Australian National University

The annual cost of foodborne illness in Australia

Final Report

For: Food Standards Australia New Zealand

15 September 2022

Overview of this report

This project is in relation to Services for the provision of the annual cost of foodborne disease illness in Australia for Food Standards Australia New Zealand (FSANZ), contract 2010-21/03. The project builds on prior economic and epidemiological projects completed by the team at the Australian National University (ANU).

The project deliverables are summarised as follows:

1. Attend a scoping meeting at the commencement of the project
2. Develop a project research plan including:
    a. Key tasks and timelines
    b. Table of contents, structure, and format of the report
    c. Structure and model format
    d. Risk register
3. Prepare an Interim Report and Costing Model
4. Prepare a Draft Report and Costing Model
5. Prepare a Final Report and Costing Model
6. Present findings and recommendations.

This document comprises deliverable 5: Final Report and Costing Model.

This final report includes a full description of the methods used to estimate direct costs; a comparison of methods used internationally to measure indirect costs together with our approach for this project; cost estimates for total infectious gastroenteritis, all priority pathogens, and sequelae; sensitivity analyses; case studies of four disease outbreaks; an overview of the costs of surveillance; and Appendices containing all model parameters and assumptions.

Table of contents

Glossary and acronyms

Acronym	*Descriptor*
ABS	Australian Bureau of Statistics
AIHW	Australian Institute of Health and Welfare
ALOS	Average length of stay
ANU	The Australian National University
AR-DRG	Australian Refined Diagnosis Related Groups
AUD	Australian Dollar
DCE	Discrete choice experiment
DMARD	Disease-modifying anti-rheumatic drug
ED	Emergency department
FDA	United States Food and Drug Administration
FSANZ	Food Standards Australia New Zealand
GBP	British pound sterling
GBS	Guillain-Barré syndrome
GP	General practitioner
HUS	Haemolytic uraemic syndrome
IBS	Irritable bowel syndrome
ICD10	The 10th International Classification of Diseases
ICD10-AM	Australian modification of the 10th International Classification of Diseases
MBS	Medicare Benefits Schedule
NGSII	National Gastroenteritis Survey II
NNDSS	National Notifiable Diseases Surveillance System
NSAID	Non-steroidal anti-inflammatory drug
NSW DPI	New South Wales Department of Primary Industries
NSWFA	New South Wales Food Authority
NZD	New Zealand Dollar
OBPR	Office of Best Practice Regulation, Australian Government Department of the Prime Minister and Cabinet
PBS	Pharmaceutical Benefits Scheme
PHU	Public health unit
QALYs	Quality-adjusted life-years
ReA	Reactive arthritis
STEC	Shiga toxin-producing *Escherichia coli*
UI	Uncertainty interval
UK	The United Kingdom
US	The United States of America
USD	United States Dollar
USDA/CDC	United States Department of Agriculture/ Centers for Disease Control and Prevention
VSL	Value of statistical life
WQS	Water Quality Study
WTP	Willingness to pay

Executive summary

Foodborne illness causes a significant health burden in Australia. Estimates of both the extent of foodborne illness and the costs arising from illness are essential for measuring the impact on the population. In 2010 it was estimated that Australians experience almost 16 million episodes of gastroenteritis each year, with about one quarter of these due to contaminated food. This report updates these numbers to circa 2019 and estimates the associated costs to individuals and the health system. As foodborne disease interventions are often targeted at specific causes of illness, costs are also provided for ten high-priority pathogens.

We estimate that foodborne illness and its sequelae costs Australia AUD 2.44 billion each year. The largest component of this cost is lost productivity due to non-fatal illness, followed by premature mortality and direct costs (including hospitalisations and other health care use). While costs due to lost productivity are lower under the more conservative friction cost model, it remains the largest component cost for foodborne illness due to all causes.

The pathogen with the highest individual cost is *Campylobacter* (AUD 365 million per year), while norovirus, other pathogenic *E. coli*, and *Salmonella* are all estimated to cost Australians over AUD 100 million each year. Lost productivity is the largest component cost for most pathogens, although premature mortality is the largest cost for pathogens that typically cause more severe illness, such as *Listeria monocytogenes*, Shiga toxin-producing *Escherichia Coli*, and *Salmonella*. Table 1 and

Figure **1** provide estimates of burden and cost by pathogen, including costs arising from sequelae.

Significant advances in this report include the incorporation of estimated willingness to pay to avoid pain and suffering based on a discrete choice experiment from another FSANZ commissioned study, and the use of a simulation approach to estimating costs which provides uncertainty intervals on all estimates. A costing tool is provided with this report to allow estimates to be updated in the future. Costs associated with surveillance for foodborne pathogens and related to outbreak investigations are considered separately to the model. Likewise, industry costs due to outbreaks such as lost sales, disposal of products, recall costs, enforcement related costs and potential business costs are not included in the costing model.

Key limitations in this work include the lack of data on the long-term burden and health care usage associated with sequelae or ongoing illness due to toxoplasmosis and listeriosis. These costs are not included in this report due to unavailability of data. Costs of pain and suffering, which we approximate using willingness to pay to avoid pain and suffering, are relatively low compared to those estimated for other countries, which may represent differences in underlying preferences across countries and could suggest that greater international standardisation of methods and data collection may be required.

This report demonstrates that foodborne illness results in a substantial cost to Australia and that interventions to improve food safety across industry, retail, and consumers are needed to improve public health. Pathogen-specific costing estimates allow policymakers to target such interventions at individual pathogens, with the end goal of reducing the burden due to foodborne illness.

Figure 1: Annual cost of foodborne illness for priority pathogens, showing component costs of direct costs (health care usage; medication costs), productivity losses, pain and suffering (estimated by willingness to pay values), and premature mortality.

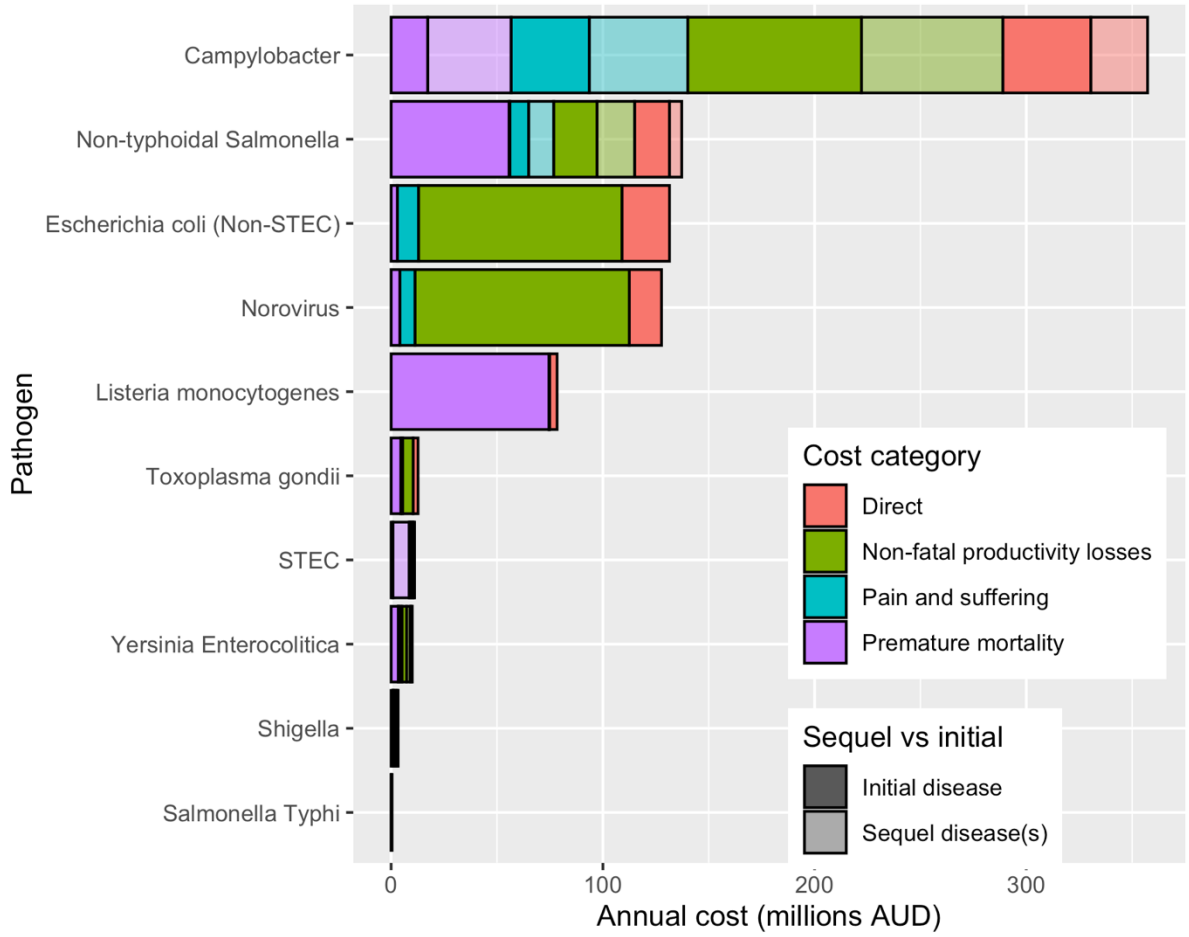


Table 1: Cases, cost per case, and total cost of illness for all foodborne pathogens, total gastroenteritis and priority pathogens.

Pathogen	Number of cases, n (90% UI)	Cost per case in AUD (90% UI)	Median costs in thousands of AUD (90% Uncertainty Intervals[†])	
			Cost of initial illness	Cost of illness and sequelae
All foodborne pathogens	4,680,000 (2,640,000 – 7,540,000)	526 (431 – 688)	2,200,000 (1,410,000 – 3,440,000)	2,440,000 (1,650,000 – 3,680,000)
Total gastroenteritis	4,670,000 (2,620,000 – 7,520,000)	507 (417 – 660)	2,100,000 (1,310,000 – 3,340,000)	2,350,000 (1,550,000 – 3,590,000)
Campylobacter	264,000 (161,000 – 432,000)	1,390 (1,150 – 1,710)	179,000 (123,000 – 277,000)	365,000 (250,000 – 553,000)
Listeria monocytogenes	101 (50.5 – 151)	785,000 (482,000 – 1,590,000)	78,400 (58,600 – 103,000)	No sequelae
Non-typhoidal *Salmonella*	61,600 (34,300 – 109,000)	2,270 (1,640 – 3,360)	103,000 (78,800 – 135,000)	140,000 (102,000 – 201,000)
Norovirus	328,000 (89,600 – 671,000)	396 (328 – 545)	128,000 (42,500 – 262,000)	No sequelae
Shigella	1,930 (662 – 4,360)	1,740 (1,310 – 3,220)	2,310 (1,370 – 3,820)	3,410 (1,840 – 6,170)
Shiga-toxin producing *Escherichia coli* (STEC)	2,630 (1,140 – 5,760)	4,330 (2,210 – 10,000)	2,470 (1,190 – 5,020)	11,700 (7,260 – 18,300)
Other pathogenic *Escherichia coli*	312,000 (120,000 – 709,000)	422 (359 – 533)	133,000 (51,900 – 306,000)	No sequelae
Salmonella Typhi	28.6 (9.57 – 64.4)	15,100 (11,700 – 33,200)	468 (189 – 956)	No sequelae
Toxoplasma gondii	15,500 (6,130 – 27,500)	840 (588 – 1,640)	13,100 (8,120 – 19,500)	No sequelae
Yersinia enterocolitica	7,170 (3,960 – 12,600)	1,430 (986 – 2,270)	7,480 (4,430 – 12,300)	10,400 (6,150 – 17,100)

[†] Uncertainty intervals are provided by the model, which incorporates distributions for inputs, capturing variability and uncertainty in data.

Acknowledgements

This work was funded by the Australian Government Department of Health. Food Standards Australia New Zealand undertook a tender process and entered a contract with the ANU to undertake this project (contract 2010/21-03). FSANZ has been responsible for managing this contract and co-ordinating peer review of the work undertaken by the ANU. The ANU project team consists of Prof Kathryn Glass, Prof Emily Lancsar, Prof Martyn Kirk, Dr Siobhan Bourke, Dr Angus McLure, and Danielle Cribb.

The team acknowledges the contributions of FSANZ staff and reference panel members from University of Western Australia (A/Prof Michael Burton), University of Tasmania (Prof Andrew Palmer), Australian Government Department of Health, Nutrition Policy Section, NSW Department of Primary Industries (Craig Shadbolt), United States Department of Agriculture (Prof Sandra Hoffmann), and UK Food Standards Agency (Nicholas Daniel). The team particularly thanks Barry Combs, Craig Shadbolt, and OzFoodNet Central staff for their assistance on the outbreak and surveillance sections of this report.

Data resources and additional information were received from FSANZ on behalf of the Centre for Health Economics Research and Evaluation (CHERE) at the University of Technology, Sydney (UTS), Freshlogic, OzFoodNet New South Wales, U.S. Food and Drug Administration, and United States Department of Agriculture.

Scope of the work

This project is in relation to Services for the provision of the annual cost of foodborne disease illness in Australia for Food Standards Australia New Zealand (FSANZ), contract 2010-21/03, using epidemiological estimates previously developed by this team [1-3]. The main outputs of this work are:

- a cost model, and
- a report on the annual cost of foodborne illness in Australia.

The cost model was used to generate estimates of costs for the report but is also a standalone product that can be updated and used by FSANZ and other regulators.

The report includes costs for foodborne gastroenteritis due to all causes and costs due to the following ten pathogens that were selected through a prioritisation process [2]:

- *Campylobacter*
- *Listeria monocytogenes*
- Norovirus
- Non-typhoidal *Salmonella*
- *Salmonella enterica* serovar Typhi (*Salmonella* Typhi)
- Shiga toxin-producing *Escherichia coli* (STEC)
- Other pathogenic *Escherichia coli*
- *Shigella*
- *Toxoplasma gondii*
- *Yersinia enterocolitica*

Additionally, costs due to four sequelae were captured where appropriate: Guillain-Barré syndrome (GBS), irritable bowel syndrome (IBS), haemolytic uraemic syndrome (HUS), and reactive arthritis (ReA).

Direct financial costs included in the model are those related to diagnosis, treatment, and management of illness such as: visits to General Practitioners (GPs), visits to the Emergency Department (ED), hospitalisations, diagnostic testing, and pharmaceutical expenses. Indirect costs associated with non-fatal illness included lost productivity which was estimated using the human capital approach (with the friction cost method used in sensitivity analysis), and non-financial costs of pain and suffering which were approximated through willingness to pay (WTP) values to avoid such pain and suffering [4]. Indirect costs associated with fatal illness were estimated using the value of a statistical life (VSL). The model excludes costs to business due to recalls and lost revenue; pain and suffering of friends or relatives; and transport, accommodation, or funeral expenses associated with hospitalisations or deaths.

In addition to costs captured by the model, this report includes sections describing costs incurred in investigating outbreaks and those relating to surveillance for foodborne disease. Four outbreak case studies were considered, and surveillance costs were summarised through consultation with federal and jurisdictional agencies.

Introduction

Globally, foodborne illness causes a significant health burden, with norovirus and *Campylobacter* among the most common causes and 40% of the global burden estimated to be borne by children under five [5]. In Australia, we estimated that there were 15.9 million episodes of gastroenteritis in 2010 of which 25% (90% uncertainty interval (UI): 13%–42%) were due to contaminated food, estimated at around 4.1 million episodes of foodborne gastroenteritis [6]. In addition, contaminated food was estimated to cause 5,140 cases of foodborne illness that were non-gastrointestinal in nature [6]. These foodborne illnesses resulted in an estimated 35,840 episodes of sequelae, 31,920 hospitalisations, and 86 deaths in 2010 [6, 7].

Estimates of the economic burden of foodborne illnesses help to inform prioritisation of types of illnesses that may warrant attention to reduce the burden of illness due to contaminated food. Prioritisation of specific control measures would require information on relative costs *and benefits* or *cost effectiveness* of such measures.

Internationally, the cost of foodborne disease has been estimated for several countries. Comparisons across countries are informative, although it must be noted that population size, pathogen incidence, and health systems can vary considerably. Hoffmann *et al.* [8] estimated that foodborne illness due to 15 (known) pathogens costs the United States USD 15.5 billion each year (2013 dollars; equivalent to AUD 25.1 billion in 2020), noting that only 20% of episodes of foodborne illness are due to a known pathogen. The largest component of this cost (84%) was due to deaths, although the study authors noted that their approach to non-fatal illness was conservative. Daniel *et al.* [9] estimated that there were 2.4 million cases of foodborne illness in the United Kingdom (UK) each year, costing an estimated GBP 9.1 billion (2018 pounds; equivalent to AUD 19.5 billion in 2020). The largest component (almost 80%) of these costs are those due to human costs of pain, grief, and suffering that were largely borne by individuals. The pathogens contributing the most to estimates for the UK were norovirus (GBP 1.7 billion; equivalent to AUD 3.64 billion in 2020), *Campylobacter* (GBP 713 million; equivalent to AUD 1.53 billion in 2020) and *Salmonella* (GBP 212 million; equivalent to AUD 454 million in 2020). In New Zealand, six foodborne diseases (campylobacteriosis, salmonellosis, norovirus, yersiniosis, STEC, and listeriosis) were estimated to cost NZD 162 million each year (2009 dollars; equivalent to AUD 194 million in 2020), with campylobacteriosis contributing the most to that total [10].

In 2006, Abelson estimated the costs of foodborne illness in Australia based on data from 2000 [11]. That study estimated total annual costs of AUD 1.2 billion (2004 dollars; equivalent to AUD 1.8 billion in 2020) [11], with productivity and lifestyle costs contributing 62% of that total. While these total costs did not include costs to industry, these were considered through case studies of

outbreaks. To update this costing, we estimated the burden of foodborne illness [1-3] and incorporated results from a FSANZ commissioned discrete choice experiment (DCE) to estimate WTP values to avoid pain and suffering due to foodborne illnesses and treated these values as the cost of avoiding such pain and suffering. The DCE encouraged respondents to focus on averted pain and suffering separate from direct costs and access to sick leave [4].

This study reports on the cost of foodborne illness in Australia, using data circa 2019 where available, with costs for gastroenteritis due to all causes and disease-specific costs for ten prioritised pathogens. We elected not to estimate the burden circa 2020, as hospitalisation data for 2020 were not yet available at the time of this report and the COVID-19 pandemic influenced notification data for pathogens causing gastroenteritis [12]. Industry and surveillance costs were considered separately through consultation with government and case studies of outbreaks. The model used to generate all estimates was provided with this report, enabling estimates to be updated in the future.

Methodology

The project harnessed prior epidemiological and economic work undertaken by the ANU team [1-3] and the Centre for Heath Economics Research and Evaluation (CHERE) [4] to estimate costs of illness due to all causes of gastroenteritis and due to each of ten prioritised pathogens. The priority pathogens were selected using a tool made up of eight criteria including incidence, absenteeism, mortality, and data availability [2]. The model and resulting costs were estimated through the following steps:

- The burden of disease (including illness, hospitalisations, deaths, and sequelae) was modelled for gastroenteritis due to all causes and for each prioritised pathogen.
- Data, circa 2019, where available, were sourced for pathogens and costs.
- The financial costs of illness, including direct and indirect costs were estimated for each of these.
- The non-financial costs of pain and suffering were included.

The model was developed in R (version 4.0.3) [13] and was provided, with associated Shiny apps [14], to enable stakeholders to interact with the model and produce cost estimates by pathogen. All disease and costing data can be updated through CSV or Excel spreadsheets, while model assumptions can be adjusted as required within the R code. A user's guide to the Shiny app is provided as Appendix A to this report. This report also summarises some costs of foodborne disease surveillance and explores costs to business through four case studies centred on foodborne disease outbreaks.

Burden of disease calculations

The approach was based on that used to estimate the burden of foodborne disease in Australia circa 2010 [6, 7]. Those papers and their appendices include detailed descriptions of the methods used to estimate the burden of disease for gastroenteritis due to all causes and the following pathogens by age group (<5, 5–64, and 65+):

- *Campylobacter*
- *Listeria monocytogenes*
- Norovirus
- Non-typhoidal *Salmonella*
- *Salmonella enterica* serovar Typhi (*Salmonella* Typhi)
- Shiga toxin-producing *Escherichia coli* (STEC)
- Other pathogenic *Escherichia coli*
- *Shigella*
- *Toxoplasma gondii*
- *Yersinia enterocolitica*

Additionally, we followed the same approach [7] to estimate incidence, hospitalisations, and deaths for four sequelae: GBS, HUS, IBS and ReA. Figure 2 presents the health outcome tree for *Campylobacter* as previously presented in an earlier report [2] to illustrate the approach. Outcome trees for all pathogens are included in Appendix C.

Incidence

Estimates of disease incidence for most pathogens were calculated using one of two approaches. Where notifiable disease surveillance data were available, our preferred approach was the *surveillance* approach, where we scaled up notifications to a total population burden of disease using under-reporting multipliers. Where such data were not available, we generally used the *pathogen fraction* approach, where we estimated the proportion of all cases of gastroenteritis that were due to that pathogen.

Our approaches to estimate disease incidence and the data sources by pathogen or illness are listed in **Error! Reference source not found.**. The main data sources are the National Gastroenteritis Survey II (NGSII) [15], the Water Quality Study (WQS) [16], and the National Notifiable Diseases Surveillance System data (NNDSS) [17]. NGSII and WQS estimates were adjusted to account for increases in population since those data were collected.

Other pathogenic *E. coli* included all pathogenic *E. coli* other than STEC. Other pathogenic *E. coli* was largely represented by Enteropathogenic *E. coli,* but also included Enteroaggerative *E. coli*, Enterotoxigenic *E. coli*, Enteroinvasive *E. coli*, and Enterohaemorrhagic *E. coli* [18, 19].

Figure 2: Health outcome tree for *Campylobacter* illustrating the disease states considered in calculations of burden. Dotted lines indicate the potential for sequelae to follow acute illness and for ongoing illness to result from sequelae, while dashed lines indicate that death may follow the preceding state.

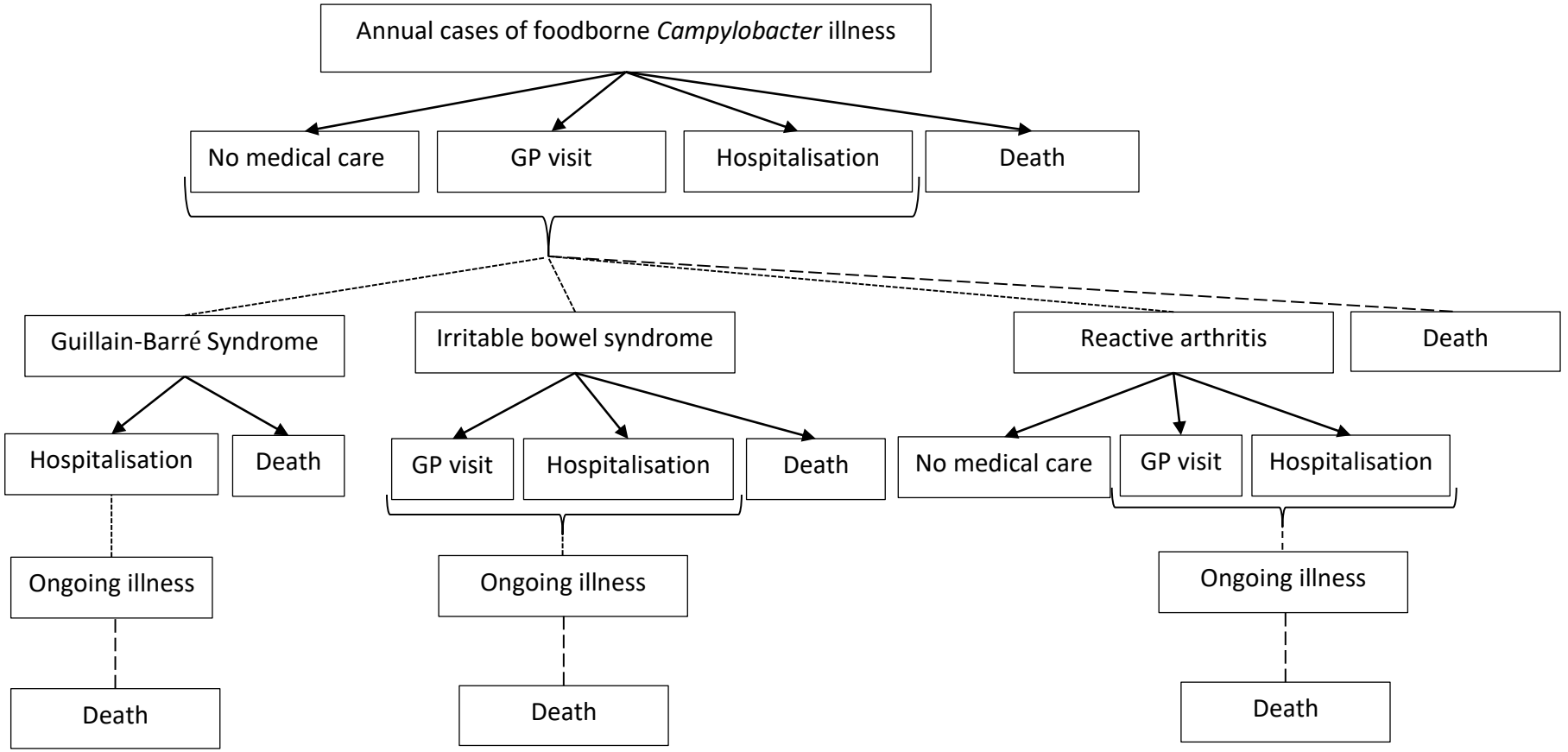


Table 2: Method for estimating incidence and main data source by pathogen or illness.

Pathogen or Illness	Data source	Approach
Total infectious gastroenteritis	NGSII	
Bacteria		
Campylobacter spp.	NNDSS	Surveillance
Listeria monocytogenes	NNDSS	Surveillance
Non-typhoidal *Salmonella*	NNDSS	Surveillance
Shigella spp.	NNDSS	Surveillance
Shiga toxin-producing *Escherichia coli* (STEC)	State surveillance	Surveillance
Other pathogenic *Escherichia coli*	NGSII & WQS	Pathogen fraction
Salmonella Typhi	NNDSS	Surveillance
Yersinia enterocolitica	State surveillance	Surveillance
Protozoa		
Toxoplasma gondii	Busselton Health Study	Seroprevalence
Viruses		
Norovirus	NGSII & WQS	Pathogen fraction

WQS = Water Quality Study; NNDSS = National Notifiable Diseases Surveillance System; NGSII = National Gastroenteritis Survey II.

For STEC, we used previously collected state-level surveillance data from South Australia, population adjusted to 2019, while for *Yersinia enterocolitica* we used previously collected state-level surveillance data from the Northern Territory, Queensland, South Australia and Western Australia, population adjusted to 2019. State-level data were used where there was no national surveillance, or we considered that an individual state had stronger surveillance than the national system. This is in line with prior epidemiological estimates for foodborne illness in Australia. State-level rates of illness by age group were applied to the national population to provide national estimates.

Data on *Toxoplasma gondii* are scarce. In previous estimates [1, 6] we used US seroprevalence data to estimate incidence and then population-adjusted it to the contemporary Australian population. We conducted a rapid review of relevant publications to identify the most appropriate seroprevalence data for this study and found a more recent seroprevalence study conducted in Busselton, Western Australia, between 2005 and 2007 [20]. As in our previous estimates, we estimated yearly incidence by age from the seroprevalence data and then assumed that 15% (95% CI: 11–21) of these incident cases were symptomatic.

The model for incidence was based on that used in our burden of disease calculations circa 2010 [6, 7], which was consistent with prior estimates for Australia [21] and the US [22, 23]. We adopted a simulation approach, implemented in R, with uncertainty in multipliers reflected by distributions for key model inputs.

Figure 3: Flow chart illustrating the approach to calculating disease annual incidence from surveillance data, with the same process conducted for each age group.

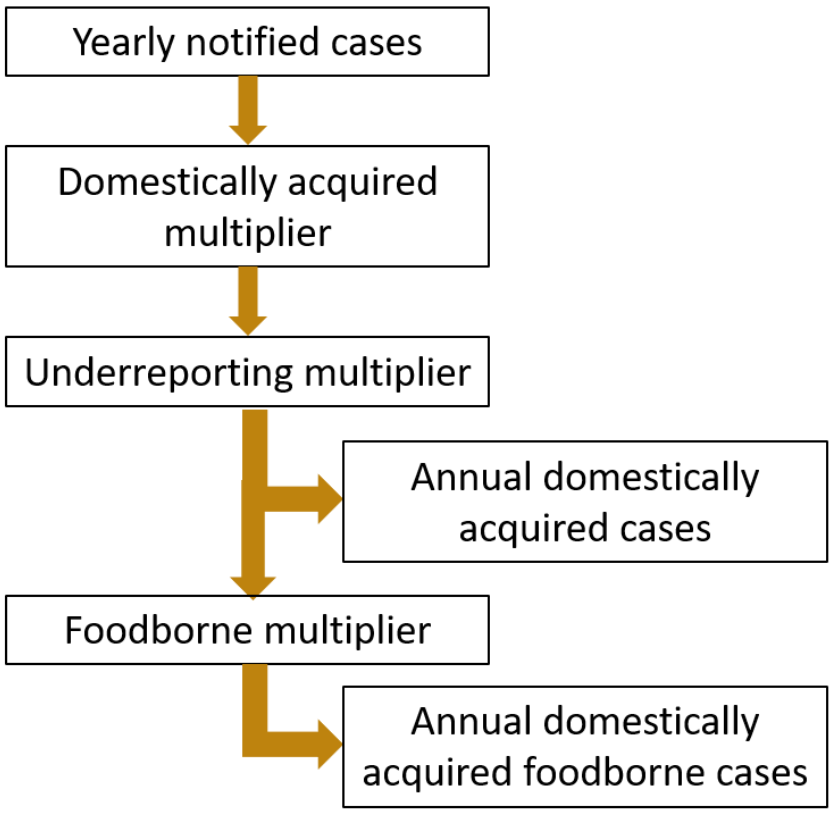


Figure **3** shows the approach to calculating incidence estimates using the surveillance approach. Under this approach, multipliers include the domestically acquired multiplier (to exclude cases acquired outside Australia), the underreporting multiplier (to scale notification data for undetected cases in the community), and the foodborne multiplier (to limit cases to those due to foodborne transmission). A full list of all multipliers and their values for each pathogen or illness is provided in Appendix B. Denominator values for rate calculations were drawn from Australian Bureau of Statistics (ABS) population estimates aggregated by age group [24].

General practice consultations and emergency department visits

For pathogens that cause gastroenteritis, we used data from the NGSII to estimate the probability that an individual with gastroenteritis consulted a GP or visited the ED, adjusting for severity of disease as described in prior work [1]. GP consultations and ED visits for pathogens that do not cause gastroenteritis were estimated based on expert opinion or assumptions of the Abelson study [11] as described previously [1]. For sequelae, Abelson costed GP consultations but not ED visits, noting that ED visits might be an alternative to GP consultations for GBS and HUS [11]. Probabilities by pathogen are provided in Appendix B.

Hospitalisations and deaths

We estimated the number of hospitalisations using separation statistics by principal diagnosis from the Australian Institute of Health and Welfare (AIHW) [18]. Hospitalisation diagnostic codes used were from the Australian modification of the 10th International Classification of Diseases (ICD10-AM) as listed in Appendix B. In our study circa 2010 [6], we collated State and Territory data (which included principal and additional diagnoses) to estimate total hospitalisations. As the AIHW data cubes included principal diagnosis only, we imputed additional diagnoses for each pathogen using the circa 2010 data, assuming the proportion of diagnoses that were principal remained the same as in 2010 study. The proportion of diagnoses that were principal in the 2010 study are listed by pathogen in Appendix B.

Deaths were estimated using data from the ABS from 2001–2010 with diagnostic codes based on the 10th International Classification of Diseases (ICD10). These estimates were adjusted for changes in population since this period but did not capture any changes in death rates for pathogens since that time. The ICD10 and ICD10-AM codes used by pathogen or illness are listed in Appendix B. For listeriosis, we identified that death data did not include neonates, and extracted data from the most recent OzFoodNet annual reports to estimate yearly deaths in neonates due to listeriosis [25-28].

As with incidence, domestically acquired and foodborne multipliers were applied to exclude travel-associated cases and those due to other routes of transmission. As in previous work, we included an under-diagnosis multiplier, as recorded hospitalisations and deaths reflect only laboratory confirmed cases.

Sequelae

As in prior work [7], we modelled the possibility of sequelae of GBS (following *Campylobacter)*, HUS (following STEC), IBS (following *Campylobacter*, *Salmonella* and *Shigella*) and ReA (following *Campylobacter*, *Salmonella*, *Shigella*, and *Y. enterocolitica*). The probabilities of these illnesses and the associated multipliers are summarised in Appendix B. These estimates were typically based on studies with up to one year of follow-up and so will not capture the rare situations where sequelae occur more than a year after the primary illness. Hospitalisations and deaths due to IBS and ReA were attributed to each pathogen according to the fraction of these sequelae attributed to each pathogen.

Ongoing illness

Most foodborne illnesses included in this report are self-limiting and do not require ongoing treatment, however a proportion of cases of listeriosis, toxoplasmosis, and the four sequelae can experience ongoing illness. Health outcome trees for each pathogen are provided elsewhere [2], and the probabilities of ongoing illness are listed by pathogen or illness in Appendix B.

Although it is likely that there are additional tests, treatments, specialist visits, and lost productivity associated with managing this ongoing illness, data for ongoing illness are very sparse, with follow-up of patients in published studies rarely lasting beyond one or two years. Given the lack of data on lost productivity and direct costs, we chose to estimate only the indirect costs associated with willingness to pay to avoid illness for these ongoing conditions, as described in more detail below. Note that excluding long-term costs will lead to an underestimate of total costs for those pathogens with ongoing illnesses; however, we believe that the likely costs associated with ongoing treatments will be relatively small compared with acute costs for most pathogens.

Specialist visits and physiotherapy

For some pathogens and sequelae, individuals may visit specialists or physiotherapists. We followed Abelson [11] in most of these assumptions, as described in [1] and summarised in Appendix B. Note that we assumed that all *S*. Typhi cases are hospitalised and there is no ongoing illness, so there are no specialist visits associated with *S*. Typhi.

Costing model

The costing model used an incidence-based costing approach, which identified, quantified, and valued resources individually, so that costs could be disaggregated [9]. Cost components included both financial and non-financial costs. Financial costs fell into two categories:

- Direct costs, which included medical practitioner visits, pathogen tests, antibiotic prescriptions, specialist visits, and individual costs including over-the-counter medications. Direct costs were sourced from the Medicare Benefits Schedule (MBS), the Pharmaceutical Benefits Scheme (PBS), and the Australian Refined Diagnosis Related Groups (AR-DRGs) and followed the methods as described in the Australian Government PBS manual of resource items [29]. All estimates were based on administrative healthcare data.
- Indirect costs included productivity losses due to morbidity and mortality which are borne by the individual, family, society, or the employer. Methods to value indirect costs are discussed below.

The non-financial component of the costing model accounted for the valuation of the human cost of foodborne illness defined here as pain and suffering. This uses willingness to pay (WTP) values for the avoidance of pain and suffering to the individual for short or long-term foodborne related illnesses and mortality as the cost associated with pain and suffering [4].

Many of the direct costs listed above (such as health care usage and testing costs) are borne by the government, while some medication costs are borne by individuals. Productivity losses are borne by individuals and employers, while pain

and suffering and premature mortality are borne by individuals. When combined, financial (direct and indirect) costs and non-financial morbidity costs provide an estimate of the total cost of foodborne illness in Australia. Additional costs related to surveillance, outbreak response, and those incurred by industry are considered separately in this report.

Comparison of approaches to measurement of indirect costs and of pain and suffering

A key issue in valuing indirect costs is the selection of the appropriate valuation method and the minimisation of double counting. There are several methods that have been used in the literature to value indirect costs including the human capital approach, the friction cost method, monetised quality adjusted life years (QALY) and the willingness to pay (WTP) approach and different methods have been used to value different indirect costs.

A comparison of indirect costs (**Table 3**: Comparison of indirect cost estimation for selected international studies.Table 3) from selected international studies demonstrates that no standard methodology to value non-direct costs in foodborne disease is universally agreed upon at present. We note that Table 3 is not designed to be comprehensive.

Examining the international literature, the UK study estimated indirect costs most comprehensively [9], while the latest US study estimated the indirect costs of foodborne disease conservatively [8]. The cost of fatalities due to foodborne illness in all studies was estimated using the country specific value of a statistical life (VSL). The UK study limited the use of the VSL to only that of its human component (pain and suffering) to avoid double counting as other costs (consumption and ambulance cost and cost of hospital treatment) were included elsewhere.

All studies used the human capital approach to estimate productivity losses due to non-fatal illness, however the inclusion of costs for carers were less clear. Both the UK and Scharff studies [9, 30] estimated carer costs for child dependents, with the UK extending this to include those above 65 years. The 2006 Australian study by Abelson included carer costs within its estimate of household time disrupted [11].

The approach to estimating the cost of pain, grief and suffering differed across studies. The two Hoffmann US studies [8, 23] did not capture such a cost arising from non-fatal illness and captured it as part of the VSL for fatal illness. The Scharff study [26] used monetarised QALY losses to capture such costs. The UK study harness WTP estimates to avoid short term and long term symptoms and disease for certain foodborne pathogens from a discrete choice experiment and contingent valuation studies while the 2006 Australian study captured pain grief and suffering in their residual lifestyle cost [9, 11] (see Table 3).

Table 3: Comparison of indirect cost estimation for selected international studies.

Cost category	Australia 2006 [11]	United States 2012 (Hoffmann) [23]	United States (Scharff)* 2012 [30]	United States (Hoffmann) USDA/CDC 2015 [8]	United Kingdom 2018 [9]	Our approach Australian foodborne illness (2021)
Fatalities	Value of a statistical life year	Value of statistical life	Value of a statistical life †	Value of a statistical life	Value of a statistical life (only the component for Human cost)	Value of a statistical life
Productivity costs due to non-fatal illness (individual)	Human capital approach	Human capital approach	Human capital approach (not included in monetarised QALY approach)	Human capital approach	Human capital approach	Human capital approach (baseline) Friction costs (sensitivity analysis)
Productivity costs (carers)	Human capital approach Household time disrupted (include carer time)	n/a	Human capital approach included caring time for children (included in monetarised QALY approach)	n/a	Human capital approach for those who are dependents e.g., age <16 or >65	Included where data are available.
Pain & suffering (financial costs)	Residual lifestyle cost estimate - by (i) estimating the amount that individuals are willing to pay to avoid an illness, and (ii) subtracting household-borne costs that have already been estimated	Non-fatal n/a Fatal VSL value	Monetised QALY losses are the product of loss of wellbeing from a condition, number of days in that condition and the economic value of one day (VSL)	Non-fatal n/a Fatal VSL value	WTP values estimated from a Discrete choice/ contingent valuation model	WTP values estimated from a Discrete Choice Experiment (DCE)
Pain and suffering (non-financial)	n/a	n/a	n/a	n/a	QALY – non-monetised	n/a

* Two separate models estimate: 1) basic cost-of-illness including economic estimates for medical costs, productivity losses, and illness-related mortality, and; 2) productivity loss estimates with a more inclusive pain, suffering, and functional disability measure based on monetised quality-adjusted life year estimates. † Included in both models

The monetising of a QALY, to account for pain and suffering caused by foodborne illness, can have a large influence on estimates of the total cost of foodborne disease. In the US, Scharff [30] estimated the cost of illness due to 31 pathogens at USD 77.7 billion (2010 dollars) in an enhanced model that attempted to capture pain and suffering using QALYs compared to USD 51.0 billion (2010 dollars) in the basic model. The Hoffmann US study which costed foodborne illness due to 14 pathogens valued the cost of foodborne disease at USD 14.1 billion (2009 dollars)[23], with Hoffmann and Anekwe publishing a further report exploring the differences between these US studies including differences in disease incidence estimates, number of pathogens included and differences in valuation methods; Scharff included monetarised QALYs to account for pain and suffering while the Hoffman studies did not [31]. That review noted that current approaches to monetising a QALY based on either the VSL or on cost of healthcare thresholds are not consistent with the economic theory of welfare measurement underlying cost-benefit analysis [31]. That view was in line with both the recommendations by the U.S. Environmental Protection Agency's Scientific Advisory Board [32] and the preferred approach by the UK Food Standards Agency [9].

To estimate indirect costs, we adopted the two approaches to estimate fatal and non-fatal foodborne disease cases.

- Non-fatal cases: i) Productivity costs were estimated using the human capital approach and ii) Costs of pain and suffering were estimated drawing on WTP values to avoid pain and suffering from the separate FSANZ commissioned discrete choice experiment (DCE) study [4]. Sensitivity analyses were conducted to compare costs estimated using the human capital approach to those using the more conservative friction cost method (discussed below).
- Fatal cases: Costs associated with lost life from foodborne illness was valued using the VSL, as recommended by the Office of Best Practice Regulation (OBPR).

The Australian DCE [4] explicitly included treatment costs and access to sick leave as attributes of the alternative between which respondents were asked to choose in the DCE task, with the impacts of each illness described by severity (mild and severe) and duration. The inclusion of these attributes helps to avoid double counting in the model, as costs due to lost productivity, treatments and medication costs are estimated elsewhere. The DCE included scenarios with out-of-pocket costs ($0 up to $250) and varying scenarios around leave ("you are able to work" / "you are unable to work and can take paid sick leave" / "you are unable to work and cannot take paid sick leave"). The CHERE study stated that the inclusion of the attribute around sick leave allowed the researchers to draw out the implications of being ill on productivity from the perspective of an employee, with the aim being to cost only pain and suffering and not double count other costs.

Human capital approach

The human capital approach measures the productivity loss (value of forgone output) due to the foodborne related illness or mortality – we used it to value the former (and used the VSL for the latter). Average current earnings are used, as well as future unclaimed earnings if the worker leaves the labour market, which can be a temporary absence or absence until retirement age if the absence is permanent. This approach may vary with country and context in terms of the costs included, such as employer-provided benefits.

Friction cost approach

The friction cost approach is more conservative than the human capital approach and estimates societal productivity loss as the short-term costs incurred by employers in replacing a lost worker [33]. It recognises that society will restore initial production levels after some period of adaptation, the length of which may depend on the availability of labour. The friction cost approach has been introduced to address some of the limitations of the human capital approach. Namely, the human capital approach ignores that work not done by the worker with foodborne illness while they are not at work is often done by co-workers or by the same worker on their return after their illness. It also assumes no temporary replacement has been employed, or equivalently that there is full employment in the economy [34].

The value of lost time depends on the length of the friction period. This length is based on the level of unemployment (when more people are unemployed it is easier to find a replacement worker), the recruitment period and training time [35]. No current guidance for the friction period is available; however, a 3-month period seems to be an accepted assumption [34, 36], although the Cost to Britain model assumed workers would not be replaced until six months of absence [37]. An empirical study by Pearce *et al.* estimated two friction periods for Australia: i) a 10-week friction replacement period for non-managers, and ii) a 12.3-week period for managerial positions [35].

The friction cost method costs the price of labour below 100% where there are compensation effects. Compensation effects are when internal workers can partially replace the missing individual or the worker could make up for some lost production on returning to work [38]. For both the human capital approach and the friction cost approach, time lost from work was estimated from the NGSII [15], while loss of earnings was estimated from ABS figures on average earnings and employment rates, taking into account gender, age and other key factors.

No standard method for measuring indirect costs is provided by the Australian OBPR nor the Australian Government Department of Prime Minister and Cabinet [34, 36]. The New Zealand Treasury reference friction cost methodology in their Guide to Social Cost Benefit Analysis [39] when discussing the social impact of

alcohol consumption on work-place productivity. However, they do not state which figures are used for productivity costs nor friction cost period.

The current Pharmaceutical Benefits Advisory Committee (PBAC) guidelines does not state a preference for the method used to costing the indirect cost of missed work [40]. However, in past iterations, the friction cost method was stated as the theoretically preferable method in comparison to the human capital method, but no guidance was given for the duration of the friction period, or the value of productivity losses due to compensation effects (i.e. where colleagues could make up some of the lost productivity) [34].

Internationally, the Dutch Health Technology Reimbursement Agency recommends the friction cost methodology. They also require the use of a friction period of 23 weeks and an average productivity costs per hour, stratified to sex and corrected for productivity (0.8) [41].

A literature review of 28 studies which used the friction method found the average friction period length was four months but reported values varied between two and six months [42]. That review also found very few studies that reported the valuation of lost productivity during the friction period. Of those who did, the most common value was 0.8 with one study choosing three different levels corresponding to three separate lengths of sick leave [43]. In this study we used a friction period length of three months and considered two friction cost values: low (0.3) and high (0.8).

Given the two approaches to measuring and valuing productivity losses (human capital and friction cost approaches), we use one in the base case and one in sensitivity analysis. The choice of which approach to use in the base case and which to use in sensitivity analysis was informed by FSANZ's preference.

Carer costs

Lost earnings due to caring for someone with a foodborne disease followed the same methodology used to cost productivity losses in this study and is reported for both the human capital method (main approach) and friction cost method (sensitivity analysis) as above. Koopmanschap *et al.* refer to this as the opportunity cost (lost earnings) methodology and considers only those carers who would have otherwise been employed [44]. This approach was used for consistency with the approach to valuing production losses of those with foodborne disease, as many informal carers would have to partially or fully withdraw from the labour force to provide care.

Pain and suffering

We drew upon willingness to pay to avoid pain and suffering data from the CHERE foodborne illnesses DCE study commissioned by FSANZ as an approximation of the cost of such pain and suffering [4]. Respondents in the CHERE DCE study were presented with conditions describing different foodborne disease that they were to imagine they had, and the choice task was

framed to ask which treatment profile they would choose for their illness. A concern with including a monetised value of the human suffering component of foodborne illnesses is the risk of overstating values and double counting [9]. In our study, we estimate costs due to lost productivity and medical expenses separately, so it is important that when study participants in the CHERE DCE estimated their WTP to avoid pain and suffering they were excluding these costs.

The CHERE DCE estimated different WTP values for duration, severity of illness, and those who receive "paid/unpaid sick leave" by out-of-pocket cost. Inclusion of duration as an attribute and the estimation of WTP for the duration of being ill due to foodborne disease, allows for the estimation of pain and suffering, separate to any other losses that the respondent may consider. This component of the study design approach helps to minimise double counting.

While the DCE did aim to avoid some sources of double counting (by the inclusion of an attribute on access to sick leave), there was no explicit consideration in the DCE study of the impact on families, whether the WTP incorporated altruism and, as such, double counting cannot be ruled out. In the VSL contingent valuation literature, great care is taken to account for altruism and possible double counting depending on the type of altruism (as per Jones-Lee's seminal work [45]). It appears from the CHERE DCE study that altruism and the potential for double counting was not considered.

Death

Fatalities were valued using the Australian Government value of statistical life (VSL) [46]. Internationally, VSL is often estimated using a WTP approach, which captures how much society is willing to pay to reduce the risk of a statistical death. The figure used for the VSL value, AUD 4.9 million, is the OBPR recommended value [46].

Cost components

The following provides the data and assumptions underlying costs components in the model. Direct costs are categorised as: health care utilisation (e.g. GP consultations, ED visits, hospitalisations, specialist appointments), medication usage (e.g. anti-diarrhoeal, painkillers, anti-nausea, anti-cramp, antibiotics), and tests (e.g. stool culture, PCR, endoscopy, bioscopy, or ultrasound). We additionally report both lost productivity and assumptions around willingness to pay to avoid pain and suffering due to illness.

Healthcare utilisation

The burden of disease calculations described above provide estimates of the numbers of GP consultations, ED visits, hospitalisations, and specialist appointments by pathogen or illness. As in Ford *et al.* [47], we assumed that all GP consultations for pathogens causing gastroenteritis were a normal consultation (15 minutes), while 25% of GP consultations for sequelae or pathogens that do not cause gastroenteritis were a long consultation (30 minutes), with the remainder as normal consultations [48]. We used MBS data to determine the health system costs of these consultations and for specialist consultations. Costs for emergency department presentations were sourced from Reeve and Haas [49].

Hospital cost data were based on AR-DRG costs, with average length of stay (ALOS) and costs listed in Appendix B. Following Ford *et al.* [47], we used a conservative assumption in selecting G67B (Oesophagitis and Gastroenteritis, Minor Complexity) for all hospitalisations for pathogens causing gastroenteritis for ages 0–4 and 5–65, and G67A (Oesophagitis and Gastroenteritis, Major Complexity) for hospitalisations for the age group 65+. We followed Abelson [11] in selecting AR-DRGs for pathogens that do not cause gastroenteritis and sequelae, but made some adjustments in the severity of AR-DRG code to ensure the ALOS was consistent with hospitalisation data coded by ICD10-AM. We made an additional change for GBS. Abelson used the AR-DRG code B71A (Cranial and Peripheral Nerve Disorders, Major Complexity), which had an ALOS of 13 days in that study; however, this coding now has an ALOS of 3.1 days, which is considerably shorter. After consultation with an expert in the use of codes for GBS, we adjusted the code to B06A (Procedures for Cerebral Palsy, Muscular Dystrophy and Neuropathy, Major Comp), which has an ALOS of 12 days, more consistent with the ALOS for patients hospitalised with GBS (ALOS of 10.1 days).

Tests and medications

We used NGSII data to estimate the probability that individuals had tests and/or treatments for pathogens causing gastroenteritis [15]. Estimates for gastroenteritis due to all causes and for norovirus were based on the full survey population, while estimates for bacterial pathogens were weighted for disease severity (see Appendix B for assumptions). Relevant disease-specific test

numbers were also sourced from the MBS. We assumed that all *S*. Typhi cases were hospitalised and there was no ongoing illness, with tests and treatments captured by hospitalisation costs. As all cases of HUS and GBS were assumed to be hospitalised, tests and medications were assumed to be captured within the hospitalisation costs. For *L. monocytogenes*, we followed Abelson [11] for tests, treatments, and specialist visits following hospitalisation. We assumed symptomatic *T. gondii* cases that sought healthcare through their GP would receive serology and full blood count (FBC) and be treated with trimethoprim and sulfamethoxazole [50]. Costs for broad classes of medications were sourced from Ford et al 2019 [47]. Details of tests and medications by pathogen or illness are provided in Appendix B, noting that some multipliers are applied to incident cases, some to GP visits, and others relate to notification numbers.

Lost productivity

Table 4 includes the model assumptions for lost productivity due to acute illnesses (i.e. not including sequelae) using data from the NGSII survey [15] for non-hospitalised cases. Our analysis of the NGSII data showed no association between the days of paid work lost and the reported duration of illness. As there were relatively few participants with severe illness in that study (e.g. only 17 reported having blood in stool), we did not have the statistical power to assess differences by severity. Consequently, we assumed the average number of days of paid work lost per case were the same for all-cause gastroenteritis and each pathogen. Given a lack of data on toxoplasmosis, we assumed non-hospitalised cases had the same profile of lost work as gastroenteritis. For hospitalised cases, we assumed cases were unable to work for the mean duration of illness provided for hospitalised cases in Table 5. We then calculated the number of days of paid work missed assuming a workforce participation rate of 67% in those aged 5–64 years (based on 80% in those aged 15–64 and 0% in those aged 5–14) and 15% in 65+ year old people, and assuming a 5-day work week (based on an average of 32–33 hours worked on average)[51]. We assumed all children aged < 5 had a care giver aged 15–64 who lost paid work (at workforce participation of 80%). For those aged 15–64 and 65+, we assumed 33% had a care giver that lost paid work, reflecting the decline in carers for those groups compared to children in the NGSII survey.

In estimating lost productivity due to sequelae (Table 6), we followed Abelson [11] in assuming the average time unable to work due to HUS was the average duration of hospitalisation plus two weeks, that time average unable to work due to IBS was the duration of time spent in healthcare (estimated at approximately 5 days), and that the average time unable to work due to GBS was 90 days. These assumptions are within the range of estimates of lost activities for IBS [52-54] and GBS [55, 56]. For reactive arthritis, we used data from a population-based study in the US to estimate that an average of 10 days of activities were missed [57], although noting that this is considerably less than the average of 53 days missed per patient in a Swedish study [58].

Table 4: Days of paid work lost by the case or by someone caring for the case by pathogen or illness.

Pathogen or Illness	Non-hospitalised cases						Hospitalised cases					
	Days lost by the case			Days lost by a carer			Days lost by the case			Days lost by a carer		
Age group	< 5	5 – 64	65+	< 5	5 – 64	65+	< 5	5 – 64	65+	< 5	5 – 64	65+
Total infectious gastroenteritis	0	0.73	0.1	0.61	0.18	0.39	0	1.5	0.5	1.6	0.5	1.0
Bacteria												
Campylobacter spp.	0	0.73	0.1	0.61	0.18	0.39	0	2.0	0.6	1.7	0.7	1.3
Listeria monocytogenes	all cases assumed hospitalised						0	6.9	1.6	8.5	2.6	3.0
Non-typhoidal *Salmonella*	0	0.73	0.1	0.61	0.18	0.39	0	2.3	0.8	2.1	0.8	1.6
Shigella spp.	0	0.73	0.1	0.61	0.18	0.39	0	2.3	0.5	2.2	0.8	1.2
Shiga toxin-producing *Escherichia coli*	0	0.73	0.1	0.61	0.18	0.39	0	2.3	0.5	2.0	0.8	1.2
Other pathogenic *Escherichia coli*	0	0.73	0.1	0.61	0.18	0.39	0	2.1	1.1	2.6	0.7	2.1
Salmonella Typhi	all cases assumed hospitalised						0	3.2	1.1	3.3	1.2	2.1
Yersinia enterocolitica	0	0.73	0.1	0.61	0.18	0.39	0	1.9	0.7	2.1	0.7	1.5
Protozoa												
Toxoplasma gondii	0	0.73	0.1	0.61	0.18	0.39	0	16.6	1.0	1.2	6.4	2.0
Viruses												
Norovirus	0	0.73	0.1	0.61	0.18	0.39	0	2.1	0.8	1.9	0.7	1.6

Table 5: Duration of illness and willingness to pay for the acute phase of illness for hospitalised and non-hospitalised cases.

Pathogen or Illness	Non-hospitalised cases		Hospitalised cases	
	Daily WTP to avoid pain and suffering (95%CI)†	Mean Duration††	Daily WTP to avoid pain and suffering (95%CI)	Mean Duration††
Total infectious gastroenteritis	Mild GI illness: $11 ($9, $12)	3 days	Severe GI illness: $23 ($22,$24)	5.3 days
Bacteria				
Campylobacter spp.	Severe GI illness: $23 ($22,$24)	6 days	Severe GI illness: $23 ($22,$24)	9.5 days
Listeria monocytogenes	all cases assumed hospitalised		Severe flu-like illness: $19 ($17,$20)	34.7 days
Non-typhoidal *Salmonella*	Severe GI illness: $23 ($22,$24)	6 days	Severe GI illness: $23 ($22,$24)	9.8 days
Shigella spp.	Severe GI illness: $23 ($22,$24)	6 days	Severe GI illness: $23 ($22,$24)	9.3 days
Shiga toxin-producing *Escherichia coli*	Severe GI illness: $23 ($22,$24)	6 days	Severe GI illness: $23 ($22,$24)	9.5 days
Other pathogenic *Escherichia coli*	Mild GI illness: $11 ($9, $12)	3 days	Severe GI illness: $23 ($22,$24)	8.6 days
Salmonella Typhi	all cases assumed hospitalised		Severe GI illness: $23 ($22,$24)	26.4 days
Yersinia enterocolitica	Severe GI illness: $23 ($22,$24)	6 days	Severe GI illness: $23 ($22,$24)	9.4 days
Protozoa				
Toxoplasma gondii	Mild flu-like illness: $8 ($6,$10)	7 days	Severe flu-like illness: $19 ($17,$20)	42.9 days
Viruses				
Norovirus	Mild GI illness: $11 ($9, $12)	2 days	Severe GI illness: $23 ($22,$24)	5.7 days

†Values from CHERE study [4]. †† Mean duration of illness for acute non-hospitalised cases from previous report [2]; duration of illness for acute hospitalised cases assumed to be ALOS in hospital in 2018/2019 plus duration of illness of non-hospitalised cases for pathogens causing gastroenteritis, and based on Abelson[11] for listeriosis, toxoplasmosis and *S.* Typhi. GI = Gastrointestinal Illness.

Table 6: Days of paid work lost by the case or by someone caring for the case for sequelae in the initial phase of illness.

Sequelae	Days lost by the case			Days lost by a carer		
Age group	< 5	5 – 64	65+	< 5	5 – 64	65+
Guillain-Barré syndrome	0	43.1	9.6	51.4	17.1	17.1
Haemolytic uraemic syndrome	0	11.0	2.5	13.1	4.4	4.4
Irritable bowel syndrome	0	2.4	0.5	2.9	1.0	1.0
Reactive arthritis	0	4.8	1.1	5.7	1.9	1.9

As before, we calculated the number of days of paid work missed by individuals and carers using Australian data on workforce participation and hours worked with assumptions concerning caregiving described above. These estimates consider lost earnings in the initial phase of illness only (i.e. within the first year of illness), and so underestimate total costs. There are a proportion of individuals (see Table 7) who have ongoing illness due to sequelae. Due to a lack of data on the impact of this illness on lost productivity and health care usage, we have not costed this and acknowledge it as a limitation of currently available data.

Willingness to pay

Table 5 summarises our assumptions on WTP to avoid pain and suffering for gastroenteritis due to all causes and for each pathogen included in the costing model, derived from the CHERE study [4]. These estimates are assumed to be the same for all age groups as the CHERE study did not differentiate costs by age. We assumed that people ill with bacterial pathogens causing gastroenteritis all experienced severe illness, as did all hospitalised cases. We base the duration of illness for non-hospitalised cases of gastroenteritis on symptom profiles for these pathogens [2] and assumed the duration of illness for hospitalised cases was the average length of stay in hospital in 2018/2019 [18] plus the duration of illness for non-hospitalised cases. For listeriosis (where all cases are assumed hospitalised), we followed Abelson [11] in assuming the duration of illness was the time spent in hospital plus three weeks and used the same assumption for *S.* Typhi and hospitalised cases of toxoplasmosis. For non-hospitalised toxoplasmosis cases, we followed Abelson in assuming a duration of illness of 7 days [11].

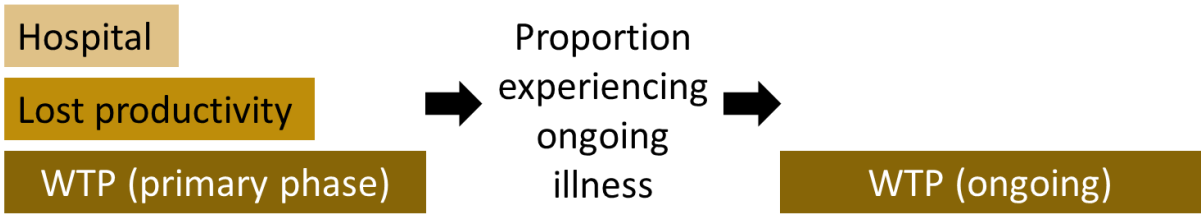
Estimates for willingness to pay to avoid sequelae reflect a longer duration of illness, with estimates of costs in the CHERE study [4] provided by year rather than by day. As the vignettes for these conditions were based around frequency of symptoms over the course of a year, we assumed the primary duration of illness was one year and considered ongoing illness separately (see below). We assumed this primary illness was severe for GBS and HUS as all incident cases are assumed to be hospitalised (Table 7). For IBS, we assumed 30% of individuals in the primary phase of illness had severe illness (in line with the proportion that attend a specialist appointment). For reactive arthritis, Abelson [11] assumed that 20% of patients seek healthcare, based on a study by Hannu *et al.* [59], and we assumed these 20% had severe illness, with the remainder experiencing mild illness.

Table 7: Duration of illness and willingness to pay to avoid pain and suffering for sequelae.

Sequelae	Yearly WTP† to avoid pain and suffering for primary phase of illness (95% CI)	Proportion with ongoing illness†† (95% Confidence Interval)	Yearly WTP† to avoid pain and suffering for ongoing illness (95%CI)	Duration of ongoing illness
Guillain-Barré syndrome	Severe GBS: $1,371 ($1,291, $1,426)	age <5: 7.5% (6.5–8.5) age 5–64: 16% (14–18) age 65+: 49% (47–50)	Mild GBS: $762 ($625, $862)	5 years
Haemolytic uraemic syndrome	Severe HUS: $1,620 ($1,595, $1,637)	16% (8%–27.7%)	Mild HUS: $901 ($778, $993)	5 years
Irritable bowel syndrome	70%: Mild IBS: $344 ($124, $506) 30%: Severe IBS: $964 ($755,$1,100)	42.9% (21.8%–66.0%)	Mild IBS: $344 ($124, $506)	5 years
Reactive arthritis	80%: Mild ReA: $605 ($461, $714) 20%: Severe ReA: $1,166 ($1,060, $1,241)	41% (29–54) of those with severe primary illness	Mild ReA: $605 ($461, $714)	5 years

†Willingness to pay values from CHERE study [4]. †† Defined as permanent disability for GBS [56], permanent disability due to chronic renal failure for HUS [60], and ongoing symptoms at 12 months for IBS and ReA [59, 61, 62].

Figure 4: Cost components for sequelae: hospitalisation numbers and length of stay were obtained from data; days of lost productivity are listed in Table 6; willingness to pay to avoid pain and suffering in the primary and ongoing phase are listed in Table 7, as is the proportion of people experiencing ongoing illness by sequelae. Due to lack of data, direct costs and lost productivity are not costed for ongoing illness.



Willingness to pay to avoid ongoing illness

For some pathogens (listeriosis and toxoplasmosis) and all four sequelae, patients can experience long-term or permanent disability. As described above, we could find no long-term studies of any of these six illnesses that would allow us to calculate direct costs or lost productivity due to ongoing illness. Due to the lack of information around the economic impact of long-term sequelae, we have estimated the ongoing costs conservatively, using just the pain and suffering relating to ongoing chronic disease. Figure 4 provides a schematic of how the individual component costs and their durations relate in the model.

Ongoing conditions for listeriosis and toxoplasmosis include long-term neurological sequelae following listeriosis [63], and chorioretinitis resulting from congenital toxoplasmosis [64], primarily in vulnerable groups including immunocompromised individuals and neonates. Although these conditions were noted in the willingness to pay analysis [4], no WTP values were calculated, preventing us from considering this analysis further.

We were, however, able to estimate willingness to pay to avoid pain and suffering from ongoing illness due to the four sequelae. For GBS, we used estimates of permanent disability by age, based on Frenzen *et al.* [56], using the conservative assumption that the WTP is to avoid the pain and suffering associated with mild illness, reflecting the improvement in symptoms following the primary phase of illness [65]. For HUS, we used estimates of the proportion of cases with chronic renal failure at 12 months to determine permanent disability, and again made the conservative assumption that the WTP is to avoid pain and suffering associated with mild illness. Long-term illness for reactive arthritis is not commonly reported, although can occur in those with severe illness [62]. We assumed that only a proportion of those with severe illness experienced illness after 1 year and used data from Leirisalo-Repo *et al.* to estimate that proportion [62]. Duration of illness for IBS is not readily estimated; however, Marshall *et al.* identified the proportion of cases with symptoms at 12 months [61]. We again assumed mild continuing illness, with a duration of 5 years. As we estimated costs at a point in time, we included 5 years of WTP for ongoing illness associated with sequelae, all costed to 2019.

Sensitivity analysis

In addition to the simulation approach, which produces uncertainty intervals on all estimates, we used sensitivity analyses to account for uncertainties in model assumptions. These sensitivity analyses included a comparison of the human capital and friction cost approaches to calculating lost productivity and assessed the sensitivity of our findings to the willingness to pay values from the CHERE study [4].

Surveillance costs and outbreak studies

We consulted with FSANZ, the Australian Government Department of Health, OzFoodNet, NSW Department of Primary Industries, and other stakeholders to characterise costs of surveillance for gastrointestinal and foodborne infections and for data on outbreaks. In addition to the standard tool for estimating total annual costs of foodborne illness, we provided a tool for costing outbreaks based on the same assumptions as detailed above but with the ability to change some key multipliers. For instance, the under-reporting multiplier can be set to one if it is believed that all cases associated with the outbreak have been identified; likewise, the domestically acquired multiplier can be set to one if all cases are known to be domestically acquired.

Estimates of the cost of foodborne illness

We first provide a summary of costs of illness for all pathogens by broad cost group (

Table 8), followed by estimates by single pathogen or illness by age group. Costs due to sequelae are included with the preceding pathogen.

Circa 2019, we estimated that foodborne illness and its sequelae costs Australia AUD 2.44 billion per year, with the largest component due to lost productivity, followed direct (healthcare) costs and premature mortality. Most (AUD 2.1 billion) of these costs arose from gastroenteritis due to all causes.

Campylobacter was estimated to have the highest annual cost (AUD 365 million) of all individual pathogens, with norovirus, other pathogenic *E. coli*, and *Salmonella* all costing over AUD 100 million each year. Lost productivity was the largest component cost for most pathogens under the human capital approach. However, premature mortality was the largest cost for pathogens that lead to more severe illness (*Salmonella*, *Listeria monocytogenes*, *Shigella*, and STEC), while direct costs (dominated by hospitalisations) were the largest costs for *Salmonella* Typhi. Due to the high mortality proportion for *Listeria monocytogenes*, the cost per case is considerably higher for this pathogen than any other (Figure 5).

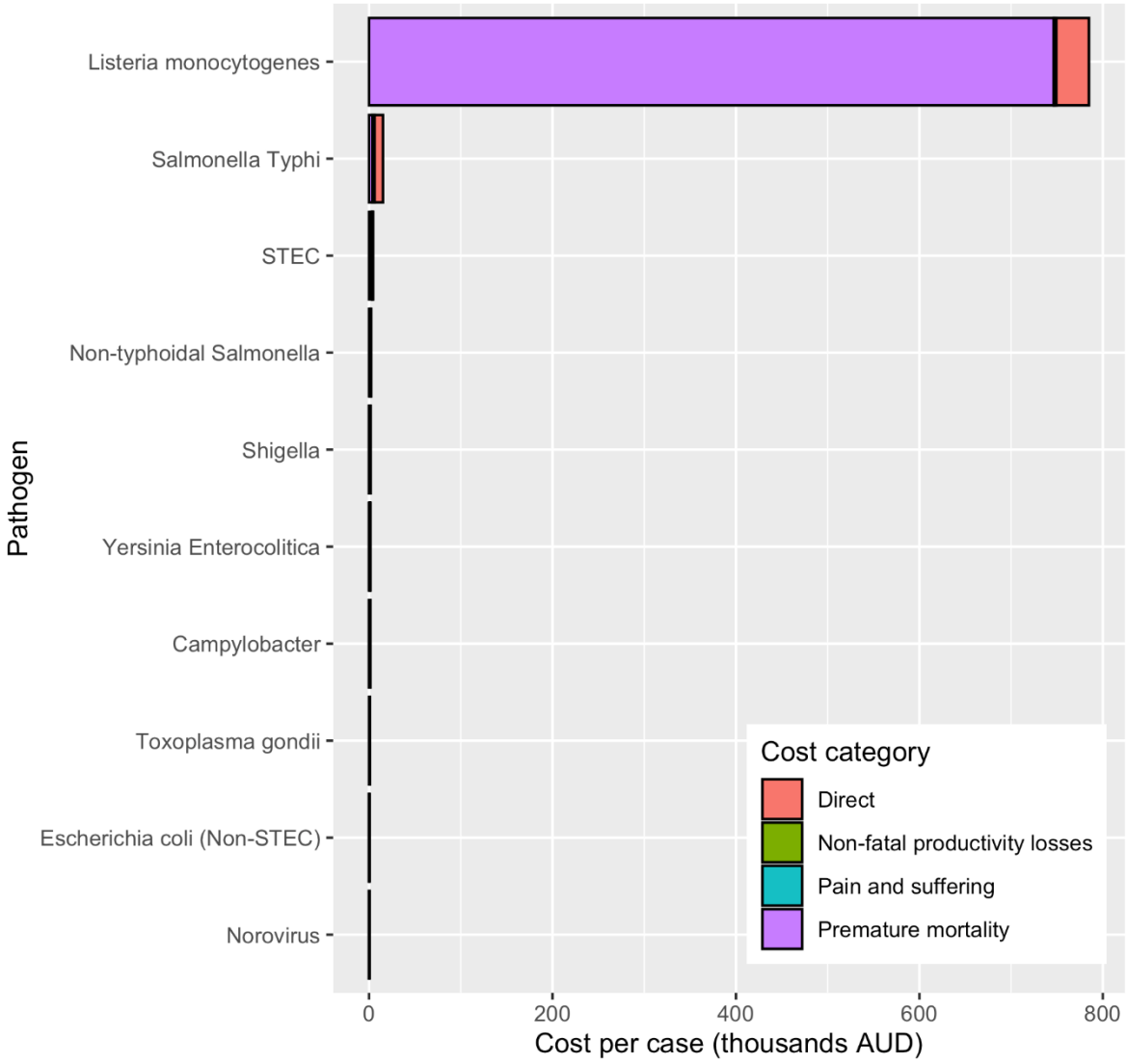
Amongst sequelae, the largest costs were due to reactive arthritis (AUD 94.7 million) and irritable bowel syndrome (AUD 88.2 million). Both Guillain-Barré Syndrome and haemolytic uraemic syndrome were rare and total costs were lower but were dominated by premature mortality. The largest cost for reactive arthritis was lost productivity, while for IBS the largest cost was the cost of pain and suffering, approximated by the willingness to pay to avoid pain and suffering due to illness.

Table 8: Estimated cost of illness by cost group for all foodborne illness, Australia circa 2019.

	Direct costs	Lost productivity	Pain and suffering†	Premature mortality	Total††
Median costs in millions of AUD (90% Uncertainty Intervals)					
All foodborne illness including sequelae	350 (256 – 470)	1,550 (887 – 2,620)	220 (146 – 321)	316 (234 – 434)	2,440 (1,650 – 3,680)
Total infectious gastroenteritis including sequelae	343 (250 – 463)	1,540 (881 – 2,610)	219 (145 – 320)	235 (157 – 351)	2,350 (1,550 – 3,590)
Pathogen-specific costs (including costs of sequelae where relevant)					
	Direct costs	**Lost productivity**	**Pain and suffering†**	**Premature mortality**	**Total††**
Campylobacter	68.8 (51.2 – 95.4)	151 (89.5 – 260)	84.6 (49.6 – 144)	57.8 (37.3 – 86.6)	365 (250 – 553)
Listeria monocytogenes	3.56 (1.78 – 5.34)	0.226 (0.113 – 0.347)	0.0652 (0.0326 – 0.0987)	74.5 (54.9 – 98.7)	78.4 (58.6 – 103)
Non-typhoidal *Salmonella*	22.4 (16.8 – 30.8)	38.8 (21.1 – 71.7)	21 (11.2 – 39.1)	56.3 (39 – 79)	140 (102 – 201)
Norovirus	15.2 (7.29 – 26.7)	101 (28 – 218)	7.15 (2.07 – 14.6)	4.09 (1.68 – 8.22)	128 (42.5 – 262)
Shigella spp.	0.73 (0.486 – 1.17)	1.2 (0.45 – 2.67)	0.627 (0.218 – 1.44)	0.746 (0.296 – 1.65)	3.41 (1.84 – 6.17)
Shiga toxin-producing *Escherichia coli*	0.801 (0.403 – 1.72)	1.19 (0.509 – 2.71)	0.557 (0.237 – 1.24)	8.8 (4.96 – 14.9)	11.7 (7.26 – 18.3)
Other pathogenic *Escherichia coli*	22.5 (8.39 – 53.5)	96.1 (35.7 – 229)	9.99 (3.8 – 22.9)	2.94 (1.2 – 6.73)	133 (51.9 – 306)
Salmonella Typhi	0.262 (0.0876 – 0.59)	0.0431 (0.0144 – 0.0972)	0.0174 (0.0058 – 0.0392)	0.107 (0.0146 – 0.428)	0.468 (0.189 – 0.956)
Toxoplasma gondii	2.36 (1.42 – 3.61)	4.94 (2.06 – 8.9)	0.882 (0.361 – 1.63)	4.55 (2.1 – 8.83)	13.1 (8.12 – 19.5)
Yersinia enterocolitica	0.997 (0.603 – 1.71)	3.87 (1.95 – 7.38)	1.78 (0.916 – 3.32)	3.41 (1.28 – 7.46)	10.4 (6.15 – 17.1)
Sequelae					
Guillain-Barré syndrome	2.91 (1.43 – 5.99)	1.82 (0.893 – 3.74)	0.214 (0.105 – 0.441)	37.3 (18.8 – 65)	42.8 (23.9 – 70.7)
Haemolytic uraemic syndrome	0.485 (0.185 – 1.22)	0.373 (0.142 – 0.938)	0.186 (0.07 – 0.472)	7.74 (4.18 – 13.6)	8.97 (5.2 – 15)
Irritable bowel syndrome	20.3 (14.4 – 29)	30.6 (20 – 47.4)	34.9 (17.8 – 62.8)	2 (0.984 – 4.55)	88.2 (58.1 – 137)
Reactive arthritis	10.5 (7.73 – 15.1)	57 (31.3 – 100)	26.1 (14.1 – 47)	0.701 (0.206 – 1.92)	94.7 (54.6 – 162)

†Using willingness to pay to avoid pain and suffering †† Totals reflect the median of model simulations, so will not equal the sum of individual columns.

Figure 5: Cost per case for each pathogen included in the model, Australia circa 2019.



Gastroenteritis due to all causes

Circa 2019, we estimated that there were 4.67 million (90%UI: 2.63–7.52) cases of foodborne gastroenteritis due to all causes, with an associated 47,900 (90%UI: 31,600–70,300) hospitalisations and 38 (90%UI: 23–61) deaths each year. Estimates by age are provided in Appendix D (Table A2: Burden of disease by age for gastroenteritis due to all causes, Australia 2019.).

The total cost of gastroenteritis due to all causes was estimated to be AUD 2.1 billion (Table 9). The largest component cost came from lost productivity, followed by premature mortality and hospitalisations. However, premature mortality was the largest cost for those aged 65 years and older. Note that the costs here do not include sequelae, which are provided above and with individual pathogens.

Figure 6 demonstrates the component costs including contributions from sequelae.

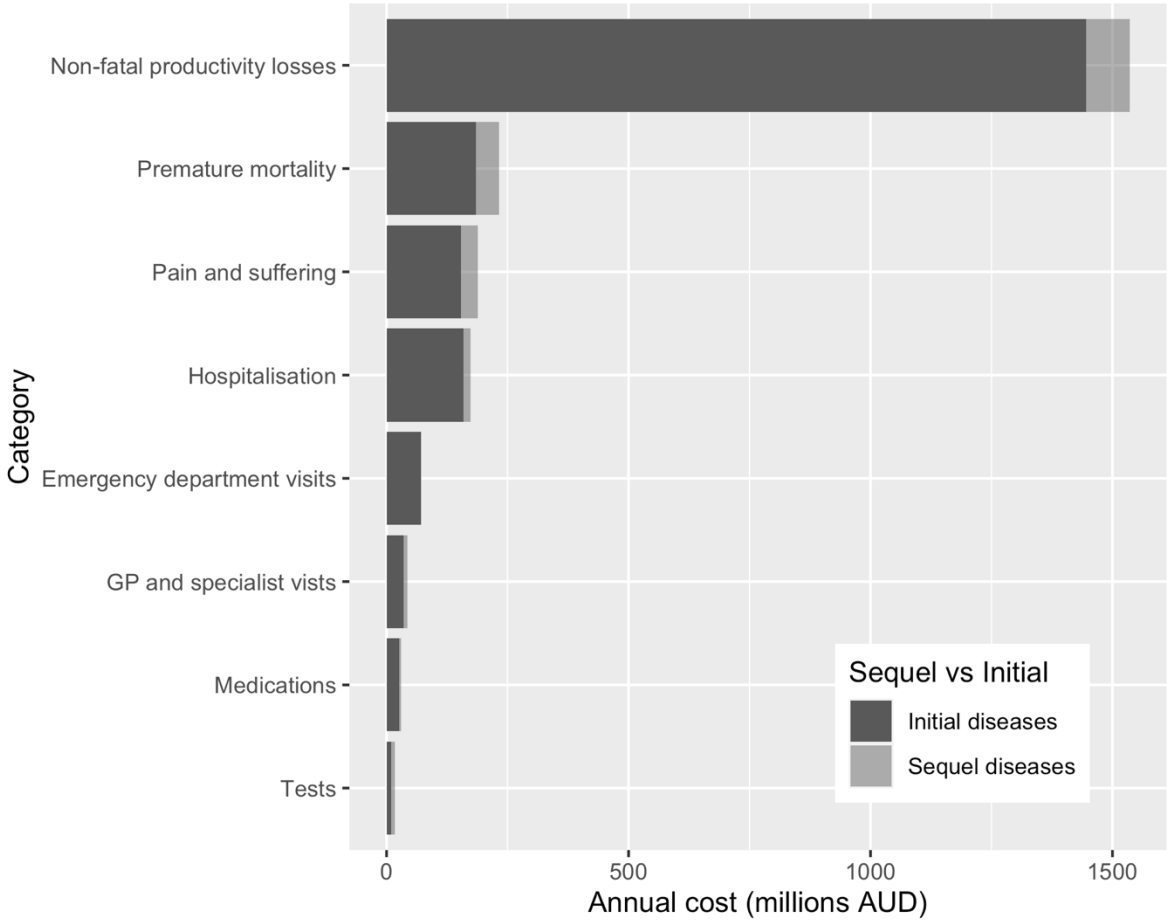
Table 9: Component costs of illness with gastroenteritis due to all causes for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total†
		All-cause gastroenteritis		
GP consults	2,170 (1,190 – 3,620)	27,400 (15,000 – 45,600)	5,600 (3,080 – 9,360)	35,200 (19,500 – 58,000)
ED visits	4,310 (2,050 – 8,600)	54,400 (25,800 – 108,000)	11,100 (5,300 – 22,100)	71,000 (35,900 – 132,000)
Hospitalisations	9,120 (4,770 – 16,000)	52,400 (27,300 – 91,800)	94,000 (49,100 – 165,000)	159,000 (103,000 – 237,000)
Tests	536 (229 – 1,190)	6,730 (2,880 – 15,000)	1,380 (590 – 3,070)	8,880 (4,200 – 18,100)
Medications	2,010 (1,050 – 3,580)	18,900 (10,400 – 31,500)	5,360 (2,800 – 9,540)	26,500 (14,700 – 43,600)
Lost productivity in non-fatal illnesses	63,700 (31,300 – 126,000)	1,190,000 (660,000 – 2,000,000)	133,000 (38,100 – 650,000)	1,450,000 (790,000 – 2,520,000)
Willingness to pay to avoid pain and suffering	9,650 (5,540 – 15,500)	119,000 (67,000 – 193,000)	25,200 (14,600 – 40,400)	154,000 (87,200 – 249,000)
Premature mortality	4,070 (1,880 – 8,280)	30,300 (15,600 – 54,500)	148,000 (77,200 – 261,000)	185,000 (111,000 – 299,000)
TOTAL†	97,300 (56,900 – 168,000)	1,510,000 (880,000 – 2,440,000)	452,000 (283,000 – 975,000)	2,100,000 (1,310,000 – 3,340,000)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns.

Figure 6: Component costs of gastroenteritis due to all causes and sequelae, Australia circa 2019.



Costs by specific pathogen

Campylobacter

Circa 2019, we estimated there were 264,000 (90%UI: 161,000–432,000) cases of foodborne campylobacteriosis, with an associated 5,640 (90%UI: 4,310–7,110) hospitalisations and 4 (90%UI: 2–5) deaths each year. We further estimated 19,800 (90%UI: 9,310–39,800) cases and 598 (90%UI: 367–878) hospitalisations each year due to reactive arthritis following foodborne campylobacteriosis, 23,200 (90%UI: 13,700–38,800) cases, 2,300 (90%UI: 1,240–4,800) hospitalisations, and 0 (90%UI: 0–1) deaths each year due to IBS following campylobacteriosis, and 98 (90%UI: 48–202) hospitalised cases and 8 (90%UI: 4–13) deaths each year due to GBS following campylobacteriosis. Table A3 in Appendix D provides age-specific estimates of burden.

The total annual cost of campylobacteriosis and its sequelae was estimated to be AUD 365 million (Table 10). For campylobacteriosis in children aged <5 and in those aged 5–64 years, the largest costs are lost productivity (representing lost work for those aged 5–64 and carer costs for children aged <5), followed by willingness to pay to avoid illness and premature mortality. In contrast, in those aged 65 years and older, the highest cost arises from hospitalisations, followed by lost productivity.

For reactive arthritis and IBS, there was a similar pattern of the highest costs arising from lost productivity and WTP to avoid pain and suffering from illness (both primary illness and ongoing illness). The primary cost drivers for GBS were premature mortality and hospitalisations. Although individual willingness to pay to avoid pain and suffering due to GBS is high (see Table 10), there are few cases of GBS each year, so total WTP costs were relatively low.

Note that we assumed no ED visits for GBS, IBS, or ReA, so those rows are not shown. Likewise, we assumed all cases of GBS would be hospitalised and that all tests and medications associated with GBS were captured within hospitalisation costs.

Table 10: Component costs of foodborne *Campylobacter* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total[††]
***Campylobacter* infections**				
GP consults	364 (199 – 647)	2,610 (1,430 – 4,650)	738 (405 – 1,320)	3,740 (2,150 – 6,420)
ED visits	1,100 (497 – 2,300)	7,870 (3,560 – 16,500)	2,230 (1,010 – 4,680)	11,400 (5,930 – 21,800)
Hospitalisations	504 (334 – 702)	6,100 (4,050 – 8,490)	13,800 (9,150 – 19,200)	20,500 (15,300 – 26,300)
Tests[†]	216	1,550	439	2,210
Medications	161 (74.6 – 314)	1,860 (1,050 – 3,250)	1,110 (591 – 2,030)	3,160 (1,850 – 5,370)
Lost productivity in non-fatal illnesses	5,710 (2,900 – 11,400)	62,600 (37,600 – 105,000)	10,200 (3,440 – 47,900)	82,000 (48,500 – 148,000)
Willingness to pay to avoid pain and suffering	3,590 (2,190 – 5,870)	25,900 (15,800 – 42,300)	7,430 (4,580 – 12,100)	36,900 (22,600 – 60,200)
Premature mortality	1,230 (226 – 3,930)	6,550 (3,110 – 12,500)	8,660 (4,150 – 16,300)	17,300 (10,600 – 26,800)
TOTAL[††]	13,400 (8,310 – 21,900)	116,000 (76,000 – 182,000)	47,000 (32,800 – 86,900)	179,000 (123,000 – 277,000)
Irritable bowel syndrome following campylobacteriosis				
GP and specialist consults	527 (311 – 885)	3,790 (2,240 – 6,360)	1,070 (631 – 1,790)	5,390 (3,180 – 9,040)
Hospitalisations	5.13 (2.31 – 12.7)	3,480 (1,660 – 8,330)	849 (407 – 2,020)	4,520 (2,430 – 9,410)
Tests	430 (254 – 720)	3,600 (2,120 – 6,050)	1,160 (683 – 1,960)	5,190 (3,060 – 8,720)
Medications	65.9 (38.9 – 111)	474 (279 – 794)	134 (79 – 224)	674 (397 – 1,130)
Lost productivity in non-fatal illnesses	2,330 (1,380 – 3,900)	19,600 (11,600 – 32,800)	2,260 (1,340 – 3,790)	24,200 (14,300 – 40,500)
Willingness to pay to avoid pain and suffering	1,150 (635 – 2,030)	8,250 (4,570 – 14,600)	2,330 (1,290 – 4,110)	11,700 (6,490 – 20,700)
Premature mortality	19.3 (0.167 – 198)	25.2 (0.219 – 263)	1,490 (587 – 4,050)	1,610 (673 – 4,170)
Willingness to pay to avoid pain and suffering from ongoing illness	1,510 (544 – 3,450)	10,800 (3,890 – 24,800)	3,060 (1,100 – 7,010)	15,700 (6,040 – 33,800)
TOTAL[††]	6,120 (3,490 – 10,700)	51,200 (30,200 – 86,400)	12,900 (7,820 – 21,300)	70,300 (42,100 – 117,000)

Reactive arthritis following campylobacteriosis

GP and specialist consults	100 (46.7 – 202)	721 (336 – 1,460)	203 (94.9 – 411)	1,030 (480 – 2,060)
Hospitalisations	345 (160 – 619)	2,690 (1,530 – 4,260)	722 (421 – 1,120)	3,810 (2,340 – 5,590)
Tests	89.4 (40.5 – 187)	643 (291 – 1,350)	182 (82.4 – 381)	919 (424 – 1,890)
Medications	156 (51.3 – 473)	1,110 (370 – 3,390)	315 (104 – 957)	1,690 (648 – 4,350)
Lost productivity in non-fatal illnesses	3,910 (1,840 – 7,850)	33,000 (15,500 – 66,300)	3,840 (1,800 – 7,700)	40,800 (19,200 – 81,900)
Willingness to pay to avoid pain and suffering	1,370 (633 – 2,770)	9,820 (4,550 – 19,900)	2,780 (1,290 – 5,630)	14,000 (6,470 – 28,300)
Premature mortality	58 (0.493 – 556)	82.9 (0.697 – 755)	110 (0.925 – 995)	435 (60.4 – 1,630)
Willingness to pay to avoid pain and suffering from ongoing illness	466 (203 – 1,000)	3,340 (1,470 – 7,230)	947 (413 – 2,040)	4,790 (2,140 – 10,100)
TOTAL††	6,630 (3,200 – 13,000)	51,900 (25,300 – 102,000)	9,350 (4,680 – 17,900)	68,000 (33,300 – 133,000)
Guillain-Barré syndrome following campylobacteriosis				
GP, specialist, and physiotherapy consults	6.51 (3.19 – 13.4)	46.8 (22.9 – 96.3)	13.2 (6.47 – 27.2)	66.5 (32.6 – 137)
Hospitalisations	279 (137 – 573)	2,000 (982 – 4,120)	566 (278 – 1,160)	2,850 (1,400 – 5,850)
Lost productivity in non-fatal illnesses	175 (86 – 360)	1,480 (724 – 3,030)	170 (83.4 – 350)	1,820 (893 – 3,740)
Willingness to pay to avoid pain and suffering	13.1 (6.44 – 27.1)	94.3 (46.3 – 194)	26.7 (13.1 – 54.9)	134 (65.8 – 276)
Premature mortality	57.7 (0.472 – 561)	4,890 (2,000 – 10,000)	31,900 (13,800 – 59,200)	37,300 (18,800 – 65,000)
Willingness to pay to avoid pain and suffering from ongoing illness	2.69 (1.29 – 5.69)	41.3 (19.8 – 87.1)	35.6 (17.2 – 74.3)	79.6 (38.5 – 167)
TOTAL††	597 (283 – 1,280)	8,920 (5,000 – 15,100)	32,800 (14,700 – 60,100)	42,800 (23,900 – 70,700)
COMBINED TOTAL	27,100 (16,800 – 44,100)	230,000 (147,000 – 368,000)	106,000 (74,600 – 158,000)	365,000 (250,000 – 553,000)

†As costs of tests were determined by numbers of notifications for 2019 (which is a fixed total) and we assume a fixed cost of the test, there was no uncertainty in this estimate. †† Totals reflect median of model simulation, so may not equal the sum of individual columns.

Listeria monocytogenes

Circa 2019, we estimated that there were 101 (90%UI: 51–151) cases and hospitalisations due to foodborne listeriosis, with 15 (90%UI: 11–20) deaths each year. The total annual cost of foodborne listeriosis was estimated to be AUD 78.4 million (Table 11), with costs dominated by premature mortality across all age groups and relatively low costs for all other categories. Table A4 in Appendix D provides age-specific estimates of burden.

Table 11: Component costs of foodborne *Listeria monocytogenes* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total†
Listeria monocytogenes				
GP consults	2.01 (0.982 – 3.23)	6.03 (2.94 – 9.68)	12.9 (6.28 – 20.7)	21.1 (10.4 – 32.8)
ED visits	3.34 (1.68 – 5.02)	10 (5.03 – 15.1)	21.4 (10.7 – 32.2)	34.8 (17.5 – 52.3)
Hospitalisations ††	336 (169 – 505)	1,010 (506 – 1,520)	2,150 (1,080 – 3,230)	3,500 (1,750 – 5,250)
Tests	0.205 (0.103 – 0.308)	0.615 (0.308 – 0.923)	1.31 (0.658 – 1.97)	2.13 (1.07 – 3.2)
Medications	0.11 (0.0552 – 0.165)	0.33 (0.166 – 0.496)	0.704 (0.353 – 1.06)	1.14 (0.574 – 1.72)
Lost productivity in non-fatal illnesses	29.1 (14.6 – 43.8)	98.1 (49.3 – 148)	98.1 (48.5 – 160)	226 (113 – 347)
Willingness to pay to avoid pain and suffering	6.27 (3.14 – 9.49)	18.8 (9.42 – 28.5)	40.1 (20.1 – 60.7)	65.2 (32.6 – 98.7)
Premature mortality	14,400 (7,910 – 24,300)	21,700 (12,800 – 34,500)	37,000 (22,600 – 56,600)	74,500 (54,900 – 98,700)
TOTAL†	14,800 (8,300 – 24,700)	22,900 (14,000 – 35,700)	39,300 (24,900 – 59,000)	78,400 (58,600 – 103,000)

† Totals reflect median of model simulation, so may not equal the sum of individual columns. †† All incident cases of *S.* Typhi were assumed to be hospitalised.

Norovirus

Circa 2019, we estimated that there were 328,000 (90%UI: 89,600–671,000) cases of illness due to foodborne norovirus, with an associated 1,530 (90%UI: 823–2,400) hospitalisations and 1 (90%UI: 0–2) deaths each year.

The total cost of foodborne norovirus was estimated at AUD 128 million (Table 12). Total costs were dominated by lost productivity across all age groups, with a total of AUD 101 million each year due to lost productivity (79% of total costs). Table A5 in Appendix D provides age-specific estimates of burden.

Table 12: Component costs of foodborne norovirus infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total[†]
Norovirus				
GP consults	152 (41.4 – 320)	1,920 (522 – 4,030)	392 (106 – 826)	2,470 (675 – 5,130)
ED visits	299 (76.9 – 728)	3,770 (968 – 9,200)	769 (199 – 1,870)	4,950 (1,300 – 11,400)
Hospitalisations	905 (246 – 1,920)	1,050 (280 – 2,240)	2,790 (762 – 5,940)	4,930 (2,480 – 8,290)
Tests	36.6 (9.05 – 100)	462 (114 – 1,260)	94.2 (23.3 – 259)	615 (159 – 1,530)
Medications	140 (37.6 – 309)	1,320 (361 – 2,780)	374 (100 – 830)	1,860 (506 – 3,860)
Lost productivity in non-fatal illnesses	4,550 (1,340 – 10,800)	83,300 (23,000 – 175,000)	8,890 (1,820 – 49,200)	101,000 (28,000 – 218,000)
Willingness to pay to avoid pain and suffering	486 (168 – 950)	5,500 (1,550 – 11,300)	1,160 (355 – 2,360)	7,150 (2,070 – 14,600)
Premature mortality	39.4 (0.309 – 445)	1,410 (337 – 3,800)	2,310 (578 – 5,910)	4,090 (1,680 – 8,220)
TOTAL[†]	6,830 (2,640 – 14,000)	99,500 (29,500 – 205,000)	18,100 (7,700 – 59,500)	128,000 (42,500 – 262,000)

[†] Totals reflect median of model simulation, so may not equal the sum of individual columns.

Non-typhoidal *Salmonella*

Circa 2019, we estimated that there were 61,600 (90%UI: 34,300–109,000) cases of foodborne salmonellosis, with an associated 3,740 (90%UI: 2,870–4,740) hospitalisations and 11 (90%UI: 8–16) deaths each year. We further estimated 5,750 (90%UI: 1,510–14,200) cases and 172 (90%UI: 47–393) hospitalisations each year due to reactive arthritis following salmonellosis and 5,400 (90%UI: 2,940–9,700) cases and 460 (90%UI: 181–1,200) hospitalisations due to IBS following salmonellosis.

The total cost of salmonellosis and its sequelae was estimated at AUD 140 million per year (in Appendix D provides age-specific estimates of burden.

Table 13). The largest costs of salmonellosis in children aged <5 were due to lost productivity in carers, followed by premature mortality and willingness to pay to avoid illness. In adults aged 5–64, premature mortality was the largest cost of illness, followed by lost productivity and willingness to pay to avoid illness. In those aged 65 years and older, costs due to premature mortality dominated the total.

For ReA and IBS in all age groups, the highest costs arose from lost productivity and WTP to avoid pain and suffering (both from primary and ongoing illness). Note that we assumed no ED visits for IBS, or ReA, so those rows are not shown. Table A6 in Appendix D provides age-specific estimates of burden.

Table 13: Component costs of foodborne *Salmonella* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	**5–64**	**65+**	**Total††**
Salmonella				
GP consults	206 (106 – 392)	537 (274 – 1,020)	122 (62 – 232)	872 (468 – 1,600)
ED visits	622 (266 – 1,380)	1,620 (696 – 3,610)	366 (158 – 815)	2,680 (1,320 – 5,360)
Hospitalisations	1,790 (1,140 – 2,600)	3,740 (2,370 – 5,400)	5,480 (3,470 – 7,940)	11,100 (8,480 – 14,100)
Tests†	214	557	126	897
Medications	91.1 (40.1 – 189)	382 (200 – 715)	183 (90.7 – 358)	663 (358 – 1,210)
Lost productivity in non-fatal illnesses	3,680 (1,980 – 7,250)	14,000 (8,220 – 24,300)	2,060 (895 – 8,370)	20,500 (12,100 – 36,400)
Willingness to pay to avoid pain and suffering	2,100 (1,200 – 3,660)	5,450 (3,100 – 9,500)	1,270 (742 – 2,190)	8,820 (5,050 – 15,400)
Premature mortality	2,540 (884 – 5,920)	15,400 (8,700 – 25,700)	36,600 (21,800 – 57,500)	55,700 (38,400 – 78,400)
TOTAL††	11,700 (7,800 – 17,900)	42,800 (30,100 – 61,100)	47,400 (31,700 – 69,400)	103,000 (78,800 – 135,000)

Irritable bowel syndrome following salmonellosis

GP and specialist consults	299 (163 – 538)	779 (425 – 1,400)	177 (96.2 – 318)	1,250 (684 – 2,260)
Hospitalisations	2.93 (1.17 – 7.79)	725 (264 – 2,080)	142 (50.9 – 415)	902 (355 – 2,350)
Tests	243 (132 – 438)	739 (401 – 1,340)	192 (104 – 346)	1,180 (639 – 2,120)
Medications	37.3 (20.3 – 67.2)	97.4 (53 – 175)	22.1 (12 – 39.8)	157 (85.4 – 282)
Lost productivity in non-fatal illnesses	1,320 (718 – 2,370)	4,030 (2,200 – 7,250)	373 (203 – 671)	5,730 (3,120 – 10,300)
Willingness to pay to avoid pain and suffering	650 (334 – 1,230)	1,700 (872 – 3,200)	384 (198 – 726)	2,730 (1,400 – 5,160)
Premature mortality	10.7 (0.0855 – 117)	5.16 (0.0421 – 58.8)	248 (77.6 – 801)	290 (96.9 – 872)
Willingness to pay to avoid pain and suffering from ongoing illness	851 (293 – 2,050)	2,220 (770 – 5,350)	502 (175 – 1,220)	3,650 (1,360 – 8,240)
TOTAL[††]	3,470 (1,830 – 6,470)	10,500 (5,610 – 19,400)	2,140 (1,110 – 4,020)	16,200 (8,630 – 29,700)

Reactive arthritis following salmonellosis

GP and specialist consults	70.8 (18.5 – 176)	185 (48.4 – 459)	41.8 (11 – 104)	298 (77.9 – 738)
Hospitalisations	239 (73.9 – 485)	683 (173 – 1,730)	147 (36.2 – 388)	1,090 (299 – 2,500)
Tests	62.9 (16.3 – 161)	164 (42.3 – 422)	37.2 (9.61 – 95.9)	267 (69.4 – 671)
Medications	107 (23.1 – 385)	279 (60.7 – 1,010)	63 (13.7 – 228)	489 (117 – 1,470)
Lost productivity in non-fatal illnesses	2,760 (726 – 6,830)	8,470 (2,220 – 21,000)	789 (207 – 1,950)	12,000 (3,160 – 29,700)
Willingness to pay to avoid pain and suffering	965 (253 – 2,400)	2,520 (659 – 6,260)	570 (149 – 1,420)	4,050 (1,060 – 10,100)
Premature mortality	37.8 (0.316 – 405)	18.9 (0.151 – 223)	20 (0.16 – 248)	137 (14.5 – 667)
Willingness to pay to avoid pain and suffering from ongoing illness	327 (82.7 – 866)	854 (217 – 2,250)	194 (49 – 511)	1,390 (357 – 3,570)
TOTAL[††]	4,690 (1,270 – 11,300)	13,400 (3,540 – 32,600)	1,930 (512 – 4,690)	20,000 (5,320 – 48,500)
COMBINED TOTAL	20,100 (12,600 – 33,200)	67,200 (44,000 – 106,000)	51,900 (35,500 – 74,600)	140,000 (102,000 – 201,000)

[†]As costs of tests were determined by numbers of notifications for 2019 (which is a fixed total) and we assumed a fixed cost per test, there was no uncertainty in this estimate. [††] Totals reflect median of model simulation, so may not equal the sum of individual columns.

Salmonella Typhi

Circa 2019, we estimated that there were 29 (90%UI: 10–64) hospitalised cases of illness due to domestically acquired foodborne *Salmonella* Typhi each year.

The total cost of *Salmonella* Typhi was estimated at 0.47 million per year (Table 14). We assumed that all tests and medications were covered by hospitalisation costs, so these rows have been omitted from Table 14. The largest costs overall and for most age groups were those due to hospitalisations, with premature mortality being the highest cost for those aged 65 years and older. Table A7 in Appendix D provides age-specific estimates of burden.

Table 14: Component costs of foodborne *Salmonella* Typhi infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	**5–64**	**65+**	**Total**[†]
***Salmonella* Typhi**				
GP consults	0.318 (0.102 – 0.762)	2.32 (0.744 – 5.6)	0.026 (0.008 – 0.064)	2.68 (0.869 – 6.35)
ED visits	1.17 (0.393 – 2.64)	8.6 (2.88 – 19.4)	0.098 (0.033 – 0.22)	9.88 (3.3 – 22.2)
Hospitalisations[††]	29.6 (9.91 – 66.7)	217 (72.7 – 489)	2.47 (0.826 – 5.56)	249 (83.4 – 561)
Lost productivity in non-fatal illnesses	3.98 (1.33 – 9.01)	38.8 (13 – 87.5)	0.31 (0.101 – 0.76)	43.1 (14.4 – 97.2)
Willingness to pay to avoid pain and suffering	2.06 (0.69 – 4.65)	15.1 (5.06 – 34.1)	0.17 (0.058 – 0.39)	17.4 (5.8 – 39.2)
Premature mortality	17.5 (0.142 – 185)	17.7 (0.146 – 188)	22.5 (0.187 – 235)	107 (14.6 – 428)
TOTAL[†]	64.5 (20.5 – 229)	327 (117 – 712)	26 (2.9 – 239)	468 (189 – 956)

[†] Totals reflect median of model simulations, so may not equal the sum of individual columns. [††] All incident cases of *S.* Typhi are assumed to be hospitalised.

Shigella

Circa 2019, we estimated that there were on average 1,930 (90%UI: 662–4,360) cases of foodborne shigellosis, with an associated 90 (90%UI: 47–155) hospitalisations and less than one death each year. We further estimated 158 (90%UI: 52–371) cases and 5 (90%UI: 1–14) hospitalisations each year due to reactive arthritis following shigellosis and 169 (90%UI: 57–388) cases and 16 (90%UI: 4–54) hospitalisations each year due to IBS following shigellosis.

The total cost of shigellosis and its sequelae was estimated to be AUD 3.41 million (Table 15). The highest costs of shigellosis in most age groups was due to lost productivity and premature mortality, although in people aged 65 and over, the largest cost arose from hospitalisation.

Given relatively low incidence of shigellosis, costs associated with sequelae following shigellosis were also low compared to those following more common illnesses of salmonellosis or campylobacteriosis. For reactive arthritis and IBS, there was a similar pattern of the highest costs arising from lost productivity and WTP to avoid pain and suffering. Note that we assumed no ED visits for IBS, or ReA, so those rows have been omitted from Table 15. Table A8 in Appendix D provides age-specific estimates of burden.

Table 15: Component costs of foodborne *Shigella* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	**5–64**	**65+**	**Total**††
Shigella				
GP consults	3.75 (1.23 – 9.09)	20.8 (6.8 – 50.3)	2.32 (0.76 – 5.6)	27.1 (9.02 – 63.9)
ED visits	11.2 (3.33 – 31.1)	61.9 (18.4 – 171)	6.91 (2.06 – 19.2)	82.1 (26 – 212)
Hospitalisations	36.4 (13.3 – 73.1)	124 (45 – 248)	40.4 (14.5 – 80.5)	207 (115 – 337)
Tests†	26.9	149	16.6	192
Medications	2.48 (0.819 – 6.01)	19.8 (6.67 – 46.3)	4.09 (1.34 – 9.89)	26.6 (9.02 – 61.4)
Lost productivity in non-fatal illnesses	68.7 (28 – 164)	539 (214 – 1,180)	31.1 (8.38 – 169)	655 (263 – 1,450)
Willingness to pay to avoid pain and suffering	38.7 (14.2 – 85.5)	211 (75.6 – 471)	23.5 (8.39 – 52.5)	273 (98.3 – 609)
Premature mortality	139 (21 – 551)	470 (132 – 1,290)	26.6 (0.217 – 271)	734 (284 – 1,640)
TOTAL††	355 (177 – 781)	1,700 (944 – 2,950)	184 (90.1 – 483)	2,310 (1,370 – 3,820)

Irritable bowel syndrome following shigellosis				
GP and specialist consults	5.47 (1.85 – 12.6)	30.3 (10.3 – 70)	3.38 (1.15 – 7.81)	39.2 (13.3 – 90.4)
Hospitalisations	0.053 (0.014 – 0.19)	27.6 (7.1 – 99.8)	2.67 (0.678 – 9.66)	31 (8.26 – 107)
Tests	4.46 (1.51 – 10.3)	28.8 (9.76 – 66.7)	3.67 (1.25 – 8.49)	36.9 (12.5 – 85.4)
Medications	0.684 (0.232 – 1.58)	3.79 (1.29 – 8.75)	0.423 (0.144 – 0.975)	4.9 (1.66 – 11.3)
Lost productivity in non-fatal illnesses	24.2 (8.22 – 55.7)	157 (53.4 – 362)	7.15 (2.43 – 16.5)	188 (64.1 – 434)
Willingness to pay to avoid pain and suffering	11.8 (3.92 – 28.5)	65.6 (21.7 – 158)	7.32 (2.42 – 17.6)	84.8 (28.1 – 204)
Premature mortality	0.183 (0.001 – 2.46)	0.187 (0.001 – 2.54)	4.62 (1.08 – 18.6)	5.67 (1.38 – 21.1)
Willingness to pay to avoid pain and suffering from ongoing illness	15.2 (3.93 – 45.6)	83.9 (21.7 – 254)	9.38 (2.41 – 28.2)	110 (29.8 – 319)
TOTAL[††]	63.4 (21.1 – 151)	409 (137 – 970)	40.8 (13.5 – 99.2)	514 (172 – 1,220)
Reactive arthritis following shigellosis				
GP and specialist consults	1.14 (0.373 – 2.69)	6.31 (2.07 – 14.9)	0.703 (0.231 – 1.67)	8.16 (2.68 – 19.3)
Hospitalisations	3.75 (1.04 – 11.7)	23 (6.31 – 71.4)	2.43 (0.665 – 7.69)	29.5 (8.38 – 89.2)
Tests	1.02 (0.326 – 2.48)	5.61 (1.81 – 13.7)	0.628 (0.202 – 1.53)	7.29 (2.38 – 17.6)
Medications	1.74 (0.451 – 6)	9.62 (2.5 – 33.2)	1.08 (0.28 – 3.69)	13.2 (3.77 – 40)
Lost productivity in non-fatal illnesses	44.4 (14.7 – 105)	289 (95.5 – 681)	13.3 (4.38 – 31.2)	347 (115 – 817)
Willingness to pay to avoid pain and suffering	15.5 (5.07 – 36.9)	85.9 (28.1 – 205)	9.58 (3.14 – 22.8)	111 (36.3 – 265)
Premature mortality	0.612 (0.005 – 7.76)	0.661 (0.005 – 8.43)	0.346 (0.003 – 4.46)	2.86 (0.315 – 16.3)
Willingness to pay to avoid pain and suffering from ongoing illness	5.26 (1.67 – 13.3)	29.3 (9.22 – 73.8)	3.26 (1.03 – 8.2)	38 (12.1 – 94.2)
TOTAL[††]	75.3 (24.8 – 178)	456 (151 – 1,080)	32.4 (10.6 – 77)	564 (186 – 1,330)
COMBINED TOTAL	513 (250 – 1,020)	2,590 (1,320 – 4,820)	268 (128 – 607)	3,410 (1,840 – 6,170)

[†]As costs of tests were determined by numbers of notifications in 2019 (which is a fixed total) and we assumed a fixed cost per test, there is no uncertainty in this estimate. [††] Totals reflect median of model simulation, so may not equal the sum of individual columns.

Shiga-toxin producing *Escherichia coli* (STEC)

Circa 2019, we estimated that there were 2,630 (90%UI: 1,140–5,760) cases of foodborne STEC and 32 (90%UI: 21–47) hospitalisations each year. We further estimated 78 (90%UI: 30–197) cases and hospitalisations due to HUS following STEC and an associated 2 (90%UI: 1–3) deaths from HUS.

The total cost of STEC and HUS was estimated to be AUD 11.7 million (

Table **16**). Within STEC cases, the main costs were due to lost productivity and premature mortality, while premature mortality was the dominant cost for HUS. We assumed all cases of HUS would be hospitalised and that all tests and medications associated with HUS are captured within hospitalisation costs. Table A9 in Appendix D provides age-specific estimates of burden.

Table 16: Component costs of foodborne STEC infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total†
STEC				
GP consults	5.67 (2.3 – 13.2)	24.7 (9.99 – 57.4)	6.45 (2.61 – 15)	37.1 (15.5 – 83.7)
ED visits	17 (6.06 – 45)	74.1 (26.4 – 198)	19.4 (6.89 – 51.6)	114 (44.7 – 278)
Hospitalisations	3.56 (1.88 – 5.88)	41.5 (22 – 68.7)	55.7 (29.5 – 92.6)	103 (67.6 – 146)
Tests†	5.64	24.6	6.41	36.6
Medications	2.83 (1.16 – 6.57)	9.19 (3.9 – 20.5)	3.33 (1.36 – 7.74)	15.5 (6.6 – 34.3)
Lost productivity in non-fatal illnesses	88.9 (34.1 – 223)	594 (260 – 1,310)	84.1 (21.6 – 459)	803 (346 – 1,850)
Willingness to pay to avoid pain and suffering	56.1 (24.2 – 123)	245 (107 – 536)	64.3 (28.1 – 140)	366 (159 – 799)
Premature mortality	135 (1.16 – 1,270)	136 (1.17 – 1,270)	172 (1.54 – 1,610)	793 (112 – 2,890)
TOTAL††	364 (126 – 1,490)	1,300 (598 – 2,830)	504 (185 – 2,000)	2,470 (1,190 – 5,020)

Haemolytic uraemic syndrome following STEC

GP consults	1.63 (0.468 – 4.87)	7.14 (2.05 – 21.2)	1.85 (0.529 – 5.53)	10.9 (3.69 – 30)
Hospitalisations	73 (27.8 – 184)	318 (121 – 801)	82.9 (31.5 – 209)	474 (180 – 1,190)
Lost productivity in non-fatal illnesses	55.8 (21.2 – 141)	286 (109 – 720)	30.7 (11.7 – 77.3)	373 (142 – 938)
Willingness to pay to avoid pain and suffering	19.5 (7.41 – 49)	84.9 (32.3 – 214)	22.1 (8.41 – 55.6)	126 (48.1 – 318)
Premature mortality	528 (92.4 – 1,860)	5,790 (2,690 – 11,400)	989 (233 – 2,990)	7,740 (4,180 – 13,600)
Willingness to pay to avoid pain and suffering from ongoing illness	8.77 (2.83 – 25.2)	38.2 (12.3 – 110)	9.94 (3.23 – 28.8)	58.2 (20.5 – 157)
TOTAL[††]	722 (239 – 2,060)	6,670 (3,430 – 12,300)	1,170 (385 – 3,170)	8,970 (5,200 – 15,000)
COMBINED TOTAL	1,220 (495 – 2,940)	8,140 (4,540 – 14,100)	1,860 (774 – 4,310)	11,700 (7,260 – 18,300)

[†]As costs of tests were determined by numbers of notifications in 2019 (which is a fixed total) and we assumed a fixed cost per test, there is no uncertainty in this estimate. [††] Totals reflect median of model simulation, so may not equal the sum of individual columns.

Other pathogenic *Escherichia coli*

Circa 2019, we estimated that there were 312,000 (90%UI: 120,000–709,000) cases of foodborne illness due to other pathogenic *E. coli*, with an associated 41 (90%UI: 21–73) hospitalisations and 1 (90%UI: 0–1) death each year.

The total cost of other pathogenic *E. coli* was AUD 133 million per year (

Table 17). Total costs were dominated by lost productivity across all age groups, with a total of AUD 96 million each year due to lost productivity (72% of total costs).

As the hospitalisation code for other pathogenic *E. coli* is probably under-used, we conducted a sensitivity analysis where the hospitalisation proportion for other pathogenic *E. coli* was increased to the overall proportion hospitalised for gastroenteritis due to all causes (an increase from approximately 1 hospitalisation per 7,600 cases to 1 hospitalisation per 100 cases). This resulted in an increase in the costs due to hospitalisations to AUD 10.6 million (90% UI AUD 3.36 – 31.3 million) per year and an increase in the total annual cost of other pathogenic *E. coli* to AUD 144 million (90% UI AUD 56.3 – 332 million) per year. Note that hospitalisations for other pathogenic *E. coli* that are not coded as *E. coli* are likely captured by other codes included for gastroenteritis due to all causes. Thus this calculation does not change the overall total cost of foodborne illness as those codes are included in the analysis. Table A10 in Appendix D provides age-specific estimates of burden.

Table 17: Component costs of foodborne other pathogenic *E. coli* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total[†]
Other pathogenic *E. coli*				
GP consults	269 (98.6 – 651)	3,390 (1,240 – 8,200)	692 (254 – 1,680)	4,390 (1,630 – 10,400)
ED visits	803 (262 – 2,230)	10,100 (3,300 – 28,100)	2,060 (674 – 5,740)	13,400 (4,620 – 34,700)
Hospitalisations	2.99 (1.13 – 6.92)	40.3 (15.2 – 93.4)	98.4 (37.4 – 229)	149 (73.7 – 284)
Tests	35.9 (11.4 – 103)	450 (143 – 1,290)	92 (29.4 – 264)	595 (204 – 1,590)
Medications	118 (39.5 – 308)	2,420 (899 – 5,760)	1,040 (373 – 2,570)	3,620 (1,360 – 8,460)
Lost productivity in non-fatal illnesses	4,160 (1,450 – 10,900)	79,400 (29,800 – 184,000)	8,560 (1,830 – 49,200)	96,100 (35,700 – 229,000)
Willingness to pay to avoid pain and suffering	617 (235 – 1,420)	7,780 (2,960 – 17,800)	1,590 (607 – 3,650)	9,990 (3,800 – 22,900)
Premature mortality	55.7 (0.469 – 599)	1,830 (581 – 5,260)	691 (140 – 2,600)	2,940 (1,200 – 6,730)
TOTAL[†]	6,290 (2,360 – 15,200)	107,000 (41,800 – 242,000)	16,100 (5,590 – 59,900)	133,000 (51,900 – 306,000)

[†] Totals reflect median of model simulation, so may not equal the sum of individual columns.

Toxoplasma gondii

Circa 2019, we estimated that there were 15,500 (90%UI: 6,130–27,500) cases of symptomatic foodborne toxoplasmosis, with an associated 35 (90%UI: 18–58) hospitalisations and 1 (90%UI: 0–2) deaths each year.

We estimated an annual cost of toxoplasmosis of AUD 13.1 million (Table 18). Lost productivity and premature mortality were the largest costs of illness, followed by hospitalisations. Note that we assumed no ED visits for toxoplasmosis, so this row is excluded from Table 18. Table A11 in Appendix D provides age-specific estimates of burden.

Table 18: Component costs of foodborne *Toxoplasma gondii* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	5–64	65+	Total[†]
Toxoplasma gondii				
GP and specialist consults	38.2 (14.5 – 77.4)	173 (68 – 334)	7.15 (2.76 – 14.1)	221 (88.4 – 414)
Hospitalisations	70.3 (27 – 134)	1,260 (489 – 2,400)	420 (162 – 800)	1,790 (940 – 2,960)
Tests	20.7 (7.82 – 42.2)	92.7 (35.5 – 181)	3.34 (0.999 – 7.14)	118 (45.9 – 224)
Medications	35.3 (13.3 – 71.7)	158 (60.4 – 307)	5.69 (1.7 – 12.1)	201 (78.1 – 381)
Lost productivity in non-fatal illnesses	584 (209 – 1,330)	4,180 (1,760 – 7,520)	80.1 (21 – 414)	4,940 (2,060 – 8,900)
Willingness to pay to avoid pain and suffering	152 (59.2 – 297)	696 (284 – 1,280)	31 (13.2 – 56.9)	882 (361 – 1,630)
Premature mortality	65.2 (0.559 – 663)	2,490 (827 – 5,990)	1,590 (445 – 4,400)	4,550 (2,100 – 8,830)
TOTAL[†]	1,070 (466 – 2,130)	9,460 (5,430 – 14,700)	2,230 (989 – 5,070)	13,100 (8,120 – 19,500)

[†] Totals reflect median of model simulation, so may not equal the sum of individual columns.

Yersinia enterocolitica

Circa 2019, we estimated that there were 7,170 (90%UI: 3,960–12,600) cases of foodborne yersiniosis, with an associated 38 (90%UI: 29–49) hospitalisations and 1 (90%UI: 0–2) death each year. We further estimated 820 (90%UI: 280–1,780) cases and 24 (90%UI: 7–66) hospitalisations each year due to reactive arthritis following yersiniosis.

The total annual cost of yersiniosis and ReA following yersiniosis was estimated to be AUD 10.4 million (Table 19). The largest costs for yersiniosis arose from lost productivity and premature mortality, followed by willingness to pay to avoid pain and suffering. For reactive arthritis following yersiniosis, the largest costs were due to lost productivity. Table A12 in Appendix D provides age-specific estimates of burden.

Table 19: Component costs of foodborne *Yersinia enterocolitica* infections and sequelae for different age groups, Australia circa 2019.

Median costs in thousands of AUD (90% Uncertainty Intervals)

	<5	**5–64**	**65+**	**Total**[†]
Yersinia enterocolitica				
GP consults	15.9 (8.04 – 30.2)	66 (33.3 – 125)	18.7 (9.43 – 35.5)	101 (53.6 – 186)
ED visits	48 (20.4 – 107)	198 (84.7 – 442)	56.2 (24 – 125)	311 (151 – 622)
Hospitalisations	12.5 (7.79 – 17.9)	41.6 (26 – 59.6)	65.4 (40.9 – 93.8)	120 (90 – 153)
Tests[††]	14.3	59.4	16.8	90.6
Medications	7.95 (4.06 – 15.1)	24.5 (13.2 – 44.1)	9.66 (4.93 – 18.4)	42.4 (23 – 75.7)
Lost productivity in non-fatal illnesses	250 (119 – 521)	1,550 (833 – 2,800)	238 (65.4 – 1,220)	2,130 (1,130 – 4,090)
Willingness to pay to avoid pain and suffering	157 (86.8 – 275)	651 (360 – 1,140)	185 (102 – 324)	992 (549 – 1,740)
Premature mortality	175 (1.44 – 1,550)	2,470 (776 – 6,080)	223 (1.91 – 2,000)	3,380 (1,250 – 7,430)
TOTAL[†]	771 (368 – 2,140)	5,280 (2,980 – 9,230)	992 (430 – 3,080)	7,480 (4,430 – 12,300)

Reactive arthritis following yersiniosis

GP consults	6.69 (2.29 – 14.6)	27.8 (9.48 – 60.7)	7.87 (2.68 – 17.2)	42.4 (14.5 – 92.3)
Hospitalisations	22.2 (6.35 – 62.8)	101 (28.7 – 289)	27.3 (7.73 – 78.5)	154 (45.3 – 419)
Tests	5.96 (2.01 – 13.5)	24.8 (8.29 – 56)	7 (2.36 – 15.9)	38 (12.9 – 84.2)
Medications	10.1 (2.72 – 33.4)	42.2 (11.4 – 138)	11.9 (3.21 – 39.3)	69.5 (21.1 – 189)
Lost productivity in non-fatal illnesses	262 (89.3 – 567)	1,280 (436 – 2,770)	149 (50.7 – 322)	1,690 (576 – 3,660)
Willingness to pay to avoid pain and suffering	91.3 (30.9 – 200)	379 (128 – 832)	107 (36.3 – 236)	577 (196 – 1,270)
Premature mortality	3.55 (0.0293 – 43.3)	2.89 (0.0233 – 34.9)	3.85 (0.0325 – 48.1)	18.6 (2.07 – 98)
Willingness to pay to avoid pain and suffering from ongoing illness	31 (10.2 – 72.8)	129 (42.1 – 301)	36.4 (11.9 – 85.2)	198 (65.8 – 452)
TOTAL[†]	443 (151 – 966)	2,010 (687 – 4,370)	363 (123 – 792)	2,820 (962 – 6,120)
COMBINED TOTAL	1,280 (618 – 2,770)	7,420 (4,230 – 12,500)	1,410 (665 – 3,570)	10,400 (6,150 – 17,100)

[†] Totals reflect median of model simulation, so may not equal the sum of individual columns. [††] As costs of tests are determined by numbers of notifications for 2019 (which is a fixed total) and we assume a fixed cost of the test, there is no uncertainty in this estimate.

Sensitivity analyses for the costing model

In addition to estimates of uncertainty generated by the simulation model, we explored the sensitivity of the model findings to assumptions around lost productivity and considered the impact of using WTP values from the CHERE study [4].

Model of lost productivity

Our main results used the human capital approach to estimate lost productivity arising from morbidity. We compared these estimates to those produced using the more conservative friction cost approach, where costs were truncated after three months and reduced by a multiplicative factor with two parameter settings: high (factor of 0.8) and low (factor of 0.3).

Table 20 provides a comparison of the three approaches to measuring and valuing lost productivity for all pathogens. As the estimated average time unable to work for each pathogen was significantly less than the threshold of three months, the impact of the friction cost model was to reduce costs by the multiplicative factor. For sequelae, only estimates of the average duration of lost productivity were available. While these mean durations were below the threshold of three months in each case, it is possible that some individuals are absent for work for longer than this threshold. Thus, modelling the full distribution of duration of illness might lead to further reductions in costs estimated through the friction cost approach.

Cost of pain and suffering approximated via willingness to pay to avoid pain and suffering

To make policy recommendations, policy makers need to determine the costs and benefits of an intervention. In Australia, every national policy proposal must be accompanied by a regulation impact statement (RIS), where cost benefit analysis is a key component [66]. Establishing appropriate willingness to pay (WTP) values is an important undertaking, but it can be challenging to measure the WTP for "intangible" health outcomes such as pain and suffering. In this costing study, we use WTP values to avoid pain and suffering, not as a benefit, but as an approximation of the cost of such pain and suffering.

Table **21** provides a comparison of WTP for pain and suffering values elicited from the Australian study compared to the UK study [9, 67, 68] for selected pathogens and illnesses, making assumptions around duration of illness to allow comparison with the UK approach. Estimated WTP values from the UK study were higher than those reported for the Australian study across all pathogens and illness reported. These differences are considerable for some illnesses (three to eleven times greater in magnitude), although estimates are similar for the acute phase of illness for both *Campylobacter* and *Salmonella*.

Table 20: Comparison of the three approaches to lost productivity.

Median costs in thousands of AUD (90% Uncertainty Intervals) due to lost productivity

	Friction (Low)	Friction (High)	Human Capital
All foodborne pathogens	464,000 (266,000 – 785,000)	1,240,000 (710,000 – 2,090,000)	1,550,000 (887,000 – 2,620,000)
Total infectious gastroenteritis	462,000 (264,000 – 784,000)	1,230,000 (705,000 – 2,090,000)	1,540,000 (881,000 – 2,610,000)
Campylobacter	45,300 (26,800 – 78,100)	121,000 (71,600 – 208,000)	151,000 (89,500 – 260,000)
Listeria monocytogenes	67.9 (34 – 104)	181 (90.6 – 278)	226 (113 – 347)
Non-typhoidal *Salmonella*	11,600 (6,340 – 21,500)	31,000 (16,900 – 57,300)	38,800 (21,100 – 71,700)
Norovirus	30,400 (8,410 – 65,400)	81,000 (22,400 – 174,000)	101,000 (28,000 – 218,000)
Shigella spp.	359 (135 – 801)	959 (360 – 2,140)	1,200 (450 – 2,670)
Shiga toxin-producing *Escherichia coli*	358 (153 – 813)	954 (407 – 2,170)	1,190 (509 – 2,710)
Other pathogenic *Escherichia coli*	28,800 (10,700 – 68,600)	76,900 (28,600 – 183,000)	96,100 (35,700 – 229,000)
Salmonella Typhi	12.9 (4.32 – 29.2)	34.5 (11.5 – 77.8)	43.1 (14.4 – 97.2)
Toxoplasma gondii	1,480 (619 – 2,670)	3,950 (1,650 – 7,120)	4,940 (2,060 – 8,900)
Yersinia enterocolitica	1,160 (586 – 2,210)	3,090 (1,560 – 5,900)	3,870 (1,950 – 7,380)

Table 21: Comparison of UK and Australian estimates of average willingness to pay to avoid pain and suffering for selected pathogens and illnesses.

Pathogen or illness (duration)	UK WTP (pounds)	UK WTP (AUD)*	AUS WTP (AUD)
All-cause infectious gastroenteritis (3 days)	60	124	33
Campylobacter/Salmonella (6 days)	77	159	138
GBS (1 year)	7,581	15,617	1,371
Reactive arthritis (1 year)	1,584	3,263	717
Irritable bowel syndrome (1 year)	13,653	28,125	530

*Converted using CCEMG – EPPI-Centre Cost Converter

Table 22 provides estimates of total willingness to pay for selected pathogens if UK WTP values were used in our costing model compared to those estimated using the Australian study. If substituted into our cost model, UK WTP estimates for all-cause gastro would make the cost of pain and suffering (approximated as the WTP to avoid such pain and suffering) the second largest component of the total cost of gastroenteritis, with a total cost of acute illness increasing from AUD 2.1 billion to AUD 2.5 billion. While estimates of WTP for campylobacteriosis and salmonellosis were similar between the two studies, the estimates for sequelae following these illnesses differed considerably. Use of the UK WTP values substantially increased the total cost of illness (including sequelae) due to *Campylobacter* from AUD 365 million to AUD 1.06 billion. For *Salmonella*, costs increase from AUD 140 million to AUD 305 million.

Table 22: Comparison of total costs due to willingness to pay to avoid pain and suffering for selected pathogens and illnesses using UK WTP values compared to using Australian WTP values.

Pathogen or illness (duration)	UK WTP values (millions 2019 AUD)	Australian WTP values (millions 2019 AUD)
All-cause infectious gastroenteritis – acute illness	579	154
Campylobacter – acute illness	42.0	36.5
Campylobacter – including sequelae	760	63.1
Salmonella – acute illness	9.79	8.50
Salmonella – including sequelae	180	15.5

Outbreak case studies

To explore economic costs associated with specific outbreaks of foodborne illness, including costs of control efforts and costs to businesses, we considered the following case studies. These studies were selected in consultation with FSANZ and members of the steering committee, taking into consideration pathogens that were fully costed in this report.

Salmonella Typhimurium in a bakery setting (2016)

An investigation into an outbreak of foodborne illness associated with a bakery was initiated by a notification from the hospital emergency department that people who had all eaten food purchased from the same bakery were presenting with gastroenteritis [69]. An epidemiological investigation initiated by the local public health unit (PHU) and the New South Wales Food Authority (NSWFA) found 203 people with illness following consumption of food from the bakery. In total, 45% (91/203) of cases were confirmed to have *Salmonella*, of which 83 were *Salmonella* Typhimurium and 81 had the same MLVA type.

The investigation identified that cases had purchased foods over a seven-day period, with common foods including bread rolls, mayonnaise, mayonnaise/margarine mix, and salad fillings. Among confirmed cases of *Salmonella*, 73% (58/91) presented to ED and 35% (32/91) were admitted to hospital.

An environmental investigation into the bakery detected *S.* Typhimurium in ready-to-eat foods on the premises and concluded that food handling practices were unsatisfactory. The bakery was closed for six weeks while these issues were corrected and fined AUD 120,000 (2016 dollars) for hygiene offences.

Using the outbreak tool, we calculated the following costs to the healthcare system associated with the outbreak. We assumed that all 203 cases were due to *Salmonella* acquired from the bakery and made the conservative assumption that all cases, hospitalisations, deaths, and ED visits were identified but only 91 cases were tested and that there were an additional 74 GP consultations. As we did not have access to data on the age of cases, we assumed they were all aged 5–64.

The total costs associated with cases detected in this outbreak were AUD 215,000, with the largest costs arising from lost productivity, followed by hospitalisations, with no cost due to premature mortality as no cases associated with this outbreak died. Note that as the total numbers of tests, ED visits, GP visits, and hospitalisations are described without any uncertainty from the outbreak report and we assumed a fixed cost for each of these, the totals for these items in Table 23 do not have 90% uncertainty intervals. These costs were incurred over one week of sales, so we might assume weekly costs equivalent to

this if the bakery was kept open without correcting these issues. Estimates from the NSW Food Authority put investigation costs at approximately $4,500 in testing of food samples and $7,200 in staff time, including field officers, coordination, and briefing (Craig Shadbolt, pers. com., 25 November 2021).

Table 23: Costs associated with *Salmonella* Typhimurium outbreak, 2016.

	Cost in AUD (2019 dollars) (90% Uncertainty Intervals)
GP consults *	2,870
ED visits *	20,000
Hospitalisations *	62,800
Tests *	5,560
Medications	2,040 (1,530 – 2,630)
Lost productivity in non-fatal illnesses	91,000 (79,600 – 105,000)
Willingness to pay to avoid illness*	30,800 (29,600 – 32,000)
Premature mortality*	0
TOTAL	215,000 (204,000 – 229,000)

* Costs associated with these events do not have intervals since we assume the number of items is known and there a fixed cost per item.

Listeria monocytogenes in rockmelons (2018)

Over the period February-May 2018, a multi-jurisdictional outbreak of *Listeria monocytogenes* infections affecting four jurisdictions was detected and linked to a rockmelon grower in New South Wales (NSW). There were a total of 22 confirmed cases, seven deaths, and one miscarriage (costed as an additional death). Within the 22 confirmed cases, the outbreak affected ten cases in elderly people in NSW, Victoria, and Queensland. A trade-level recall was issued in late February, and the onset of the last case was on the 10th of April 2018.

A summary of the costs associated with the outbreak cases is provided in Table 24. In this calculation, we assumed that confirmed cases were under-reported and adopted the same under-reporting multiplier as in our main costing model (see Appendix B) with all cases domestically acquired as in our main model. We made the conservative assumption that all deaths associated with the outbreak were reported. As data on hospitalisations and health service usage of these cases were not reported, we assumed that severity was consistent with broader human cases of listeriosis, and so estimated these cases were associated with 83 (90%UI: 39–141) GP visits, 83 (90%UI: 39–141) specialist visits, 43 (90%UI: 21–64) ED presentations, and 43 (90%UI: 21–64) hospitalisations.

The estimated total cost of the outbreak was AUD 40.8 million, with the largest component cost due to premature mortality. This total outbreak cost is considerable and of similar magnitude to the total yearly estimated cost due to listeriosis circa 2019, indicating the significance of this outbreak.

Table 24: Costs associated with the outbreak of *Listeria monocytogenes* in rockmelons in 2018.

	Cost in AUD (90% Uncertainty Intervals)
GP and specialist consults	8,920 (4,390 – 13,900)
ED visits	14,700 (7,340 – 22,200)
Hospitalisations	1,480,000 (738,000 – 2,230,000)
Tests	902 (450 – 1,360)
Medications	485 (241 – 729)
Lost productivity in non-fatal illnesses	110,000 (54,700 – 167,000)
Willingness to pay to avoid illness	27,600 (13,800 – 41,800)
Premature mortality*	39,200,000
TOTAL	40,800,000 (40,000,000 – 41,700,000)

* Costs associated with these events do not have intervals since we assume the number of items is known and a fixed cost per item.

In addition to costs associated with cases of listeriosis, there were considerable financial costs borne both by the implicated producer and by other rockmelon producers not involved in the outbreak. The implicated rockmelon producer ceased production for six weeks and conducted regular mandatory and additional voluntary testing. More broadly, all major Australian supermarkets withdrew rockmelons from late February 2018 until late March or April 2018. Some export markets (Indonesia, Kuwait, and Bahrain) temporarily banned all Australian rockmelons for varying durations of time, and other export markets (Malaysia and United Arab Emirates) temporarily introduced additional testing requirements for rockmelons [70, 71].

Data in Table 25 from a report for FSANZ by Freshlogic [72] are informative about the potential impact of the outbreak on the rockmelon industry. A comparison of 2019 to 2017 shows a 14% higher price, a reduction in volume of 47% and a reduction in market value of $13.1 million (40%).

Table 25: Economic output of the rockmelon industry from 2017 (prior to the outbreak) until 2019.

	2017	2018	2019
Price per kilo	$1.23	$1.11	$1.41
Volume in tonnes	26,720	8,321	14,090
Market value	$33 million	$9.3 million	$19.9 million

Salmonella Enteritidis in eggs (2019)

A widespread public health response involving health authorities, food regulators, and agriculture departments followed an extended period of detection of *Salmonella* Enteritidis in people, mainly from New South Wales (NSW). Prior to this outbreak, human cases of *Salmonella* Enteritidis were predominantly associated with individuals who had been infected outside Australia and returned from overseas travel.

In this outbreak, cases acquired locally in NSW, Victoria, Queensland, and Tasmania were linked using genomics to isolates from multiple egg layer farms in NSW and one farm in Victoria. The food regulatory response included eight distinct food recalls at both trade and consumer level over the period from September 2018 until June 2019. Consumer-level recalls are more extensive, aiming to recover food from all parts of the production and distribution arc, including from consumers. Trade-level recalls are used for food that is within the supply chain but not available for direct purchase by consumers, and so focus on the production and distribution chain but may also consider catering establishments.

Overall there were 235 confirmed cases with onset of illness between 18th May 2018 to 23rd May 2019, and one case died. We assumed no underreporting of deaths. Unlike point source outbreaks, we would expect confirmed cases to be only a fraction of the total cases in the community and adopt the same under-reporting multiplier as in our main costing model but set the domestically acquired multiplier to one. As data on hospitalisations and health service usage of these cases were not reported, we assumed that severity was consistent with broader human cases of salmonellosis. We estimated that there were a total of 1,180 (90%UI: 662–2,060) cases of salmonellosis (notified and not notified), associated with 426 (90%UI: 218–807) GP visits, 144 (90%UI: 62–318) ED presentations and 58 (90%UI: 23–144) hospitalisations.

Table 26 presents the costs associated with the human cases of illness, with a total cost of AUD 5.7 million, the largest component of this being due to premature mortality.

A rapid benefit-cost analysis (BCA) conducted on behalf of the NSW Department of Primary Industries in 2019 to compare the scenario of no targeted action against *Salmonella* Enteritidis with two scenarios involving more extensive tracing, surveillance, and actions on affected farms [73]. Costing of interventions against costs associated with *Salmonella* Enteritidis outbreaks, including human costs, lost exports, and costs of control. The analysis forecast benefits under both control scenarios (approximately AUD 100 million by 2021, rising to AUD 300 million by 2035). The report concluded that intervening was clearly economically viable and should be implemented.

Table 26: Costs associated with the outbreak of *Salmonella* Enteritidis from May 2018 until June 2019.

	Cost in AUD (90% Uncertainty Intervals)
GP consults	16,500 (8,490 – 31,200)
ED visits	49,700 (21,400 – 110,000)
Hospitalisations	113,000 (45,100 – 281,000)
Tests *	14,400
Medications	11,800 (6,190 – 21,800)
Lost productivity in non-fatal illnesses	433,000 (236,000 – 781,000)
Willingness to pay to avoid illness	168,000 (94,200 – 294,000)
Premature mortality*	4,900,000
TOTAL	5,720,000 (5,350,000 – 6,370,000)

* Costs associated with these events do not have intervals since we assume the number of items is known and a fixed cost per item.

Salmonella Weltevreden associated with frozen meals (2019)

In 2019, Australian health departments linked an outbreak of *Salmonella* Weltevreden to consumption of a frozen microwave meal product that had been distributed nationally. Although *Salmonella* does not grow when frozen, it can survive freezing and will not be killed unless the product is reheated thoroughly to above 75°C. A consumer-level recall of the product occurred on the 19th of October 2019, which was updated on the 29th of October 2019, as the product had been available for sale across much of Australia.

Over the period October 2019 to February 2020, investigators identified 83 confirmed cases of *Salmonella* Weltevreden. No deaths were reported with this outbreak, and we assume that reporting of deaths was accurate. However, due to the widespread distribution of the product, the confirmed cases are likely to be only a fraction of the total cases in the community. We used the same under-reporting multiplier as in our main costing model and set the domestically acquired multiplier to one. As data on the other health outcomes of these cases were not reported, we assumed similar severity to the general model of salmonellosis. We estimated that there were a total of 415 (90%UI: 233–725) cases of salmonellosis (reported and unreported), associated with 151 (90%UI: 77–284) GP visits, 51 (90%UI: 22–112) ED presentations and 21 (90%UI: 8–50) hospitalisations.

Table 27 presents the costs estimated for this outbreak. Unlike other outbreaks in this section, there were no reported deaths, and the largest component of the total cost was due to lost productivity.

Table 27: costs associated with *Salmonella* Weltevreden outbreak: October 2019 - February 2020.

	Cost in AUD (90% Uncertainty Intervals)
GP consults	5,820 (2,980 – 11,000)
ED visits	17,600 (7,530 – 38,700)
Hospitalisations	40,100 (15,900 – 98,500)
Tests*	5,070
Medications	4,150 (2,180 – 7,690)
Lost productivity in non-fatal illnesses	153,000 (83,000 – 274,000)
Willingness to pay to avoid illness	59,200 (33,100 – 104,000)
TOTAL	289,000 (160,000 – 515,000)

* Costs associated with these events do not have intervals since we assume the number of items is known and a fixed cost per item.

Surveillance and control costs

The World Health Organization defines public health surveillance as "the systematic collection, analysis, and interpretation of the morbidity and mortality data essential to the planning, implementation, and evaluation of public health practice and the timely dissemination of this information for public health action" [74]. In the context of foodborne disease, the primary tasks involved in surveillance and control include laboratory testing of clinical samples; molecular typing of foodborne pathogens; epidemiological investigations into human cases, clusters, or outbreaks of illness; prevention/control measures in response to identified outbreaks; enhanced surveillance of specific pathogens; regulation of food-related businesses; and sampling of food, food-producing animals, and the environment.

Foodborne disease surveillance and control in Australia involves agencies at national, jurisdictional, and local levels. Key agencies and networks include:

- OzFoodNet was established in 2000 as a collaboration between the Australian Government and jurisdictional health authorities to identify and respond to outbreaks of foodborne diseases and to provide information on foodborne disease. OzFoodNet funds epidemiologist(s) in every jurisdiction with a coordinating epidemiologist in the Office of Health Protection and Response in the Australian Government Department of Health.
- Communicable Diseases Network Australia (CDNA) provides leadership on the prevention and control of communicable diseases in Australia, which includes foodborne disease.
- Public Health Laboratory Network (PHLN) is a national network of laboratories in Australia with expertise in all aspects of public health microbiology. PHLN includes the major public health laboratory in each jurisdiction. The network aims to provide national advice relating to public health laboratories and to build on the existing capability of public health laboratories to respond to communicable disease outbreaks.
- Food Standards Australia New Zealand (FSANZ) is a statutory authority that develops food standards for Australia and New Zealand. In Australia, FSANZ coordinates food surveillance and prepares standards for primary production and processing and food hygiene. The agency is also responsible for coordinating food recalls and national food incident response.
- Food Regulation Standing Committee (FRSC) is responsible for coordinating policy advice on food regulations and ensuring a nationally consistent approach to the implementation and enforcement of food standards.

In each jurisdiction, staff from a range of organisations, including health departments, food safety agencies, and local government contribute directly to foodborne disease investigations and control of foodborne disease outbreaks. For example, within disease control sections of health departments and public health units, many staff not funded through OzFoodNet contribute to direct surveillance and investigation of foodborne disease.

Surveillance for foodborne pathogens

Australian states and territories are responsible for surveillance and control of infectious diseases, including those transmitted by foods. Each jurisdiction has public health legislation requiring doctors and laboratories diagnosing notifiable infections to report them to the state or territory health department. Health departments then transmit de-identified data on cases to the Australian Government Department of Health under the National Health Security Act (2007). National data on notifiable infections are housed in the National Notifiable Disease Surveillance System. The core dataset includes jurisdiction, age, sex, Indigenous status, postcode of residence, date of onset, and date of report. Additional data on species, type, and vaccination status of cases are included where appropriate.

In 2010, OzFoodNet commenced using the National Enhanced Listeriosis Surveillance System (NELSS) to collect additional data (molecular subtyping and interview data) on all notified listeriosis cases in Australia. Case interviews are conducted at time of diagnosis by jurisdictional health staff with the aim of detecting clusters and initiating public health investigation and response in a timely manner. From 2016, whole genome sequencing data with fortnightly phylogenetic analysis were included in reporting [28].

Pathogens and diseases of relevance for foodborne disease surveillance that are captured by NNDSS include botulism, *Campylobacter*, cholera, HUS, hepatitis A, hepatitis E, *Listeria monocytogenes*, *Salmonella*, STEC, *Shigella*, and Typhoid/Paratyphoid fever. Surveillance of these pathogens involves staff at the Australian Government, jurisdictional health departments, local public health unit, and local government levels, with tasks spanning epidemiological investigations, database maintenance, data entry and checking, and reporting.

OzFoodNet plays a critical role in coordinating surveillance associated with foodborne disease, including both investigation into sporadic cases and outbreak investigations. Over 2011–2016, the OzFoodNet outbreak register tracked an average of 168 outbreaks per year, of which 154 were foodborne or suspected to be foodborne. Eleven outbreaks were multi-jurisdictional [25-28]. An earlier section of this report explored example outbreaks in more detail. The Australian Government provided a financial contribution of $1.86 million in the 2020/2021

financial year to states and territories to support the enhanced disease surveillance and response to foodborne outbreaks [75].

In addition to staff funded through OzFoodNet, each jurisdiction employs staff to support foodborne disease surveillance and outbreak investigation. Roles include epidemiologists, data entry staff, data managers, environmental health officers, and public health physicians. Other agencies such as local government, Food Safety, and Departments of Agriculture often play a direct role in the environmental investigation and control of outbreaks, including through food and animal sampling as described below. As staff may work across multiple pathogen groups, disaggregating costs associated with foodborne illness is challenging and we have not attempted it here.

Laboratory testing, typing, and sequencing

Laboratory testing encompasses clinical samples from human cases and non-clinical samples from food, animal, and environmental surveillance (described separately below). Testing of clinical samples is typically funded through Medicare and is covered by our costing model above. If a sample tests positive for a foodborne pathogen, it may be further typed or whole genome sequenced. This typing and sequencing occurs at reference laboratories, and smaller jurisdictions (ACT, NT, Tasmania) will typically forward samples to another jurisdiction with a reference laboratory.

Typing and sequencing practices vary by pathogen and jurisdiction, making costs difficult to calculate nationally. For example, an analysis of testing and typing costs for *Salmonella* in Australia circa 2018 found that sequencing costs were approximately USD 70–100 per isolate, while typing using MLVA (multiple locus variable number of tandem repeats analysis) costed between USD 25 and USD 100 per isolate [76]. Key staff costs associated with testing and typing include laboratory staff, data-entry staff, and bioinformaticians.

Sampling of food and food-producing animals

In addition to sampling of clinical samples, there is considerable sampling of food and food-producing animals for pathogens causing foodborne illness. Much of this sampling takes place at a jurisdictional level, with different bodies responsible for this sampling in different jurisdictions.

For example, in NSW, the NSW Food Authority (NSWFA) conducts inspections at the processing, storage, distribution, and retail stages of food production. In the financial year July 2019 – June 2020, the NSWFA submitted 4,540 samples for testing, with 3,622 associated with food safety compliance [77].

Food regulation

Within Australia, food regulation consists of a range of laws, policies, standards, and processes to:

- Protect the health and safety of consumers
- Ensure consumers can make informed choices
- Promote healthy food choices
- Support the food industry to provide diverse and affordable food

FSANZ plays a key role in food regulation in Australia, with an annual budget of AUD 29.9 million in 2019–2020 [78].

Summary

Although extensive costs of all aspects of the surveillance and regulation of foodborne disease are difficult to estimate, components of these costs include:

- Surveillance of foodborne pathogens, including a financial contribution of $1.86 million for OzFoodNet, with considerable additional staff supporting public health surveillance of foodborne illness.
- Laboratory testing, typing, and sequencing of clinical samples.
- Sampling of food and food-producing animals, including testing and typing of these samples.
- Food regulation, including $29.9 million for FSANZ.

Given the complexity of the system for surveillance and control of foodborne pathogens in Australia, an extensive analysis would be required to provide full costings.

Study comparisons and data limitations

International comparison of incidence by pathogen

The notified incidence of known pathogens differs between countries (see Table A1 for examples). Previous collaborative work involving multiple countries (including Ireland, Canada, the US, and Australia) looked at differences in symptom profiles and other factors but was unable to reach a definitive conclusion on the factors driving these differences. However, these differences must be acknowledged when comparing cost estimates by country, and cross-country comparisons remains a key area for future research.

International comparison of cost per case

An international comparison of cost per case demonstrates variation in pathogen-specific costs (

Table 28). Where there are two or more studies to compare with, the Australian costs lie within the international estimates for all pathogens except STEC and *T. gondii*, where the Australian costs are lower. Given the considerable discrepancy for *T. gondii,* there may be a need for further studies on this pathogen.

International comparison of willingness to pay values

As demonstrated in the sensitivity analysis, choice of WTP values can considerably impact final costs. Previous research has found that WTP values can be sensitive to the elicitation format, including the framing of the question used to estimate them [79]. While both the UK and Australian study applied DCE methods, the framing of the task and attributes/characteristics included in the studies to derive the WTP measures differed. The UK study used two parallel approaches: EQ-5D-3L (EuroQuol 5 dimension, 3 level) health questionnaire and a vignette descriptions of symptoms. The Australian study used a vignette approach with two levels (mild and severe) for each condition. One main difference between the two studies was how productivity losses were accounted for. The UK study controlled for productivity losses to the extent that participants were encouraged to think about pain, grief, and suffering in isolation of the other attributes (e.g. loss of income), when completing the choice task [67]. In contrast, the Australian study explicitly included an additional attribute for sick leave to allow for an effect separate from productivity losses [4].

Table 28: Comparison of international estimates of cost per case for selected pathogens converted using the CCEMG – EPPI-Centre Cost Converter.

		Australia	UK†	US††	Netherlands*	New Zealand**
Campylobacter	Local currency	-	£ 2,400	USD 2,283	€ 940	NZD 872
	2019 AUD	1,382	5,060	3,642	1,679	1,028
Non-typhoidal *Salmonella*	Local currency	-	£ 6,700	USD 3,568	€ 860	NZD 5,622
	2019 AUD	2,273	14,125	5,692	1,536	6,629
Listeria monocytogenes	Local currency	-	£ 230,700	USD 1,781,549	€ 48,000	NZD 660,000
	2019 AUD	776,000	486,354	2,842,258	8,573	778,188
Norovirus	Local currency	-	£ 4,400	USD 413	€ 190	NZD 362
	2019 AUD	390	9,276	659	339	427
Shigella spp.	Local currency	-	£ 7,500	USD 1,051	-	-
	2019 AUD	1,767	15,811	1,677	-	-
Shiga toxin-producing *Escherichia coli*	Local currency	-	£ 8,400	USD 4,298	€ 5,200	NZD 69,667
	2019 AUD	4,449	17,709	6,857	9, 287	82,142
Other pathogenic *Escherichia coli*	Local currency	-	-	USD 243	-	-
	2019 AUD	426	-	388	-	-
Salmonella Typhi	Local currency	-	-	-	-	-
	2019 AUD	16,207	-	-	-	-
Toxoplasma gondii	Local currency	-	-	USD 38,114	€ 61,000	-
	2019 AUD	845	-	60,807	108,944	-
Yersinia enterocolitica	Local currency	-	-	USD 2,848	-	NZD 404
	2019 AUD	1,450	-	4,544	-	476

† Daniel 2020 [9] shown as 2018 £ followed by 2019 AUD. †† Hoffmann 2015 [8] shown as 2013 USD followed by 2019 AUD. * Lagerweij 2020 [80] shown as 2020 € followed by 2019 AUD ** Gadiel 2010 [10] shown in 2009 NZD followed by 2019 AUD.

Table 29: Comparison of costs in the 2006 Abelson report and this study in thousands of AUD, converted using the CCEMG – EPPI-Centre Cost Converter.

	Abelson study		This study
	2004 AUD	2019 AUD	2019 AUD
Gastroenteritis due to all causes	811,000	1,202,183	2,100,000
Listeriosis	83,100	123,183	78,400
Toxoplasmosis	1,710	2,535	13,100
Haemolytic uraemic syndrome	6,740	9,991	8,970
Irritable bowel syndrome	36,500	54,106	88,200
Guillain-Barré syndrome	25,400	37,652	42,800
Reactive arthritis	40,000	59,234	94,700

Comparison with prior estimates for Australia

Prior estimates of the cost of foodborne illness were produced by Abelson et al in 2006 with most costs circa 2004. That study estimated the total cost of foodborne illness at AUD 1.25 billion per year, with lost productivity contributing AUD 771 million (62%) of costs. In comparison, this study estimated a total cost of AUD 2.44 billion per year, with lost productivity contributing AUD 1.55 billion (64%) of costs. The Abelson report did not provide individual costs for pathogens causing gastroenteritis (such as *Salmonella* and *Campylobacter*) but did calculate costs for sequelae and pathogens that do not cause gastroenteritis (such as *Listeria monocytogenes* and *T. gondii*). Table 29 provides a comparison of costs for the two studies.

Key data limitations

We were not able to estimate any costs due to ongoing illness following toxoplasmosis or listeriosis and included only ongoing willingness to pay to avoid pain and suffering for the four sequelae considered here. This was due to an absence of long-term studies of direct costs and lost productivity in individuals with these illnesses. Data on the number of individuals with ongoing illness due to toxoplasmosis or listeriosis are poor. This, together with the lack of long-term studies following individuals with these ongoing illnesses in addition to the four main sequelae is a notable gap in evidence required to cost foodborne illness.

Data on incidence of symptomatic toxoplasmosis are not available. As in previous work [2], we used seroprevalence data to infer overall incidence and assumed a proportion of these incident cases were symptomatic (in line with Scallan *et al.* [81]). Our rapid review of relevant papers identified recent seroprevalence estimates from a study conducted in Australia [20]. Although the sample size for this Busselton study was lower than that of the US study we used in prior work, we decided it was more appropriate to use as it was both more recent and based in Australia. Estimates of incidence from this study were considerably higher

than in previous work (approximately a factor of 4 times higher), and this led to higher estimates of symptomatic toxoplasmosis in this project and overall higher costs estimated for toxoplasmosis than in the previous estimation study.

Conclusions

Circa 2019, foodborne illness and its sequelae costs Australia AUD 2.44 billion each year (90% uncertainty interval: 1.65–3.68 billion), with lost productivity the largest contributor to this total cost. High-cost pathogens include *Campylobacter* (AUD 365 million per year), and *Salmonella*, norovirus, and other pathogenic *E. coli*, that are each estimated to cost over AUD 100 million each year.

These estimates provide evidence to support foodborne disease control efforts, while pathogen-specific costs also provide one piece of evidence to inform the prioritisation of interventions towards those causing the greatest burden to society. The additional studies needed to inform this prioritisation are those to assess the cost effectiveness (considering incremental costs and benefits) of proposed interventions [82]. Costs by age group and itemised by components also assist in identifying the populations at risk and key component costs to better target interventions.

Although lost productivity is the largest component of the costs for most pathogens and illnesses, premature mortality is the leading cost for pathogens that cause severe illness (*Listeria monocytogenes* and *Salmonella*), and the cost of pain and suffering, approximated via the willingness to pay to avoid pain and suffering, is the largest cost for irritable bowel syndrome.

As lost productivity is a key contributor to total and pathogen-specific costs, we conducted a sensitivity analysis on the model for lost productivity, comparing the human capital approach with the more conservative friction cost approach. As the mean duration of lost work estimated for pathogens and illnesses were typically less than the three-month cut-off generally assumed by the friction cost model, these alternate models adjust lost productivity costs by a multiplicative fraction. The difference in the methodology reflects who bears the burden, the employer (estimated via the friction cost method) or the individual (estimated by the human capital method) and the type of productivity losses over time [83]. As demonstrated here, the total cost varies considerably with method. While the human capital methodology is considered to overestimate production costs and does not account for coping mechanisms, the friction cost method has been criticised for underestimating productivity losses. It assumes that a replacement can be found in the period and only considers a single friction period and not the multiplier effect of employees, including moving jobs and creating a chain of vacancies each with their own friction period [83]. Additionally it values leisure time lost due to illness as zero [84]. By testing both approaches we provide information on likely upper bound cost of productivity loss based on the human capital approach and a likely lower bound based on the friction cost approach. The decision of which method to adopt should be carefully considered in relation to the cost burden and the absentee time impact.

Given the availability of Australian-based WTP values to avoid pain and suffering, these have been used in this study in preference to international figures which may not be readily transferable to an Australia setting due to country specific differences and differences in preferences by country. The Australian values are lower than that estimated in a similar study for the UK [67]. A sensitivity analysis adopting the UK willingness to pay values showed increases in costs associated with all-cause gastroenteritis and to pathogens such as *Salmonella* and *Campylobacter*, primarily through differences in willingness to pay for sequelae. As the UK study did not cost *T. gondii* or report willingness to pay values for illness components relevant to *Listeria monocytogenes*, we were not able to directly compare those pathogens.

Owing to a lack of long-term data on ongoing illness following listeriosis or toxoplasmosis, costs due to continuing ill health or disability from these illnesses are not included in this study. Consistent with other studies [9, 85], premature mortality dominates costs for listeriosis; however, the Netherlands identified ongoing costs as the next largest component for listeria (9% of the total cost in the Netherlands), indicating a need to better quantify ongoing illness in future studies. Further, it is notable that non-STEC pathogenic *E. coli* is one of the pathogens with highest estimated cost in this study, yet it is very poorly understood and the data underlying the estimates are from old studies. Further research may be needed here to better understand the burden and potential control measures.

The inclusion of a costing tool with this report will enable health and food regulatory authorities to update cost estimates and to apply them to cost outbreaks. Although many of the epidemiological inputs to this costing can be readily updated from publicly available datasets, estimates of incidence for all-cause gastro and for pathogens that are non-notifiable rely on studies that are now several years old. Additional studies may be needed to ensure estimates remain contemporary.

References

1. Glass K, Ford L, Hall G, Wong D, Kirk M. The cost of foodborne illness in Australia, circa 2015: age- and sex-specific estimates of incidence, hospitalisations and deaths due to contaminated food. Report to the New South Wales Food Authority.; 2016.

2. Glass K, Ford L, Hall G, Wong D, Kirk M. Health outcome trees for priority foodborne pathogens and conditions for economic costing. Report to Food Standards Australia New Zealand. 2016.

3. Ford L, Glass K, Kirk M. The cost of foodborne illness in Australia, circa 2015: Health care usage and absenteeism due to foodborne illness. Report to the New South Wales Food Authority. 2018.

4. Manipis K, Mulhern B, Haywood P, Viney R, Goodall S. Estimating the willingness-to-pay to avoid the consequences of foodborne illnesses: a discrete choice experiment. Eur J Health Econ. 2022.

5. Havelaar AH, Kirk MD, Torgerson PR, Gibb HJ, Hald T, Lake RJ, et al. World Health Organization Global Estimates and Regional Comparisons of the Burden of Foodborne Disease in 2010. PLoS Med. 2015;12(12):e1001923.

6. Kirk M, Ford L, Glass K, Hall G. Foodborne illness, Australia, circa 2000 and circa 2010. Emerg Infect Dis. 2014;20(11):1857-64.

7. Ford L, Kirk M, Glass K, Hall G. Sequelae of foodborne illness caused by 5 pathogens, Australia, circa 2010. Emerg Infect Dis. 2014;20(11):1865-71.

8. Hoffmann S, Maculloch B, Batz M. Economic Burden of Major Foodborne Illnesses Acquired in the United States. Economic Information Bulletin. 2015;140.

9. Daniel N, Casadevall N, Sun P, Sugden D, Aldin V. The Burden of Foodborne Disease in the UK 2018. 2020.

10. Gadiel D, Abelson P. The economic cost of foodborne disease in New Zealand. Applied Economics Pty Ltd; 2010.

11. Abelson P, Potter Forbes M, Hall G. The annual cost of foodborne illness in Australia. 2006.

12. Bright A, Glynn-Robinson A-J, Kane S, Wright R, Saul N. The effect of COVID-19 public health measures on nationally notifiable diseases in Australia: preliminary analysis. Communicable Diseases Intelligence. 2020;44.

13. R Core Team. R: : A language and environment for statistical computing. Vienna, Austria2021 [Available from: https://www.R-project.org/.

14. Chang W, Cheng J, Allaire J, Sievert C, Schloerke B, Xie Y, et al. Shiny: Web Application Framework for R. R package version 1.7.1. 2021 [Available from: https://CRAN.R-project.org/package=shiny.

15. Kirk M. National Gastroenteritis Survey II (NGSII). 2008.

16. Hellard ME, Sinclair MI, Forbes AB, Fairley CK. A Randomized, Blinded, Controlled Trial Investigating the Gastrointestinal Health Effects of Drinking Water Quality. Environmental Health Perspectives. 2001;109(8):773-8.

17. Australian Government Department of Health. National Notifiable Diseases Surveillance System 2020 [Available from: http://www9.health.gov.au/cda/source/cda-index.cfm].

18. Australian Government Institute of Health and Welfare. Principal Diagnosis data cubes 2020 [Available from: https://www.aihw.gov.au/reports/hospitals/principal-diagnosis-data-cubes/contents/data-cubes.

19. Kaper JB, Nataro JP, Mobley HLT. Pathogenic Escherichia coli. Nature Reviews Microbiology. 2004;2(2):123-40.

20. Molan A, Nosaka K, Hunter M, Wang W. Seroprevalence and associated risk factors of Toxoplasma gondii infection in a representative Australian human population: The Busselton health study. Clinical Epidemiology and Global Health. 2020;8(3):808-14.

21. 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.

22. Mead PS, Slutsker L, Dietz V, McCaig LF, Bresee JS, Shapiro C, et al. Food-related illness and death in the United States. Emerg Infect Dis. 1999;5(5):607-25.

23. Hoffmann S, Batz M, Morris Jr J. Annual Cost of Illness and Quality-Adjusted Life Year Losses in the United States Due to 14 Foodborne Pathogens. Journal of Food Protection. 2012;75(7):1292-302.

24. Australian Bureau of Statistics. National, state and territory population. 3101.0 Australian Demographic Statistics; TABLES 51-59 2021 [Available from: https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population.

25. The OzFoodNet Working Group. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet network, 2011. Commun Dis Intell. 2015;39(2).

26. The OzFoodNet Working Group. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet network, 2012. Commun Dis Intell. 2018;42.

27. The OzFoodNet Working Group. Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet network, 2013-2015. Commun Dis Intell. 2021;45.

28. The OzFoodNet Working Group. Monitoring the incidence and causes of disease potentially transmitted by food in Australia: Annual report of the OzFoodNet network, 2016. Comunicable Diseases Intelligence. 2021;45.

29. Australian Government Department of Health. Manual of resource items and their associated unit costs - December 2016. In: The Pharmaceutical Benefits Scheme, editor. 2016.

30. Scharff R. Economic Burden from Health Losses Due to Foodborne Illness in the United States. Journal of Food Protection. 2012;75(1):123-31.

31. Hoffmann S, Anekwe T. Making Sense of Recent Cost-of- Foodborne-Illness Estimates. 2013.

32. Hubbell B. QALY Paper for Environmental and Resource Economics. 2002.

33. Pike J, Grosse SD. Friction Cost Estimates of Productivity Costs in Cost-of-Illness Studies in Comparison with Human Capital Estimates: A Review. Appl Health Econ Health Policy. 2018;16(6):765-78.

34. Australian Government Department of Health. Guidelines for preparing a submission to the Pharmaceutical Benefits Advisory Committee, Version 4.3. In: Department of Health, editor. Version 4.3 ed2016.

35. Pearce A, Manipis K, Haywood P, Hanly P, Goodall S. Local Inputs for A Societal Perspective: Estimating the Friction Period in Australia. Value in Health. 2018;21:S88.

36. Wilson D, Kwon A, Anderson J, Thein R. Return on investment 2: evaluating the cost-effectiveness of needle and syringe programs in Australia 2009. In: National Centre in HIV Epidemiology and Clinical Research, editor. 2009.

37. Health and Safety Executive. Costs to Britain of workplace fatalities and self-reported injuries and ill health, 2018/19. 2020.

38. Cancer Research Economics Support Team. Productivity Losses and How they are Calculated. 2019.

39. New Zealand Treasury. Guide to Social Cost Benefit Analysis. 2015.

40. Australian Government Department of Health. Guidelines for preparing a submission to the Pharmaceutical Benefits Advisory Committee, Version 5.0. In: Department of Health, editor. Version 5.0 ed2016.

41. Tan SS, Bouwmans CA, Rutten FF, Hakkaart-van Roijen L. Update of the Dutch Manual for Costing in Economic Evaluations. Int J Technol Assess Health Care. 2012;28(2):152-8.

42. Kigozi J, Jowett S, Lewis M, Barton P, Coast J. Estimating productivity costs using the friction cost approach in practice: a systematic review. Eur J Health Econ. 2016;17(1):31-44.

43. Ponto KA, Merkesdal S, Hommel G, Pitz S, Pfeiffer N, Kahaly GJ. Public health relevance of Graves' orbitopathy. J Clin Endocrinol Metab. 2013;98(1):145-52.

44. Koopmanschap MA, van Exel JN, van den Berg B, Brouwer WB. An overview of methods and applications to value informal care in economic evaluations of healthcare. Pharmacoeconomics. 2008;26(4):269-80.

45. Jones-Lee M. The Value of Life: An Economic Analysis: University of Chicago Press; 1976. 162 p.

46. Australian Government Department of Prime Minister and Cabinet Office of Best Practice Regulation. Best Practice Regulation Guidance Note: Value of statistical life. 2019.

47. Ford L, Haywood P, Kirk MD, Lancsar E, Williamson DA, Glass K. Cost of Salmonella Infections in Australia, 2015. Journal of Food Protection. 2019;82(9):1607-14.

48. Australian Government Institute of Health and Welfare. Patients' out-of-pocket spending on Medicare services, 2016-17. 2018.

49. Reeve R, Haas M. Estimating the cost of Emergency Department presentations in NSW. CHERE Working Paper 2014/01. Open Publications of UTS Scholars. 2014.

50. Rajapakse S, Chrishan Shivanthan M, Samaranayake N, Rodrigo C, Deepika Fernando S. Antibiotics for human toxoplasmosis: a systematic review of randomized trials. Pathog Glob Health. 2013;107(4):162-9.

51. Australian Bureau of Statistics. Labour Force, Australia, Detailed: Detailed monthly and quarterly Labour Force Survey data, including hours, regions, families, job search, job duration, casual, industry and occupation, Sept 2021 2021 [updated 21/10/2021. Available from: https://www.abs.gov.au/statistics/labour/employment-and-unemployment/labour-force-australia-detailed/latest-release.

52. Hillilä MT, Färkkilä NJ, Färkkilä MA. Societal costs for irritable bowel syndrome--a population based study. Scand J Gastroenterol. 2010;45(5):582-91.

53. Buono JL, Carson RT, Flores NM. Health-related quality of life, work productivity, and indirect costs among patients with irritable bowel syndrome with diarrhea. Health Qual Life Outcomes. 2017;15(1):35.

54. Brun-Strang C, Dapoigny M, Lafuma A, Wainsten JP, Fagnani F. Irritable bowel syndrome in France: quality of life, medical management, and costs: the Encoli study. Eur J Gastroenterol Hepatol. 2007;19(12):1097-103.

55. Forsberg A, de Pedro-Cuesta J, Widén Holmqvist L. Use of healthcare, patient satisfaction and burden of care in Guillain-Barre syndrome. J Rehabil Med. 2006;38(4):230-6.

56. Frenzen PD. Economic cost of Guillain-Barré syndrome in the United States. Neurology. 2008;71(1):21-7.

57. 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(12):1689-96.

58. Söderlin MK, Kautiainen H, Jonsson D, Skogh T, Leirisalo-Repo M. The costs of early inflammatory joint disease: a population-based study in southern Sweden. Scandinavian Journal of Rheumatology. 2003;32(4):216-24.

59. Hannu T, Mattila L, Rautelin H, Pelkonen P, Lahdenne P, Siitonen A, et al. Campylobacter-triggered reactive arthritis: a population-based study. Rheumatology. 2002;41(3):312-8.

60. 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(2):125-31.

61. 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. Clinical Gastroenterology and Hepatology. 2007;5(4):457-60.

62. Leirisalo-Repo M, Helenius P, Hannu T, Lehtinen A, Kreula J, Taavitsainen M, et al. Long-term prognosis of reactive salmonella arthritis. Ann Rheum Dis. 1997;56(9):516-20.

63. de Noordhout CM, Devleesschauwer B, Angulo FJ, Verbeke G, Haagsma J, Kirk M, et al. The global burden of listeriosis: a systematic review and meta-analysis. Lancet Infect Dis. 2014;14(11):1073-82.

64. Havelaar AH, Kemmeren JM, Kortbeek LM. Disease burden of congenital toxoplasmosis. Clin Infect Dis. 2007;44(11):1467-74.

65. Wang Y, Lang W, Zhang Y, Ma X, Zhou C, Zhang H-L. Long-term prognosis of Guillain-Barré syndrome not determined by treatment options? Oncotarget. 2017;8(45):79991-80001.

66. Australian Government Department of Prime Minister and Cabinet. The Australian Government Guide to Regulation. Canberra, Australia; 2014.

67. Economics for the Environment Consultancy Ltd, University of Manchester, University of Liverpool. Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (Phase 2): Final Report for the Food Standards Agency (FSA) and Food Standards Scotland (FSS). 2017.

68. Daly E, Odzemiroglu E, Mistry R, Gianferrara E. Consumer willingness to pay for food safety health outcomes: Final report. 2013.

69. Communicable Diseases Branch. NSW OzFoodNet Annual Surveillance Report: 2016. Sydney; 2017.

70. Fullelove D. In-market visits: Dubai, Saudi Arabia, Bahrain, Kuwait. 2019.

71. Fullelove D. In-market visits: Japan, Singapore and Malaysia. 2019.

72. Freshlogic. Assessment of economic impact of food safety incidences in fresh fruit and vegetables: report for Food Standards Australia & New Zealand. 2020.

73. The Centre for International Economics. Draft Report: Rapid cost-benefit analysis framework: Biosecurity emergency response - Report for NSW Department of Primary Industries. 2019.

74. World Health Organization. Foodborne disease outbreaks : guidelines for investigation and control2008.

75. Federal Financial Relations. OzFoodNet Program: National Partnership for Streamlined Agreements 2020 [Available from: https://federalfinancialrelations.gov.au/sites/federalfinancialrelations.gov.au/files/2021-06/ozfoodnet_combinedsignatures.pdf.

76. Ford L, Glass K, Williamson DA, Sintchenko V, Robson JMB, Lancsar E, et al. Cost of whole genome sequencing for non-typhoidal Salmonella enterica. PLOS ONE. 2021;16(3):e0248561.

77. NSW Food Authority. Annual Report, 2019-2020. 2020.

78. Australian Government Department of Health. Budget 2019-20: Portfolio Budget Statements 2019-20. Budget Related Paper No. 1.9. Health Portfolio. 2019.

79. van der Pol M, Ryan M, Donaldson C. Valuing food safety improvements using willingness to pay. Appl Health Econ Health Policy. 2003;2(2):99-107.

80. Lagerweij GR, Pijnacker R, Friesema IHM, Mughini Gras L, Franz E. Disease burden of food-related pathogens in the Netherlands, 2019. 2020.

81. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson M-A, Roy SL, et al. Foodborne illness acquired in the United States--major pathogens. Emerg Infect Dis. 2011;17(1):7-15.

82. Shiell A, Gerard K, Donaldson C. Cost of illness studies: an aid to decision making? Health Policy. 1987;8:317-23.

83. van den Hout WB. The value of productivity: human-capital versus friction-cost method. Ann Rheum Dis. 2010;69(Suppl 1):i89.

84. Brouwer WB, Koopmanschap MA. The friction-cost method : replacement for nothing and leisure for free? Pharmacoeconomics. 2005;23(2):105-11.

85. Haagsma J, van der Zanden, B.P., Tariq, L., van Pelt, W., van Duynhoven, Y.T.P.H., Havelaar, A.H. Disease burden and costs of selected foodborne pathogens in the Netherlands, 2006. Report 330331001/2009. 2009.

86. Australian Bureau of Statistics. National, state and territory population 2021 [Available from: https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/dec-2020.

87. Hall G, Yohannes K, Raupach J, Becker N, Kirk M. Estimating Community Incidence of *Salmonella*, *Campylobacter*, and Shiga Toxin-producing *Escherichia coli* Infections, Australia. Emerg Infect Dis. 2008;14(10):1601-9.

88. Vally H, Glass K, Ford L, al e. Proportion of illness acquired by foodborne transmission for nine enteric pathogens in Australia: An expert elicitation. Foodborne Pathogens and Disease. 2014;1(9):727-33.

89. Sinclair MI, Hellard ME, Wolfe R, Mitakakis TZ, Leder K, Fairley CK. Pathogens causing community gastroenteritis in Australia. Journal of Gastroenterology and Hepatology. 2005;20(11):1685-90.

90. Canavan C, West J, Card T. The epidemiology of irritable bowel syndrome. Clin Epidemiol. 2014;6:71-80.

91. Hannu T, Mattila L, Siitonen A, Leirisalo-Repo M. Reactive arthritis attributable to Shigella infection: a clinical and epidemiological nationwide study. Ann Rheum Dis. 2005;64(4):594-8.

92. World Health Organization. WHO Model Formulary 2008. 2009.

93. Uotila TM, Antonen JA, Paakkala AS, Mustonen JT, Korpela MM. Outcome of reactive arthritis after an extensive Finnish waterborne gastroenteritis outbreak: a 1-year prospective follow-up study. Clin Rheumatol. 2013;32(8):1139-45.

Appendix A: User's guide to the costing tool

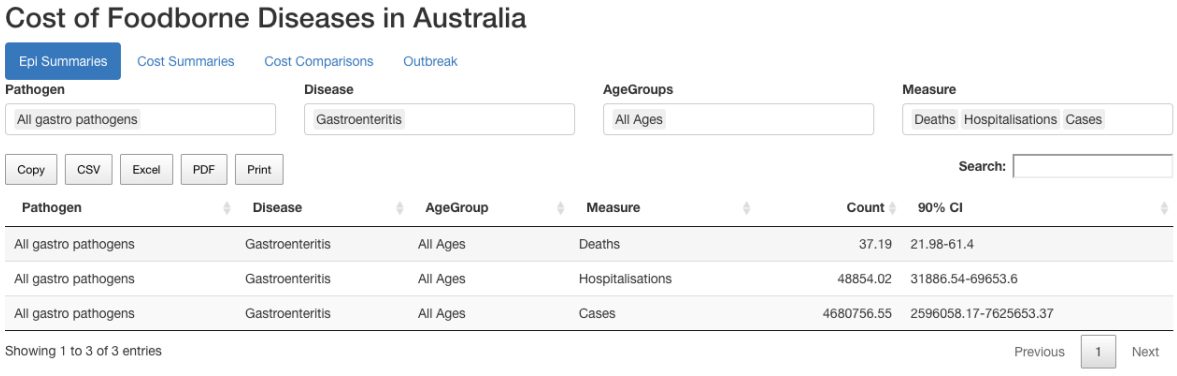
The model was developed by Dr Angus McLure, with code for the model presented here available on GitHub (https://github.com/AngusMcLure/FSANZ-ANU-Foodborne-Illness-Costing).

Guide to the user interface

The user interface has four tabs to support different uses of the model.

The first three tabs provide an alternative way to explore and summarise the national estimates of burden and costs associated foodborne disease. The first tab "Epi Summaries" provides epidemiological estimates of the national burden of disease for each pathogen or illness, circa 2019. The second tab "Cost Summaries" provides totals for each pathogen or illness in broad cost categories (direct costs, non-fatal productivity losses, pain and suffering, and premature mortality). The third tab "Cost comparisons" provides more detail on individual costs, listing costs such as tests and medications and health care usage individually. The final tab is used to cost outbreaks.

Epi Summaries



The "Epi Summaries" tab compares and summarises the national estimates, circa 2019, of the counts of cases, hospitalisations, and deaths for all costed pathogens and illnesses. The *pathogen* field is used to specify the pathogen to consider (or select totals across all pathogens or all pathogens causing gastroenteritis), while the *disease* field can include the primary illness and any sequelae resulting from this illness. The *age group* field allows for counts by age group (<5, 5–64, 65+) or a total over all ages, while the *measure* field includes the measure to be considered (cases, hospitalisations, or deaths). Multiple selections

can be made for each field to provide a comparison over pathogens or by age. The resulting table contains the count estimate and the simulated 90% intervals.

Cost Summaries

The "Cost Summaries" tab compares and summarises the national estimates, circa 2019, of the costs associated with each pathogen and illness included in this report. As with the Epi Summaries tab, the "Cost Summaries" tab has multiple fields to specify *pathogen*, *disease*, and *age group*. The final selection for this tab is the choice of method for estimating lost productivity, which can be human capital, friction high, or friction low. Details of the underlying assumptions for these different models are provided in this report. The resulting table contains costs in thousands of Australian dollars, with a 90% uncertainty interval.

Cost Comparisons

The "Cost Comparisons" tab is like the “Cost Summaries” tab, but provides a more detailed comparison of individual costs, with potential to compare costs due to specific categories of premature mortality, ED presentations, GP and specialist consultations, hospitalisations, medications, tests, pain and suffering, pain and suffering due to ongoing illness, and lost productivity. This tab allows for side-by-side comparisons of costs across age groups, pathogen, disease (initial diseases and sequelae), and cost category. As above, three alternative models for lost productivity are available.

Outbreak

The "Outbreak" tab allows the estimation of costs associated with an outbreak. After choosing one of the ten pathogens modelled in this report and entering the number of confirmed cases (required), deaths (optional), or hospitalisations (optional), the tool will estimate the costs, reporting them in the same format as presented in the ‘Cost Summaries Tab’. The tool provides options to adjust the confirmed cases for underreporting, non-foodborne exposure routes, and overseas acquired cases using the pathogen-specific multipliers used in the burden model in this report. If the number of deaths or hospitalisations are not provided, the tool will estimate these numbers by multiplying the number of cases by the proportion of cases that died or required hospitalisation due to infection with that pathogen in the national burden model in this report. Similarly, the tool will estimate the number of sequelae (where relevant) by multiplying the number of cases by the proportion of cases that developed sequelae in the national burden model in this report. The estimated (or provided) number of cases, sequelae, deaths, and hospitalisations are then used to generate estimates of costs.

Appendix B: Model assumptions

Pathogen and illness-specific health-care usage assumptions

The following tables summarise multipliers and data sources for gastroenteritis due to all causes and for each pathogen and sequelae, in line with Kirk *et al.* and Ford *et al.* [6, 7]. The definitions of each multiplier and model parameter are as follows:

Term	*Definition*
Bacterial multiplier	Proportion of sequelae due to the associated pathogen
Correction factor	Adjustment when data does not include all states
Domestically acquired multiplier	Proportion of cases, hospitalisations and deaths acquired in Australia
ED proportion	Proportion of cases that visit the emergency department
Foodborne multiplier	Proportion of cases, hospitalisations and deaths acquired from food
Gastroenteritis multiplier	Proportion of Australians experiencing gastroenteritis
GP proportion	Proportion of cases that attend general practice
Hospitalisation code	International Classification of Diseases 10-AM code
Mortality code	International Classification of Diseases 10 code
Ongoing illness proportion	Proportion of cases that experience ongoing illness
Percent hospitalisations principal	Percent of all hospitalisations where the diagnosis is coded as the principal reason for admission
Sequelae multiplier	Proportion of cases of the associated pathogen that lead to this sequelae
Under-diagnosis multiplier	Adjustment for requirement for laboratory testing to confirm hospitalisations and deaths
Under-reporting multiplier	Adjustment for under-notification of incident cases

Gastroenteritis due to all causes

Model input*	***Source or Distribution***	***Ref***
Gastroenteritis multiplier[†]	Pert (2.5%=0.64, median=0.74, 97.5%=0.84)	[15]
Foodborne multiplier	Pert (2.5%=0.13, median=0.25, 97.5%=0.42)	[6]
GP proportion	Pert (2.5%=0.156, median=0.196,97.5%=0.234)	[15]
ED proportion	Pert (2.5%=0.025, median=0.044,97.5%=0.074)	[15]
Hospitalisation codes	A01.0, A02.0-A02.9, A03.0-A03.9, A04.0, A04.1, A04.3-A04.6, A05.0, A05.2-A05.4, A07.1, A07.2, A08.0-A08.2, A08.5, A09.0, A09.9	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	71%	[6]
Mortality codes	A01.0, A02, A03, A04.0, A04.1, A04.3-A04.6, A04.8, A04.9, A05.0, A05.2-A05.4, A05.8, A05.9, A07.1, A07.2, A07.8, A07.9, A08.0-A08.4, A08.5, A09	[6]

* No under-reporting multiplier or domestically acquired multiplier as incidence based on community surveillance where all cases were locally acquired. [†] Yearly probability of gastroenteritis due to any cause.

Campylobacter

Model input	***Source or Distribution***	***Ref***
Notifications	NNDSS data	[17]
Correction factor*	1.5	[86]
Domestically acquired multiplier	Pert (min=0.91, mode=0.97, max=0.99)	[6]
Under-reporting multiplier	Lognormal (mean=10.45, sd=2.98)	[87]
Foodborne multiplier	Pert (5%=0.62, median=0.77, 95%=0.89)	[88]
GP proportion	Pert (2.5%=0.241, median=0.367,97.5%=0.501)	[15]
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	[15]
Hospitalisation code	A04.5: Campylobacter enteritis	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	79%	[6]
Mortality code	A04.5: *Campylobacter enteritis*	[6]

* Used for years where *Campylobacter* was not notifiable in New South Wales

Listeria monocytogenes

Model input*	***Source or Distribution***	***Ref***
Notifications	NNDSS data	[17]
Domestically acquired multiplier	Assumed 100%	[6]
Under-reporting multiplier	Pert (5%=1, median=2, 95%=3)	[6]
Foodborne multiplier	Pert (min=0.9, mode=0.98, max=1)	[88]
GP visits per incident case	Pert (min=1, mode=2, max=3)	[11]
Specialist visits per incident case	Pert (min=1, mode=2, max=3)	[11]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Mortality code	A32: Listeriosis	[6]
Ongoing illness proportion (congenital)	Pert (2.5%=0.034, median= 0.066, 97.5%=0.104)	[63]
Ongoing illness proportion (non-congenital)	Pert (2.5%=0.012, median=0.042, 97.5%=0.074)	[63]

* All incident cases assumed to be hospitalised and all hospitalised cases assumed to visit ED before admission

Non-typhoidal Salmonella

Model input	***Source or Distribution***	***Ref***
Notifications	NNDSS data	[17]
Domestically acquired multiplier	Pert (min=0.7, mode=0.85, max=0.95)	[6]
Under-reporting multiplier	Lognormal (mean=7.44, sd=2.38)	[87]
Foodborne multiplier	Pert (5%=0.53, median=0.72, 95%=0.86)	[88]
GP proportion	Pert (2.5%=0.241, median=0.367, 97.5%=0.501)	[15]
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	[15]
Hospitalisation code	A02.0-A02.9: Salmonellosis	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	77%	[6]
Mortality code	A02: other *Salmonella* infections	[6]

Norovirus

*Model input**	*Source or Distribution*	*Ref*
Gastroenteritis multiplier†	Pert (2.5%=0.64, median=0.74, 97.5%=0.84)	[15]
Pathogen fraction multiplier	Pert (2.5%=0.0772, median=0.0982, 97.5%=0.1226)	[89]
Foodborne multiplier	Pert (5%=0.05, median=0.18, 95%=0.35)	[88]
GP proportion	Pert (2.5%=0.156, median=0.196,97.5%=0.234)	[15]
ED proportion	Pert (2.5%=0.025, median=0.044,97.5%=0.074)	[15]
Hospitalisation code	A08.1: Acute gastroenteropathy due to Norwalk agent	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	37%	[6]
Mortality code	A08.1: Acute gastroenteropathy due to Norwalk agent	[6]

* No under-reporting multiplier or domestically acquired multiplier as based on community surveillance where all cases were locally acquired. † Yearly probability of gastroenteritis due to any cause.

Salmonella Typhi

*Model input**	*Source or Distribution*	*Ref*
Notifications	NNDSS data	[17]
Domestically acquired multiplier	Pert (min=0.02, mode=0.11, max=0.25)	[6]
Under-reporting multiplier	Pert (2.5%=1, median=2, 97.5%=3)	[6]
Foodborne multiplier	Pert (min=0.02, mode=0.75, max=0.97)	[88]
GP visits per incident case	Pert (min=1, mode=2, max=3)	[1]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	93%	[6]
Mortality code	A01: Typhoid and paratyphoid fevers	[6]

* All incident cases assumed to be hospitalised and all hospitalised cases assumed to visit ED before admission

Shigella

Model input	*Source or Distribution*	*Ref*
Notifications	NNDSS data	[17]
Domestically acquired multiplier	Pert (min=0.45, mode=0.7, max=0.84)	[6]
Under-reporting multiplier	Lognormal (mean=7.44, sd=2.38)	[87]
Foodborne multiplier	Pert (5%=0.05, median=0.12, 95%=0.23)	[88]
GP proportion	Pert (2.5%=0.241, median=0.367, 97.5=0.501)	[15]
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	[15]
Hospitalisation code	A03.0-A03.9: Shigellosis	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	76%	[6]
Mortality code	A03: Shigellosis	[6]

Shiga toxin-producing Escherichia coli

Model input	*Source or Distribution*	*Ref*
Notifications	State-level surveillance data	[6]
Domestically acquired multiplier	Pert (min=0.93, mode=0.99, max=1)	[6]
Under-reporting multiplier	Lognormal (mean=8.83, sd=3.7)	[87]
Foodborne multiplier	Pert (5%=0.32, median=0.56, 95%=0.82)	[88]
GP proportion	Pert (2.5%=0.241, median=0.367,97.5%=0.501)	[15]
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	[15]
Hospitalisation code	A04.3: Enterohemorrhagic *E. coli* infection	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	59%	[6]
Mortality code	A04.3: Enterohemorrhagic *E. coli* infection	[6]

Other pathogenic Escherichia coli

Model input*	***Source or Distribution***	***Ref***
Gastroenteritis multiplier	Pert (2.5%=0.64, median=0.74, 97.5%=0.84)	[15]
Pathogen fraction multiplier[†]	Pert (2.5%=0.0525, median=0.074, 97.5%=0.0914)	[89]
Foodborne multiplier	Pert (5%=0.08, median=0.23, 95%=0.55)	[88]
GP proportion	Pert (2.5%=0.241, median=0.367, 97.5=0.501)	[15]
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	[15]
Hospitalisation code	A04.0: Enteropathogenic *E. coli* infection; A04.1: Enterotoxigenic *E. coli* infection; A04.2: Enteroinvasive *E. coli* infection A04.4: Other intestinal *E. coli* infection	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	59%	[6]
Mortality code	A04.0: Enteropathogenic *E. coli* infection; A04.1: Enterotoxigenic *E. coli* infection; A04.2: Enteroinvasive *E. coli* infection A04.4: Other intestinal *E. coli* infection	[6]

* No under-reporting multiplier or domestically acquired multiplier as based on community surveillance where all cases were locally acquired. [†] Yearly probability of gastroenteritis due to any cause.

Toxoplasma gondii

Model input	***Source or Distribution***	***Ref***
Illness	Seroprevalence data	[20]
Domestically acquired multiplier	Pert (min=0.7, mode=0.85, max=0.95)	[6]
Proportion symptomatic	Pert (min=0.11, mode=0.15, max=0.21)	[6]
Foodborne multiplier	Pert (min=0.04, mode=0.31, max=0.74)	[6]
GP proportion	Pert (min=0, mode=0.2, max=0.4)	[11]
ED proportion	Assumed no ED visits	[11]
Specialist visits per hospitalisation	Pert (min=1, median=2, max=3)	[11]
Hospitalisation code	B58.0-B58.9: Toxoplasmosis	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	39%	[6]
Mortality code	B58: Toxoplasmosis	[6]
Ongoing illness	Pert (2.5%=0.003, median=0.005, 97.5%=0.007)	[1]

Yersinia enterocolitica

Model input	***Source or Distribution***	***Ref***
Notifications	State-level surveillance data	[6]
Domestically acquired multiplier	Pert (min=0.8, mode=0.9, max=1)	[6]
Under-reporting multiplier	Lognormal (mean=7.44, sd=2.38)	[87]
Foodborne multiplier	Pert (min=0.28, mode=0.84, max=0.94)	[6]
GP proportion	Pert (2.5%=0.241, median=0.367,97.5%=0.501)	[15]
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	[15]
Hospitalisation code	A04.6: Enteritis due to *Yersinia enterocolitica*	[18]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	64%	[6]
Mortality code	A04.6: Enteritis due to *Yersinia enterocolitica*	[6]

Guillain-Barré syndrome

Model input*	***Source or Distribution***	***Ref***
Sequelae multiplier	Pert (min=0.000192, mode=0.000304, max=0.000945)	[7]
Domestically acquired multiplier	Pert (min=0.91, mode=0.97, max=0.99)	[7]
Bacterial multiplier	Pert (min=0.048, mode=0.31, max=0.717)	[7]
Foodborne multiplier†	Pert (2.5%=0.1, median=0.25, 97.5%=0.43)	[88]
GP visits per incident case	Pert (2.5%=3.56, median=3.6, 97.5%=3.66)	[1]
ED proportion	Assumed no ED visits	[11]
Specialist visits per incident case	Pert (2.5%=2.5, median=3, 97.5%=3.5)	[11]
Physiotherapy visits per incident case	Pert (2.5%=5.5, median=6, 97.5%=6.5)	[11]
Underdiagnosis multiplier‡	Pert (min=1, mode=2, max=3)	[6]
Mortality code	G61.0: Guillain-Barré syndrome	[6]
Ongoing illness proportion (<5)	Pert (2.5%=0.065, median=0.075, 97.5%=0.085)	[56]
Ongoing illness proportion (5-64)	Pert (2.5%=0.14, median=0.16, 97.5%=0.18)	[56]
Ongoing illness proportion (65+)	Pert (2.5%=0.47, median=0.49, 97.5%=0.50)	[56]

* All incident cases are assumed to be hospitalised, and no additional ED visit costed; † Includes bacterial multiplier and applied to deaths only as only foodborne *Campylobacter* cases included in estimates of incidence and hospitalisation; ‡ Deaths only.

Haemolytic uraemic syndrome

*Model input**	*Source or Distribution*	*Ref*
Sequelae multiplier	Pert (2.5%=0.017, median=0.03, 97.5%=0.051)	[7]
Domestically acquired multiplier	Pert (min=0.93, mode=0.99, max=1)	[6]
Bacterial multiplier	Pert (min=0.3, mode=0.608, max=0.852)	[7]
Foodborne multiplier†	Pert (2.5%=0.17, median=0.33, 97.5%=0.53)	[88]
GP visits per incident case	Pert (2.5%=1, median=3, 97.5%=5)	[1]
ED proportion	Assumed no ED visits	[11]
Underdiagnosis multiplier‡	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	30%	[6]
Mortality code	D59.3: Hemolytic-uremic syndrome	[6]
Ongoing illness proportion	Pert (2.5%=0.08, median=0.16, 97.5%=0.277)	[60]

* All incident cases are assumed to be hospitalised, and no additional ED visit costed; † Includes bacterial multiplier and applied to deaths only as only foodborne STEC cases included in estimates of incidence and hospitalisation; ‡ Deaths only.

Irritable bowel syndrome

Model input	*Source or Distribution*	*Ref*
Sequelae multiplier (all prior illnesses†)	Pert (2.5%=0.072, median=0.088, 97.5%=0.104)	[7]
Domestically acquired multiplier	Pert (5%=0.88, median=0.91, 95%=0.94)	[7]
Foodborne multiplier*	Pert (2.5%=0.068, median=0.13, 97.5%=0.33)	[88]
GP visits per incident case	Pert (2.5%=4.27, median=4.5, 97.5%=4.73)	[1]
ED proportion	Assumed no ED visits	[1]
Specialist visits per incident case	Pert (2.5%=0.286, median=0.3, 97.5%=0.315)	[90]
Hospitalisation code	K58.0: Irritable bowel with diarrhea; K58.9: Irritable bowel without diarrhea	[6]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	69%	[6]
Mortality code	K58: Irritable bowel syndrome	[6]
Ongoing illness proportion	Pert (2.5%=0.218, median=0.429, 97.5%=0.66)	[61]

* Includes bacterial multiplier and applied to deaths and hospitalisations only as only foodborne cases included in estimates of incidence. †IBS is a possible sequelae for *Campylobacter, Salmonella* and *Shigella*.

Reactive arthritis

Model input	***Source or Distribution***	***Ref***
Sequelae multiplier (*Campylobacter*)	Pert (min=0.028, mode=0.07, max=0.16)	[7]
Sequelae multiplier (*Salmonella*)	Pert (min=0, mode= 0.085, max=0.26)	[7]
Sequelae multiplier (*Shigella*)	Pert (min=0.012, mode=0.097, max=0.098)	[7]
Sequelae multiplier (*Y. enterocolictica*)	Pert (min=0, mode=0.12, max=0.231)	[7]
Domestically acquired multiplier	Pert (5%=0.86, median=0.91, 95%=0.95)	[7]
Bacterial multiplier	Pert (min=0.5, median=0.66, max=0.947)	[7]
Foodborne multiplier*	Pert (5%=0.36, median=0.48, max=0.61)	[88]
GP visits per incident case	Pert (2.5%=0.66, median=0.8, 97.5%=0.89)	[1]
ED proportion	Assumed no ED visits	[1]
Specialist visits per case per year	Pert (2.5%=0.223, median=0.24, 97.5%=0.258)	[59]
Hospitalisation code	M02.1: Postdysenteric arthropathy, multiple sites; M02.3: Reiter's disease, multiple sites; M02.8: Other reactive arthropathies, multiple sites; M03.2: Other postinfectious arthropathies in diseases classified elsewhere, multiple sites	[6]
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	[6]
Percent hospitalisations principal	50%	[6]
Mortality code	M02.1: Postdysenteric arthropathy; M02.8: Other reactive arthropathies	[6]
Ongoing illness proportion	Pert (2.5%=0.23, median=0.5, 97.5%=0.77)	[62, 91]

* Includes bacterial multiplier and applied to deaths and hospitalisations only as only foodborne cases included in estimates of incidence.

Pathogen and illness-specific medication usage assumptions

Gastroenteritis due to all causes and Norovirus

Medication†*	***Age group***	***Distribution***
Antidiarrhoeal	0–4	Pert (2.5%=0.012, mode=0.062, 97.5%=0.27)
	5–64	Pert (2.5%=0.107, median=0.145, 97.5%=0.193)
	65+	Pert (2.5%=0.232, median=0.349, 97.5%=0.489)
Painkillers	0–4	Pert (2.5%=0.29, median=0.38, 97.5%=0.47)
	5–64	Pert (2.5%=0.13, median=0.178, 97.5%=0.238)
	65+	Pert (2.5%=0.014, median=0.053,97.5%=0.186)
Anti-nausea	0–4	Pert (2.5%=0.008, median=0.04, 97.5%=0.187)
	5–64	Pert (2.5%=0.04, mode=0.065, 97.5%=0.104)
	65+	Pert (2.5%=0.035, median=0.106, 97.5%=0.279)
Anti-cramps	0–4	none
	5–64	Pert (2.5%=0.012, median=0.028, 97.5%=0.063)
	65+	Pert (2.5%=0.0002, median=0.001, 97.5%=0.004)
Antibiotics	0–4	Pert (2.5%=0.008, median=0.04, 97.5%=0.187)
	5–64	Pert (2.5%=0.006, median=0.014, 97.5%=0.035)
	65+	Pert (min=0, median=0.051, 97.5%=0.104)

* All estimates from the NGSII [15]; † Medication proportions applied to incident cases.

Bacterial pathogens causing gastroenteritis

Medication*†	***Age group***	***Distribution***
Antidiarrhoeal	0–4	Pert (min=0.0025, mode=0.003, max=0.3)
	5–64	Pert (2.5%=0.166, median=0.286, 97.5%=0.439)
	65+	Pert (min=0.094, median=0.653, max=0.906)
Painkillers	0–4	Pert (2.5%=0.12, median=0.38, 97.5%=0.65)
	5–64	Pert (2.5%=0.127, median=0.242, 97.5%=0.385)
	65+	Pert (2.5%=0.051, median=0.307, 97.5%=0.708)
Anti-nausea	0–4	Pert (min=0.0025, mode=0.003, max=0.305)
	5–64	Pert (2.5%=0.042, median=0.12, 97.5%=0.237)
	65+	Pert (2.5%=0.051, median=0.307, 97.5%=0.708)
Anti-cramps	0–4	none
	5–64	Pert (min=0.028, mode=0.077, max=0.204)
	65+	Pert (2.5%=0.051, median=0.277, 97.5%=0.708)
Antibiotics (*Shigella*)	0–4	Pert (2.5%=0.25, median=0.37, 97.5%=0.50)
	5–64	Pert (2.5%=0.25, median=0.37, 97.5%=0.50)
	65+	Pert (2.5%=0.25, median=0.37, 97.5%=0.50)
Antibiotics (all other bacterial pathogens)	0–4	Pert (2.5%= 0.005, median=0.082, 97.5%=0.305)
	5–64	Pert (2.5%= 0.016, median=0.067, 97.5%=0.169)
	65+	Pert (min=0, median=0.051, 97.5%=0.104)

* All estimates from the NGSII [15], weighted by disease severity; † Medication proportions applied to incident cases, assuming all cases of *Shigella* who visit a GP receive antibiotics.

Listeria monocytogenes

Medication*	Age group	Assumption	Ref
Antibiotics	All	All surviving cases receive 4 weeks amoxicillin	[11]

* Medication proportions applied to incident cases.

Toxoplasma gondii

Medication*	Age group	Assumption	Ref
Antibiotics	All	All cases receive 4 weeks high-dose medication	[92]

* Medication proportions applied to cases that visit a GP.

Irritable bowel syndrome

Medication‡	Age group	Assumption	Ref
Any medication†	All	Pert (5%=0.385, median=0.4, 95%=0.416)	*

* Where information sources were not available, we obtained expert opinion from clinical advisor Philip Haywood; † Includes Anti-diarrhoeals, Anti-depressants, Anti-spasmodics, Anti-cramp medication, and anti-constipation medication; ‡ Medication proportions applied to incident cases.

Reactive arthritis

Medication†	Age group	Assumption	Ref
Antibiotics	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
NSAID	All	Pert (5%=0.528, median=0.762, 95%=0.918)	[93]
Eye drops	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
Prednisone	All	Pert (5%=0.001, median=0.019, 95%=0.099)	[11]
Inter-articular glucocorticoid	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*
DMARD	All	Pert (5%=0.012, median=0.095, 95%=0.304)	[93]

* Where information sources were not available, we obtained opinions from clinical advisor Philip Haywood; † Medication proportions applied to cases that visit a GP.

Pathogen and illness-specific testing assumptions

Gastroenteritis due to all causes, other pathogenic E. coli and Norovirus

Test†*	***Age group***	***Distribution***
Stool culture	All	Pert (5%=0.016, median=0.031, 95%=0.057)

* All estimates from the NGSII [15]; † Test proportions applied to incident cases.

Bacterial pathogens causing gastroenteritis modelled using the surveillance approach

Test*	***Assumption***
Stool culture	All notifications have a stool culture

* *Campylobacter*, *Salmonella, Shigella,* STEC (population adjusted), *Yersinia enterocolitica* (population adjusted)

Listeria monocytogenes

Test*	***Age group***	***Assumption***	***Ref***
FBC	All	All surviving cases undergo this test	[11]
ESR	All	All surviving cases undergo this test	[11]

* Test proportions applied to incident cases. FBC= Full Blood Count; ESR=Erythrocyte Sedimentation Rate

Toxoplasma gondii

Test*	***Age group***	***Assumption***	***Ref***
FBC	All	All cases that visit a GP undergo this test	[1]
ESR	All	All cases that visit a GP undergo this test	[1]

* Test proportions applied to cases that visit a GP. FBC= Full Blood Count; ESR=Erythrocyte Sedimentation Rate

Irritable bowel syndrome

Test†	***Age group***	***Distribution***	***Ref***
Stool culture	All	Pert (min=0.667, mode=1, max=1)	*
Full blood count (FBC)	All	Pert (min=0.667, mode=1, max=1)	*
ESR	All	Pert (min=0.667, mode=1, max=1)	*
Liver function test	All	Pert (min=0.667, mode=1, max=1)	*
C-reactive protein	All	Pert (min=0.667, mode=1, max=1)	*
Coeliac screening	All	Pert (min=0.667, mode=1, max=1)	*
Radiology	All	Pert (5%=0.652, median=0.667, 95%=0.681)	*
Ultrasound	All	Pert (5%=0.484, median=0.5, 95%=0.516)	*
Endoscopy and biopsy	0–4	Not done	*
	5–64	Pert (5%=0.05, median=0.1, 95%=0.15)	*
	65+	Pert (5%=0.15, median=0.2, 95%=0.25)	*

* Where information sources were not available, we obtained opinions from clinical advisor Philip Haywood; †Test proportions applied to incident cases.

Reactive arthritis

Test†	***Age group***	***Distribution***	***Ref***
Stool culture	All	Pert (5%=0.097, median=0.132, 95%=0.174)	*
Serology	All	Pert (5%=0.097, median=0.132, 95%=0.174)	*
Urine test	All	Pert (5%=0.097, median=0.132, 95%=0.174)	*
C-reactive protein and Urate	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
FBC	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
ESR	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
EUC	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
ANA	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*
Rheumatoid factor	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
Renal function	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*
Blood HLA-B27	All	Pert (5%=0.16, median=0.2, 95%=0.244)	[11]
X-ray	All	Pert (5%=0.012, median=0.095, 95%=0.304)	*
Ultrasound	All	Pert (5%=0.017, median=0.034, 95%=0.062)	*
MRI	All	Pert (5%=0.002, median=0.01, 95%=0.03)	*
Joint aspiration	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*

FBC= Full Blood Count; ESR=Erythrocyte Sedimentation Rate; EUC= Electrolytes, urea, creatinine; ANA= Antinuclear Antibody; * Where information sources were not available, we obtained opinions from clinical advisor Philip Haywood; † Test proportions applied to cases that visit a GP.

Hospitalisation codes for pathogens and illnesses

*Pathogen or illness**	*AR-DRG code and description*	*ALOS (days)*	*Cost ($)*
Guillain-Barré syndrome (ALOS 10.1)	B06A: Procedures for Cerebral Palsy, Muscular Dystrophy and Neuropathy, Major Complexity	12.0	28,927
Pathogens causing gastroenteritis ages 65+	G67A Oesophagitis and Gastroenteritis, Major Complexity	3.5	6,155
Pathogens causing gastroenteritis ages <65; Irritable bowel Syndrome	G67B Oesophagitis and Gastroenteritis, Minor Complexity	1.3	1,961
Reactive arthritis (ALOS 3.0)	I66B Inflammatory Musculoskeletal Disorders, Minor Complexity	3.3	6,364
Haemolytic uraemic syndrome (ALOS 1.8)	L02B Operative Insertion of Peritoneal Catheter for Dialysis, Minor Complexity	1.4	6,065
Listeriosis (ALOS 13.8)	*50% T01A Infectious and Parasitic Diseases W GIs, Major Complexity* *50% T01B Infectious and Parasitic Diseases W GIs, Intermediate Complexity* Average	*23.1* *9.7* 16.4	*50,828* *18,592* 34,710
Toxoplasmosis (ALOS 25.9)	T01A Infectious and Parasitic Diseases W GIs, Major Complexity	23.1	50,828
***S.* Typhi (ALOS 5.3)**	*50% T64B Other Infectious and Parasitic Diseases, Intermediate complexity* *50% T64C Other Infectious and Parasitic Diseases, Minor complexity* Average	*7.7* *3.3* 5.5	*12,233* *5,199* 8,716

* For single pathogen or illness categories, the ALOS for 2018–19 corresponding to that ICD10-AM code is provided in brackets for comparison.

International death rate comparison

Table A1: comparison of death rate for different pathogens between the Netherlands, the US and Australia

Study	Cases ('000)	Deaths	Deaths per 1,000 cases
Scallan 2011 **[81]** (unspecified)	38,400	1,686	0.044
Scallan 2011 (major pathogens)	9,400	1,351	0.144
Scallan 2011 (*Campylobacter*)	845	76	0.090
Scallan 2011 (*Salmonella*)	1,028	378	0.368
Scallan 2011 (Norovirus)	5,462	149	0.027
Kirk 2014 **[6]** (all gastro)	4,110	60	0.015
Kirk 2014 (*Campylobacter*) ††	179	3	0.017
Kirk 2014 (*Salmonella*)	40	15	0.379
Kirk 2014 (Norovirus)	276	1	0.004
RIVM 2020 **[80]** (*Campylobacter*) †	73	53	0.726
RIVM 2020 (*Salmonella*) †	26	24	0.923
RIVM 2020 (Norovirus) †	585	66	0.113

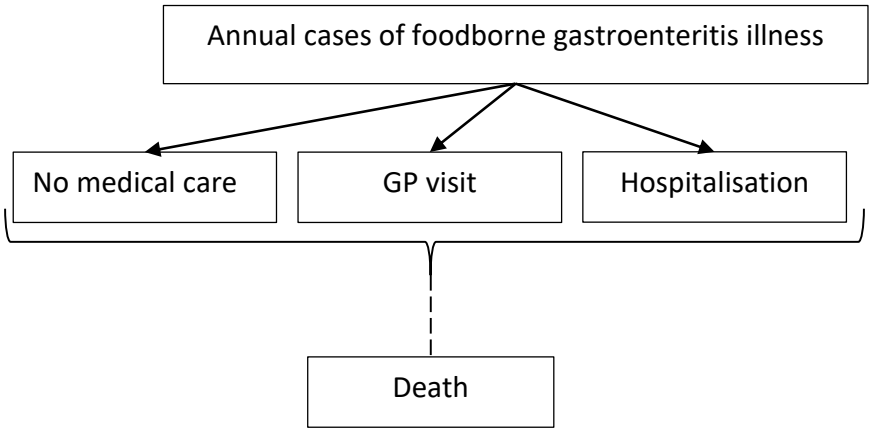
† laboratory confirmed cases †† noting an additional 6 deaths from 70 cases of GBS reported in **[7]**

Appendix C: Health outcome trees

We present the health outcome trees previously reported [2] that illustrate the disease states by pathogen. Note that these trees do not represent an individual patient's journey, but capture states associated with health costs.

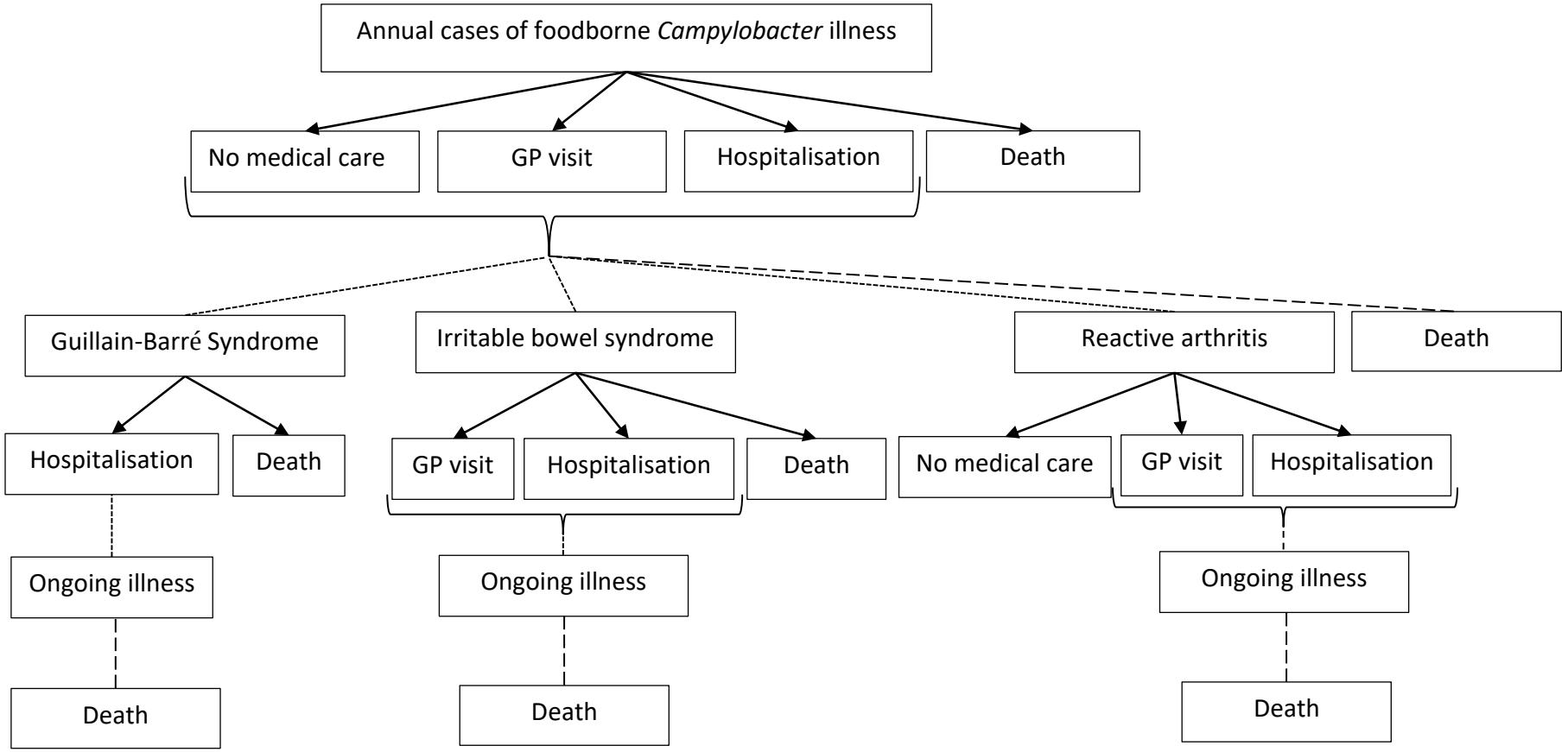
Gastroenteritis

Figure A1: Health outcome tree for gastroenteritis due to all causes; dashed lines indicate that death may follow the preceding states



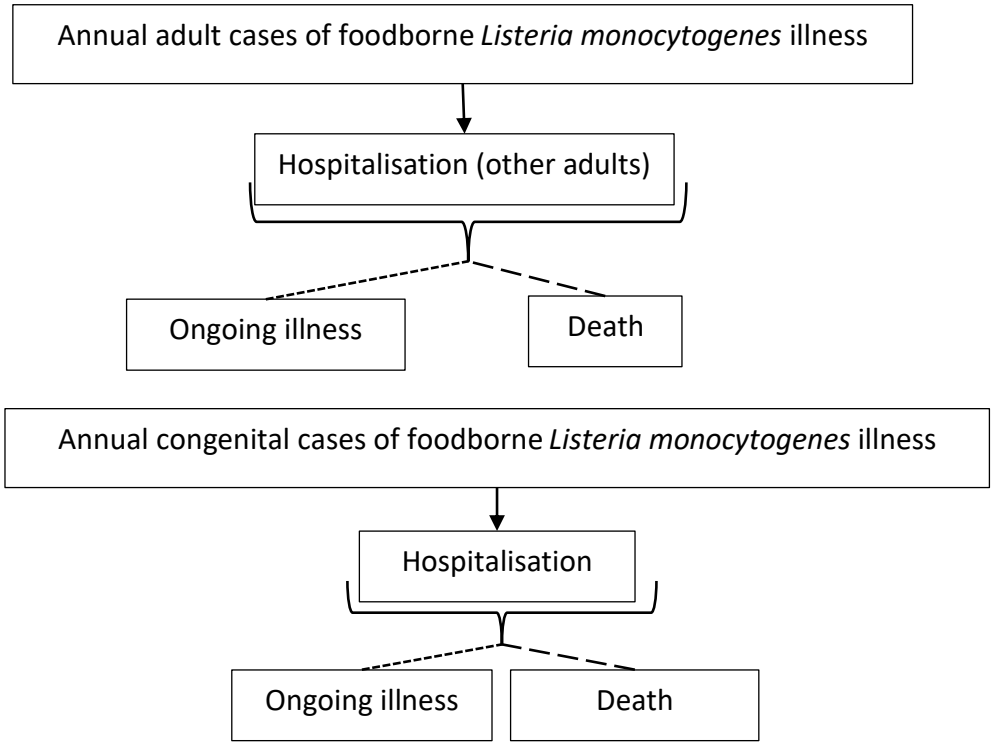
Campylobacter

Figure A2: Health outcome tree for *Campylobacter* spp.; dotted lines indicate the potential for these sequelae to follow acute illness, and for ongoing illness to result from sequelae, while dashed lines indicate that death may follow the preceding state.



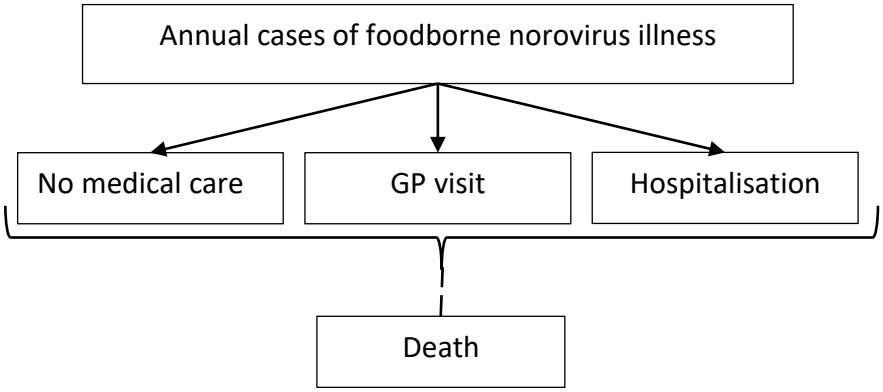
Listeria monocytogenes

Figure A3: Health outcome tree for *Listeria monocytogenes*; dotted lines indicate potential for ongoing illness following hospitalisation, while dashed lines indicate that death may follow hospitalisation.



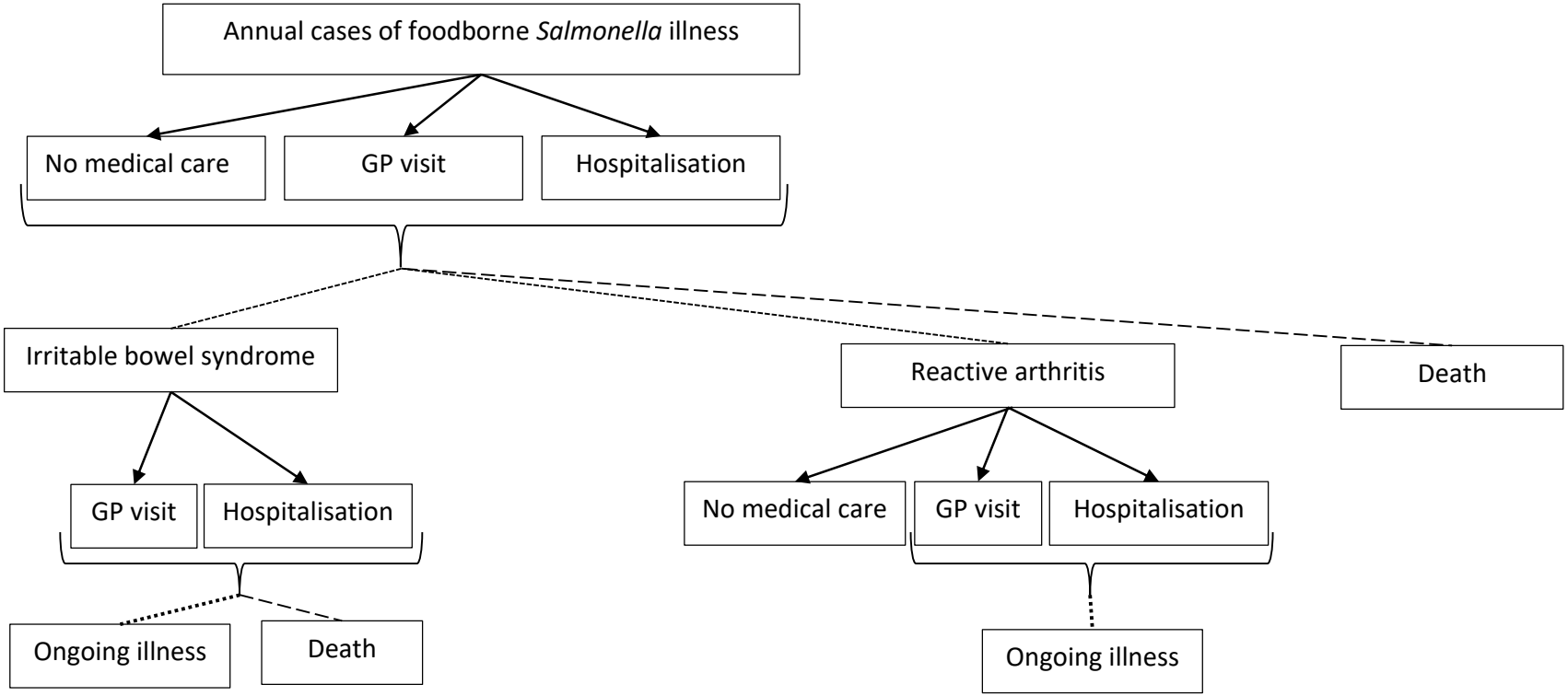
Norovirus

Figure A4: Health outcome tree for norovirus; dashed lines indicate that death may follow the preceding states.



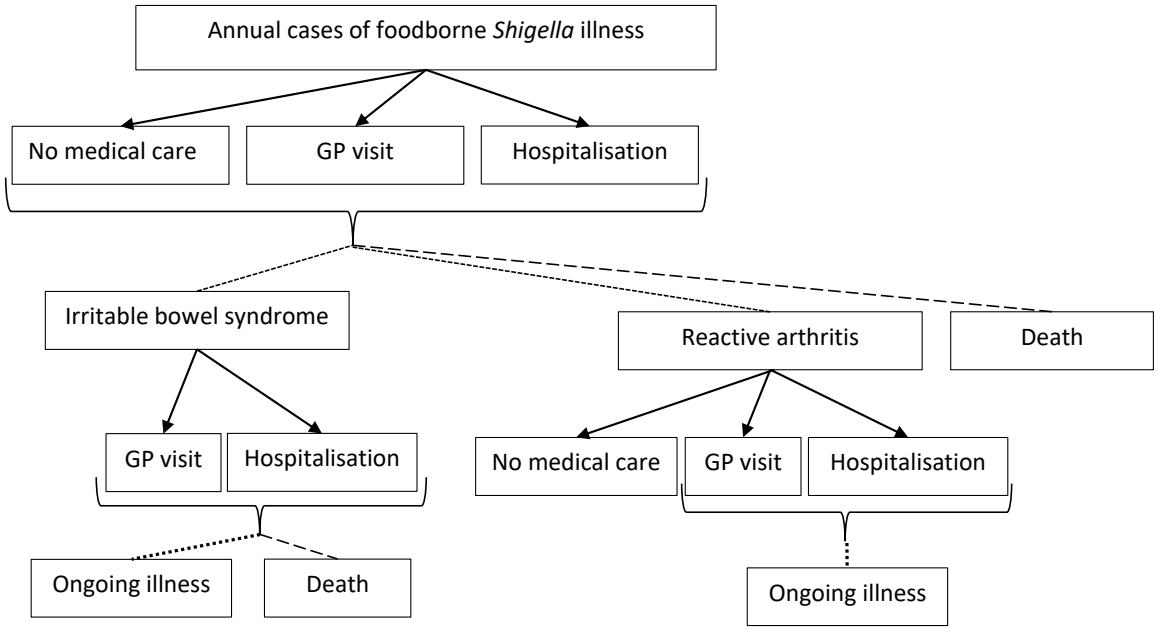
Non-typhoidal *Salmonella*

Figure A5: Health outcome tree for *Salmonella*; dotted lines indicate potential sequelae following acute illness, and potential ongoing illness following GP consultation or hospitalisation for a sequelae, while dashed lines indicate that death may follow the preceding state.



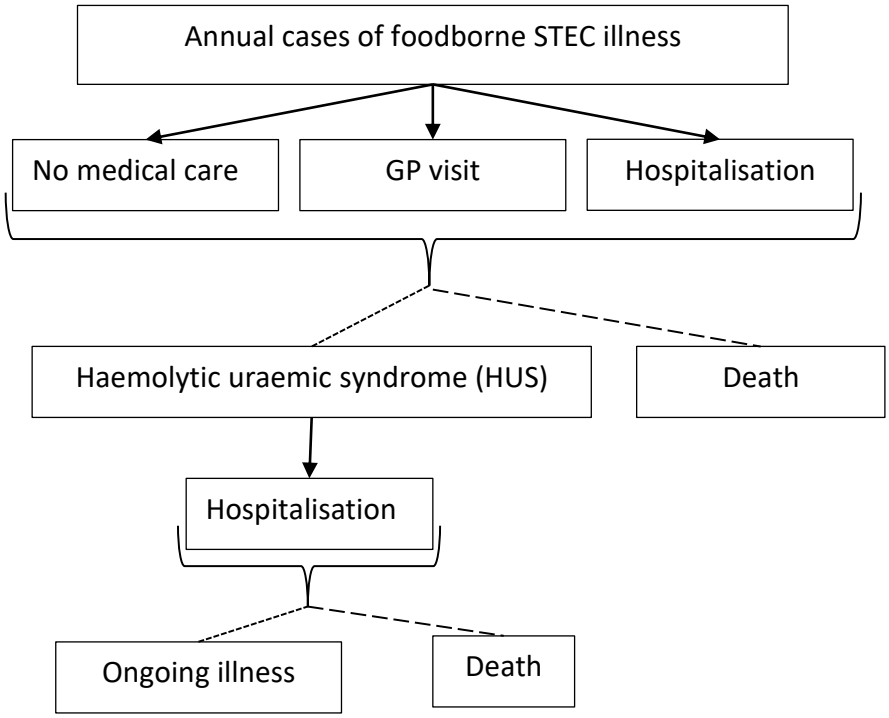
Shigella

Figure A6: Health outcome tree for *Shigella* spp.; dotted lines indicate potential sequelae following acute illness, and ongoing illness following GP visit or hospitalisation for reactive arthritis, while dashed lines indicate that death may follow the preceding state.



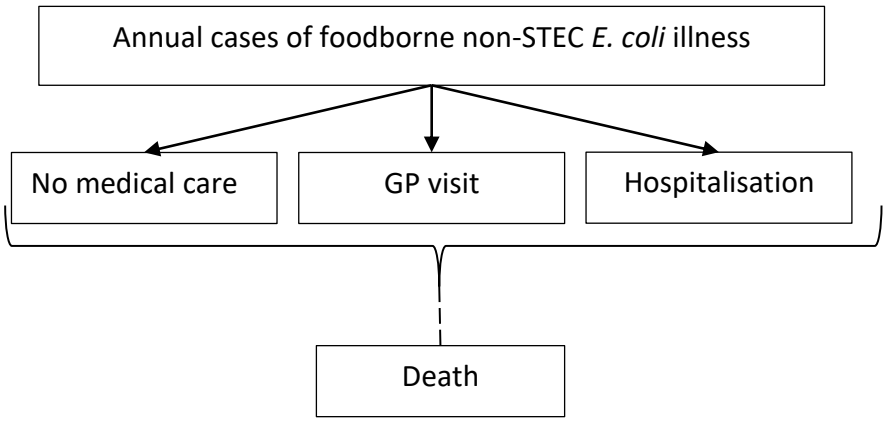
STEC

Figure A7: Health outcome tree for Shiga toxin-producing Escherichia coli (STEC); dotted lines indicate potential sequelae of haemolytic uraemic syndrome (HUS) following acute illness and potential ongoing illness following hospitalisation for HUS, while dashed lines indicate that death may follow the preceding states.



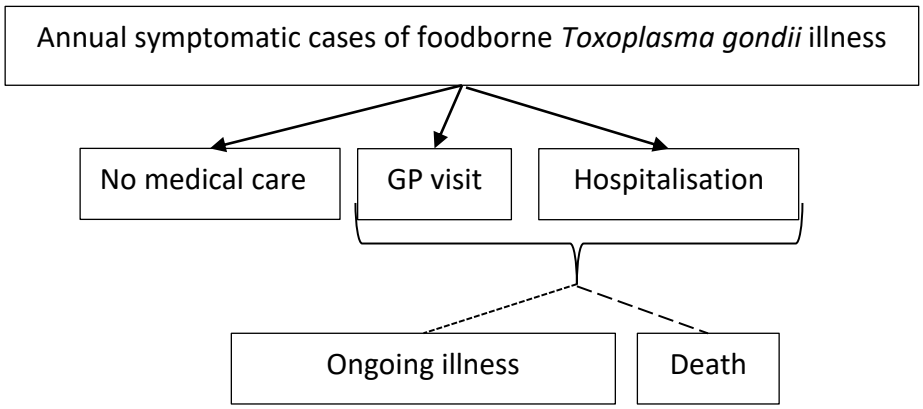
Other pathogenic *E. coli*

Figure A8: Health outcome tree for other (non-STEC) pathogenic E. coli; dashed lines indicate that death may follow the preceding states.



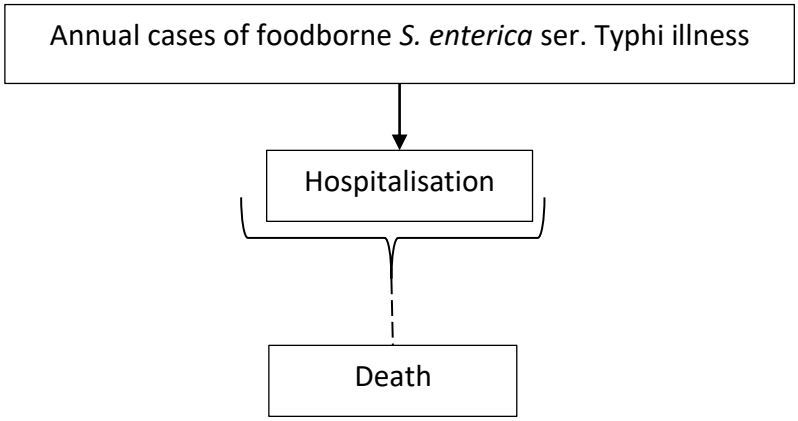
Toxoplasma gondii

Figure A9: Health outcome trees for Toxoplasma gondii; dotted lines indicate the potential for ongoing illness to follow health care; dashed lines indicate that death may follow the preceding states.



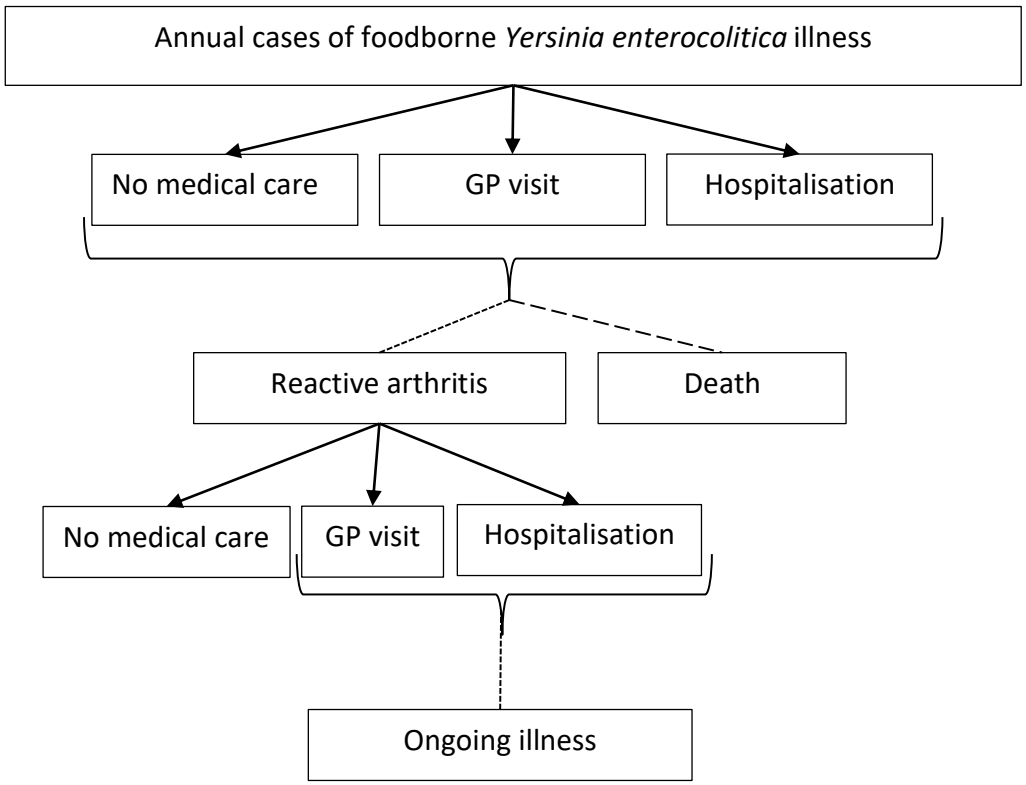
Salmonella Typhi

Figure A10: Health outcome tree for *S.* Typhi; dashed lines indicate that death may follow hospitalisation. All incident cases are assumed to be hospitalized.



Yersinia enterocolitica

Figure A11: Health outcome tree for Yersinia enterocolitica; dotted lines indicate potential sequelae following acute illness, and potential for ongoing illness to follow health care for reactive arthritis, while dashed lines indicate that death may follow the preceding states.



Appendix D: Burden of disease by age group

We provide additional estimates of the burden of disease circa 2019 by age group for all-case gastroenteritis and for each individual pathogen.

Gastroenteritis

Table A2: Burden of disease by age for gastroenteritis due to all causes, Australia 2019.

	<5	5–64	65+	Total
All-cause gastroenteritis				
Cases	288,000 (162,000 – 465,000)	3,640,000 (2,040,000 – 5,860,000)	743,000 (418,000 – 1,200,000)	4,670,000 (2,620,000 – 7,520,000)
Hospitalisations	4,650 (2,430 – 8,150)	26,700 (13,900 – 46,800)	15,300 (7,970 – 26,800)	47,900 (31,600 – 70,300)
Deaths	1 (0 – 2)	6 (3 – 11)	30 (16 – 53)	38 (23 – 61)

Campylobacter

Table A3: Burden of disease by age for *Campylobacter* and its sequelae of reactive arthritis, irritable bowel syndrome and Guillain-Barré syndrome, Australia 2019.

	<5	5–64	65+	Total
Campylobacteriosis				
Cases	25,900 (15,800 – 42,300)	186,000 (113,000 – 304,000)	52,600 (32,000 – 85,900)	264,000 (161,000 – 432,000)
Hospitalisations	257 (170 – 358)	3,110 (2,070 – 4,330)	2,240 (1,490 – 3,120)	5,640 (4,310 – 7,110)
Deaths	0 (0 – 1)	1 (1 – 3)	2 (1 – 3)	4 (2 – 5)
Reactive Arthritis				
Cases	1,940 (911 – 3,890)	13,900 (6,550 – 28,000)	3,930 (1,850 – 7,900)	19,800 (9,310 – 39,800)
Hospitalisations	54 (25 – 97)	422 (240 – 670)	113 (66 – 177)	598 (367 – 878)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
Irritable Bowel Syndrome				
Cases	2,270 (1,340 – 3,800)	16,300 (9,630 – 27,300)	4,610 (2,720 – 7,710)	23,200 (13,700 – 38,800)
Hospitalisations	3 (1 – 6)	1,780 (846 – 4,250)	433 (208 – 1,030)	2,300 (1,240 – 4,800)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 1)	0 (0 – 1)
Guillain-Barré syndrome				
Cases	10 (5 – 20)	69 (34 – 142)	20 (10 – 40)	98 (48 – 202)
Hospitalisations	10 (5 – 20)	69 (34 – 142)	20 (10 – 40)	98 (48 – 202)
Deaths	0 (0 – 0)	1 (0 – 2)	7 (3 – 12)	8 (4 – 13)

Listeria monocytogenes

Table A4: Burden of disease by age for *Listeria monocytogenes*, Australia 2019.

	<5	5–64	65+	Total
Listeriosis				
Cases	10 (5 – 15)	29 (15 – 44)	62 (31 – 93)	101 (51 – 151)
Hospitalisations†	10 (5 – 15)	29 (15 – 44)	62 (31 – 93)	101 (51 – 151)
Deaths	3 (2 – 5)	4 (3 – 7)	8 (5 – 12)	15 (11 – 20)

† All cases assumed hospitalised.

Norovirus

Table A5: Burden of disease by age for norovirus, Australia 2019.

	<5	5–64	65+	Total
Norovirus infection				
Cases	20,300 (5,540 – 41,400)	255,000 (69,800 – 523,000)	52,200 (14,300 – 107,000)	328,000 (89,600 – 671,000)
Hospitalisations	462 (125 – 980)	536 (143 – 1,140)	454 (124 – 965)	1,530 (823 – 2,400)
Deaths	0 (0 – 0)	0 (0 – 1)	0 (0 – 1)	1 (0 – 2)

Non-typhoidal *Salmonella*

Table A6: Burden of disease by age for *Salmonella* and its sequelae of reactive arthritis and irritable bowel syndrome, Australia 2019.

	<5	5–64	65+	Total
Salmonellosis				
Cases	14,700 (8,160 – 25,900)	38,300 (21,300 – 67,500)	8,670 (4,820 – 15,300)	61,600 (34,300 – 109,000)
Hospitalisations	913 (580 – 1,320)	1,910 (1,210 – 2,750)	890 (564 – 1,290)	3,740 (2,870 – 4,740)
Deaths	1 (0 – 1)	3 (2 – 5)	7 (4 – 12)	11 (8 – 16)
Reactive Arthritis				
Cases	1,370 (360 – 3,390)	3,570 (938 – 8,830)	809 (213 – 2,000)	5,750 (1,510 – 14,200)
Hospitalisations	37 (12 – 76)	107 (27 – 272)	23 (6 – 61)	172 (47 – 393)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
Irritable Bowel Syndrome				
Cases	1,280 (700 – 2,310)	3,350 (1,830 – 6,020)	760 (414 – 1,360)	5,400 (2,940 – 9,700)
Hospitalisations	1 (1 – 4)	369 (135 – 1,060)	72 (26 – 212)	460 (181 – 1,200)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)

Salmonella Typhi

Table A7: Burden of disease by age for *Salmonella Typhi*, Australia 2019.

	<5	5–64	65+	Total
Typhoid fever				
Cases	3 (1 – 8)	25 (8 – 56)	0 (0 – 1)	29 (10 – 64)
Hospitalisations†	3 (1 – 8)	25 (8 – 56)	0 (0 – 1)	29 (10 – 64)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)

† All cases assumed hospitalised.

Shigella

Table A8: Burden of disease by age for *Shigella* and its sequelae of reactive arthritis and irritable bowel syndrome, Australia 2019.

	<5	5–64	65+	Total
Shigellosis				
Cases	269 (92 – 608)	1,490 (513 – 3,370)	166 (57 – 376)	1,930 (662 – 4,360)
Hospitalisations	19 (7 – 37)	63 (23 – 126)	7 (2 – 13)	90 (47 – 155)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
Reactive Arthritis				
Cases	22 (7 – 52)	122 (40 – 287)	14 (4 – 32)	158 (52 – 371)
Hospitalisations	1 (0 – 2)	4 (1 – 11)	0 (0 – 1)	5 (1 – 14)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
Irritable Bowel Syndrome				
Cases	24 (8 – 54)	130 (44 – 301)	15 (5 – 34)	169 (57 – 388)
Hospitalisations	0 (0 – 0)	14 (4 – 51)	1 (0 – 5)	16 (4 – 54)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)

STEC

Table A9: Burden of disease by age for STEC and its sequelae of haemolytic uraemic syndrome, Australia 2019.

	<5	5–64	65+	Total
STEC infection				
Cases	405 (175 – 888)	1,770 (762 – 3,870)	460 (199 – 1,010)	2,630 (1,140 – 5,760)
Hospitalisations	2 (1 – 3)	21 (11 – 35)	9 (5 – 15)	32 (21 – 47)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 1)
Haemolytic Uraemic Syndrome				
Cases	12 (5 – 30)	52 (20 – 132)	14 (5 – 34)	78 (30 – 197)
Hospitalisations	12 (5 – 30)	52 (20 – 132)	14 (5 – 34)	78 (30 – 197)
Deaths	0 (0 – 0)	1 (1 – 2)	0 (0 – 1)	2 (1 – 3)

Non-STEC *E. coli*

Table A10: Burden of disease by age for other pathogenic *E. coli*, Australia 2019.

	<5	5–64	65+	Total
Other pathogenic *E. coli* infection				
Cases	19,300 (7,390 – 43,800)	243,000 (93,200 – 552,000)	49,700 (19,000 – 113,000)	312,000 (120,000 – 709,000)
Hospitalisations	2 (1 – 4)	21 (8 – 48)	16 (6 – 37)	41 (21 – 73)
Deaths	0 (0 – 0)	0 (0 – 1)	0 (0 – 1)	1 (0 – 1)

Toxoplasma gondii

Table A11: Burden of disease by age for *Toxoplasma Gondii*, Australia 2019.

	<5	5–64	65+	Total
Toxoplasmosis				
Cases	2,740 (1,070 – 5,090)	12,300 (4,850 – 21,800)	442 (136 – 864)	15,500 (6,130 – 27,500)
Hospitalisations	1 (1 – 3)	25 (10 – 47)	8 (3 – 16)	35 (18 – 58)
Deaths	0 (0 – 0)	1 (0 – 1)	0 (0 – 1)	1 (0 – 2)

Yersinia enterocolitica

Table A12: Burden of disease by age for *Yersinia enterocolitica* and its sequelae of reactive arthritis, Australia 2019.

	<5	5–64	65+	Total
Yersinia enterocolitica				
Cases	1,130 (626 – 1,990)	4,700 (2,600 – 8,250)	1,330 (736 – 2,340)	7,170 (3,960 – 12,600)
Hospitalisations	6 (4 – 9)	21 (13 – 30)	11 (7 – 15)	38 (29 – 49)
Deaths	0 (0 – 0)	1 (0 – 1)	0 (0 – 0)	1 (0 – 2)
Reactive arthritis				
Cases	130 (44 – 281)	538 (184 – 1,170)	152 (52 – 330)	820 (280 – 1,780)
Hospitalisations	3 (1 – 10)	16 (5 – 45)	4 (1 – 12)	24 (7 – 66)
Deaths	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)

Research School of Population Health
National Centre for Epidemiology and Population Health
+61 2 6125 2468
Kathryn.Glass@anu.edu.au

The Australian National University
Canberra ACT 2601 Australia
www.anu.edu.au

CRICOS Provider No. 00120C