were used as probable case definitions:[2]

a. Emetic *B. cereus*
   i. incubation period ≤ 6 hours and
   ii. ≥ 50% of cases reporting vomiting

b. Diarrhoeal *B. cereus*
   i. incubation period ≥ 6 hours and
   ii. < 50% of cases reporting vomiting.

Vehicle attribution

Confirmed or suspected food vehicles with a reasonable level of suspicion (for example the implicated food was the only food that was eaten by most or all cases) that were detailed in the Outbreak Register in either the food vehicle variable or in the free-text remarks variable were retained for analysis. To simplify analysis, the food vehicles were categorised according to the method of food preparation as proposed by Weingold et al.[12] Only the information provided in the Outbreak Register was used to apply categories and no assumptions were made about foods commonly served together. An additional food variable was created to record if a high starch food, such as rice or pasta, was reported. The number and percentage of outbreaks reporting each food category are reported.

Data analysis

Median values and ranges were calculated for numerical variables including number of cases, number of hospitalisations, number of deaths, median age, percentage of each gender, median incubation period and duration and percentage for each symptom. Histograms were constructed in Microsoft Excel using outbreak data aggregated by year based on onset date of the outbreak. Overall rates for each state and territory were calculated using population data from the Australian Bureau of Statistics,[13] and compared using Poisson regression using StataSE 13.

The per cent incidence of symptoms was calculated using the number of cases reporting the illness as the numerator, and the number of cases interviewed about the symptom as the denominator, where possible. For outbreaks where the number of cases reporting the symptoms was higher than the number interviewed, or the number interviewed was missing, the total number ill was used as the denominator. If an outbreak had no information for any symptom, the percentage of each symptom was reported as missing.

Results

A total of 107 confirmed bacterial toxin-mediated outbreaks were reported during the period 2001 to 2013, affecting 2,219 people across all states and territories with the exception of Tasmania, where no outbreaks occurred during this period. Of these people, 47 were hospitalised and 13 died; 12 deaths (92%) were residents of aged care facilities. The number of outbreaks per year by jurisdiction is shown in Figure 1. Victoria had more outbreaks than any other state (46 outbreaks, 43%), followed by Queensland (29 outbreaks, 27%) and New South Wales (22 outbreaks 21%). The rate of bacterial toxin-mediated outbreaks reported per 10 million people for each state or territory is shown in Table 1. Comparing the rates for the states with 20 or more outbreaks, Victoria (6.8 outbreaks per 10 million) reported 2.8 times as many bacterial toxin-mediated outbreaks than New South Wales (2.5 outbreaks per 10 million), and 1.3 times as many outbreaks as Queensland (5.4 outbreaks per 10 million).

Figure 2 shows the number of outbreaks reported each year, by aetiology. Outbreaks caused by *C. perfringens* were the most frequently reported cause of bacterial toxin-mediated outbreaks (81 outbreaks, 76%; Figure 2, Table 2). All but one of the deaths were during outbreaks caused by *C. perfringens* (12 deaths, 92%).

Symptomology

Outbreaks caused by *S. aureus* had the shortest median incubation period (3 hours) of the 3 types of bacterial toxin-mediated infection (Table 3), while outbreaks caused by *C. perfringens* had the longest median incubation period (12 hours). Duration of illness was comparable between outbreaks caused by the different pathogens. Diarrhoea was the most commonly reported symptom in all outbreaks. Vomiting and nausea were most common in outbreaks caused by *S. aureus.*

Food vehicle attribution

The most frequently reported category of food associated with bacterial toxin-mediated foodborne outbreaks was the category of 'solid masses of potentially hazardous foods', such as lasagne, which was reported in 31 outbreaks (29%) (Table 4). An additional 17 outbreaks (16%) were associated with 'liquid or semi-solid mixtures of potentially hazardous foods', such as gravy. Half of the outbreaks (13 outbreaks) caused by *S. aureus,*

Figure 1: Laboratory confirmed bacterial toxin-mediated outbreaks, Australia, 2001 to 2013, by year and state or territory

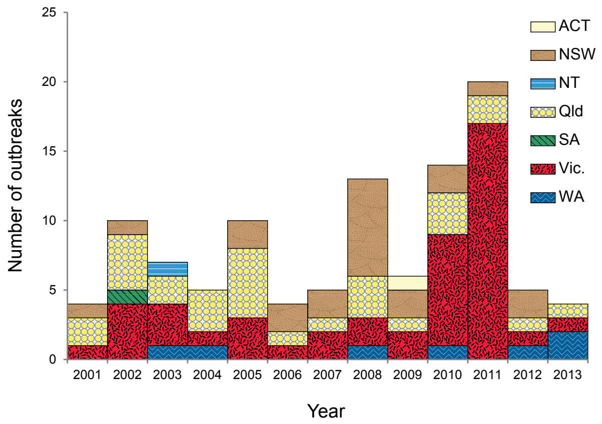

Figure 2: Laboratory confirmed bacterial toxin-mediated foodborne outbreaks, Australia, 2001 to 2013, by aetiology and year

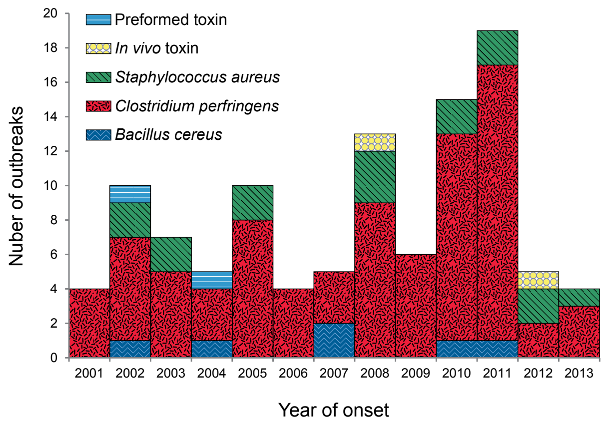

Table 1: Rate of laboratory confirmed bacterial toxin-mediated outbreaks reported per 10 million people, Australia, 2001 to 2013, by state or territory

State or territory*	Number of outbreaks	Rate per 10 million people	Incidence rate ratio	95% confidence interval
Vic.	46	6.8	Reference	Reference
Qld	29	5.4	0.78	0.50 – 1.27
NT	1	3.5	0.52	0.07 – 3.77
NSW	22	2.5	0.36	0.22 – 0.60
WA	7	2.5	0.15	0.17 – 0.82
ACT	1	2.2	0.33	0.05 – 2.37
SA	1	0.5	0.07	0.01 – 0.52
Tas.	0	0.0	0.00	0

Table 2: Epidemiology of bacterial toxin-mediated outbreaks, Australia, 2001 to 2013

		Staphylococcus aureus	*Bacillus cereus*	*Clostridium perfringens*	Preformed toxin	*In vivo* toxin
Number of outbreaks		16	6	81	2	2
Total number of cases		200	114	1,533	288	84
Median number of cases per outbreak (range)		8 (2–38)	18 (3–37)	13 (2–100)	144 (16–272)	42 (9–75)
Hospitalisations		18*	0†	14*	15†	0†
Deaths‡		1†	0†	12†	0†	0†
Per cent of outbreaks with one or more deaths		6.3†	0†	6.2†	0†	0†
Median per cent ill (range)		48 (13.3–88.9)§	26 (14.8–32.0)§	19 (0.7–100)*	8 (8.4)§	52 (4.1–100)†
Median age		31*	36§	81*	39†	20§
Median per cent sex	Male	39*	41§	34*	0‡	50§
	Female	62*	59§	66*	0‡	50§

* 75% to 89% complete.
† ≥90% complete.
‡ Deaths were temporally associated with gastroenteritis but the contribution of gastroenteritis to death is unknown.
§ 50% to 74% complete.

Table 3: Incubation period, duration of illness and median per cent of commonly reported symptoms in bacterial toxin-mediated foodborne outbreaks, Australia, 2001 to 2013, by aetiology

	Staphylococcus aureus		*Bacillus cereus*		*Clostridium perfringens*		Preformed toxin		*In vivo* toxin	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Incubation period (hours)	3*	2–7	8.5*	2–12	12†	6–17	4*	2–6	12‡	12–12
Duration of illness (hours)	18‡	3–72	23.5‡	0–48	24§	3–204	24‡	24–24	36 *	24–48
Diarrhoea (%)	82§	0–100	97*	0–100	100*	53–100	86*	72–100	100*	100–100
Abdominal pain (%)	67§	0–100	35*	0–88	0*	0–100	88*	76–100	33*	0–67
Vomiting (%)	100§	43–100	14*	0–100	0*	0–74	66*	50–83	0*	0–0
Nausea (%)	83§	0–100	29*	0–100	0*	0–100	87*	74–100	0*	0–0

* ≥90% complete
† <50% complete
‡ 75% to 89% complete.
§ 50% to 74% complete.

B. cereus, preformed toxin and *in vivo* toxin had a starch-based food such as rice, pasta or noodles listed as part of the implicated food vehicle, whereas only 5 outbreaks (6%) caused by *C. perfringens* had starch as part of the food vehicle.

Contributing factors

All bacterial toxin-mediated outbreaks that had a contributing factor for microbial growth recorded (63 outbreaks) had at least one contributing factor for microbial growth that can be categorised as temperature abuse, including 'slow cooling', 'inadequate refrigeration', 'delay between preparation and consumption', 'insufficient cooking', 'inadequate thawing' or 'inadequate hot holding temperature' (Table 5). The temperature abuse growth factor was confirmed for 32 (51%) of these outbreaks. Confirmation was via observation during inspection for 15 outbreaks, verbally during inspection for 15 outbreaks and was only confirmed with measured evidence for 2 outbreaks.

Table 4: Food categories implicated in toxin-mediated outbreaks, Australia 2001 to 2013

	Staphylococcus aureus		*Bacillus cereus*		*Clostridium perfringens*		Preformed toxin		*In vivo* toxin	
	%	n	%	n	%	n	%	n	%	n
Solid masses of potentially hazardous foods	43	7	50	3	24	19	50	1	50	1
Liquid or semi-solid mixtures of potentially hazardous foods	6	1	33	2	16	13	0	0	50	1
Roasted meat/poultry/fish	19	3	0	0	7	6	0	0	0	0
Cook/serve foods	13	2	0	0	4	3	0	0	0	0
Salads prepared with one or more cooked ingredients	6	1	0	0	0	0	0	0	0	0
Salads with raw ingredients	0	0	0	0	0	0	0	0	0	0
Multiple foods	0	0	17	1	0	0	50	1	0	0
Baked goods	6	1	0	0	3	2	0	0	0	0
Sandwiches	0	0	0	0	0	0	0	0	0	0
Beverages	6	1	0	0	0	0	0	0	0	0
Unknown food vehicle	0	0	0	0	47	38	0	0	0	0

Table 5: Contributing factors for microbial growth after contamination of food vehicle, Australia, 2001 to 2013

	Staphylococcus aureus		*Bacillus cereus*		*Clostridium perfringens*		Preformed toxin		*In vivo* toxin	
	%	n	%	n	%	n	%	n	%	n
Foods left at room or warm temperature	56	9	33	2	16	13	100	2	100	2
Inadequate refrigeration	38	6	17	1	11	9	50	1	0	0
Slow cooling	6	1	0	0	30	24	0	0	0	0
Delay between preparation and consumption	6	1	17	1	12	10	50	1	50	1
Inadequate hot holding temperature	13	2	33	2	2	2	0	0	50	1
Insufficient cooking	0	0	33	2	1	1	0	0	0	0
Inadequate thawing	0	0	0	0	0	0	0	0	0	0
Anaerobic packaging/modified atmosphere	0	0	0	0	0	0	0	0	0	0
Other source of contamination	0	0	0	0	0	0	0	0	0	0
Unknown	19	3	17	1	49	40	0	0	0	0

The temperature abuse growth factor was assumed or suspected, or no level of evidence was provided for the remaining 31 outbreaks.

Similarly, 85% of outbreaks that had a contributing factor for microbial survival (40 of 47 outbreaks) had a contributing factor for microbial survival that can be categorised as temperature abuse, including 'insufficient time/temperature during cooking', 'insufficient time/temperature during reheating' or 'inadequate thawing and cooking' (Table 6). The temperature abuse survival factor was confirmed for 9 (23%) of these outbreaks. Confirmation was via observation for 2 outbreaks, verbally during inspection for 6 outbreaks and confirmed with measured evidence for 1 outbreak. The temperature abuse survival factor was assumed or suspected, or no level of evidence was provided for the remaining 31 outbreaks.

Food preparation and consumption settings

The food implicated in bacterial toxin-mediated foodborne outbreaks was prepared and eaten in the same location for 78 outbreaks (73%). The implicated food in the remaining 29 outbreaks (27%) was prepared in a commercial location before being eaten in the home, for example eating a takeaway meal from a restaurant at home. The most commonly reported food preparation locations for all aetiologies were res-

Table 6: Contributing factors for microbial survival after contamination of food vehicle, Australia, 2001 to 2013

	Staphylococcus aureus		*Bacillus cereus*		*Clostridium perfringens*		Preformed toxin		*In vivo* toxin	
	%	n	%	n	%	n	%	n	%	n
Insufficient time/temperature during reheating	0	0	33	2	41	33	0	0	0	0
Insufficient time/temperature during cooking	6	1	33	2	5	4	0	0	100	2
Other source of contamination	13	2	17	1	2	2	100	2	0	0
Inadequate or failed disinfection	6	1	0	0	0	0	0	0	50	1
Inadequate acidification	0	0	0	0	0	0	0	0	0	0
Inadequate thawing and cooking	0	0	0	0	0	0	0	0	0	0
Unknown	75	12	33	2	56	45	50	1	0	0

Table 7: Setting where the food was prepared, Australia 2001 to 2013

	Staphylococcus aureus		*Bacillus cereus*		*Clostridium perfringens*		Preformed toxin		*In vivo* toxin	
	%	n	%	n	%	n	%	n	%	n
Aged care	0	0	0	0	47	38	0	0	50	1
Restaurant	19	3	33	2	19	15	50	1	0	0
Commercial caterer	25	4	33	2	11	9	0	0	50	1
Takeaway	13	2	17	1	2	2	0	0	0	0
Hospital	0	0	0	0	6	5	0	0	0	0
Institution	0	0	0	0	6	5	0	0	0	0
National franchised fast food restaurant	13	2	17	1	1	1	0	0	0	0
Fair/festival/mobile service	6	1	0	0	0	0	50	1	0	0
Private residence	0	0	0	0	2	2	0	0	0	0
Other	6	1	0	0	1	1	0	0	0	0
Camp	6	1	0	0	0	0	0	0	0	0
Child care	6	1	0	0	0	0	0	0	0	0
Grocery store/delicatessen	6	1	0	0	0	0	0	0	0	0
Military	0	0	0	0	1	1	0	0	0	0
Private caterer	0	0	0	0	1	1	0	0	0	0
Unknown	0	0	0	0	1	1	0	0	0	0

taurants (21 outbreaks, 20%) and commercial caterers (16 outbreaks, 15%; Table 7). Only 2 outbreaks (2%) were due to food prepared in a private home. Food preparation businesses (including restaurants, commercial caterers, takeaway locations, grocery stores, delicatessens, fairs, festivals and mobile food services) were the most commonly reported food preparation setting associated with bacterial toxin-mediated foodborne outbreaks, (51 outbreaks, 48%). A total of 42 outbreaks (39%), all caused by *C. perfringens* (alone or with *B. cereus* in the *in vivo* toxin category), were associated with meals prepared and/or consumed in aged care facilities (Table 8). The incidence of aged care associated outbreaks varies from year to year, ranging from no aged care outbreaks in 2001 to 75% of outbreaks in 2013 and a median of 25% of outbreaks per year. Restaurants were the second most frequently reported location for consumption of food (21 outbreaks, 20%; Table 8).

Further attribution of *Bacillus cereus* outbreaks

Using the probable case definition, in particular the percentage of cases that reported vomiting, 1 outbreak caused by *B. cereus* (17%) was likely to have been caused by the emetic toxin (incubation period 2 hours, 100% of cases reported vomiting), while the remaining 5 outbreaks were likely to have been caused by the diarrhoeal toxin (Table 9).

Table 8: Setting where the food was consumed, Australia, 2001 to 2013

	Staphylococcus aureus		*Bacillus cereus*		*Clostridium perfringens*		Preformed toxin		*In vivo* toxin	
	%	n	%	n	%	n	%	n	%	n
Aged care	0	0	0	0	51	41	0	0	50	1
Restaurant	13	2	33	2	17	14	0	0	0	0
Private residence	19	3	50	3	5	4	0	0	0	0
Commercial caterer	13	2	17	1	4	3	50	1	50	1
Other	13	2	0	0	5	4	0	0	0	0
Institution	0	0	0	0	6	5	0	0	0	0
Community	13	2	0	0	4	3	0	0	0	0
Hospital	0	0	0	0	4	3	0	0	0	0
Fair/festival/mobile service	6	1	0	0	0	0	50	1	0	0
Military	0	0	0	0	1	1	0	0	0	0
National franchised fast food restaurant	6	1	0	0	0	0	0	0	0	0
Child care	6	1	0	0	0	0	0	0	0	0
Function	6	1	0	0	0	0	0	0	0	0
Camp	6	1	0	0	0	0	0	0	0	0
Cruise/airline	0	0	0	0	1	1	0	0	0	0
School	0	0	0	0	1	1	0	0	0	0
Unknown	0	0	0	0	1	1	0	0	0	0

Table 9: Informative variables and assessment of probable toxin type for confirmed and suspected *Bacillus cereus* outbreaks (emetic or diarrhoeal), Australia, 2001 to 2013

Probable *B. cereus* toxin type	Incubation (hours)	Symptoms: Vomiting (%)	Symptoms: Diarrhoea (%)	Food vehicle
Emetic	2	100	0	Fried rice and honey chicken
Diarrhoeal	6	0	100	Multiple foods
Diarrhoeal	8	16	100	Boiled gefilte fish (fish balls)
Diarrhoeal	9	67	67	Mashed potato and gravy
Diarrhoeal	10	3	97	Rice
Diarrhoeal	12	13	96	Rice (and/or beef curry)

Discussion

This study was the first to examine the epidemiology of bacterial toxin-mediated foodborne outbreaks in Australia. The incidence of bacterial toxin-mediated foodborne outbreaks fluctuated over the 13 year analysis period (2001 to 2013), but there was no overall trend in the change in incidence. During the analysis period, 107 outbreaks were confirmed to be caused by a bacterial toxin in Australia. In comparison, during the same period 571 outbreaks of salmonellosis, 80 outbreaks of ciguatera fish poisoning and 68 outbreaks of campylobacteriosis were investigated in Australia[9,10,14–30] Victoria reported more outbreaks per 100,000 people caused by bacterial toxins than any other jurisdiction. From the data available, it is unclear whether this was due to a higher incidence of bacterial toxin-mediated outbreaks in Victoria, or if other factors were involved.

The median incubation periods and symptomology of *S. aureus,*[31] *B. cereus*[6] and *C. perfringens*[5] in Australian outbreaks were similar to that observed elsewhere. Only 1 outbreak caused by *B. cereus* was likely to have been caused by the emetic toxin (17%). The food vehicle for this outbreak included rice (fried rice and honey chicken), consistent with findings that the *B. cereus* emetic toxin is associated with rice.[2,3,32] This distribution of a greater number of diarrhoeal outbreaks than emetic is consistent with the epidemiology of *B. cereus* in North America and Northern Europe, and different to that seen in countries with high rates of rice consumption such as Japan.[2]

The 2 most commonly reported food vehicle categories were 'solid masses of potentially hazardous foods' and 'liquids or semi-solid mixtures of potentially hazardous foods'. Without careful temperature control, both of these categories of foods can spend a long period of time at temperatures that promote microbial growth due to the density of the food. This finding is in contrast with a study examining bacterial toxin-mediated foodborne outbreaks in the United States of America (USA), which found that 'roasted meat and poultry' was the most commonly reported food category.[33]

All outbreaks that reported a contributing factor for microbial growth and 85% of outbreaks that reported a contributing factor for microbial survival reported at least one factor that was associated with temperature abuse of the food, although this was not always confirmed. Temperature abuse refers to inappropriate holding of food products between 4°C and 60°C, which is the optimal temperature for growth of most pathogenic microorganisms.[34] This is a particular problem with toxin-producing bacteria as even reheating or cooking the food does not remove the preformed toxin (*S. aureus* and emetic *B. cereus*) or the bacterial spores (*C. perfringens* and diarrhoeal *B. cereus*).[2,4,35]

The most commonly reported location for preparation of the food vehicle that was implicated in bacterial toxin-mediated foodborne outbreaks was at food preparation businesses such as restaurants and commercial caterers (48%), while the implicated food was prepared in private homes in only 2% of the outbreaks. This is in contrast to a study in the USA, which found that 16% of bacterial toxin-mediated outbreaks were associated with food prepared in the home.[33] Similarly, a study in the European Union found that homes were the most commonly reported setting for outbreaks of *S. aureus* and the third most commonly reported setting for outbreaks of *C. perfringens*.[36] However, the European Union study did not distinguish between preparation and consumption settings. Education of all food preparation services on safe food practices, with a focus on increased awareness of temperature abuse of foods that are difficult to cool or warm rapidly, including high risk dishes, would reduce the incidence of bacterial toxin-mediated foodborne outbreaks in food preparation businesses.

The most commonly reported location for preparation and consumption of the food implicated in *C. perfringens* outbreaks was aged care facilities (39% of all outbreaks, 51% of *C. perfringens* outbreaks). Foods in aged care facilities are often prepared in bulk and stored for a period of time before serving, increasing the risk of bacterial toxin outbreaks.[37] Food prepared in aged care facilities was not reported as a major risk factor for bacterial toxin-mediated foodborne outbreaks in the USA.[33,38] The short duration and mild symptoms associated with bacterial toxin-mediated illness means that cases and outbreaks in the general community are less likely to be detected and investigated than cases and outbreaks in aged care facilities. However, residents of aged care facilities are a vulnerable population, and the outcome of bacterial toxin-mediated illnesses may be more severe in the aged care population and as such, staff are trained to be particularly observant of symptoms of gastroenteritis.[39] Indeed, almost all deaths were associated with bacterial toxin-mediated outbreaks occurred in aged care facilities (92%), consistent with studies showing higher mortality during foodborne outbreaks in aged care facilities.[37,40–42] Prevention of bacterial toxin-mediated foodborne outbreaks in aged care facilities through education and awareness of ways to avoid temperature abuse of food served in aged care facilities is important in protecting this vulnerable population. Food safety in aged care facilities is regulated by Food Standards Australia New Zealand Standard 3.3.1 *Food Safety Programs for Food Service to Vulnerable Persons* (https://www.comlaw.gov.au/Series/F2012L00290). This standard was introduced in 2008 and requires implementation of a food safety program by food businesses that prepare food for vulnerable people, including the elderly. However, despite the introduction of this Standard during the period of this study, there has been no decrease in the frequency of bacterial toxin-mediated outbreaks in aged care facilities.

Only outbreaks that were laboratory confirmed to be caused by a bacterial toxin were included in this study. As it can be difficult to confirm the causative agent in bacterial toxin-mediated outbreaks, and few laboratories in Australia are able to test for these pathogens, many outbreaks that were possibly caused by bacterial toxins but not laboratory confirmed have not been included in this study. This may have biased the analysis towards outbreaks that were more likely to be confirmed, such as larger outbreaks, outbreaks in vulnerable populations such as aged care or commercial enterprises complying with regulations; the results of this study should be considered in this context. However, a larger study that incorporated suspected outbreaks showed no differences in the epidemiology of confirmed bacterial toxin-mediated outbreaks and suspected bacterial toxin-mediated outbreaks.[43] Similarly, the outbreaks reported in the OzFoodNet Outbreak Register are likely to be only a proportion of the total number of outbreaks caused by bacterial toxins, as these outbreaks are often not reported or investigated due to the short duration and relatively mild symptoms in healthy adults compared with other infectious causes of foodborne gastroenteritis such as *Salmonella*.[44]

In conclusion, bacterial toxin-mediated foodborne outbreaks are most frequently reported to be associated with dense large volume foods prepared by food preparation businesses such as restaurants, and in aged care facilities. As bacterial toxin-mediated outbreaks disproportionately affect the vulnerable residents of aged care facilities, education and training of food handlers in these facilities should be a priority.

Author details

Dr Fiona J May[1]
Dr Benjamin G Polkinghorne[2]
Dr Emily J Fearnley[3]

1. Master of Philosophy in Applied Epidemiology Scholar, National Centre for Epidemiology and Population Health, Research School of Population Health, College of Medicine, Biology and Environment, Australian National University and Australian Government Department of Health
2. OzFoodNet Coordinating Epidemiologist, Australian Government Department of Health
3. Research Fellow, National Centre for Epidemiology and Population Health, Research School of Population Health, College of Medicine, Biology and Environment, Australian National University

Corresponding author: Dr Fiona May, Queensland Health, PO Box 2368, Fortitude Valley BC QLD 4006, Telephone: +61 7 3624 1212. Email: Fiona.May@health.qld.gov.au

References

1. Argudin MA, Mendoza MC, Rodicio MR. Food poisoning and *Staphylococcus aureus* enterotoxins. *Toxins (Basel)* 2010;2(7):1751–1773.
2. Stenfors Arnesen LP, Fagerlund A, Granum PE. From soil to gut: *Bacillus cereus* and its food poisoning toxins. *FEMS Microbiol Rev* 2008;32(4):579–606.
3. Ehling-Schulz M, Frenzel E, Gohar M. Food-bacteria interplay: pathometabolism of emetic *Bacillus cereus*. *Front Microbiol* 2015;6:704.
4. Tranter HS. Foodborne staphylococcal illness. *Lancet* 1990;336(8722):1044–1046.
5. Food and Drug Administration. *Clostridium perfringens*. In: *Bad Bug Book, Foodborne Pathogenic Microorganisms and Natural Toxins.* 2nd edn; 2012. p. 83–86.
6. Food and Drug Administration. *Bacillus cereus*. In: *Bad Bug Book, Foodborne Pathogenic Microorganisms and Natural Toxins.* 2nd edn; 2012. p. 92–95.
7. Hennekinne JA, De Buyser ML, Dragacci S. *Staphylococcus aureus* and its food poisoning toxins: characterization and outbreak investigation. *FEMS Microbiol Rev* 2012;36(4):815–836.
8. Kirk MD, McKay I, Hall GV, Dalton CB, Stafford R, Unicomb L, et al. Food safety: foodborne disease in Australia: the OzFoodNet experience. *Clin Infect Dis* 2008;47(3):392–400.
9. OzFoodNet Working Group. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet network, 2011. *Commun Dis Intell* 2015;39(2):E236–E264.
10. OzFoodNet Working Group. OzFoodNet quarterly report, 1 October to 31 December 2013. *Commun Dis Intell* 2015;39(3):E478–E484.
11. Centers for Disease Control and Prevention. Guide to confirming a diagnosis in foodborne disease. 2013. Accessed on 20 May 2015. Available from: http://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/confirming_diagnosis.html
12. Weingold SE, Guzewich JJ, Fudala JK. Use of Foodborne Disease Data for HACCP Risk Assessment. *J Food Prot* 1994;57(9):820–830.
13. Australian Bureau of Statistics. Table 4, 3101.0 – Australian Demographic Statistics, December 2014. Accessed on 27 August 2015. Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202014?OpenDocument
14. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: annual report of the OzFoodNet network, 2010. *Commun Dis Intell* 2012;36(3):E213–E241.
15. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: annual report of the OzFoodNet Network, 2009. *Commun Dis Intell* 2010;34(4):396–426.
16. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: annual report of the OzFoodNet Network, 2008. *Commun Dis Intell* 2009;33(4):389–413.
17. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: annual report of the Ozfoodnet Network, 2006. *Commun Dis Intell* 2007;31(4):345–365.
18. Burden and causes of foodborne disease in Australia: Annual report of the OzFoodNet network, 2005. *Commun Dis Intell* 2006;30(3):278–300.
19. Reported foodborne illness and gastroenteritis in Australia: annual report of the OzfoodNet network, 2004. *Commun Dis Intell* 2005;29(2):165–192.
20. Foodborne disease investigation across Australia: annual report of the OzFoodNet network, 2003. *Commun Dis Intell* 2004;28(3):359–389.
21. Foodborne disease in Australia: incidence, notifications and outbreaks. Annual report of the OzFoodNet network, 2002. *Commun Dis Intell* 2003;27(2):209–243.
22. OzFoodNet quarterly report, 1 July to 30 September 2012. *Commun Dis Intell* 2013;37(3):E260–E266.
23. OzFoodNet quarterly report, 1 January to 31 March 2012. *Commun Dis Intell* 2012;36(4):E353–E360.
24. OzFoodNet quarterly report, 1 April to 30 June 2012. *Commun Dis Intell* 2013;37(1):E73–E78.
25. Ashbolt R, Givney R, Gregory JE, Hall G, Hundy R, Kirk M, et al. Enhancing foodborne disease surveillance across Australia in 2001: the OzFoodNet Working Group. *Commun Dis Intell* 2002;26(3):375–406.
26. Fullerton K, OzFoodNet Working G. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: annual report of the OzFoodNet Network, 2007. *Commun Dis Intell* 2008;32(4):400–424.
27. OzFoodNet Working Group. OzFoodNet quarterly report, 1 July to 30 September 2013. *Commun Dis Intell* 2015;39(2):E280–E284.
28. OzFoodNet Working Group. OzFoodNet quarterly report, 1 April to 30 June 2013. *Commun Dis Intell* 2014;38(4):E376–E382.

29. OzFoodNet Working Group. OzFoodNet enhanced foodborne disease surveillance, 1 January to 31 March 2013. *Commun Dis Intell* 2014;38(1):E70–E77.

30. OzFoodNet Working Group. OzFoodNet quarterly report, 1 October to 31 December 2012. *Commun Dis Intell* 2013;37(4):E418–E426.

31. Food and Drug Administration. *Staphylococcus aureus*. In: *Bad Bug Book, Foodborne Pathogenic Microorganisms and Natural Toxins*. 2nd edn; 2012. p. 87–91.

32. Gilbert RJ, Parry JM. Serotypes of *Bacillus cereus* from outbreaks of food poisoning and from routine foods. *J Hyg (Lond)* 1977;78(1):69–74.

33. Bennett SD, Walsh KA, Gould LH. Foodborne disease outbreaks caused by *Bacillus cereus, Clostridium perfringens,* and *Staphylococcus aureus*—United States, 1998–2008. *Clin Infect Dis* 2013;57(3):425–433.

34. Food Standards Australia New Zealand. Australia New Zealand Food Standards Code – Standard 3.2.2 – Food Safety Practices and General Requirements (Australia only). 2014.

35. Lindstrom M, Heikinheimo A, Lahti P, Korkeala H. Novel insights into the epidemiology of *Clostridium perfringens* type A food poisoning. *Food Microbiol* 2011;28(2):192–198.

36. European Food Safety Authority. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2014. *EFSA Journal 2015* 2015;13(12):4329.

37. Kirk MD, Veitch MG, Hall GV. Gastroenteritis and food-borne disease in elderly people living in long-term care. *Clin Infect Dis* 2010;50(3):397–404.

38. Grass JE, Gould LH, Mahon BE. Epidemiology of food-borne disease outbreaks caused by *Clostridium perfringens,* United States, 1998–2010. *Foodborne Pathog Dis* 2013;10(2):131–136.

39. Australian Government Department of Social Services. *Gastro-Info gastroenteritis kit for aged care: resources to assist residential aged care homes in preventing, identifying and managing outbreaks of gastroenteritis*. 2014. Accessed on 16 November 2015. Available from: https:// https://agedcare.health.gov.au/publications-articles/resources-learning-training/gastro-info-gastroenteritis-kit-for-aged-care-resources-to-assist-residential-aged-care-homes-in-preventing-identifying-managing-outbreaks-of-gastroenteritis

40. Kirk MD, Lalor K, Raupach J, Combs B, Stafford R, Hall GV, et al. Food- and waterborne disease outbreaks in Australian long-term care facilities, 2001–2008. *Foodborne Pathog Dis* 2011;8(1):133–139.

41. Levine WC, Smart JF, Archer DL, Bean NH, Tauxe RV. Foodborne disease outbreaks in nursing homes, 1975 through 1987. *JAMA* 1991;266(15):2105–2109.

42. Ryan MJ, Wall PG, Adak GK, Evans HS, Cowden JM. Outbreaks of infectious intestinal disease in residential institutions in England and Wales 1992–1994. *J Infect* 1997;34(1):49–54.

43. May FJ. Epidemiology of foodborne and emerging infectious diseases in Australia, 2014 to 2015: Australian National University; 2015.

44. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000 and circa 2010. *Emerg Infect Dis* 2014;20(11):1857–1864.