Sequelae of Foodborne Illness Caused by 5 Pathogens, Australia, Circa 2010

Laura Ford, Martyn Kirk, Kathryn Glass, and Gillian Hall

In Australia circa 2010, 4.1 million (90% credible interval [CrI] 2.3–6.4 million) episodes of foodborne gastroenteritis occurred, many of which might have resulted in sequelae. We estimated the number of illnesses, hospitalizations, and deaths from Guillain-Barré syndrome, hemolytic uremic syndrome, irritable bowel syndrome, and reactive arthritis that were associated with contaminated food in Australia. Data from published studies, hospital records, and mortality reports were combined with multipliers to adjust for different transmission routes. We used Monte Carlo simulation to estimate median estimates and 90% CrIs. In Australia, circa 2010, we estimated that 35,840 (90% CrI 25,000–54,000) illnesses, 1,080 (90% CrI 700–1,600) hospitalizations, and 10 (90% CrI 5–14) deaths occurred from foodborne gastroenteritis–associated sequelae. *Campylobacter* spp. infection was responsible for 80% of incident cases. Reducing the incidence of campylobacteriosis and other foodborne diseases would minimize the health effects of sequelae.

Foodborne gastroenteritis is a major source of illness in Australia, causing an estimated 4.1 million (90% credible interval [CrI] 2.3–6.4 million) illnesses, 30,600 (90% CrI 28,000–34,000) hospitalizations, and 60 (90% CrI 53–63) deaths each year (*1*). In addition to the direct effects of these illnesses, infection with some pathogens can result in sequelae, which can be severe, require multiple hospitalizations, and be costly to society (*2*). We report on the effects of sequelae associated with Guillain-Barré syndrome (GBS), hemolytic uremic syndrome (HUS), irritable bowel syndrome (IBS), and reactive arthritis (ReA) from 5 pathogens acquired from contaminated food in Australia.

Each of these 4 sequel illnesses are preceded by different gastrointestinal infections and have unique characteristics. GBS, a rare but serious autoimmune illness, affects the nervous system and causes acute flaccid paralysis. GBS can occur as a sequel to *Campylobacter* spp. infection 10 days–3 weeks after gastrointestinal illness (*3*,*4*). HUS is characterized by acute renal failure, hemolytic anemia, and thrombocytopenia and can result from infection with Shiga toxin–producing *Escherichia coli* (STEC) ≈4–10 days after onset of gastroenteritis (*5*,*6*). IBS is a gastrointestinal disorder that causes abdominal pain and bowel dysfunction. It is not life threatening, but it can cause substantial health effects after illness with *Campylobacter* spp., nontyphoidal *Salmonella enterica* serotypes (hereafter referred to as nontyphoidal *Salmonella* spp.), or *Shigella* spp. (*7*,*8*). ReA is a type of spondyloarthritis that can develop up to 4 weeks after an enteric infection from *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., or *Yersinia enterocolitica* (*9*). We estimated the number of illnesses, hospitalizations, and deaths resulting from GBS, HUS, IBS, and ReA from selected foodborne pathogens in Australia in a typical year circa 2010.

Author affiliation: Australian National University, Canberra, Australian Capital Territory, Australia

DOI: http://dx.doi.org/10.3201/eid2011.131316

Methods

We estimated the effects of foodborne sequelae acquired in Australia circa 2010 using data from multiple sources in Australia and from international peer-reviewed literature. We defined foodborne sequelae as illnesses occurring after bacterial gastroenteritis caused by eating contaminated food. Sequelae were defined as the secondary adverse health outcomes resulting from a previous infection by a microbial pathogen and clearly distinguishable from the initial health event (*10*). Illness can be acute, such as with HUS, or chronic (lasting for many years), as with IBS. We estimated incidence, hospitalizations, and deaths with uncertainty bounds using Monte Carlo simulation in @Risk version 6 (http://www.palisade.com/), which incorporates uncertainty in both data and inputs. Each stage of our calculation was represented by a probability distribution, and our final estimates of incidence, hospitalizations, and deaths were summarized by the median and 90% CrI. Similar to a recent study in the United States (*11*), we used empirical distributions for source distributions, such as the number of hospitalizations or deaths, to avoid assumptions about the expected shape of these distributions. All other inputs were modeled by using the PERT (project evaluation and review technique) distribution, which enables the input of a minimum, maximum, and modal value, or 3 percentile points, such as a median value and 95% bounds. We used this distribution widely in our analyses because

it enables asymmetric distributions and can be produced from many data sources, including expert elicitation data. The Australian National University Human Research Ethics Committee approved the study.

Incidence of Sequelae

Several pathogens are associated with the development of sequelae. Community estimates of foodborne illness from Kirk et al. (*1*) for *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., STEC, and *Y. enterocolitica* were used for estimating the incidence of foodborne sequelae (Table 1). Although *Shigella* spp. and nontyphoidal *Salmonella* spp. have been associated with HUS and STEC has been associated with IBS and ReA, data on which to base estimates are limited. In addition, although other pathogens, such as *Chlamydia trachomatis*, *Clostridium difficile*, *Giardia lamblia*, and norovirus, have been associated with these sequelae (*12–15*), we assessed only pathogens commonly associated with sequelae, domestically acquired, and with a foodborne transmission pathway. A "sequelae multiplier," which is the proportion of sequelae cases that develop after enteric infection with a specific bacterial pathogen, was applied to our estimates of domestically acquired foodborne gastroenteritis cases caused by that pathogen (*1*). For each sequel illness, we reviewed relevant studies published during 1995–2012 using systematic reviews and studies using Australian data where possible to estimate the relevant sequelae multipliers. We reviewed articles about sequelae after infection with *Campylobacter* spp., *E. coli*, nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica*, and we estimated sequelae multipliers for GBS, HUS, IBS, and ReA after bacterial gastrointestinal infection on the basis of these reviews (Table 2). Relevant articles and additional information are documented in online Technical Appendix 1 (http://wwwnc.cdc.gov/EID/article/20/11/13-1316-Techapp1.pdf).

Our sequelae multiplier for GBS was based on 30.4 (range 19.2–94.5) cases of GBS per 100,000 cases of campylobacteriosis using data from studies from the United Kingdom, Sweden, and the United States (*16–18*). For HUS, the sequelae multiplier used was 3% (95% CI 1.7%–5.4%) from a South Australian study on STEC and HUS notifications during 1997–2009 (*19*). On the basis of data from Haagsma et al. (*20*), we assumed that 8.8% (95% CI 7.2%–10.4%) of foodborne disease caused by *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. result in IBS. We used a separate sequelae multiplier for each pathogen that resulted in ReA. We assumed that 7% (range 2.8%–16%) of foodborne cases of *Campylobacter* spp., 8.5% (range 0%–26%) of foodborne cases of nontyphoidal *Salmonella* spp., 9.7% (range 1.2%–9.8%) of foodborne cases of *Shigella* spp., and 12% (range 0%–23.1%) of foodborne cases of *Y. enterocolitica* result in ReA (see full reference list in online Technical Appendix 1). Total foodborne IBS and ReA cases reflect the sum of modeled IBS and ReA cases from these 3 and 4 pathogens, respectively. Details on the sequelae multipliers and incidence estimation methods are in online Technical Appendix 1 and online Technical Appendix 2 (http://wwwnc.cdc.gov/EID/article/20/11/13-1316-Techapp2.pdf).

We compared the incidence of sequelae circa 2010 to that of sequelae circa 2000 by applying the same sequelae multipliers to estimates of the incidence of acute gastroenteritis to specific pathogens in 2006–2010 and 1996–2000, respectively. The estimates of incidence of acute gastroenteritis were based on notification data for *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., STEC, and *Y. enterocolitica* (*19*,*21*,*22*), (online Technical Appendix 3, http://wwwnc.cdc.gov/EID/article/20/11/13-1316-Techapp3.pdf).

Hospitalizations and Deaths

To estimate hospitalizations associated with IBS from foodborne *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. and hospitalizations associated with ReA from foodborne *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica*, we used hospitalization data for 2006–2010 from all Australian states and territories, according to the International Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM) codes. To estimate deaths for all 4

Table 1. Pathogens associated with GBS, HUS, IBS, and ReA included in this study, Australia, circa 2010*

Pathogen	GBS	HUS	IBS	ReA
Campylobacter spp.	X		X	X
Nontyphoidal *Salmonella* spp.†			X	X
Shigella spp.			X	X
Shiga toxin–producing *Escherichia coli*		X		
Yersinia enterocolitica				X

*GBS, Guillain-Barré syndrome; HUS, hemolytic uremic syndrome; IBS, irritable bowel syndrome; ReA, reactive arthritis.
†Nontyphoidal *S. enterica* serotypes.

Table 2. Sequelae multipliers extracted from the literature about domestically acquired foodborne bacterial gastroenteritis*

Sequelae	ICD-10-AM code	Incidence after bacterial infection, %
GBS, median (range)	G61.0	0.0304 (0.0192–0.0945)
HUS, median (95% CI)	D59.3	3 (1.7–5.1)
IBS, median (90% CrI)	K58.0 K58.9	8.8 (7.2–10.4)
ReA, median (range)	M02.1 M02.3 M02.8 M03.2	7–12 (0–26)

*CrI. credible interval; GBS, Guillain-Barré syndrome; HUS, hemolytic uremic syndrome; IBS, irritable bowel syndrome; ICD-10-AM, International Classification of Diseases, Tenth Revision, Australian Modification; ReA, reactive arthritis.

sequelae illnesses resulting from the respective foodborne pathogens, we used national death data for 2001–2010 from the Australian Bureau of Statistics, using ICD-10-AM codes (online Technical Appendix 4, http://wwwnc.cdc.gov/EID/article/20/11/13-1316-Techapp4.pdf). Principal diagnosis and additional diagnoses were included for hospitalizations, and underlying and contributing causes were included for deaths. Because we had only 1 year of hospitalization data for Victoria and 2 years for New South Wales, we extrapolated from these data to derive a distribution of the number of hospitalizations across all states, which was modeled as an empirical distribution. For these states, we assumed the same number of hospitalizations each year to adjust for missing data. Because of the severity of GBS and HUS, hospitalization estimates for these illnesses were not modeled, and all persons with estimated incident cases from contaminated food were considered to have been hospitalized.

We estimated incidences of hospitalization and death using a statistical model that incorporates uncertainty in case numbers and in multipliers using probability distributions (Figure), which is adjusted from the hospitalization estimation flow chart in Kirk et al. (*1*). We assumed that all estimated incident foodborne *Campylobacter*-associated GBS and STEC-associated HUS case-patients were hospitalized, so those cases were not modeled; however, multipliers were still needed for GBS and HUS to estimate deaths. Sequelae-associated deaths were estimated by using the same methods as for hospitalizations (Figure). Input data arose from the data sources discussed above or from multipliers that are discussed below.

Domestically Acquired Multiplier

The "domestically acquired multiplier" adjusted for the proportion of case-patients who acquired their infection in Australia. We estimated domestically applied multipliers for the antecedent bacterial gastrointestinal pathogens using notifiable surveillance data from each state, extrapolated to give national estimates (*1*). We adopted the domestically acquired multiplier for *Campylobacter* spp. of 0.97 (90% CrI 0.91–0.99) for GBS and the domestically acquired multiplier for STEC 0.79 (90% CrI 0.73–0.83) for HUS (*1*). For IBS and ReA, a combined domestically acquired multiplier for *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. for IBS and *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp. and *Y. enterocolitica* for ReA was calculated as a weighted average of the domestically acquired multipliers for each pathogen, weighted by the total number of IBS and ReA cases for each pathogen, respectively (online Technical Appendix 4; online Technical Appendix 5, http://wwwnc.cdc.gov/EID/article/20/11/13-1316-Techapp5.pdf).

Proportion Foodborne Multiplier

For each of the 4 sequelae, we calculated the proportion of hospitalizations and deaths from foodborne pathogens using 2 multipliers: a "bacterial multiplier" to attribute the proportion of overall cases of each of the sequelae illnesses to specific pathogens and a "foodborne multiplier" to attribute illnesses to foodborne exposure. The bacterial multiplier, which was the proportion of sequel cases attributable to their antecedent bacterial pathogen, was extracted from systematic reviews for GBS and HUS (*4*,*23*) and multiplied by the foodborne proportion for *Campylobacter* spp. and STEC, respectively. For IBS and ReA, from the literature we extracted a midpoint and range of the proportion of cases that resulted from infectious gastroenteritis (*12*,*20*,*24*). The IBS bacterial multiplier was then further multiplied by a foodborne multiplier for *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp., which was calculated as a weighted average of the foodborne multipliers for each pathogen, weighted by the total number of IBS cases for each pathogen. The ReA bacterial multiplier was then also multiplied by the foodborne multiplier for *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica* by using a weighted average of the foodborne multipliers for each pathogen as was done for IBS (online Technical Appendices 4 and 5).

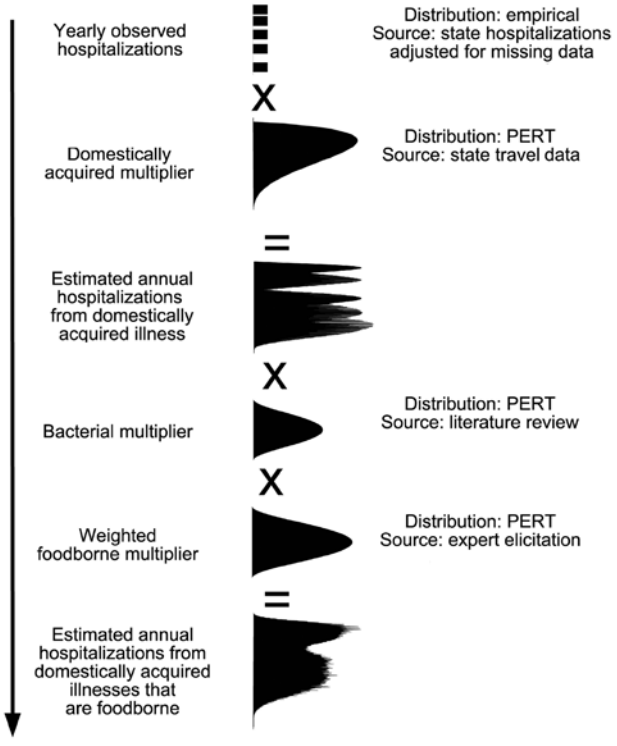


Figure. Flow chart for the approach used to calculate the estimated annual number of hospitalizations for sequelae associated with foodborne illness caused by 5 pathogens, Australia, circa 2010.

Results

Incidence

We estimated that, circa 2010 in Australia, 70 (90% CrI 30–150) new cases of *Campylobacter*-associated GBS, 70 (90% CrI 25–200) new cases of STEC-associated HUS, 19,500 (90% CrI 12,500–30,700) new cases of *Campylobacter*-, nontyphoidal *Salmonella*– and *Shigella*-associated IBS, and 16,200 (90% CrI 8,750–30,450) new cases of *Campylobacter*-, nontyphoidal *Salmonella*-, *Shigella*-, and *Y. enterocolitica*–associated ReA were domestically acquired and caused by contaminated food (Table 3). We estimated that 35,840 (90% CrI 25,000–54,000) domestically acquired sequel illnesses resulted from foodborne gastroenteritis—an incidence rate of 1,620 (90% CrI 1,150–2,450) sequelae cases per million population. *Campylobacter* spp. infection resulted in the largest number of sequelae cases annually; ≈80% of the 36,000 sequel illnesses were attributable to *Campylobacter* spp. alone.

Comparison with Estimates Circa 2000

Using data circa 2000, we estimated that 50 GBS cases, 55 HUS cases, 14,800 IBS cases, and 12,500 ReA cases occurred each year. Elsewhere, we estimated that the rate of foodborne campylobacteriosis was approximately 13% higher in 2010 than 2000 (*1*); this increase led to a 13% increase in *Campylobacter*-associated GBS in 2010 over 2000. Similarly, we estimated that the rate of foodborne salmonellosis was 24% higher in 2010 than in 2000 (*1*). These factors combine to explain much of the increase in IBS and ReA. The rate of STEC-associated HUS remained about the same in 2000 and 2010 (online Technical Appendix 3).

Hospitalizations and Deaths

We estimated that, circa 2010 in Australia, 1,080 (90% CrI 700–1,600) hospitalizations for sequelae illnesses occurred from domestically acquired foodborne gastroenteritis, equating to 50 (90% CrI 30–70) hospitalizations per million population per year (Table 4). We estimated a total of 10 (90% CrI 5–14) deaths from sequelae to domestically acquired foodborne gastroenteritis—a rate of 0.5 (90% CrI 0.2–0.6) deaths per million population per year (Table 4).

Discussion

Our study demonstrates that foodborne gastroenteritis in Australia results in substantial severe and disabling sequelae. We estimated a yearly rate of 1,620 incident cases of sequelae illnesses, 50 hospitalizations, and 0.5 deaths per million population circa 2010. In addition, a comparison with estimates recalculated for 2000 indicates an increase in the rates of GBS, IBS, and ReA since 2000, which is consistent with and directly related to rising levels of antecedent foodborne illnesses caused by *Campylobacter* spp. and nontyphoidal *Salmonella* spp. during this period (*1*). This increase highlights the importance of quantifying sequelae when estimating the effects of foodborne disease and provides further impetus for reducing illness from foodborne bacterial pathogens.

The impact of *Campylobacter* spp. infection in the community is high. Approximately 179,000 cases of foodborne campylobacteriosis occur in Australia each year (*1*), and *Campylobacter* spp. was responsible for 80% of the foodborne sequelae illness estimated in this study. The reported rate of infection from *Campylobacter* spp. in Australia has increased since 2010 (*1*) and is higher than in many other industrialized countries. For example, the rate of *Campylobacter* spp. for Australia was ≈10 times higher than that for the United States (*25*), double that for the Netherlands (*26*), and slightly higher than that for the United Kingdom (*27*). In the Netherlands, a lower rate of acute *Campylobacter* spp. gastroenteritis has contributed to lower estimates of rates of sequel illnesses than our estimates for GBS, IBS, and ReA (*26*).

In New Zealand, food safety interventions have been effective in lowering campylobacteriosis rates and sequelae. In 2006, high campylobacteriosis notification rates (>3,800 cases per million population) prompted increased research on *Campylobacter* spp., which resulted in the introduction of food safety and poultry industry interventions, including *Campylobacter* spp. performance targets at primary processing plants and promotion of freezing all fresh poultry meat (*28*). By 2008, the rate of campylobacteriosis notifications decreased by 54% to 1,615 cases per million population (*28*). In addition, after these interventions in New Zealand, the rate of GBS hospitalizations decreased by 13% (*29*). The less dramatic decrease in GBS than in campylobacteriosis might be explained by the fact that *Campylobacter* spp. is not the only cause of GBS. If Australia were to experience decreases similar to those in New Zealand, we would expect the rate of foodborne campylobacteriosis in the community to drop from approximately 8,400 to 3,864 cases per million population. Sequelae would decrease from 1,620 to 870 cases per million population per year. Furthermore, total GBS-associated hospitalizations, including GBS from all causes and readmissions, would decrease from ≈73 to 63 hospitalizations per million population annually.

A comparison of our foodborne *Campylobacter*-associated GBS incidence estimates with raw hospitalization data showed many more hospitalizations than incident cases. This finding probably is attributable to repeat hospitalizations. We took a conservative approach by basing incidence estimates on community estimates of campylobacteriosis and assuming that all persons with incident cases were hospitalized. A yearly median of 1,536 (range

Table 3. Estimated number of sequelae illnesses resulting from domestically acquired foodborne bacterial gastroenteritis, Australia, circa 2010*

Sequelae, pathogen	Median no. Illnesses (90% CrI)	Median rate (90% CrI)†
GBS, *Campylobacter* spp.	70 (30–150)	3.1 (2–6)
HUS, STEC	70 (25–200)	3.3 (1–9)
IBS		
Campylobacter spp	15,600 (9,000–26,500)	915 (570–1,440)
Nontyphoidal *Salmonella* spp.‡	3,500 (1,900–6,500)	
Shigella spp.	30 (10–80)	
Total§	19,500 (12,500–30,700)	
ReA		
Campylobacter spp.	12,500 (5,500–25,500)	765 (415–1,375)
Nontyphoidal *Salmonella* spp.‡	3,250 (700–9,000)	
Shigella spp.	29 (10–75)	
Yersinia enterocolitica	150 (50–300)	
Total§	16,200 (8,500–30,000)	
Total	35,840 (25,000–54,000)	1,620 (1,150–2,450)

*CrI, credible interval; GBS, Guillain-Barré syndrome; HUS, hemolytic uremic syndrome; IBS, irritable bowel syndrome; ReA, reactive arthritis; STEC, Shiga toxin–producing *Escherichia coli*.
†No. cases per million population.
‡i.e., nontyphoidal *S. enterica* serotypes.
§Simulated values, which might not add to total because of rounding and variation over simulations.

1,428–1,632) primary and additional GBS diagnoses occurred in Australian hospitals during 2006–2010 (including GBS from all causes and readmissions) and equates to a median rate of 73.1 (range 64.7–77.4) GBS-associated hospitalizations per million population each year. This rate is within the range from a New Zealand study, which found a median rate of 56.3 (range 42.1–75.9) GBS-associated hospitalizations during a 13-year period, with ≈41% of case-patients being readmitted, resulting in 23.2 (range 15.3 29.3) incident GBS hospitalizations per million population each year (*29*). If we assume that 41% of Australia's 1,536 GBS hospitalizations are readmissions and apply the domestically acquired multiplier and foodborne proportion multiplier used to estimate GBS-associated deaths (online Technical Appendix 4), we would estimate 170 (90% CrI 60–265) incident foodborne *Campylobacter*-associated GBS hospitalizations. This point estimate is higher than our current estimate of 70, although the credible interval includes our estimate. A validation study of medical records of persons with GBS would enable us to better characterize readmissions for GBS.

Our approach has several limitations. First, our comparison of sequelae estimates for 2000–2010 assumes a constant rate of sequelae illness after gastrointestinal infection over time. Although our methods provide an indirect method of assessing changes in sequelae incidence over time, the approach is useful because it enables comparison of the population-level effect of sequelae at these 2 time points. Second, our study measured incidence and not prevalence of sequelae. We estimated the number of new cases every year and did not quantify the long-term effects of these sequelae. Third, our study does not estimate all sequelae illness from foodborne disease pathogens. We did not include sequelae, such as end-stage renal disease, inflammatory bowel disease, and encephalitis, in our estimates. We chose GBS, HUS, IBS, and ReA for this study because they were known, well studied, and well characterized in available data sources. These provide a good basis to begin to understand the effects of foodborne sequelae and the policy implications of reducing illness from preceding bacterial pathogens.

Our estimates for GBS, HUS, IBS, and ReA incidence relied heavily on the quality of the literature we reviewed. We used Australian data and systematic reviews wherever possible. The Australian hospitalization and deaths data we used were of high quality and included both principal and additional diagnoses from all states. However, because data were missing from some states in some years, we extrapolated from these data to the remaining years. Finally, ICD-10 and ICD-10-AM coding can be problematic when co-morbid conditions are present, when hospital transfers occur, or when diagnostic criteria are inconsistent. Therefore, our estimates for sequelae hospitalizations and deaths may be conservative because they do not account for these coding errors.

Table 4. Estimated number of sequelae-associated hospitalizations and deaths caused by domestically acquired foodborne bacterial gastroenteritis, Australia, circa 2010*

	Hospitalizations		Deaths	
Sequelae	Median no. (90% CrI)	Rate (90% CrI)†	Median no. (90% CrI)	Rate (90% CrI)†
GBS	70 (30–150)	3.1 (2–6)	6 (2–10)	0.3 (0.1–0.5)
HUS	70 (25–200)	3.3 (1–9)	2 (1–3)	0.1 (0.03–0.12)
IBS	915 (550–1,400)	43 (25–70)	2 (1–2)	0.1 (0.05–0.11)
ReA	25 (20–40)	1 (1–2)	0	0
Total	1,080 (700–1,600)	50 (30–70)	10 (5–14)	0.5 (0.2–0.6)

*CrI, credible interval. GBS, Guillain-Barré syndrome; HUS, hemolytic uremic syndrome; IBS, irritable bowel syndrome; ReA, reactive arthritis; STEC, Shiga toxin–producing *Escherichia coli*.
†Cases per million population.

The sequelae estimates from this study showed that the impact of foodborne *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., STEC, and *Y. enterocolitica* was much greater then when consideration is given simply to the initial acute illness. *Campylobacter* spp. infection, in particular, was highlighted as an increasing problem in Australia. Our estimates provide a basis for costing studies, which can be useful for developing food safety policies and interventions. Finally, our study highlights the need for better data from large population-based studies in Australia to further characterize sequelae, as well as foodborne pathogens.

Acknowledgments

We thank John Bates, Kathryn Brown, Duncan Craig, Margaret Curran, Patricia Desmarchelier, Gerard Fitszimmons, Katie Fullerton, Joy Gregory, David Jordan, Tony Merritt, Jennie Musto, Nevada Pingault, Jane Raupach, Craig Shadbolt, Martha Sinclair, Lisa Szabo, Hassan Vally, and Mark Veitch for their assistance with this study. We also thank the OzFoodNet network, public health laboratories, and health department staff in Australia for the robust collection of data on foodborne diseases.

This project was funded by the Australian Government Department of Health and Ageing, Food Standards Australia New Zealand and New South Wales Food Authority.

Ms Ford is a research assistant in the infectious disease and modelling group at the National Centre for Epidemiology and Population Health at the Australian National University. Her research interests include infectious diseases.

References

1. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000 and circa 2010. Emerg Infect Dis. 2014;20:1852–9.
2. Abelson P, Potter Forbes M, Hall G. The annual cost of foodborne illness in Australia. Canberra (Australia): Commonwealth Department of Health and Ageing; 2006.
3. Hughes RA, Rees JH. Clinical and epidemiological features of Guillain-Barré syndrome. J Infect Dis. 1997;176(Suppl2):S92–8. http://dx.doi.org/10.1086/513793
4. Poropatich KO, Walker CL, Black RE. Quantifying the association between *Campylobacter* infection and Guillain-Barré syndrome: a systematic review. J Health Popul Nutr. 2010;28:545–52.
5. Elliott EJ, Robins-Browne RM. Hemolytic uremic syndrome. Curr Probl Pediatr Adolesc Health Care. 2005;35:310–30. http://dx.doi.org/10.1016/j.cppeds.2005.06.002
6. López EL, Contrini MM, Glastein E, Ayala SG, Santoro R, Ezcurra G, et al. An epidemiologic surveillance of Shiga-like toxin-producing *Escherichia coli* infection in Argentinean children: risk factors and serum Shiga-like toxin 2 values. Pediatr Infect Dis J. 2012;31:20–4. http://dx.doi.org/10.1097/INF.0b013e31822ea6cf
7. Thabane M, Kottachchi DT, Marshall JK. Systematic review and meta-analysis: the incidence and prognosis of post-infectious irritable bowel syndrome. Aliment Pharmacol Ther. 2007;26:535–44. http://dx.doi.org/10.1111/j.1365-2036.2007.03399.x
8. Dai N, Cong Y, Yuan H. Prevalence of irritable bowel syndrome among undergraduates in southeast China. Dig Liver Dis. 2008;40:418–24. http://dx.doi.org/10.1016/j.dld.2008.01.019
9. Kim PS, Klausmeier TL, Orr DP. Reactive arthritis: a review. J Adolesc Health. 2009;44:309–15. http://dx.doi.org/10.1016/j.jadohealth.2008.12.007
10. Parkin R, Davies-Cole J, Balbus J. A definition for chronic sequelae applied to campylobacter and Guillian-Barré syndrome (GBS). Ann Epidemiol. 2000;10:473. http://dx.doi.org/10.1016/S1047-2797(00)00108-3
11. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, et al. Foodborne illness acquired in the United States—major pathogens. Emerg Infect Dis. 2011;17:7–15. http://dx.doi.org/10.3201/eid1701.P11101
12. Hannu T. Reactive arthritis. Best Pract Res Clin Rheumatol. 2011;25:347–57. http://dx.doi.org/10.1016/j.berh.2011.01.018
13. Alvarado AS, Brodsky SV, Nadasdy T, Singh N. Hemolytic uremic syndrome associated with *Clostridium difficile* infection. Clin Nephrol. 2014;81:302–6. http://dx.doi.org/10.5414/CN107691
14. D'Anchino M, Orlando D, De Feudis L. *Giardia lamblia* infections become clinically evident by eliciting symptoms of irritable bowel syndrome. J Infect. 2002;45:169–72. http://dx.doi.org/10.1016/S0163-4453(02)91038-8
15. Marshall JK, Thabane M, Borgaonkar MR, James C. Postinfectious irritable bowel syndrome after a food-borne outbreak of acute gastroenteritis attributed to a viral pathogen. Clin Gastroenterol Hepatol. 2007;5:457–60. http://dx.doi.org/10.1016/j.cgh.2006. 11.025
16. Tam CC, Rodrigues LC, Petersen I, Islam A, Hayward A, O'Brien SJ. Incidence of Guillain-Barré syndrome among patients with *Campylobacter* infection: a general practice research database study. J Infect Dis. 2006;194:95–7. http://dx.doi.org/10.1086/504294
17. McCarthy N, Giesecke J. Incidence of Guillain-Barré syndrome following infection with *Campylobacter jejuni*. Am J Epidemiol. 2001;153:610–4. http://dx.doi.org/10.1093/aje/153.6.610
18. Allos BM. Association between *Campylobacter* infection and Guillain-Barré syndrome. J Infect Dis. 1997;176(Suppl 2):S125–8. http://dx.doi.org/10.1086/513783
19. Vally H, Hall G, Dyda A, Raupach J, Knope K, Combs B, et al. Epidemiology of Shiga toxin producing *Escherichia coli* in Australia, 2000–2010. BMC Public Health. 2012;12:63–71. http://dx.doi.org/10.1186/1471-2458-12-63
20. Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH. Disease burden of post-infectious irritable bowel syndrome in the Netherlands. Epidemiol Infect. 2010;138:1650–6. http://dx.doi.org/10.1017/S0950268810000531
21. Government of Australia. National Notifiable Disease Surveillance System (NNDSS). [cited 2013 Apr 5]. http://www9.health.gov.au/cda/source/cda-index.cfm
22. Hall G, Kirk M. Foodborne illnesses in Australia: annual incidence circa 2000. Canberra (Australia): Commonwealth Department of Health and Ageing; 2005 April. report no. 0642825769.
23. Walker CL, Applegate JA, Black RE. Haemolytic-uraemic syndrome as a sequela of diarrhoeal disease. J Health Popul Nutr. 2012;30:257–61. http://dx.doi.org/10.3329/jhpn.v30i3.12288
24. Schwille-Kiuntke J, Frick JS, Zanger P, Enck P. Post-infectious irritable bowel syndrome—a review of the literature. Z Gastroenterol. 2011;49:997–1003. http://dx.doi.org/10.1055/s-0031-1281581
25. Vally H, Hall G, Scallan E, Kirk MD, Angulo FJ. Higher rate of culture-confirmed *Campylobacter* infections in Australia than in the USA: is this due to differences in healthcare-seeking behaviour or stool culture frequency? Epidemiol Infect. 2009;137:1751–8. http://dx.doi.org/10.1017/S0950268809990161
26. Havelaar AH, Haagsma JA, Mangen MJ, Kemmeren JM, Verhoef LP, Vijgen SM, et al. Disease burden of foodborne pathogens in the Netherlands, 2009. Int J Food Microbiol. 2012;156:231–8. http://dx.doi.org/10.1016/j.ijfoodmicro.2012.03.029
27. Tam CC, Rodrigues LC, Viviani L, Dodds JP, Evans MR, Hunter PR, et al. Longitudinal study of infectious intestinal disease in the UK (IID2

study): incidence in the community and presenting to general practice. Gut. 2012;61:69–77. http://dx.doi.org/10.1136/gut.2011.238386
28. Sears A, Baker MG, Wilson N, Marshall J, Muellner P, Campbell DM, et al. Marked campylobacteriosis decline after interventions aimed at poultry, New Zealand. Emerg Infect Dis. 2011;17:1007–15. http://dx.doi.org/10.3201/eid/1706.101272
29. Baker MG, Kvalsvig A, Zhang J, Lake R, Sears A, Wilson N. Declining Guillain-Barré syndrome after campylobacteriosis control, New Zealand, 1988–2010. Emerg Infect Dis. 2012;18:226–33. http://dx.doi.org/10.3201/eid1802.111126

Address for correspondence: Martyn Kirk, National Centre for Epidemiology and Population Health, The Australian National University, Canberra, ACT 0200, Australia; email: martyn.kirk@anu.edu.au

Article DOI: http://dx.doi.org/10.3201/eid2011.131316

Sequelae of Foodborne Illness Caused by 5 Pathogens, Australia, Circa 2010

Technical Appendix 1

Sequelae Incidence after Bacterial Gastroenteritis: The Sequelae Multiplier

For each sequel, a multiplier was used that estimated the proportion of bacterial gastroenteritis cases that developed into chronic sequelae. This appendix summarizes the relevant studies published during 1995–2012, which we selected for review, as well as the sequelae multipliers that were estimated for Guillain-Barré syndrome (GBS), hemolytic uremic syndrome (HUS), irritable bowel syndrome (IBS), and reactive arthritis (ReA).

GBS

A few studies have quantified the incidence of GBS illness following *Campylobacter* spp. infection by using large cohorts of patients or the literature (online Technical Appendix 1 Table 1). In a population-based cohort study in the United Kingdom, including 2 months of follow-up, 3 cases of GBS occurred among 15,587 *Campylobacter* spp. cases. This yielded a rate of 19.2 cases of GBS per 100,000 cases of campylobacteriosis (*1*). In Sweden, 0.03% of a cohort of 29,567 persons with laboratory-confirmed *C. jejuni* infection developed GBS illness after 2 months of follow-up, yielding an annual incidence of 30.4 cases of GBS per 100,000 cases (95% CI 13.9–57.8) of *C. jejuni* infection (*2*). In a literature review, Allos (*3*) estimated that in the United States, GBS develops in 1 of every 1,058 cases, or 94.5 per 100,000 cases, of *C. jejuni* infection. Baker et al. (*4*) performed a study of hospital records in New Zealand, which found a rate of 414 cases of GBS per 100,000 *Campylobacter* spp. hospitalizations.

For the sequelae multiplier, a midpoint of 30.4 cases of GBS per 1000,000 cases of campylobacteriosis was taken from the study by McCarthy and Gieseke (*2*) using a minimum value of 19.2 per 100,000 from the UK study and a maximum value of 94.5 per 100,000 from the study by Allos (*3*). Although the study by Baker et al. (*4*) is a valuable one, we excluded it from

the calculation of our sequelae multiplier because persons hospitalized with *Campylobacter* spp. infection may not be representative of *Campylobacter* spp. cases in the community.

Technical Appendix 1 Table 1. Incidence of GBS after infection with *Campylobacter* spp.*

Reference	Study years	Type of study	Country	No. GBS cases/*Campylobacter* spp. patients	Incidence per 100,000 (95% CI)
Baker et al. (*4*)	1995–2008	Cohort	New Zealand	35/8,448 hospitalizations	414 (373–459)
Tam et al. (*1*)	1991–2001	Cohort	UK	3/15,587 cases	19.2 (17.1–21.5)
McCarthy and Giesecke (*2*)	1987–1995	Cohort	Sweden	9/29,563 cases	30.4 (13.9–57.8)
Allos (*3*)	1964–1996†	Review and estimation	Global/USA	1/1058 cases	94.5 (2.4–525)

*GBS, Guillain-Barré syndrome.
†Years of reviewed studies.

HUS

A variety of organisms, drugs and conditions can initiate the symptoms of HUS, but the majority of HUS cases are post-diarrheal—usually caused by Shiga toxin–producing *Escherichia coli* (STEC) (*5*). In developed communities, STEC is the most commonly implicated organism in HUS (*6*), and in children, 90% of HUS cases are due to STEC (*5*). HUS is also associated with *Shigella dysenteria* serotype 1, particularly in less developed communities (*6*); however, a recent systematic review was unable to find an adequate number of studies to quantify the association between *S. dysenteria* serotype 1 and HUS (*7*). In addition, in a few studies, HUS has been associated with *Clostridium difficile* and *Salmonella enterica* serotype Typhi, but the evidence is limited (*8–10*). Therefore we estimated food-related HUS cases as a sequel to STEC, which may create an underestimation of HUS if there are food-related HUS cases in Australia from other organisms.

Several sources have reported that 3%-7% of sporadic STEC infections develop into HUS (*11–14*). Australian studies support this estimate range. Vally et al. (*15*) examined South Australian surveillance data and identified 14 HUS cases and 460 STEC cases, resulting in an estimate of 3% of STEC cases developing into HUS. Sixty percent of HUS case-patients were ≤15 years of age. In addition, in a case–control study in 6 Australian jurisdictions, 113 STEC case-patients were identified, 44 of whom were infected with O157 and 66 who were infected with non-O157 (*14*). Eight (7%) of all the STEC cases, 1 (2%) case-patient with O157, and 7 (10%) case-patients infected with non-O157 developed HUS (*14*). Although STEC O157 is more commonly associated with HUS worldwide (*6*), data on geographic differences in STEC serotypes suggest that in Australia, "non-O157:H7 STEC strains predominate," and STEC O157:H7 is not as frequently implicated in "diarrhea-associated HUS" (*16*).

Overseas studies have reported higher proportions of STEC infections developing into HUS. In a cohort study of Argentinian children, aged ≤15 years, 8 (8.6%) of 93 STEC patients developed HUS (*17*). Through enhanced surveillance in the Netherlands, Van Duynhoven et al. (*18*) found that HUS developed in 12 of 82 (14.6%) patients. Seventy-five percent of HUS case-patients were ≤15 years (*18*). With the highest proportion from all reviewed studies, a Swiss linkage study found that HUS developed in 13 (29.5%) of 44 STEC patients, all of whom were ≤15 years of age (*19*). Several studies on the incidence of HUS after STEC outbreaks have found that ≈20% of STEC cases develop into HUS (*20–23*). However, Sigmundsdottir et al. found no HUS cases among 9 STEC outbreak patients in Iceland (*24*) (Technical Appendix 1 Table 2).

A sequelae multiplier proportion of 3% (95% CI 1.7%–5.4%) was chosen, based on the South Australian study by Vally et al. (*15*). This study was chosen because STEC surveillance in South Australia is more complete than for other Australian states (*11*) and would therefore give a more representative estimate for Australia than the other available studies.

Technical Appendix 1 Table 2. Incidence of HUS after STEC*

Reference	Study years	Study type	Country	Age of HUS case-patients	No. HUS cases/no. STEC cases	STEC cases developing into HUS, %
Bradley et al. (*20*)	2008	Epidemiology investigation and case–control: after an outbreak	USA	Median: 46 y (range1–88 y), 60% adult	11/56	20
Lopez et al. (*17*)	2006	Prospective cohort	Argentina	≤15 y	8/93	8.6
Neil et al. (*21*)	2009	Case–control: after an outbreak	USA	Not stated	10/57	18
Vally et al. (*15*)	1997–2009	Surveillance	Australia	Range: <5–60+, 60% aged ≤15 y	14/460	3
Frank et al. (*22*)	2011	Surveillance: after an outbreak	Germany	Median: 42, 88% aged >15 y	845/3816	22
Kappelli et al. (*19*)	2000–2009	Linkage	Switzerland	Median: 3.5 y (range 0–15 y)	13/44	29.5
McPherson et al. (*14*)	2003–2007	Case–control	Australia	Median: 4 y (range 1–62)	8/113	7
Sigmundsdottir et al. (*24*)	2007	Cohort: after an outbreak	Iceland	Not stated	0/9	0
Rangel et al. (*25*)	1982–2002	Outbreak surveillance	USA	Not stated	354/8598	4.1
Jay et al. (*23*)	1999	Epidemiology investigation and case–control: after an outbreak	USA	Not stated	3/13	23
Van Duynhoven et al. (*18*)	1999–2001	Enhanced surveillance	The Netherlands	Range: 0–70 y, 75% aged ≤15 y	12/82	14.6

*HUS, hemolytic uremic syndrome; STEC, Shiga toxin–producing *Escherichia coli*.

IBS

There have been a few systematic reviews and/or meta-analyses on the association between intestinal infection and post-infectious IBS (PI-IBS). A recent review suggests the proportion of persons developing IBS following gastrointestinal infection is 4%–35% (*26*). In

2010, Haagsma et al. (*27*) found that 1 year after infection from nontyphoidal *S. enterica* serotypes (hereafter referred to as nontyphoidal *Salmonella* spp.), nontyphoidal *Salmonella* spp., *Shigella* spp., or *Campylobacter* spp., IBS developed in 9% (95% CI 7.2–10.7) of patients. Similarly, in a systematic review of 18 studies, Thabane et al. (*28*) found a pooled incidence of PI-IBS of 10% (95% CI 9.4–85.6). Comparably, Halvorson et al. (*29*) reviewed 8 studies on nontyphoidal *Salmonella* spp., *Shigella* spp., bacterial unspecified, or unspecified, and their association with IBS, and calculated a median prevalence of IBS of 9.8% (interquartile range 4.0–13.3) in the exposed group and 1.2% Interquartile rate range 0.04–1.8) in the control group. A review by Smith and Bayles (*30*) found a mean prevalence of PI-IBS of 15% from 15 studies, with species of *Campylobacter*, nontyphoidal *Salmonella* spp., and/or *Shigella* as the most common agents of infection.

In the United Kingdom, Neal et al. (*31*) performed a postal survey and found that 25% of subjects had persistently altered bowel habits after bacterial gastroenteritis from nontyphoidal *Salmonella* spp., *Shigella* spp., or *Campylobacter* spp.; however, only 7% met the Rome criteria for new IBS. Also in the United Kingdom, Parry et al. (*32*) looked at the relationship between IBS and bacterial gastroenteritis from *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., *E. coli* O157, and *Aeromonas sobria*, and calculated an incidence of new IBS of 16.7% in the exposed group and 1.9% in the control group.

Studies looking at singular pathogens have also found an association between infectious gastroenteritis outbreaks and IBS. After an outbreak in 2002 in Spain, Mearin et al. (*33*) noted that before the outbreak, the prevalence of IBS was similar in case-patients and controls (2.9% vs. 2.3%); however, 3 months after the outbreak, IBS prevalence in case-patients had increased (9.2% vs. 1.7%), and 12 months after the outbreak, prevalence in case-patients remained higher (10.2% vs. 0.7%). The cumulative incidence was 7.4% at 3 months, 10.9% at 6 months, and 11.6% at 12 months. In Korea, 12 months after a *Shigella* spp. outbreak, Ji et al. (*34*) found that IBS had developed in 15 (14.9%) of 101 case-patients and 6 of 102 (5.9%) controls. In Canada, 2–3 years after an outbreak of *E. coli* O157:H7 and *Campylobacter* spp., 27.5% of 904 subjects with self-reported gastroenteritis reported IBS, and 36.2% of 464 subjects with clinically suspected gastroenteritis reported IBS (*35*). In a pediatric cohort from the Canadian outbreak, the cumulative incidence of PI-IBS for exposed subjects was 10.5% vs. a cumulative incidence in controls of 2.5% (*36*).

There have been studies on the association of *G. lamblia* with IBS; however, these have produced inconsistent results. While Wensaas et al. (*37*) found a high prevalence of IBS in exposed patients 2 years after acute giardiasis, Penrose et al. (*38*) found no linear association between *G. lamblia* and IBS, and a study by D'Anchino et al. (*39*) concluded that *G. lamblia* infection is a trigger for exacerbating preexisting IBS but could not conclude that *G. lamblia* causes IBS. PI-IBS has also been shown to develop after norovirus. Marshall et al. (*40*) performed a 2-year study after a norovirus outbreak; of the 89 respondents who reported an acute enteric illness during the outbreak and did not have preexisting IBS, 23.6% reported symptoms consistent with PI-IBS at 3 months versus 3.4% who reported symptoms but remained well during the outbreak. However, at 6, 12, and 24 months, the prevalence of IBS did not differ statistically among exposed and unexposed individuals, suggesting that PI-IBS might be more transient after viral gastroenteritis than it is after bacterial dysentery (*40*) (Technical Appendix 1 Table 3).

The meta-analysis by Haagsma et al. (*27*), which suggests that IBS develops in ≈9% (95% CI 7.2%–10.7%) of *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. case-patients at 10–12 months of follow-up was chosen as the sequelae multiplier to simulate the plausible proportion of these bacterial pathogens that cause IBS using an alternate PERT distribution. While studies of multiple pathogens have found different rates of PI-IBS depending on etiology, this proportion was chosen for all 3 pathogens because it is a pooled rate that comes from a recent meta-analysis and is similar to PI-IBS rates after bacterial gastroenteritis that were reported in other studies (*28*,*29*,*41*).

Technical Appendix 1 Table 3. Incidence of IBS after infection with enteric pathogens, Australia, circa 2010*

Reference	Year of publication	Study years	Country	Study type	Foodborne pathogen	IBS patients after infectious gastroenteritis, %
Koh et al. (*41*)	2012	2008–2010	Korea	Prospective cohort	Nontyphoidal *Salmonella* spp., *Shigella* spp., STEC O157, *Vibrio cholerae*	9.2% at 3 mo†, 12.3% at 6 mo†
Wensaas et al. (*37*)	2012	2007–2008	Norway	Historic cohort	*Giardia lamblia*	46.1% at 3 y
Schwille-Kiuntke et al. (*26*)	2011	-	Global	Systematic review	*Campylobacter* spp., E*scherichia coli*, *G. lamblia*, norovirus, nontyphoidal *Salmonella* spp, *Shigella* sp., *Trichinella britovi*; bacterial, viral, and parasitic gastroenteritis and travelers' diarrhea	4%–36% Incidence range
Thabane et al. (*36*)	2010	2002–2008	Canada	Outbreak study	*E. coli* O157:H7, *Campylobacter* spp.	10.5%†
Haagsma et al. (*26*)	2010	-	The Netherlands	Meta-analysis	*Campylobacter* spp., nontyphoidal *Salmonella* spp.,	9% (95% CI 7.2–10.7)

Reference	Year of publication	Study years	Country	Study type	Foodborne pathogen	IBS patients after infectious gastroenteritis, %
					Shigella spp.	at 1 y
Marshall et al. (*35*)	2009	2002–2008	Canada	Outbreak study	*E. coli* O157:H7, *Campylobacter* spp.	27.5% (self-reported), 36.2% (clinically suspected)
Thabane et al. (*28*)	2007	-	Canada, China, Israel, Korea, New Zealand, UK, USA	Systematic review and meta-analysis	*Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., confirmed bacterial gastroenteritis, and self-reported illness	10% (95% CI 9.4–85.6), 4%–32% incidence range
Marshall et al. (*40*)	2007	2002–2004	Canada	Outbreak study	Norovirus	23.6% at 3 mo
Smith and Bayles (*30*)	2007	-	Canada, China, Korea, Spain, UK, USA	Systematic review	*Campylobacter* spp., Cryptosporidium spp., E.*coli*, *G. lamblia*, nontyphoidal *Salmonella* spp., *Shigella* spp.	15% (range 3.4–31.6)‡
Halvorson et al. (*29*)	2006	-	Canada, China, Korea, Spain, UK, USA	Systematic review and meta-analysis	Nontyphoidal *Salmonella* spp., *Shigella* spp., bacterial, and unspecified	9.8% (IQR 4.0–13.3)‡
Ji et al. (*34*)	2005	2001–2002	Korea	Outbreak study	*Shigella* spp.	14.9% at 1 y
Mearin et al. (*33*)	2005	2002–2003	Spain	Cohort study after an outbreak	Nontyphoidal *Salmonella* spp.	7.4% at 3 mo†, 10.9% at 6 mo†, 11.6% at 1 y†
Parry et al. (*32*)	2003	2000–2001	UK	Prospective case–control study	*Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., STEC O157, *Aeromonas sobria*	16.7% at 6 mo
Neal et al. (*31*)	1997	1994	UK	Cross-sectional	*Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp.	7% at 6 mo

*IBS, irritable bowel syndrome; IQR, interquartile range; nontyphoidal *Salmonella* spp., nontyphoidal *S. enterica* serotypes; STEC, Shiga toxin–producing *E. coli*.
†Cumulative incidence.
‡Median prevalence.

ReA

The causes of ReA are ambiguous because no formal definition or agreed-upon diagnostic criteria exist (*42*,*43*). Although the primary focus of the infection is usually through the gut or urogenital track, ReA has also been associated with respiratory pathogens (*42*). The classical gastrointestinal microbes resulting in ReA are *Yersinia enterocolitica,* nontyphoidal *Salmonella* spp., *Shigella* spp., and *Campylobacter* spp (*43*). and most agree that the term "ReA" should be applied only to infection caused by these gastrointestinal pathogens and *Chlamydia* spp (*43*); however, nonclassical ReA forms have been associated by a variety of other bacteria, including *Brucella* and *Staphylococcus*, and many authors have applied the term ReA for arthritis after infection with *C. difficile*, *Cryptosporidium*, *Giardia lamblia*, *E. coli*, and *Strongyloides* spp (*43*,*44*). With the majority of the literature focusing on the 4 classical gastrointestinal pathogens as triggers for ReA, we chose to use these to estimate the incidence of ReA due to contaminated food. If other enteric pathogens are in fact associated with ReA, our estimates of foodborne ReA may be conservative.

We were unable to find any published systematic reviews that report a global incidence rate for ReA after infection with the bacterial pathogens *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica*. Because there are no diagnostic criteria for ReA, the case definition and the resulting incidences vary (*42*). The literature suggests that the incidence of ReA as a sequel to bacterial gastroenteritis varies by the enteric pathogen. For each of the bacterial enteric pathogens that precede ReA, we compiled papers that reported the proportion of cases that developed into ReA published in 2000 or later where all enteric cases were confirmed by a laboratory (Technical Appendix 1 Table 4). Because there is still quite a bit of variation in incidence in studies by pathogen, the median and range for *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica* from the studies in Technical Appendix 1 Table 4 were calculated for the sequelae multiplier and used to simulate a distribution of the plausible proportion of cases that result in this sequel using an alternate PERT or PERT distribution, respectively. From the literature, we assume that 7% (range 2.8%-16%) of foodborne *Campylobacter* spp., 8.5% (range 0%-26%) of foodborne nontyphoidal *Salmonella* spp., 9.7% (range 1.2%-9.8%) of foodborne *Shigella* spp., and 12% (range 0%-23.1%) of foodborne *Y. enterocolitica* result in ReA. These distributions were then applied to the estimates of domestically acquired foodborne cases for each of the preceding bacterial pathogens.

Technical Appendix 1 Table 4. ReA incidence* by foodborne pathogen, Australia, 2010

Reference	Study years	Study type	Country	ReA cases/gastroenteritis cases
				ReA cases/*Campylobacter* spp. cases
Schonberg-Norio et al. (*45*)	2002	Cross sectional	Finland	8/201 (4.0%)
Doorduyn et al. (*46*)	2005	Case–control	The Netherlands	20/434 (4.6%)
Townes et al. (*47*)	2002–2004	Cohort	USA	302/2384 (12.7%)
Schiellerup et al. (*48*)	2002–2003	Case–case comparison	Denmark	131/1003 (13.1%)
Pope et al. (*49*)	1966–2006	Review	Europe	1%–5%
Rees et al. (*50*)	1998–1999	Cohort	USA	9/324 (2.8%)
Hannu (*51*)	1997–1998	Cohort	Finland	45/609 (7.4%)
Locht and Krogfelt (*52*)	1997–1999	Cohort	Denmark	27/173 (15.6%)
				ReA cases/nontyphoidal *Salmonella* spp. cases
Arnedo-Pena et al. (*53*)	2005	Outbreak study	Spain	6/67 (9%)
Doorduyn et al. (*46*)	2005	Case–control	The Netherlands	8/181 (4.4%)
Townes et al. (47)	2002–2004	Cohort	USA	204/1356 (15.0%)
Schiellerup et al. (*48*)	2002–2003	Case–case comparison	Denmark	104/619 (16.8%)
Lee et al. (*54*)	1999	Outbreak study	Australia	38/261 (14.6%)
Rees et al. (*50*)	1998–1999	Cohort	USA	2/100 (2.0%)
Buxton et al. (*55*)	1999–2000	Case–control	Canada	17/66 (25.7%)
Hannu et al. (*56*)	1999	Outbreak study	Finland	5/63 (7.9%)
Rudwaleit et al. (*57*)	1998	Outbreak study	Germany	0/286 (0%) (children only)
Urfer et al. (*58*)	1993	Outbreak study	Switzerland	1/156 (0.6%)
				ReA cases/*Shigella* spp. cases
Townes et al. (*47*)	2002–2004	Cohort	USA	29/298 (9.7%)
Schiellerup et al. (*48*)	2002–2003	Case–case comparison	Denmark	10/102 (9.8%)
Rees et al. (*50*)	1998–1999	Cohort	USA	1/81 (1.2%)

Reference	Study years	Study type	Country	ReA cases/gastroenteritis cases
				ReA cases/*Yersinia enterocolitica* cases
Huovinen et al. (*59*)	2006	Case–control	Finland	11/248 (4.4%)
Townes et al. (*47*)	2002–2004	Cohort	USA	5/35 (14.3%)
Schiellerup et al. (*48*)	2002–2003	Case–case comparison	Denmark	21/91 (23.1%)
Rees et al. (*50*)	1998–1999	Cohort	USA	0/8 (0%)
Hannu et al. (*60*)	1998	Outbreak study	Finland	4/33 (12.1%)

*Incidence of ReA after *Campylobacter* spp. infection: median 7%, range 2.8%–16%; after *Salmonella* spp. infection: median 8.5%, range 0%–26%; after *Shigella* spp. infection: median 9.7%, range 1.2%–9.8%; after *Yersinia enterocolitica* infection: median 12%, range 0%–23.1%. ReA, reactive arthritis. Nontyphoidal *Salmonella* spp., nontyphoidal *S. enterica* serotypes.

References

1. Tam CC, Rodrigues LC, Petersen I, Islam A, Hayward A, O'Brien SJ. Incidence of Guillain-Barré syndrome among patients with *Campylobacter* infection: a general practice research database study. J Infect Dis. 2006;194:95–7. PubMed http://dx.doi.org/10.1086/504294

2. McCarthy N, Giesecke J. Incidence of Guillain-Barré syndrome following infection with *Campylobacter jejuni*. Am J Epidemiol. 2001;153:610–4. PubMed http://dx.doi.org/10.1093/aje/153.6.610

3. Allos BM. Association between *Campylobacter* infection and Guillain-Barré syndrome. J Infect Dis. 1997;176(Suppl 2):S125–8. PubMed http://dx.doi.org/10.1086/513783

4. Baker MG, Kvalsvig A, Zhang J, Lake R, Sears A, Wilson N. Declining Guillain-Barré syndrome after campylobacteriosis control, New Zealand, 1988–2010. Emerg Infect Dis. 2012;18:226–33. PubMed http://dx.doi.org/10.3201/eid1802.111126

5. Siegler R, Oakes R. Hemolytic uremic syndrome; pathogenesis, treatment, and outcome. Curr Opin Pediatr. 2005;17:200–4. PubMed http://dx.doi.org/10.1097/01.mop.0000152997.66070.e9

6. Elliott EJ, Robins-Browne RM. Hemolytic uremic syndrome. Curr Probl Pediatr Adolesc Health Care. 2005;35:310–30. PubMed http://dx.doi.org/10.1016/j.cppeds.2005.06.002

7. Walker CL, Applegate JA, Black RE. Haemolytic-uraemic syndrome as a sequela of diarrhoeal disease. J Health Popul Nutr. 2012;30:257–61. PubMed http://dx.doi.org/10.3329/jhpn.v30i3.12288

8. Alvarado AS, Brodsky SV, Nadasdy T, Singh N. Hemolytic uremic syndrome associated with *Clostridium difficile* infection. Clin Nephrol. 2014;81:302–6. PubMed

9. Albaqali A, Ghuloom A, Al Arrayed A, Al Ajami A, Shome DK, Jamsheer A, et al. Hemolytic uremic syndrome in association with typhoid fever. Am J Kidney Dis. 2003;41:709–13. PubMed http://dx.doi.org/10.1053/ajkd.2003.50135

10. Baker NM, Mills AE, Rachman I, Thomas JE. Haemolytic-uraemic syndrome in typhoid fever. BMJ. 1974;2:84–7. PubMed http://dx.doi.org/10.1136/bmj.2.5910.84

11. McPherson M, Kirk MD, Raupach J, Coombs B, Butler JR. Economic costs of Shiga toxin–producing *Escherichia coli* infection in Australia. Foodborne Pathog Dis. 2011;8:55–62. PubMed http://dx.doi.org/10.1089/fpd.2010.0608

12. Mead PS, Griffin PM. *Escherichia coli* O157:H7. Lancet. 1998;352:1207–12. PubMed http://dx.doi.org/10.1016/S0140-6736(98)01267-7

13. Beutin L, Zimmerman S, Gleier K. Human infections with Shiga toxin–producing *Escherichia coli* other than serogroup O157 in Germany. Emerg Infect Dis. 1998;4:635–9. PubMed http://dx.doi.org/10.3201/eid0404.980415

14. McPherson M, Lalor K, Combs B, Raupach J, Stafford R, Kirk MD. Serogroup-specific risk factors for Shiga toxin–producing *Escherichia coli* infection in Australia. Clin Infect Dis. 2009;49:249–56. PubMed http://dx.doi.org/10.1086/599370

15. Vally H, Hall G, Dyda A, Raupach J, Knope K, Combs B, et al. Epidemiology of Shiga toxin producing *Escherichia coli* in Australia, 2000–2010. BMC Public Health. 2012;12:63–71. PubMed http://dx.doi.org/10.1186/1471-2458-12-63

16. Elliott EJ, Robins-Browne RM, O'Loughlin EV, Bennett-Wood V, Bourke J, Henning P, et al. Nationwide study of haemolytic uraemic syndrome: clinical, microbiological, and epidemiological features. Arch Dis Child. 2001;85:125–31. PubMed http://dx.doi.org/10.1136/adc.85.2.125

17. López EL, Contrini MM, Glastein E, Ayala SG, Santoro R, Ezcurra G, et al. An epidemiologic surveillance of Shiga-like toxin producing *Escherichia coli* infection in Argentinean children: risk factors and serum Shiga-like toxin 2 values. Pediatr Infect Dis J. 2012;31:20–4. PubMed http://dx.doi.org/10.1097/INF.0b013e31822ea6cf

18. Van Duynhoven YT, De Jager CM, Heuvelink AE, Van Der Zwaluw WK, Maas HM, Van Pelt W, et al. Enhanced laboratory-based surveillance of Shiga-toxin–producing *Escherichia coli* O157 in the Netherlands. Eur J Clin Microbiol Infect Dis. 2002;21:513–22. PubMed http://dx.doi.org/10.1007/s10096-002-0756-7

19. Käppeli U, Hächler H, Giezendanner N, Cheasty T, Stephan R. Shiga toxin–producing *Escherichia coli* O157 associated with human infections in Switzerland, 2000–2009. Epidemiol Infect. 2011;139:1097–104. PubMed

20. Bradley KK, Williams JM, Burnsed LJ, Lytle MB, McDermott MD, Mody RK, et al. Epidemiology of a large restaurant-associated outbreak of Shiga toxin–producing *Escherichia coli* O111:NM. Epidemiol Infect. 2012;140:1644–54. PubMed http://dx.doi.org/10.1017/S0950268811002329

21. Neil KP, Biggerstaff G, MacDonald JK, Trees E, Medus C, Musser KA, et al. a novel vehicle for transmission of *Escherichia coli* O157:H7 to humans: multistate outbreak of *E. coli* O157:H7 infections associated with consumption of ready-to-bake commercial prepackaged cookie dough—United States, 2009. Clin Infect Dis. 2012;54:511–8. PubMed http://dx.doi.org/10.1093/cid/cir831

22. Frank C, Werber D, Cramer JP, Askar M, Faber M, an der Heiden M, et al. Epidemic profile of Shiga-toxin–producing *Escherichia coli* O104:H4 outbreak in Germany. N Engl J Med. 2011;365:1771–80. PubMed http://dx.doi.org/10.1056/NEJMoa1106483

23. Jay MT, Garrett V, Mohle-Boetani JC, Barros M, Farrar JA, Rios R, et al. A multistate outbreak of *Escherichia coli* O157:H7 infection linked to consumption of beef tacos at a fast-food restaurant chain. Clin Infect Dis. 2004;39:1–7. PubMed http://dx.doi.org/10.1086/421088

24. Sigmundsdottir G, Atladottir A, Hardadottir H, Gudmundsdottir E, Geirsdottir M, Briem H. STEC O157 outbreak in Iceland, September–October 2007. Euro Surveill. 2007;12:E0711012. PubMed

25. Rangel JM, Sparling PH, Crowe C, Griffin PM, Swerdlow DL. Epidemiology of *Escherichia coli* O157:H7 outbreaks, United States, 1982–2002. Emerg Infect Dis. 2005;11:603–9. PubMed http://dx.doi.org/10.3201/eid1104.040739

26. Schwille-Kiuntke J, Frick JS, Zanger P, Enck P. Post-infectious irritable bowel syndrome—a review of the literature. Z Gastroenterol. 2011;49:997–1003. PubMed http://dx.doi.org/10.1055/s-0031-1281581

27. Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH. Disease burden of post-infectious irritable bowel syndrome in the Netherlands. Epidemiol Infect. 2010;138:1650–6. PubMed http://dx.doi.org/10.1017/S0950268810000531

28. Thabane M, Kottachchi DT, Marshall JK. Systematic review and meta-analysis: the incidence and prognosis of post-infectious irritable bowel syndrome. Aliment Pharmacol Ther. 2007;26:535–44. PubMed http://dx.doi.org/10.1111/j.1365-2036.2007.03399.x

29. Halvorson HA, Schlett CD, Riddle MS. Postinfectious irritable bowel syndrome—a meta-analysis. Am J Gastroenterol. 2006;101:1894–9. PubMed http://dx.doi.org/10.1111/j.1572-0241.2006.00654.x

30. Smith JL, Bayles D. Postinfectious irritable bowel syndrome: a long-term consequence of bacterial gastroenteritis. J Food Prot. 2007;70:1762–9. PubMed

31. Neal KR, Hebden J, Spiller R. Prevalence of gastrointestinal symptoms six months after bacterial gastroenteritis and risk factors for development of the irritable bowel syndrome: postal survey of patients. BMJ. 1997;314:779–82. PubMed http://dx.doi.org/10.1136/bmj.314.7083.779

32. Parry SD, Stansfield R, Jelley D, Gregory W, Phillips E, Barton JR, et al. Does bacterial gastroenteritis predispose people to functional gastrointestinal disorders? A prospective, community-based, case–control study. Am J Gastroenterol. 2003;98:1970–5. PubMed

33. Mearin F, Perez-Oliveras M, Perello A, Vinyet J, Ibanez A, Coderch J, et al. Dyspepsia and irritable bowel syndrome after a *Salmonella* gastroenteritis outbreak: one-year follow-up cohort study. Gastroenterology. 2005;129:98–104. PubMed http://dx.doi.org/10.1053/j.gastro.2005.04.012

34. Ji S, Park H, Lee D, Song YK, Choi JP, Lee SI. Post-infectious irritable bowel syndrome in patients with *Shigella* infection. J Gastroenterol Hepatol. 2005;20:381–6. PubMed http://dx.doi.org/10.1111/j.1440-1746.2005.03574.x

35. Marshall JK. Post-infectious irritable bowel syndrome following water contamination. Kidney Int Suppl. 2009;Feb(112):S42–3. PubMed http://dx.doi.org/10.1038/ki.2008.618

36. Thabane M, Simunovic M, Akhtar-Danesh N, Garg AX, Clark WF, Collins SM, et al. An outbreak of acute bacterial gastroenteritis is associated with an increased incidence of irritable bowel syndrome in children. Am J Gastroenterol. 2010;105:933–9. PubMed http://dx.doi.org/10.1038/ajg.2010.74

37. Wensaas KA, Langeland N, Hanevik K, Morch K, Eide GE, Rortveit G. Irritable bowel syndrome and chronic fatigue 3 years after acute giardiasis: historic cohort study. Gut. 2012;61:214–9. PubMed http://dx.doi.org/10.1136/gutjnl-2011-300220

38. Penrose AS, Wells EV, Aiello AE. Infectious causation of chronic disease: examining the relationship between *Giardia lamblia* infection and irritable bowel syndrome. World J Gastroenterol. 2007;13:4574–8. PubMed

39. D'Anchino M, Orlando D, De Feudis L. *Giardia lamblia* infections become clinically evident by eliciting symptoms of irritable bowel syndrome. J Infect. 2002;45:169–72. PubMed http://dx.doi.org/10.1016/S0163-4453(02)91038-8

40. Marshall JK, Thabane M, Borgaonkar MR, James C. Postinfectious irritable bowel syndrome after a food-borne outbreak of acute gastroenteritis attributed to a viral pathogen. Clin Gastroenterol Hepatol. 2007;5:457–60. PubMed http://dx.doi.org/10.1016/j.cgh.2006.11.025

41. Koh SJ, Lee DH, Lee SH, Park YS, Hwang JH, Kim JW, et al. Incidence and risk factors of irritable bowel syndrome in community subjects with culture-proven bacterial gastroenteritis. Korean J Gastroenterol. 2012;60:13–8. PubMed http://dx.doi.org/10.4166/kjg.2012.60.1.13

42. Hannu T. Reactive arthritis. Best Pract Res Clin Rheumatol. 2011;25:347–57. PubMed http://dx.doi.org/10.1016/j.berh.2011.01.018

43. Townes JM. Reactive arthritis after enteric infections in the United States: the problem of definition. Clin Infect Dis. 2010;50:247–54. PubMed http://dx.doi.org/10.1086/649540

44. Girschick HJ, Guilherme L, Inman RD, Latsch K, Rihl M, Sherer Y, et al. Bacterial triggers and autoimmunie rheumatic diseases. Clin Exp Rheumatol. 2008;26(Suppl 48):S12–7. PubMed

45. Schönberg-Norio D, Mattila L, Lauhio A, Katila ML, Kaukoranta SS, Koskela M, et al. Patient-reported complications associated with *Campylobacter jejuni* infection. Epidemiol Infect. 2010;138:1004–11. PubMed http://dx.doi.org/10.1017/S0950268809991099

46. Doorduyn Y, Van Pelt W, Siezen CL, Van Der Horst F, Van Duynhoven YT, Hoebee B, et al. Novel insight in the association between salmonellosis or campylobacteriosis and chronic illness, and the role of host genetics in susceptibility to these diseases. Epidemiol Infect. 2008;136:1225–34. PubMed http://dx.doi.org/10.1017/S095026880700996X

47. Townes JM, Deodhar AA, Laine ES, Smith K, Krug HE, Barkhuizen A, et al. Reactive arthritis following culture-confirmed infections with bacterial enteric pathogens in Minnesota and Oregon: a population-based study. Ann Rheum Dis. 2008;67:1689–96. PubMed http://dx.doi.org/10.1136/ard.2007.083451

48. Schiellerup P, Krogfelt KA, Locht H. A comparison of self-reported joint symptoms following infection with different enteric pathogens: effect of HLA-B27. J Rheumatol. 2008;35:480–7. PubMed

49. Pope JE, Krizova A, Garg AX, Thiessen-Philbrook H, Ouimet JM. *Campylobacter* reactive arthritis: a systematic review. Semin Arthritis Rheum. 2007;37:48–55. PubMed http://dx.doi.org/10.1016/j.semarthrit.2006.12.006

50. Rees JR, Pannier MA, McNees A, Shallow S, Angulo FJ, Vugia DJ. Persistent diarrhea, arthritis, and other complications of enteric infections: a pilot survey based on California FoodNet

surveillance, 1998–1999. Clin Infect Dis. 2004;38(Suppl 3):S311–7. PubMed http://dx.doi.org/10.1086/381601

51. Hannu T, Mattila L, Rautelin H, Pelkonen P, Lahdenne P, Siitonen A, et al. *Campylobacter*-triggered reactive arthritis: a population-based study. Rheumatology (Oxford). 2002;41:312–8. PubMed http://dx.doi.org/10.1093/rheumatology/41.3.312

52. Locht H, Krogfelt KA. Comparison of rheumatological and gastrointestinal symptoms after infection with *Campylobacter jejun*i/*coli* and enterotoxigenic *Escherichia coli*. Ann Rheum Dis. 2002;61:448–52. PubMed http://dx.doi.org/10.1136/ard.61.5.448

53. Arnedo-Pena A, Beltran-Fabregat J, Vila-Pastor B, Tirado-Balaguer MD, Herrero-Carot C, Bellido-Blasco JB, et al. Reactive arthritis and other musculoskeletal sequelae following an outbreak of *Salmonella* Hadar in Castellon, Spain. J Rheumatol. 2010;37:1735–42. PubMed http://dx.doi.org/10.3899/jrheum.091250

54. Lee AT, Hall RG, Pile KD. Reactive joint symptoms following an outbreak of *Salmonella* Typhimurium phage type 135a. J Rheumatol. 2005;32:524–7. PubMed

55. Buxton JA, Fyfe M, Berger S, Cox MB, Northcott KA. Reactive arthritis and other sequelae following sporadic *Salmonella* Typhimurium infection in British Columbia, Canada: a case control study. J Rheumatol. 2002;29:2154–8. PubMed

56. Hannu T, Mattila L, Siitonen A, Leirisalo-Repo M. Reactive arthritis following an outbreak of *Salmonella* Typhimurium phage type 193 infection. Ann Rheum Dis. 2002;61:264–6. PubMed http://dx.doi.org/10.1136/ard.61.3.264

57. Rudwaleit M, Richter S, Braun J, Sieper J. Low incidence of reactive arthritis in children following a *Salmonella* outbreak. Ann Rheum Dis. 2001;60:1055–7. PubMed http://dx.doi.org/10.1136/ard.60.11.1055

58. Urfer E, Rossier P, Mean F, Krending MJ, Burnens A, Bille J, et al. Outbreak of *Salmonella* Braenderup gastroenteritis due to contaminated meat pies: clinical and molecular epidemiology. Clin Microbiol Infect. 2000;6:536–42. PubMed http://dx.doi.org/10.1046/j.1469-0691.2000.00148.x

59. Huovinen E, Sihvonen LM, Virtanen MJ, Haukka K, Siitonen A, Kuusi M. Symptoms and sources of *Yersinia enterocolitica*-infection: a case–control study. BMC Infect Dis. 2010;10:122. PubMed http://dx.doi.org/10.1186/1471-2334-10-122

60. Hannu T, Mattila L, Nuorti JP, Ruutu P, Mikkola J, Siitonen A, et al. Reactive arthritis after an outbreak of *Yersinia pseudotuberculosis* serotype O:3 infection. Ann Rheum Dis. 2003;62:866–9. PubMed http://dx.doi.org/10.1136/ard.62.9.866

Article DOI: http://dx.doi.org/10.3201/eid2011.131316

Sequelae of Foodborne Illness Caused by 5 Pathogens, Australia, Circa 2010

Technical Appendix 2

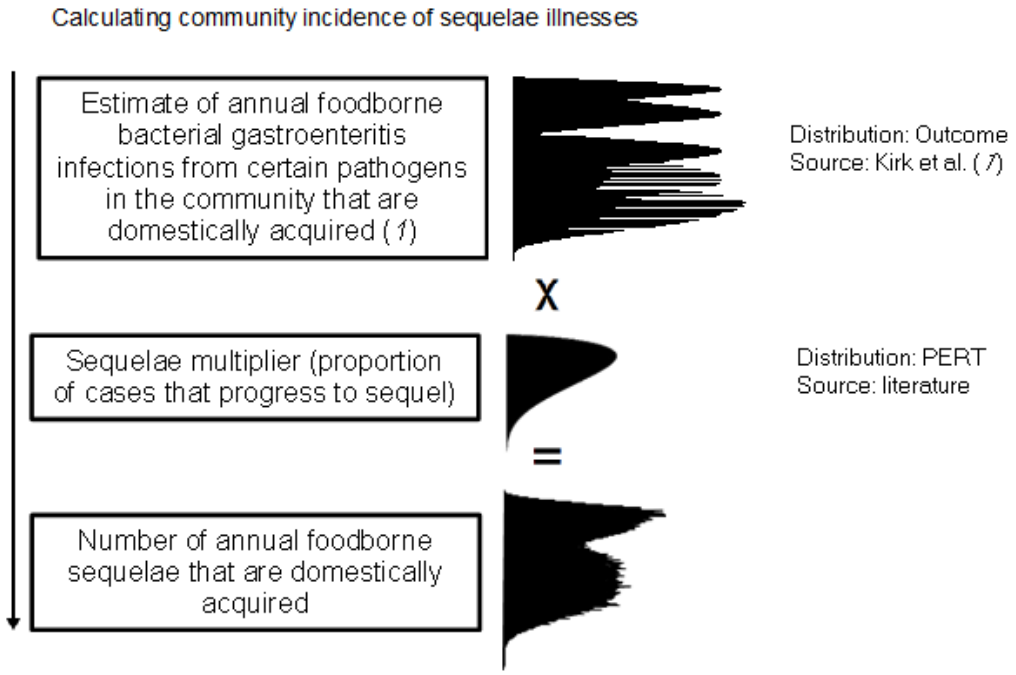
Methods to Estimate Sequelae Incidence

For all 4 sequelae illnesses, we used data from notifiable surveillance (either national or state notifications) to estimate incidence of acute gastroenteritis due to relevant pathogens and then adjusted this using a sequelae multiplier, which is the proportion of bacterial infections that lead to sequelae illnesses (online Technical Appendix 1, http://wwwnc.cdc.gov/EID/article/20/11/13-1316-Techapp1.pdf). This approach is displayed in the Technical Appendix 2 Figure, where the left-hand column describes each input or output distribution, the central column illustrates the distribution, and the right-hand column describes the type and source of data underlying each input distribution. The final estimate is produced from a statistical model that incorporates uncertainty in case numbers in multipliers using probability distributions. That is, at each stage of the calculation, the estimate is represented by a probability distribution, and our final estimates and credible intervals are computed from this distribution. Further details on the estimation of incidence of acute illness due to each of the causal pathogens can be found in Kirk et al. (*1*).

The sequelae multiplier was modelled by using the PERT (Project Evaluation and Review Techniques) distribution, which is widely used for expert elicitation and risk assessment studies. It is based on the beta distribution and allows the input of minimum, maximum, and modal values. The alternate PERT distribution can be specified by 3 percentile points, such as a median value and 95% credible intervals (CrIs). Alternate PERT was used for the hemolytic uremic syndrome and irritable bowel syndrome sequelae multiplier, as the multiplier used was from another study that used median and 95% CIs. Alternate PERT was also used for reactive arthritis sequelae multipliers to enable a median value to be input, except in the case of the *Shigella*-associated reactive arthritis, where an alternate PERT distribution would not fit the data, and a PERT distribution was used instead. PERT allows for asymmetric distributions and can be easily produced from many data sources.

Reference

1. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000–circa 2010. Emerg Infect Dis. 2014;20:zzz–zzz. http://dx.doi.org/10.3201/eid2011.131315



Technical Appendix 2 Figure. Flowchart for the approach used to calculate the estimated number of sequelae cases in the community, Australia, circa 2010. PERT, project evaluation and review technique.

Article DOI: http://dx.doi.org/10.3201/eid2011.131316

Sequelae of Foodborne Illness Caused by 5 Pathogens, Australia, Circa 2010

Technical Appendix 3

Comparison with Estimates from 2000

Hall et al. estimated incidence, hospitalizations, and deaths for these 4 sequelae illnesses in Australia circa 2000 (*1*). Because methods and data sources have changed since the 2000 estimation effort, we recalculated incidence estimates for the sequelae in 2000 using our current methods and equivalent data from that earlier time period to validly compare rates over time. We used National Notifiable Disease Surveillance System data from 1996 to 2000 to recalculate the estimates for the incidence of all cases of gastroenteritis due to foodborne *Campylobacter* spp., nontyphoidal *Salmonella enterica* serotypes (hereafter referred to as nontyphoidal *Salmonella* spp.), *Shigella* spp., and *Yersinia enterocolitica* (*2*,*3*), and South Australian data from 1998–2000 (*3*) to recalculate the 2000 estimate for the incidence of gastroenteritis due to Shiga toxin–producing *Escherichia coli* (STEC). Further details on the method and recalculated circa 2000 estimates for *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. can be found in the methods section and Table 3 of Kirk et al. (*4*). The estimates of foodborne illness from STEC and *Y. enterocolitica* for circa 2000 were calculated solely for this paper, using the same methods described in Kirk et al. (*4*) and the data described above.

Sequelae multipliers for the 2010 estimates were then applied to the recalculated 2000 estimates of incidence of acute gastroenteritis. The Technical Appendix 3 Table presents a comparison of the recalculated incidence estimates of sequelae of Guillain-Barré syndrome, hemolytic uremic syndrome, irritable bowel syndrome, and reactive arthritis for 2000 and 2010. Changes in sequelae illness from 2000 to 2010 reflect changes in the incidence of the preceding bacterial pathogen because the rate of sequelae after foodborne gastroenteritis, otherwise referred to as the sequelae multiplier, is assumed to be constant over this time period.

Technical Appendix 3 Table. Comparison of incidence estimates and rates of 4 sequelae, Australia, circa 2000 and 2010*

	2000		2010		
Illness	Incidence (90% CrI)	Rate per million (90% CrI)	Incidence (90% CrI)	Rate per million (90% CrI)	Rate ratio (90% CrI)
GBS	50 (25–100)	2.8 (1–6)	70 (30–150)	3.1 (2–6)	1.13 (0.5–3.6)
HUS	55 (15–175)	3 (1–9)	70 (25–200)	3 (1–9)	1 (0.3–3.5)
IBS	14,800 (9,500–23,500)	850 (550–1,350)	19,500 (12,500–30,700)	915 (570–1,440)	1.07 (0.5–2.0)
ReA	12,500 (6,700–23,000)	730 (380–1,325)	16,200 (8,750–30,400)	765 (415–1,375)	1.06 (0.4–2.5)

*GBS, Guillain-Barré syndrome; HUS, hemolytic uremic syndrome; IBS, irritable bowel syndrome; ReA, reactive arthritis; CrI, credible interval.

References

1. Hall G, Kirk M. Foodborne illnesses in Australia: annual incidence circa 2000. Report no. 0642825769. Canberra (ACT): Commonwealth Department of Health and Ageing; 2005.

2. Government of Australia. National Notifiable Disease Surveillance System (NNDSS). Commonwealth of Australia; 2013 [cited 2013 April 5]. http://www9.health.gov.au/cda/source/cda-index.cfm

3. Hall G. OzFoodNet Working Group. How much gastroenteritis in Australia is due to food? Report no. NCEPH working paper no. 51. Sponsored by the Commonwealth Department of Health and Ageing. Canberra (Australia): National Centre for Epidemiology and Population Health. 2004.

4. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000–circa 2010. Emerg Infect Dis. 2014;20:zzz–zzz. http://dx.doi.org/10.3201/eid2011.131315

Article DOI: http://dx.doi.org/10.3201/eid2011.131316

Sequelae of Foodborne Illness Caused by 5 Pathogens, Australia, Circa 2010

Technical Appendix 4

Methods to Estimate Sequelae Hospitalizations and Deaths

To estimate hospitalizations due to irritable bowel syndrome (IBS) and reactive arthritis (ReA), we used hospitalization data for 2006–2010 from all Australian states and territories, using International Classification of Disease, Tenth Revision, Australian Modification (ICD-10-AM) codes. All estimated incident foodborne *Campylobacter*-associated Guillain-Barré syndrome (GBS) and Shiga toxin–producing *Escherichia coli* (STEC)–associated hemolytic uremic syndrome (HUS) cases were considered hospitalized, so were not modeled. The estimate for hospitalizations due to GBS and HUS is the estimate for GBS and HUS incidence. To estimate deaths for all 4 sequelae illnesses, we used national deaths data for 2001–2010 from the Australian Bureau of Statistics, using ICD-10 codes (Technical Appendix 4 Table 1). The final estimate included 2 multipliers, which are discussed below.

Technical Appendix 4 Table 1. Mortality and hospitalization codes for each sequel, Australia, 2010*

Sequelae	Mortality ICD-10 code and description	Hospitalization ICD-10-AM code and description
Guillain-Barré syndrome	G610: Guillain-Barré syndrome	–
Hemolytic uremic syndrome	D593: Hemolytic uremic syndrome	–
Irritable bowel syndrome	K58: Irritable bowel syndrome	K58.0: Irritable bowel syndrome with diarrhea K58.9: Irritable bowel syndrome without diarrhea
Reactive arthritis	M021: Postdysenteric arthropathy M028: Other reactive arthropathies	M02.1: Postdysenteric arthropathy M02.3: Reiter's disease M02.8: Other reactive arthropathies M03.2: Other postinfectious arthropathies in diseases classified elsewhere

*ICD-10-AM, International Classification of Diseases, Tenth Revision; AM, Australian Modification; –, all patients with incident cases are assumed to have been hospitalized so hospitalization data not used for this pathogen.

Domestically Acquired Multiplier

This multiplier adjusts for the proportion of case-patients who acquired infection in Australia with values for each sequelae in Technical Appendix 4 Table 2. For GBS, we adopted the domestically acquired multiplier for *Campylobacter* spp. (*1*). Given the relatively small numbers of notified cases of HUS, we adopted the domestically acquired multiplier for STEC (*1*). The domestically acquired multiplier for IBS was calculated as a weighted average of the

domestically acquired multipliers for *Campylobacter* spp., nontyphoidal *Salmonella enterica* serotypes (hereafter referred to as nontyphoidal *Salmonella* spp.), and *Shigella* spp., weighted by the total number of IBS cases for each pathogen. Similarly, the domestically acquired multiplier for ReA was calculated as a weighted average of the domestically acquired multipliers for *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Yersinia enterocolitica*, weighted by the total number of ReA cases for each pathogen.

Technical Appendix 4 Table 2. Domestically acquired multipliers*

Sequelae	Domestically acquired multiplier
Guillain-Barré syndrome	0.97 (range 0.91–0.99)
Hemolytic uremic syndrome	0.99 (range 0.93–1.00)
Irritable bowel syndrome	0.91 (90% CrI 0.88–0.94)
Reactive arthritis	0.91 (90% CrI 0.86–0.95)

*CrI, credible interval.

Proportion Foodborne Multiplier

This multiplier adjusts for the proportion of illness that is acquired from food and was required only to estimate hospitalizations and deaths. Sequelae can arise from a source other than a bacterial pathogen, from a bacterial pathogen that was not foodborne, or from a foodborne pathogen. Only this latter category is considered a foodborne source. The proportion foodborne multiplier is the simulated product of the bacterial multiplier and the weighted foodborne multiplier and can be found in Technical Appendix 4 Table 3. The approach for calculating the proportion foodborne multiplier for each sequel is described as follows:

Technical Appendix 4 Table 3. Proportion foodborne multiplier*

Sequelae	Foodborne multiplier
Guillain-Barré syndrome	0.25 (90% CrI 0.1–0.43)
Hemolytic uremic syndrome	0.33 (90% CrI 0.17–0.53)
Irritable bowel syndrome	0.13 (90% CrI 0.08–0.20)
Reactive arthritis	0.48 (90% CrI 0.36–0.62)

*CrI, credible interval.

GBS

There have been several reviews, as well as many case–control and cross-sectional studies, that estimated the percentage of GBS cases attributable to *Campylobacter* spp. (Technical Appendix 4 Table 3). Poropatich et al. (*8*) performed a systematic review of 30 case–control studies and concluded that 31.0% of GBS cases might be attributable to a previous infection due to *Campylobacter* spp. (*8*). The other global systematic review of GBS incidence does not look at *Campylobacter* spp. specifically or perform a meta-analysis (*9*). Other (nonsystematic) reviews have found that 13%–72% (*10*) and 8%–50% (*11*) of GBS occurs as a sequel to campylobacteriosis. We assume that 31% (range 4.8%–72%) of cases of GBS arise

from *Campylobacter* spp. (*2*). Multiplied together with the *Campylobacter* spp. foodborne multiplier of 0.77 (90% CrI 0.62–0.89) (*1*) led to a foodborne multiplier for GBS of 0.25 (90% CrI 0.11–0.43).

Technical Appendix 4 Table 4. Proportion of Guillain-Barré syndrome attributable to *Campylobacter* spp.*

Reference	Study years	Country	Study type	No. GBS cases	No. *Campylobacter* spp. cases based on	GBS cases attributable to campylobacteriosis
Poropatich et al. (*8*)	**1982–2010**	**Global**	**Systematic review**	**2,502**	**Stool samples or serology**	**31% (range 4.8%–71.7%)**
McGrogan et al. (*9*)	1980–2008	Global	Systematic review	–	–	6%–26%
Islam et al. (*12*)	2006–2007	Bangladesh	Prospective case-control	100	Stool samples and serology	57%
Sivadon-Tardy et al. (*13*)	1999–2005	France	Cross sectional	237	Stool samples and serology	27%
Tam et al. (*14*)	1991–2001	UK	Nested case-control	553	Corrected community incidence estimate	20%
Sivadon-Tardy et al. (*15*)	1996–2001	France	Cross sectional	263	Serology	22%
Takahashi et al. (*16*)	1990–2003	Japan	Case-control	1049	Stool samples and serology	11%
Tam et al. (*17*)	2000–2001	UK	Estimation	1146	Community incidence estimate	13.7%
Hadden and Gregson (*10*)	–	Global	Review	–	Serology	13%–72%
Nachamkin et al. (*11*)	–	USA	Review	–	Stool samples or serology	Best estimate 30%–40% (range 8%–50%)

*Boldface indicates chosen proportion for foodborne multiplier calculation.

HUS

Technical Appendix 4 Table 5 presents the percentage of cases of HUS that arise from STEC estimated in 4 different papers, including a global systematic review. From this, we assumed that 61% (range 30%–85%) of HUS cases arise from STEC, modelled as a PERT distribution. Multiplied with the STEC foodborne multiplier of 0.56 (90% credible interval [CrI] 0.32–0.83) (*1*) led to a foodborne multiplier for HUS of 0.33 (90% CrI 0.18–0.54).

Technical Appendix 4 Table 5. Proportion of HUS attributable to STEC*

Reference	Study years	Study type	Country	No. STEC isolations/no. HUS cases	STEC cases that develop into HUS
Walker et al. (*18*)	**1980–2011**	**Systematic review**	**Global**	**–**	**60.8% (range 30%–85.2%)**
Askar et al. (*19*)	2011	Surveillance	Germany	273/470	58%
Elliot et al. (*20*)	1994–1998	Surveillance	Australia	36/70	51%
Van de Kar (*21*)	1989–1993	Case control	The Netherlands	88/113	77.8%

*HUS, hemolytic uremic syndrome; STEC, Shiga toxin–producing *Escherichia coli*. Boldface indicates chosen proportion for foodborne multiplier calculation.

IBS

We estimated the proportion of IBS cases from *Campylobacter* spp., nontyphoidal *Salmonella* spp., or *Shigella* spp. based on the proportion of IBS considered to be postinfectious in the literature. In 1962, Chaudhary and Truelove (*22*) reported IBS occurring from infective dysentery, with 34 (26.2%) of 130 patients dating symptoms back to an attack of gastroenteritis.

More recently, review studies have estimated that 6%-17% (*23*) and 7%–33% of IBS is postinfectious (*24*). In the meta-analysis and estimation by Haagsma et al. (*25*), the authors considered that 17% of IBS is due to campylobacteriosis, salmonellosis, or shigellosis from the top end of the range of 6%-17% by Spiller and Garsed (*23*). We assumed 17% of IBS to be triggered by a gastrointestinal infection (*25*), with a range of 7%–33% from the review by Schwille-Kiuntke et al. (*24*). Because more than just *Campylobacter* spp., nontyphoidal *Salmonella* spp. and *Shigella* spp. can cause postinfectious IBS, this may be an overestimate.

A foodborne multiplier for the combined 3 pathogens of 73% (90% CrI 64%–82%) was calculated as a weighted average of the foodborne multipliers for each pathogen, weighted by the total number of IBS cases for each pathogen. Multiplied by the above PERT distribution of 17% (range 6%–33%), gave a foodborne multiplier for IBS of 13% (90% CrI 8%–20%).

Technical Appendix 4 Table 6. Proportion of IBS attributable to infectious gastroenteritis*

Reference	Publication year	Study type	Country	No. postinfectious IBS cases/IBS cases	IBS that is postinfectious, %
Chaudhary and Truelove (*22*)	1962	Epidemiologic report	UK	34/130	26.2
Spiller and Garsed (*23*)	2009	Review	Global	–	6–17
Haagsma et al. (*25*)	**2010**	**Meta-analysis and estimation**	**The Netherlands**	**–**	**17**
Schwille-Kiuntke et al. (*24*)	**2013**	**Review**	**Global**	**–**	**7–33**

*IBS, irritable bowel syndrome. Boldface indicates chosen proportion for foodborne multiplier calculation.

ReA

In a review of ReA, Hannu et al. (*4*) compiled population-based studies on the annual incidence of ReA—both from enteric and urogenital infection. We used this compilation and calculated the proportion of ReA due to enteric infection by dividing the enteric incidence by the total incidence found in each study (Technical Appendix 4 Table 7). We used the midpoint and range of the proportions from these studies for the bacterial multiplier. We therefore assumed a median of 66.7% of ReA is due to an enteric infection, with a range of 50%–94.7%. If enteric infections preceding ReA are from other infections besides campylobacteriosis, salmonellosis, shigellosis, or yersiniosis, using this distribution to estimate ReA cases from these infections may cause an overestimation.

We adjusted for the proportion foodborne using a weighted average of the foodborne multipliers for *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica*, weighted by the total number of ReA cases for each pathogen. This gave a foodborne multiplier of 72% (90% CrI 60%–82%). Multiplied by the above alternate PERT

distribution of median 66.7% (range 50%–94.7%), gave a foodborne multiplier for reactive arthritis of 48% (90% CrI 36%–61%).

Technical Appendix 3 Table 7. Proportion of ReA attributable to enteric infection*

Reference	Country	Year	Incidence per 100,000			No. ReA due to enteric infection/total no. enteric infections
			Enteric	Urogenital	Total	
Isomaki et al. (*26*)	Finland	1978	14	13	27	14/27 (51.9%)
Kvien et al. (*27*)	Norway	1994	5	5	10	5/10 (50%)
Savolainen et al. (*28*)	Finland	2000	7	3	10	7/10 (70%)
Soderlin et al. (*29*)	Sweden	2002	18	1	19	18/19 (94.7%)
Townes et al. (*30*)	USA	2008	0.6–3.1	NA	NA	NA
Hanova et al. (*31*)	Czech Republic	2010	6	3	≈9	6/9 (66.7%)

*Adapted from the table of annual incidence of reactive arthritis based on population studies in Hannu et al. (*4*). NA, not applicable.

References

1. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000–circa 2010. Emerg Infect Dis. 2014;20:zzz–zzz. http://dx.doi.org/10.3201/eid2011.131315

2. Olden KW. Diagnosis of irritable bowel syndrome. Gastroenterology. 2002;122:1701–14. PubMed http://dx.doi.org/10.1053/gast.2002.33741

3. Townes JM. Reactive arthritis after enteric infections in the United States: the problem of definition. Clin Infect Dis. 2010;50:247–54. PubMed http://dx.doi.org/10.1086/649540

4. Hannu T. Reactive arthritis. Best Pract Res Clin Rheumatol. 2011;25:347–57. PubMed http://dx.doi.org/10.1016/j.berh.2011.01.018

5. Hall G, Kirk M, Becker N, Gregory J, Unicomb L, Millard G, et al. Estimating foodborne gastroenteritis, Australia. Emerg Infect Dis. 2005;11:1257–64. PubMed http://dx.doi.org/10.3201/eid1108.041367

6. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, et al. Foodborne illness acquired in the United States—major pathogens. Emerg Infect Dis. 2011;17:7–15. PubMed http://dx.doi.org/10.3201/eid1701.P11101

7. Mead PS, Slutsker L, Dietz V, McCraig LF, Bresee JS, Shapiro C, et al. Food-related illness and death in the United States. Emerg Infect Dis. 1999;5:607–25. PubMed http://dx.doi.org/10.3201/eid0505.990502

8. Poropatich KO, Walker CL, Black RE. Quantifying the association between *Campylobacter* infection and Guillain-Barré syndrome: a systematic review. J Health Popul Nutr. 2010;28:545–52. PubMed http://dx.doi.org/10.3329/jhpn.v28i6.6602

9. McGrogan A, Madle GC, Seaman HE, de Vries CS. The epidemiology of Guillain-Barré syndrome worldwide. A systematic literature review. Neuroepidemiology. 2009;32:150–63. PubMed http://dx.doi.org/10.1159/000184748

10. Hadden RD, Gregson NA. Guillain–Barré syndrome and *Campylobacter jejuni* infection. Symp Ser Soc Appl Microbiol. 2001;(30):145S–54S. PubMed http://dx.doi.org/10.1046/j.1365-2672.2001.01363.x

11. Nachamkin I, Allos BM, Ho T. *Campylobacter* species and Guillain-Barré syndrome. Clin Microbiol Rev. 1998;11:555–67. PubMed

12. Islam Z, Jacobs BC, van Belkum A, Mohammad QD, Islam MB, Herbrink P, et al. Axonal variant of Guillain-Barré syndrome associated with *Campylobacter* infection in Bangladesh. Neurology. 2010;74:581–7. PubMed http://dx.doi.org/10.1212/WNL.0b013e3181cff735

13. Sivadon-Tardy V, Orlikowski D, Porcher R, Ronco E, Caudie C, Roussi J, et al. Guillain-Barré syndrome, greater Paris area. Emerg Infect Dis. 2006;12:990–3. PubMed

14. Tam CC, O'Brien SJ, Petersen I, Islam A, Hayward A, Rodrigues LC. Guillain-Barré syndrome and preceding infection with *Campylobacter*, influenza and Epstein-Barr virus in the general practice research database. PLoS ONE. 2007;2:e344. PubMed http://dx.doi.org/10.1371/journal.pone.0000344

15. Sivadon-Tardy V, Orlikowski D, Rozenberg F, Caudie C, Sharshar T, Lebon P, et al. Guillain-Barré syndrome, greater Paris area. Emerg Infect Dis. 2006;12:990–3. PubMed http://dx.doi.org/10.3201/eid1206.051369

16. Takahashi M, Koga M, Yokoyama K, Yuki N. Epidemiology of *Campylobacter jejuni* isolated from patients with Guillain-Barré and Fisher syndromes in Japan. J Clin Microbiol. 2005;43:335–9. PubMed http://dx.doi.org/10.1128/JCM.43.1.335-339.2005

17. Tam CC, O'Brien SJ, Adak GK, Meakins SM, Frost JA. *Campylobacter coli*—an important foodborne pathogen. J Infect. 2003;47:28–32. PubMed http://dx.doi.org/10.1016/S0163-4453(03)00042-2

18. Walker CL, Applegate JA, Black RE. Haemolytic-uraemic syndrome as a sequela of diarrhoeal disease. J Health Popul Nutr. 2012;30:257–61. PubMed http://dx.doi.org/10.3329/jhpn.v30i3.12288

19. Askar M, Faber MS, Frank C, Bernard H, Gilsdorf A, Fruth A, et al. Update on the ongoing outbreak of haemolytic uraemic syndrome due to Shiga toxin–producing *Escherichia coli* (STEC) serotype O104, Germany, May 2011. Euro Surveill. 2011;16: pii: 19883. PubMed

20. Elliott EJ, Robins-Browne RM, O'Loughlin EV, Bennett-Wood V, Bourke J, Henning P, et al. Nationwide study of haemolytic uraemic syndrome: clinical, microbiological, and epidemiological features. Arch Dis Child. 2001;85:125–31. PubMed http://dx.doi.org/10.1136/adc.85.2.125

21. van de Kar NC, Roelofs HG, Muytjens HL, Tolboom JJ, Roth B, Proesmans W, et al. Verocytotoxin-producing *Escherichia coli* infection in hemolytic uremic syndrome in part of western Europe. Eur J Pediatr. 1996;155:592–5. PubMed

22. Chaudhary NA, Truelove SC. The irritable colon syndrome: a study of the clinical features, predisposing causes, and prognosis in 130 cases. Q J Med. 1962;31:307–22. PubMed

23. Spiller R, Garsed K. Postinfectious irritable bowel syndrome. Gastroenterology. 2009;136:1979–88. PubMed http://dx.doi.org/10.1053/j.gastro.2009.02.074

24. Schwille-Kiuntke J, Frick JS, Zanger P, Enck P. Post-infectious irritable bowel syndrome—a review of the literature. Z Gastroenterol. 2011;49:997–1003. PubMed http://dx.doi.org/10.1055/s-0031-1281581

25. Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH. Disease burden of post-infectious irritable bowel syndrome in the Netherlands. Epidemiol Infect. 2010;138:1650–6. PubMed http://dx.doi.org/10.1017/S0950268810000531

26. Isomäki H, Raunio J, von Essen R, Hämeenkorpi R. Incidence of inflammatory rheumatic diseases in Finland. Scand J Rheumatol. 1978;7:188–92. PubMed http://dx.doi.org/10.3109/03009747809095652

27. Kvien TK, Glennas A, Melby K, Granfors K, Andrup O, Karstensen B, et al. Reactive arthritis: incidence, triggering agents and clinical presentation. J Rheumatol. 1994;21:115–22. PubMed

28. Savolainen E, Kaipiainen-Seppanen O, Kroger L, Luosujarvi R. Total incidence and distribution of inflammatory joint diseases in a defined population: results from the Kuopio 2000 arthritis survey. J Rheumatol. 2003;30:2460–8. PubMed

29. Söderlin MK, Kautiainen H, Puolakkainen M, Hedman K, Söderlund-Venermo M, Skogh T, et al. Infections preceding early arthritis in southern Sweden: a prospective population-based study. J Rheumatol. 2003;30:459–64. PubMed

30. Townes JM, Deodahar AA, Laine ES, Smith K, Krug HE, Barkhuizen A, et al. Reactive arthritis following culture-confirmed infections with bacterial enteric pathogens in Minnesota and Oregon: a population-based study. Ann Rheum Dis. 2008;67:1689–96. PubMed http://dx.doi.org/10.1136/ard.2007.083451

31. Hanova P, Pavelka K, Holcatova I, Pikhart H. Incidence and prevalence of psoriatic arthritis, ankylosing spondylitis, and reactive arthritis in the first descriptive population-based study in the Czech Republic. Scand J Rheumatol. 2010;39:310–7. PubMed http://dx.doi.org/10.3109/03009740903544212f

Article DOI: http://dx.doi.org/10.3201/eid2011.131316

Sequelae of Foodborne Illness Caused by 5 Pathogens, Australia, Circa 2010

Technical Appendix 5

Model Inputs for 4 Sequelae Illnesses Due to Contaminated Food

Incidence

Technical Appendix 5 Table 1. Guillain-Barré Syndrome

Model input, source, and comments	Distribution	Data for model input
Antecedent bacterial gastroenteritis cases: estimated number of foodborne *Campylobacter* spp. cases (*1*)	Outcome	5%, median, 95% values: 108500, 179000, 290000 (circa 2010) 82500, 139000, 227000 (circa 2000)
Sequelae multiplier: this proportion was a midpoint between estimates from the literature reported in Tam et al. (*2*), McCarthy and Gieseke (*3*), and Allos et al. (*4*)	PERT	Minimum, modal, maximum values: 0.000192, 0.000304, 0.000945
Total foodborne illness: foodborne *Campylobacter* spp. cases × Sequelae multiplier	Outcome	5%, median, 95% values: 30, 75, 150 (circa 2010) 25, 50, 100 (circa 2000)
Rate of foodborne illness from *Campylobacter* spp. per million population	Outcome	5%, median, 95% values: 2, 3.1, 6 (circa 2010) 1, 2.8, 6 (circa 2000)

Technical Appendix 5 Table 2. Hemolytic uremic syndrome

Model input, source, and comments	Distribution	Data for model input
Antecedent bacterial gastroenteritis cases: estimated number of foodborne STEC cases (*1*)	Outcome	5%, median, 95% values: 950, 2350, 5850 (circa 2010) 550, 1900, 5000 (circa 2000)
Sequelae multiplier: this proportion is from Vally et al. (*5*)	Alternate PERT	2.5%, Median, 97.5% values: 0.017, 0.03, 0.051
Total foodborne illness: foodborne STEC cases × Sequelae multiplier	Outcome	5%, median, 95% values: 25, 70, 200 (circa 2010) 15, 55, 175 (circa 2000)
Rate of foodborne illness from STEC per million	Outcome	5%, median, 95% values: 1, 3.3, 9 (circa 2010) 1, 3.0, 9 (circa 2000)

*STEC, Shiga toxin–producing *Escherichia coli*.

Technical Appendix 5 Table 3. Irritable bowel syndrome

Model input, source, and comments	Distribution	Data for model input
Antecedent bacterial gastroenteritis cases:		
Estimated number of foodborne *Campylobacter* spp. cases (*1*)	Outcome	5%, median, 95% values: 108500, 179000, 290000 (circa 2010) 82500, 139000, 227000 (circa 2000)
Estimated number of foodborne nontyphoidal *Salmonella* spp. cases (*1*)	Outcome	5%, median, 95% values: 21200, 39600, 73400 (circa 2010) 15000, 28000, 50000 (circa 2000)
Estimated number of foodborne *Shigella* spp. cases (*1*)	Outcome	5%, median, 95% values: 150, 350, 850 (circa 2010) 175, 515, 1300 (circa 2000)
Sequelae multiplier: This proportion was from Haagsmsa et al. (*6*)	Alternate PERT	2.5%, Median, 97.5% values: 0.072, 0.088, 0.104
Total foodborne illness Foodborne *Campylobacter* spp. cases × Sequelae multiplier +	Outcome	5%, median, 95% values: 12500, 19500, 30700 (circa 2010)

Model input, source, and comments	Distribution	Data for model input
Foodborne nontyphoidal *Salmonella* spp. cases × Sequelae multiplier + Foodborne *Shigella* spp. cases × Sequelae multiplier		9500, 14800, 23500 (circa 2000)
Rate of foodborne illness per million	Outcome	5%, median, 95% values: 570, 915, 1440 (circa 2010) 550, 850, 1350 (circa 2000)

Technical Appendix 5 Table 4. Reactive arthritis

Model input, source, and comments	Distribution	Data for model input
Antecedent bacterial gastroenteritis cases:		
Estimated number of foodborne *Campylobacter* spp. cases (*1*)	Outcome	5%, median, 95% values: 108500, 179000, 290000 (circa 2010) 82500, 139000, 227000 (circa 2000)
Estimated number of foodborne nontyphoidal *Salmonella* spp. cases (*1*)	Outcome	5%, median, 95% values: 21200, 39600, 73400 (circa 2010) 15000, 28000, 50000 (circa 2000)
Estimated number of foodborne *Shigella* spp. cases (*1*)	Outcome	5%, median, 95% values: 150, 350, 850 (circa 2010) 175, 515, 1300 (circa 2000)
Estimated number of foodborne *Yersinia enterocolitica* cases (*1*)	Outcome	5%, median, 95% values: 650, 1150, 1950 (circa 2010) 300, 800, 1650 (circa 2000)
Sequelae multipliers: The proportion for each of the 4 pathogens was calculated from the literature. See Technical Appendix 1 for further explanation.		
Campylobacter spp. sequelae multiplier	Alternate PERT	Minimum, median, maximum values: 0.028, 0.07, 0.16
Nontyphoidal *Salmonella* spp. sequelae multiplier	Alternate PERT	Minimum, median, maximum values: 0, 0.085, 0.26
Shigella spp. sequelae multiplier	PERT	Minimum, modal, maximum values: 0.012, 0.097, 0.098
Yersinia enterocolitica sequelae multiplier	Alternate PERT	Minimum, median, maximum values: 0, 0.12, 0.231
Total foodborne illness: Foodborne *Campylobacter* spp. cases × Sequelae multiplier + Foodborne nontyphoidal *Salmonella* spp. cases × Sequelae multiplier + Foodborne *Shigella* spp. cases × Sequelae multiplier + Foodborne *Y. enterocolitica* cases × Sequelae multiplier	Outcome	5%, median, 95% values: 8750, 16200, 30400 (circa 2010) 6700, 12500, 23000 (circa 2000)
Rate of foodborne illness from *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp. and *Y. enterocolitica* per million	Outcome	5%, median, 95% values: 415, 765, 1375 (circa 2010) 380, 730, 1325 (circa 2000)

Hospitalizations and Deaths

Technical Appendix 5 Table 5. Guillain-Barré syndrome

Model input, source, and comments	Distribution	Data for model input
Average number of deaths per year: Australian Bureau of Statistics death data	Empirical	2001–2010: 24.5
Population adjustment: Australian resident population June quarter, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202011?OpenDocument [cited 2012 Aug 16]	Empirical	By year (2001–2010): 19413240, 19651438, 19895435, 20127363, 20394791, 20697880, 21015936, 21384427, 21778845, 22065317
Domestically acquired multiplier: *Campylobacter* spp. domestic acquired multiplier	PERT	Minimum, modal, maximum values: 0.91, 0.97, 0.99
Foodborne multiplier: derived from: Bacterial multiplier—the proportion of Guillain-Barré syndrome that is attributable to *Campylobacter* spp. from Poropatich et al. (*7*) × *Campylobacter* spp. foodborne proportion (*1*)	Outcome PERT Alternate PERT	5%, median, 95% values: 0.1, 0.25, 0.43 Minimum, modal, maximum values: 0.048, 0.31, 0.717 5%, median, 95% values: 0.62, 0.77, 0.89
Total foodborne deaths: circa 2010	Outcome	5%, median, 95% values: 2, 6, 10
Rate of foodborne deaths per million: circa 2010	Outcome	5%, median, 95% values: 0.1, 0.3, 0.5

Technical Appendix 5 Table 6. Hemolytic uremic syndrome*

Model input, source, and comments	Distribution	Data for model input

Model input, source, and comments	Distribution	Data for model input
Average number of deaths per year: Australian Bureau of Statistics death data	Empirical	2001–2010: 4.2
Population adjustment: Australian resident population June quarter, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202011?OpenDocument [cited 2012 Aug 16]	Empirical	By year (2001–2010): 19413240, 19651438, 19895435, 20127363, 20394791, 20697880, 21015936, 21384427, 21778845, 22065317
Domestically acquired multiplier: STEC domestically acquired multiplier	PERT	Minimum, modal, maximum values: 0.93, 0.9 1
Foodborne multiplier: derived from: Bacterial multiplier—the proportion of HUS that is attributable to STEC from Walker et al. (*8*) × STEC foodborne proportion (*1*)	Outcome PERT Alternate PERT	5%, median, 95% values: 0.17, 0.33, 0.53 Minimum, modal, maximum values: 0.3, 0.608, 0.852 5%, median, 95% values: 0.32, 0.56, 0.83
Total foodborne deaths: circa 2010	Outcome	5%, median, 95% values: 1, 2, 3
Rate of foodborne deaths per million: circa 2010	Outcome	5%, median, 95% values: 0.03, 0.1, 0.12

*HUS, hemolytic uremic syndrome; STEC, Shiga toxin–producing *Escherichia coli*.

Technical Appendix 5 Table 7. Irritable bowel syndrome

Model input, source, and comments	Distribution	Data for model input
Yearly observed hospitalizations: state and territory hospitalization data	Empirical	By year (2006–2010): 7851, 7933, 7753, 8128, 7762
Average number of deaths per year: Australian Bureau of Statistics death data	Empirical	2001–2010: 13.1
Population adjustment: Australian resident population June quarter, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202011?OpenDocument [cited 2012 Aug 16]	Empirical	By year (2001–2010): 19413240, 19651438, 19895435, 20127363, 20394791, 20697880, 21015936, 21384427, 21778845, 22065317
Domestically acquired multiplier: a weighted multiplier from *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. domestic multipliers	Alternate PERT	5%, median, 95% values: 0.88, 0.91, 0.94
Foodborne multiplier: derived from: Bacterial multiplier—proportion of IBS that is post-infectious extracted from the literature (*6,9*) × weighted *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. foodborne proportion (*1*)	Outcome Alternate PERT Alternate PERT	5%, median, 95% values: 0.08, 0.13, 0.33 5%, median, 95% values: 0.06, 0.17, 0.33 5%, median, 95% values: 0.64, 0.73, 0.82
Total foodborne hospitalizations: circa 2010	Outcome	5%, median, 95% values: 550, 915, 1400
Total foodborne deaths: circa 2010	Outcome	5%, median, 95% values: 1, 2, 2
Rate of foodborne hospitalizations per million: circa 2010	Outcome	5%, median, 95% values: 25, 43, 70
Rate of foodborne deaths per million: circa 2010	Outcome	5%, median, 95% values: 0.05, 0.1, 0.11

Technical Appendix 5 Table 8. Reactive arthritis

Model input, source, and comments	Distribution	Data for model input
Yearly observed hospitalizations: State and Territory hospitalization data	Empirical	By year (2006–2010): 63, 50, 50, 70, 70
Average number of deaths per year: Australian Bureau of Statistics death data	Empirical	2001–2010: 0
Population adjustment: Australian resident population June quarter, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3101.0Dec%202011?OpenDocument [cited 2012 Aug 16]	Empirical	By year (2001–2010): 19413240, 19651438, 19895435, 20127363, 20394791, 20697880, 21015936, 21384427, 21778845, 22065317
Domestically acquired multiplier: Weighted multiplier of *Campylobacter* spp., nontyphoidal *Salmonella* spp., *Shigella* spp., and *Y. enterocolitica* domestic multipliers	Alternate PERT	5%, median, 95% values: 0.86, 0.91, 0.95
Foodborne multiplier: derived from: Bacterial multiplier—proportion of ReA that is post-infectious extracted from the literature (*10*) × weighted *Campylobacter* spp., nontyphoidal *Salmonella* spp., and *Shigella* spp. foodborne proportion (*1*).	Alternate PERT Alternate PERT Alternate PERT	5%, median, 95% values:0.36, 0.48, 0.61 Minimum, median, maximum values: 0.5, 0.66, 0.947 5%, median, 95% values: 0.60, 0.72, 0.82
Total foodborne hospitalizations: circa 2010	Outcome	5%, median, 95% values: 20, 25, 40
Total foodborne deaths: circa 2010	Outcome	5%, median, 95% values: 0, 0, 0
Rate of foodborne hospitalizations per million: circa 2010	Outcome	5%, median, 95% values: 1, 1, 2
Rate of foodborne deaths per million: circa 2010	Outcome	5%, median, 95% values: 0, 0, 0

References

1. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000–circa 2010. Emerg Infect Dis. 2014;20:zzz–zzz. http://dx.doi.org/10.3201/eid2011.131315

2. McCarthy N, Giesecke J. Incidence of Guillain-Barré syndrome following infection with *Campylobacter jejuni*. Am J Epidemiol. 2001;153:610–4. PubMed http://dx.doi.org/10.1093/aje/153.6.610

3. Tam CC, Rodrigues LC, Petersen I, Islam A, Hayward A, O'Brien SJ. Incidence of Guillain-Barré syndrome among patients with *Campylobacter* infection: a general practice research database study. J Infect Dis. 2006;194:95–7. PubMed http://dx.doi.org/10.1086/504294

4. Baker MG, Kvalsvig A, Zhang J, Lake R, Sears A, Wilson N. Declining Guillain-Barré syndrome after campylobacteriosis control, New Zealand, 1988–2010. Emerg Infect Dis. 2012;18:226–33. PubMed http://dx.doi.org/10.3201/eid1802.111126

5. Vally H, Hall G, Dyda A, Raupach J, Knope K, Combs B, et al. Epidemiology of Shiga toxin producing *Escherichia coli* in Australia, 2000–2010. BMC Public Health. 2012;12:63–71. PubMed http://dx.doi.org/10.1186/1471-2458-12-63

6. Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH. Disease burden of post-infectious irritable bowel syndrome in the Netherlands. Epidemiol Infect. 2010;138:1650–6. PubMed http://dx.doi.org/10.1017/S0950268810000531

7. Poropatich KO, Walker CL, Black RE. Quantifying the association between *Campylobacter* infection and Guillain-Barré syndrome: a systematic review. J Health Popul Nutr. 2010;28:545–52. PubMed http://dx.doi.org/10.3329/jhpn.v28i6.6602

8. Walker CL, Applegate JA, Black RE. Haemolytic-uraemic syndrome as a sequela of diarrhoeal disease. J Health Popul Nutr. 2012;30:257–61. PubMed http://dx.doi.org/10.3329/jhpn.v30i3.12288

9. Schwille-Kiuntke J, Frick JS, Zanger P, Enck P. Post-infectious irritable bowel syndrome—a review of the literature. Z Gastroenterol. 2011;49:997–1003. PubMed http://dx.doi.org/10.1055/s-0031-1281581

10. Hannu T. Reactive arthritis. Best Pract Res Clin Rheumatol. 2011;25:347–57. PubMed http://dx.doi.org/10.1016/j.berh.2011.01.018