



National Centre for Epidemiology & Population Health

**How much Gastroenteritis in Australia
is due to food?
Estimating the Incidence of Foodborne Gastroenteritis
in Australia**

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NCEPH Working Paper Number 51

September 2004

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ISBN 0-9579769-3-3
ISSN 1033-1557

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Published by the National Centre for Epidemiology & Population Health
The Australian National University
Canberra ACT 0200 Australia

CONTENTS

LIST OF TABLES.....	4
LIST OF FIGURES.....	4
PREFACE: OzFOODNET.....	5
EXECUTIVE SUMMARY.....	6
ESTIMATING THE LEVEL OF FOODBORNE GASTROENTERITIS	8
1. Background	8
2. Estimation Methods	10
2.1 Assessing Uncertainty.....	10
2.2 Literature review and Delphi process	10
2.3 Data sources	11
2.4 Estimating the total amount of infectious gastroenteritis in Australia.....	13
2.5 Estimating the plausible number of cases of infectious gastroenteritis due to each 'known' pathogen	14
2.6 Estimating the proportion of cases of gastroenteritis due to foodborne transmission.....	20
2.7 Estimating the plausible number of cases due to foodborne transmission in Australia	21
3. Estimation results	21
4. Discussion of the estimation study.....	25
APPENDICES	30
Appendix 1. Under-reporting factors	31
Appendix 2. Delphi process	32
REFERENCES	33

LIST OF TABLES

Table 1	Source of data	p14
Table 2	Factors used to adjust primary raw data	p15
Table 3	Specific pathogens that cause gastroenteritis and are reported to the surveillance systems	p16
Table 4	Under-reporting factors for Moderate, Bloody and Serious illness	p17
Table 5	Outbreak data from Victoria 1998-2002	p18
Table 6	Data on pathogens from the WQTS longitudinal study in Melbourne, 1998 and laboratory data.	p20
Table 7	Gastroenteritis in Australia in a 'typical' year ~2000: Total number of cases and number of foodborne cases among known pathogens	p23
Table 8	Number and incidence of all cases of gastroenteritis and of foodborne Gastroenteritis in Australia in a 'typical' year ~2000	p24

LIST OF FIGURES

Figure 1	Notified cases represent only a proportion of the burden of foodborne infectious disease	p12
Figure 2	Simulation of 'Plausible distribution of number of cases of gastroenteritis in Australia around the year 2000' Simulated N=1000	p13
Figure 3	Plausible distribution of number of cases of foodborne gastroenteritis in Australia in a 'typical' year ~2000. Simulated N=1000.	p24

PREFACE: OZFOODNET

The overall brief of OzFoodNet is to enhance the surveillance and understanding of foodborne illness in Australia. OzFoodNet is a collaboration of foodborne disease epidemiologists largely based in Commonwealth and State/Territory health departments, and many other players who make up the wider OzFoodNet working group. The collaboration started in November 2000 and is funded by the Commonwealth Dept of Health and Ageing.

This paper is the second from two linked OzFoodNet/NCEPH projects, namely the *Community Gastroenteritis Survey* and *Estimating the Level of Foodborne Gastroenteritis in Australia*. The study team comprises the following people:

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Special acknowledgement is also due to Professor Niels Becker, Ass/Professor Scott Cameron, Dr Craig Dalton, Dr Edmond Hsu, Dr Karin Leder, Dr Paul Mead, and Dr Mark Veitch for considerable input with various aspects of the project. Thanks are also given to many other people who were involved at different times.

EXECUTIVE SUMMARY

Estimating the Incidence of Foodborne Gastroenteritis in Australia

- Of the 17 million episodes of gastroenteritis identified in a year in the gastroenteritis survey, it is estimated that about 32%, or 5.4 (Credible interval: 4.0-6.9) million cases are due to foodborne transmission. This equates to an incidence of 0.29 episodes per person per year; on average, every Australian can expect to experience an episode of foodborne illness every three to four years.
- Other similar studies to estimate the amount of foodborne gastroenteritis have been done recently in US [1] and UK [2]. The Australian estimate is remarkably similar to that reported for the United States of America, but higher than in the United Kingdom. In America, 36% of all gastroenteritis was estimated to be due to foodborne transmission and the incidence estimate is 0.28 cases per person per year.
- Almost four and a half million cases (Credible interval: 3.5-5.3) of gastroenteritis were estimated to be due to 'known' pathogens. This leaves over 12 million of the total 17 million cases estimated from the gastroenteritis survey unaccounted for. Of the known causes, about 1.6 million (Credible interval: 1.59-1.68) are due to bacterial infections, 2.3 million (Credible interval: 1.74-2.82) due to viral infections and 0.7 million (Credible interval: 0.44-0.97) due to parasites. About 58% of bacterial, 21% of viral and 14% of parasitic gastroenteritis is estimated as foodborne, with an overall total estimate of 32% (Credible interval: 24-40%) of all gastroenteritis due to foodborne transmission. The pathogens responsible for the greatest number of episodes of foodborne gastroenteritis are Caliciviruses, *E. coli*, *Campylobacter* and *Salmonella*.

Comment on Methods

- Using the methodology described in this report for estimating the number of foodborne cases, the estimate of the incidence of all gastroenteritis is crucial for the final estimate of foodborne disease.
- The case definition used in this study includes both severe and milder gastroenteritis [10]
- The definition of gastroenteritis should be the same when comparing across countries and times, as even an apparently small change in the definition can cause a large impact on the incidence. Standardization of methods is crucial when studies are being compared over time or place for comparison of results to be meaningful.
- The simulation method used to account for uncertainty in this Australian estimation has an interpretation akin to Bayesian inference and is simple to use. It is important to emphasise that there is a range of plausible values rather than one single point value, and this technique is a means of interpreting the available data in a reasonable way. Results are given with a ‘credible interval’ which can be interpreted in a way similar to a 95% confidence interval.
- In this Australian calculation overseas acquired infections were accounted for and not included.

Future estimations

- Monitoring of foodborne disease is necessary to evaluate improvements or otherwise in the control of foodborne disease. It would be worthwhile repeating the current study in 5-10 years time to identify any trends in Australia.
- Improved data are needed in order to improve estimations. In particular, these include:
 - Data to allow better estimates of the under-reporting fraction. This includes not only further analysis of available data, but collection of new data from laboratories
 - Further longitudinal studies with pathogen identificationEnhanced outbreak data collection

- In order to compare estimations, a standardised methodology is needed. In particular, the major issues are:
 - standardised definition of gastroenteritis
 - standardised data collection method for the gastroenteritis survey
 - standardised method of estimating the foodborne component

ESTIMATING THE LEVEL OF FOODBORNE GASTROENTERITIS

1. Background

The focus on ‘foodborne’ gastroenteritis comes from interest in the safety of the food chain. Ongoing monitoring of the level of foodborne gastroenteritis assists in evaluating intervention and control strategies aimed at food safety at a national level. The purpose of estimating the burden of foodborne gastroenteritis in this study is to provide a baseline against which trends can be measured over time.

The routes of transmission of infectious gastroenteritis vary across the known pathogens, with many having more than one route. Transmission can be from person-to-person, from the environment, by food, or by water. Some pathogens that cause infectious gastroenteritis are thought to be totally foodborne, such as *Bacillus cereus*, while others have only a small component of illness caused by the foodborne route, such as Rotavirus.

To estimate the burden of foodborne gastroenteritis two key estimates are required; firstly, the total amount of gastroenteritis in the country and secondly, the proportion of gastroenteritis that is foodborne. The product of these two estimates gives the total number of cases of foodborne gastroenteritis. This is the basic methodology that was used in the US recently [1] and which is applied to Australia in this report. As there is an inherent degree of uncertainty in the data used in these calculations, a new method using simulation has been employed to take account of this.

Total gastroenteritis

The total amount of infectious gastroenteritis in Australia in one year is known from the gastroenteritis survey described in the working paper titled “Results from the National Gastroenteritis Survey 2001-2002”.

Foodborne gastroenteritis

To estimate the proportion of infectious gastroenteritis that is foodborne, gastroenteritis identified as caused by 'known' pathogens is studied. The definition of 'foodborne' includes any infectious gastroenteritis caused by ingestion of food, including food contaminated early in the food chain, during processing, just before eating by food handlers, washing in contaminated water or by contact with unhygienic surfaces.

There is a large array of 'known' pathogens that cause infectious gastroenteritis, and each one has different characteristics with different laboratory tests needed to identify the various types of micro-organism. There are also many cases of gastroenteritis with 'unknown' pathogens where a pathogen is not identified at all but that are clinically assessed as 'presumed infectious'. Among the group of 'unknown' but presumed infectious cause, are cases where a known pathogen is present but is not identified, either because the stool was not tested in a laboratory, or it was not tested for the pathogen specifically, or the test resulted in a false negative. Also in this group are cases where the pathogen is as yet totally unknown. There are numerous pathogens that are now considered commonplace that were unknown only a few decades ago, including *Salmonella*, *Campylobacter*, and viruses. It is likely that there are many more that are major causes of morbidity, some of which will become apparent with time and investigation.

With the assumption that the proportion of gastroenteritis due to foodborne transmission among the 'unknown' causes is the same as for 'known' causes, the estimate of the proportion foodborne among all 'known' pathogens is used as proxy for estimating the proportion of all infectious gastroenteritis that is foodborne. For each known pathogen in Australia, the total number of cases of gastroenteritis caused by that micro-organism, and the number due to foodborne transmission, has been estimated as described in the following sections.

The overall objective of this study was to estimate the number of cases of foodborne gastroenteritis in a 'typical year around 2000', and to take account of uncertainty in the estimate.

2. Estimation Methods

2.1 Assessing Uncertainty

While statistical uncertainty can be measured by concepts like the standard error and confidence intervals, much of the uncertainty in the data needed for these calculations is not statistical and is inherent in the data itself, largely due to paucity of information. Simulation is used to take account of this, using the concept of a ‘plausible distribution of values for Australia around the year 2000’, instead of a point estimate. Such interval estimates are credibility intervals, with an interpretation akin to credibility intervals in Bayesian inferences.

Wherever uncertainty exists for a factor used in the calculations, a simulated distribution of ‘plausible values’ is used to model the uncertainty in that factor. In the absence of definitive statistically sound data, the decisions about the plausible distribution of values are based on ‘a reasonable interpretation ‘ of real data. This means that the parameters of the ‘plausible distribution’ are not necessarily based on a statistically derived value, but on interpretation of the best available data. The properties of the different distributions are used to simulate a 1000 ‘plausible’ values within a range, with the ‘most likely’ values having the greatest frequency. Where the properties of the distribution resulted in a few simulated values becoming negative at the lowest extreme, these were ignored so that all simulated ranges were from at least zero as the minimum value.

The width of the ‘credible interval’ of the final estimate is hence determined by the precision with which each of the component probabilities are estimated.

2.2 Literature review and Delphi process

For each known pathogen, a study of the literature was undertaken. The objective of the review for each pathogen was primarily to identify suitable data sources for estimating the number of cases in Australia, and to identify sources for estimating the proportion of transmission that is by food. Data on transmission modes was particularly scant, and the literature review was supplemented by opinion from a Delphi process. The ‘Delphi process’ was used to fill gaps in data and to ensure that there was agreement that the necessary assumptions and decisions were generally acceptable to foodborne disease experts. This

included a survey and consultation with ten Australian foodborne disease epidemiologists and infectious diseases clinicians experienced in foodborne disease, about the proportion of gastroenteritis for each pathogen that is foodborne. Some details are given in Appendix 2.

2.3 Data sources

Data was drawn from the OzFoodNet National Gastroenteritis Survey 2001/2, the National Notifiable Surveillance System 1996-2000, the Victorian and South Australian Surveillance Systems 1998-2001, the Victorian Outbreak Database 1998-2001, the Water Quality and Treatment Survey in Melbourne 1998 and Laboratories in Queensland and South Australia.

OzFoodNet National Gastroenteritis Survey 2001/2

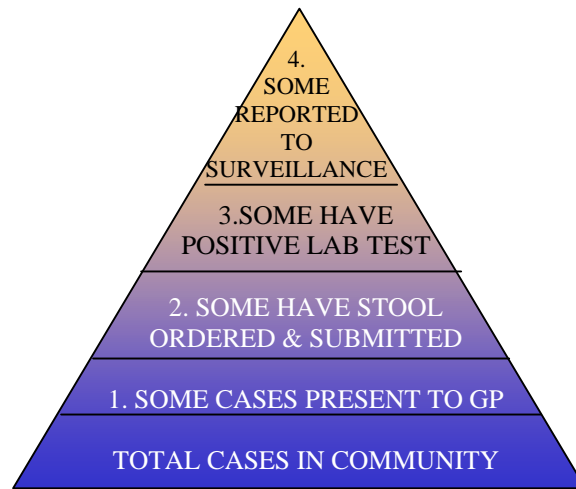
The total amount of gastroenteritis comes from the gastroenteritis survey described in the working paper titled “Results from the National Gastroenteritis Survey 2001-2002”.

Notifiable Surveillance System 1996-2000

There is mandatory reporting of illnesses due to certain pathogens to the state and territory surveillance systems by doctors and, in all but one state, by laboratories. However, it is inevitable that the surveillance will not capture all cases in the community, as many cases will not even present to a doctor, and of those that do, many will not have a stool test taken. There has been little work done in Australia on under-reporting to the surveillance systems, and the under-reporting fractions for different pathogens are largely unknown in this country. The state systems have some differences in reporting practices and the fraction of all community cases that are actually reported probably varies by locality. Ultimately, data from the state systems is reported to the National Notifiable Diseases Surveillance System (NNDSS).

Figure 1 shows the multiple steps in the process of notifying a case of foodborne disease.

Figure 1 Notified cases represent only a proportion of the burden of foodborne infectious disease



The under-reporting fraction is the product of the proportions at each step of the pyramid:

$$\text{Under Reporting Fraction} = P_{\text{Doctor}} \times P_{\text{Stool}} \times P_{\text{LabPos}} \times P_{\text{Reported}}$$

An ‘over-reporting fraction’ is theoretically possible if extra cases are erroneously entered on the surveillance database. This is unlikely to be a consistent occurrence. The inverse of the under-reporting fraction is the factor used to calculate the number of cases in the community from the surveillance data.

Victorian Outbreak Database 1998-2001

For some pathogens the best available data is from the database of outbreak investigations in the state of Victoria. During investigation the number of cases was recorded and this is used as the raw starting data to estimate the number of cases of gastroenteritis in the community. Adjustments are made to account for under-reporting.

Water Quality and Treatment Survey in Melbourne 1997-99

A randomised controlled trial of the effect of filtering drinking water was carried out in Melbourne in 1997-1999 [3]. Six hundred families with children were followed for 15 months, and all cases of gastroenteritis were reported. The filtering had no effect on diarrhoea incidence. About one third of gastroenteritis cases submitted a stool sample for testing. For each pathogen, the proportion of positive stool tests form the basis for estimating the number of cases nationally, by applying the proportion to the total number of cases of gastroenteritis nationally in one year.

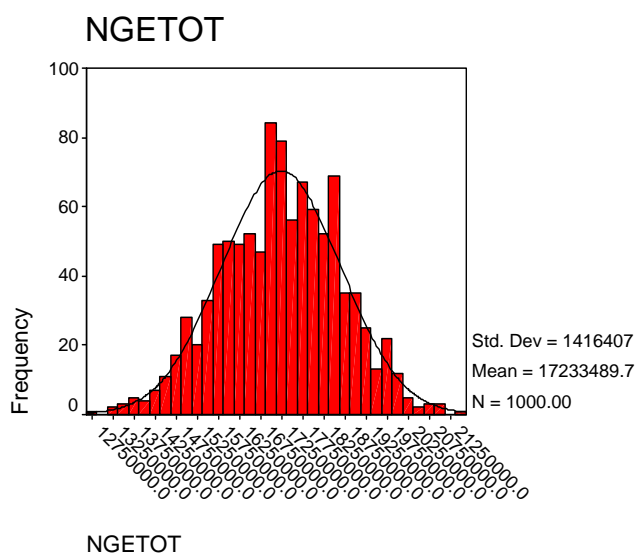
Laboratories in Queensland and South Australia.

The proportion of stools submitted for testing that are positive for a particular pathogen is used to calculate the estimate of all gastroenteritis due to that pathogen.

2.4 Estimating the total amount of infectious gastroenteritis in Australia

The results of the national survey of gastroenteritis that ran from September 2001 to August 2002 (see the working paper titled “Results from the National Gastroenteritis Survey 2001-2002”) were weighted by state, age, sex, and household size. There were an estimated 17.2 million (95% CI, 14.5 - 19.9) cases of gastroenteritis across Australia in 2001/2. These data were used to simulate a ‘plausible distribution of the number of cases of gastroenteritis in Australia around the year 2000’. Each simulated value (N=1000) represents a possible estimate. The decision about the parameters describing the ‘plausible distribution’ were informed by the standard error from the gastroenteritis survey giving a ‘credible interval’ of 14.5 to 19.9 million. The most common values are around 17.2 million while values closer to the extremes of the ‘credible interval’ are expected to be less likely, as shown in Figure 2.

Figure 2 Simulation of ‘Plausible distribution of number of cases of gastroenteritis in Australia around the year 2000’ Simulated N=1,000



2.5 Estimating the plausible number of cases of infectious gastroenteritis due to each ‘known’ pathogen

The objective was to estimate the number of cases due to each of all known pathogens in Australia in a ‘typical year’ around 2000 and then to estimate the number of these that were foodborne. A total of 26 ‘known’ pathogens were considered. In order to estimate the total number of cases of infectious gastroenteritis caused by these pathogens each year in Australia, data were drawn from sources as listed in the following Table 1. Some pathogens were not considered to cause foodborne-gastroenteritis in Australia, leaving 17 pathogens for further exploration.

Table 1 Sources of data

Surveillance data National or State 1996-2001	Outbreak data Victoria 1998-2002	Longitudinal data Melbourne 1998	Laboratory data SA and Qld	Not foodborne-GE cases in Australia
<i>Campylobacter</i>	<i>Bacillus cereus</i>	<i>E coli</i> other	<i>Aeromonas</i>	<u>Not foodborne</u> <i>Clostridium difficile</i>
<i>Salmonella</i>	<i>Clostridium perfringens</i>	Caliciviruses	<i>Vibrio parahaemolyticus</i>	<u>Not GE</u> <i>Brucella</i> spp
<i>Shigella</i>	<i>Staph aureus</i>	Rotavirus		<i>Listeria</i>
Shiga Toxin Like <i>E.coli</i>	<i>Vibrio vulnificus</i>	Astro/Adeno viruses		<i>Toxoplasma gondii</i>
		<i>Cryptosporidium parvum</i>		Hepatitis A
		<i>Cyclospora cayetanensis</i>		<u>Only acquired OS</u> <i>Salmonella</i> Typhi
		<i>Giardia lamblia</i>		<i>Vibrio cholera</i> 0136
				<u>No cases in Aust</u> <i>Trichinella spiralis</i> Botulism

Adjustments were made for population coverage, proportion acquired overseas, and under-reporting to surveillance. The various factors used to calculate the plausible number of cases in Australia in a typical year varied according to the type of primary data source as shown in Table 2.

Table 2 Factors used to adjust primary raw data

Primary data source	Factors used to adjust primary raw data		
1. Surveillance data National or State	Proportion of population covered	Proportion acquired overseas	Proportion reported to surveillance from community
2. Outbreak data Victoria	Proportion of population covered	Under-reporting of outbreaks compared with surveillance	Proportion reported to surveillance from community
3. Longitudinal survey data Melbourne	Proportion stools with pathogen	Gastroenteritis total in Australia	
4. Laboratory data SA and Qld	Proportion stools with pathogen	Gastroenteritis total in Australia	

(i) Surveillance data

The specific pathogens that cause gastroenteritis and are reported to the NNDSS are listed in Table 3, together with the number of notifications from 1996-2000. The pathogens include *Campylobacter*, *Salmonella*, *Shigella*, *Shiga Toxin Like E.coli* and *Yersinia*. The South Australian Surveillance System has enhanced surveillance of bloody *E. Coli* so data for this pathogen was from SA only. New South Wales does not notify *Campylobacter*.

Table 3 Specific pathogens that cause gastroenteritis and are reported to the surveillance systems

Pathogen/ syndrome	Campylo bacter	Salmonella	Shigella	Shiga Toxin Like E.coli	Yersinia
Comments	66% of population reports		Not found in Hellard study	South Australia screens all bloody stools (8% population)	Dropped after 2001 as declined. Not found in Hellard study
Overseas acquired	4%	8%	40%	21%	2%
Data used in estimation	All states except NSW	All states & territories	All states & territories	SA only	All states & territories
Illness severity	Moderate	Moderate	Bloody stools	Bloody stools	Moderate
Nreports/yr					
1996	12176	5791	679	-	212
1997	11829	6953	797	-	202
1998	13445	7712	612	18	171
1999	12803	7436	554	51	128
2000	13528	6111	487	41	74

Adjustments for population and overseas acquired cases

Data on some pathogens were from a proportion of the Australian population only and so adjustments were made accordingly. Estimates of the proportion of overseas-acquired infections came from the Victorian and South Australian notification systems. Data were adjusted by removing the proportion of cases that were acquired overseas.

Adjustment for under-reporting of illnesses from the community to the notification database

Given the paucity of pathogen specific data about under-reporting in Australia, the illnesses due to pathogens notified to the Australian Surveillance System were classified by severity, and under-reporting factors for Moderate illness, Bloody diarrhoea and Serious illness were estimated for Australia, similar to the strategy used in the US [1]. These factors were estimated using information from Victorian outbreak data 1998-2002, results from the Melbourne Water Quality Gastroenteritis Study [3] [4] and the OzFoodNet/NCEPH National

Gastroenteritis Survey 2002 [10]. A plausible distribution for the notifiable fraction is used rather than a single estimate, to allow for the uncertainty in the estimates.

The under-reporting factors for Moderate, Bloody and Serious illness are shown in Table 4.

Table 4 Under-reporting factors for Moderate, Bloody and Serious illness.

Severity of illness	Information used for estimation	Estimate and Credible interval
Moderate illness	Australian Surveillance data Melbourne WQTS ¹ Victorian outbreak data ² for Salmonella National Gastroenteritis Survey Hunter Salmonella case-control study ³	1 in 15 (5 to 25)
Bloody diarrhoea	National Gastroenteritis Survey	1 in 9 (1 to 17)
Serious illness	Mead 1999 ⁴	1 in 2 (1 to 3)

Sources:

¹Hellard, 2002 [3]

²Joy Gregory, DHS Victoria, 2002[5]

³Kefle Yohannes, MAppEpid Bound Volume, 2002[6]

⁴Mead 1999[1]

In the calculations for determining the under-reporting factor, the sensitivity of laboratory tests was estimated to be about 90% (based on estimates for *Salmonella* and *Shigella* testing in Australia, D. Lightfoot personal communication) and laboratory reporting to surveillance was estimated at 100%. More details of the information used to estimate the under-reporting factors are given in Appendix 1.

The simulation distributions based on the raw data for each pathogen in the Surveillance Systems was multiplied by the simulated distributions of the relevant under-reporting factor to produce estimates and credibility intervals of the total number of cases of gastroenteritis in one year in Australia due to each of these pathogens.

(ii) Outbreak data

A number of pathogens are identified in outbreaks but are not reported to surveillance as individual cases. Outbreak data maintained by the Victorian department of health represented the best source of data for three such pathogens, namely *Bacillus cereus*, *Clostridium perfringens* and *Staphylococcus aureus*. This data is shown in Table 5.

Table 5 Outbreak data from Victoria 1998-2002

Pathogen	<i>Bacillus cereus</i>	<i>Clostridium perfringens</i>	<i>Staphylococcus aureus</i>
Ncases/yr			
1998	9	32	0
1999	0	72	33
2000	37	73	40
2001	0	61	0
2002(6mths only)	0	28	7

Source Data supplied by J.Gregory, DHS Victoria.

The raw data of the number of cases identified during outbreaks between 1998 and 2002 was used to simulate a plausible distribution of the number identified in a ‘typical year’ by adjusting for population, under-reporting of outbreaks to surveillance and under-reporting of community cases to surveillance.

Adjustments for population

The data is from the population of Victoria which is 25% of the total Australian population so the population factor was four.

Adjustment for under-reporting of outbreaks compared with surveillance

The ‘outbreak factor’ describes the relationship between the number of cases identified in outbreaks, and the number of cases that would have been identified by surveillance had the micro-organism been a notifiable illness. Since the pathogens of interest are not actually reported to surveillance, the outbreak factor was based on data for *Salmonella* which was reported to both surveillance and the outbreak database in Victoria 1998-2002. The plausible distribution of the outbreak factor was deduced from a comparison of the number of notifications of *Salmonella* and the number of cases of *Salmonella* identified in outbreaks.

On average, there were 14 times as many notifications in Victoria as cases identified in outbreaks, with variability each year. The outbreak factor was simulated as a normal distribution with mean 14, and a credible interval of 6-22.

Adjustment for under-reporting of illnesses from the community to the notification database

The illness severity for the three pathogens is classed as ‘moderate’, so the under-reporting factor for moderate illness was used.

(iii) Survey and laboratory data

The number of cases of illness due to *E. coli* (other than enterohemorrhagic *E. coli*), Caliciviruses, Rotavirus, Astro/Adeno viruses, *Cryptosporidium parvum*, *Cyclospora cayetanensis*, *Giardia Lamblia*, and *Toxoplasmosis gondii* were derived from the longitudinal study in Melbourne conducted in 1997-9 [3].

The number of cases of illness due to *Aeromonas* was derived from laboratory data in South Australia in 1994-5 [7] and Queensland laboratory data 2001 was used for *Vibrio parahaemolyticus* (data from Russell Stafford personal communication).

The proportion of stools positive for these pathogens is shown in Table 6.

Table 6 Data on pathogens from the WQTS longitudinal study in Melbourne 1998, and laboratory data.

Pathogen	N stools tested And N positives	Proportion	95%CI
	1998/9 Melbourne	(Hellard	2001)
<i>E. coli</i> other	53/791	0.067	0.051-0.081
Caliciviruses	75/703	0.107	0.085-0.132
Rotavirus	11/791	0.014	0.007-0.025
Astro/Adeno viruses	9/791	0.011	0.005-0.021
<i>Cryptosporidium parvum</i>	13/791	0.016	0.009-0.028
<i>Cyclospora cayetanensis</i>	Nil	-	-
<i>Giardia lamblia</i>	20/791	0.025	0.016-0.039
<i>Toxoplasmosis gondii</i>	Nil	-	
Laboratory data			
<i>Aeromonas</i>	248/107600	0.002	0.0020-0.0026
<i>Vibrio parahaemolyticus</i>	2/30880	0.00006	0.00001-0.0002

The estimate of the number of cases of gastroenteritis in a year in Australia due to each of these pathogens was based on a simulated binomial distribution for the proportion of stools that were found in the survey, multiplied by the simulated distribution of the total amount of gastroenteritis in Australia (see Figure 2 previously).

2.6 Estimating the proportion of cases of gastroenteritis due to foodborne transmission

For each ‘known’ pathogen, the proportion of cases of illness that are foodborne was estimated from Victorian outbreak data, a literature review, and from the Delphi process.

Outbreak data that gave a proportion of cases that were assessed as of foodborne origin was available for *Bacillus cereus* (100% foodborne), *Campylobacter* (88%), *Clostridium perfringens* (100%), *Salmonella* (97%), *Shigella* (0%), Calicivirus (24%), Rotavirus (0%), *Cryptosporidium parvum* (0%) and *Giardia lamblia* (0%). This data was used in the Delphi process to arrive at a consensus of a plausible range for the proportion foodborne for each pathogen.

The plausible range of the number of *foodborne* cases for each ‘known’ pathogen was obtained by multiplying the number (simulated plausible range) of all cases of gastroenteritis by the proportion (simulated plausible range) foodborne.

2.7 Estimating the plausible number of cases due to foodborne transmission in Australia

For each of the ‘known’ pathogens, the total number of cases of gastroenteritis, and the total number of *foodborne* cases, were obtained by adding the values across all pathogens. The overall proportion of foodborne cases among ‘known’ pathogens was then calculated by dividing the number (simulated plausible range) of foodborne cases by the number (simulated plausible range) of total cases.

By assuming that the proportion of gastroenteritis that is foodborne is the same for both the ‘known’ and the ‘unknown’ cases of gastroenteritis, the total number of cases of foodborne gastroenteritis was then obtained by multiplying the total number (simulated plausible range) of cases of gastroenteritis in the country by the overall proportion (simulated plausible range) foodborne. The credible interval for the final estimate is hence determined by the simulated plausible ranges used in all the components of the arithmetic functions.

3. Estimation results

For each pathogen, Table 7 shows

- the total number of cases of gastroenteritis,
- the proportion of cases that were estimated to be foodborne,
- and the number of cases due to foodborne transmission

About four and a half million cases (Credible interval: 3.7-5.5) of gastroenteritis were estimated to be due to the ‘known’ pathogens. This leaves over 12 million of the total 17 million cases estimated from the gastroenteritis survey unaccounted for. Of the known causes, about 1.6 million (Credible interval: 1.17-2.10) are due to bacterial infections, 2.3 million (Credible interval: 1.74-2.82) are due to viral infections and 0.7 million (Credible interval: 0.44-0.97) are due to parasites. About 58% of bacterial, 21% of viral and 14% of

parasitic gastroenteritis is estimated as foodborne, with an overall total estimate of 32% (Credible interval: 24-40%) of all gastroenteritis due to foodborne transmission. The pathogens responsible for the greatest number of episodes of foodborne gastroenteritis are Caliciviruses, *E. coli*, *Campylobacter* and *Salmonella*.

The *total number of cases of foodborne gastroenteritis* was then obtained by multiplying the plausible distribution of the total number of cases of gastroenteritis (17.2 million; Credible interval: 14.5 to 19.9), by the proportion that is estimated to be foodborne (0.32; Credible interval: 0.24-0.40). The resultant number of cases of foodborne gastroenteritis has mean 5.4 million with a credibility interval of 4.0-6.9 million cases of foodborne gastroenteritis per year in Australia. These results are summarised in Figure 3 and Table 8.

Among the cases of foodborne gastroenteritis, 1.5 million (Credible interval: 1.0-1.9) are due to 'known' pathogens and the remainder are due to 'unknown' pathogens. The incidence of foodborne gastroenteritis is estimated at 0.29 (Credible interval: 0.23-0.35) cases per person per year.

Table 7 Gastroenteritis in Australia in a ‘typical’ year~2000: Total number of cases and number of foodborne cases among known pathogens

PATHOGEN	Total Number of cases of GE in Australia			Proportion of cases of GE that are foodborne			Number of cases of GE that are foodborne		
	Median	Credible interval		Median	Credible interval		Median	Credible interval	
		Low	High		Low	High		Low	High
BACTERIA									
<i>Aeromonas</i>	39444	31702	47186	0.25	0.12	0.38	9768	4141	15395
<i>Bacillus cereus</i>	6900	0	15842	1	1.00	1.00	6900	0	15842
<i>Campylobacter</i>	276507	89772	463242	0.75	0.67	0.83	208246	66834	349658
<i>Clostridium perfringens</i>	43085	437	85733	1	1.00	1.00	43085	437	85733
<i>E. coli</i> (SLTEC bloody)	3041	0	6451	0.65	0.48	0.82	1927	0	4206
<i>E. coli</i> (other diarrhea)	1151638	796527	1506749	0.5	0.32	0.68	562979	294812	831146
<i>Salmonella</i>	91974	26355	157593	0.87	0.81	0.93	80605	23085	138125
<i>Shigella</i>	3216	0	6928	0.1	0.04	0.16	298	0	737
<i>Staphylococcus aureus</i> food poisoning	14189	0	29773	1	1.00	1.00	14189	0	29773
<i>Vibrio parahaemolyticus</i>	1075	0	2614	0.71	0.54	0.88	736	0	1845
<i>Yersinia</i>	2166	0	4491	0.75	0.63	0.87	1621	0	3399
Total bacteria	1639181	1175020	2103342	0.58	0.44	0.72	946985	587690	1306280
VIRUSES									
Caliciviruses	1831586	1361086	2302086	0.25	0.12	0.38	446117	192546	699688
Rotavirus	241153	98202	384104	0.02	0.01	0.03	4676	707	8645
Astro /adenovirus	189710	63394	316026	0.1	0.02	0.18	17545	0	36775
Total viruses	2276130	1735060	2817200	0.21	0.11	0.31	470161	214487	725835
PARASITES									
<i>Cryptosporidium parvum</i>	270978	254763	287193	0.1	0.02	0.18	25083	0	54277
<i>Giardia lamblia</i>	429989	232396	627582	0.05	0.01	0.09	20282	0	41105
Total parasites	703996	442081	965911	0.14	0.04	0.24	65953	18168	113738
TOTAL	4639364	37486101	5513367	0.32	0.24	0.40	1476822	1030642	1923002

Figure 3 Plausible distribution of number of cases of foodborne gastroenteritis in Australia in a typical year ~ 2000. Simulated N=1000.

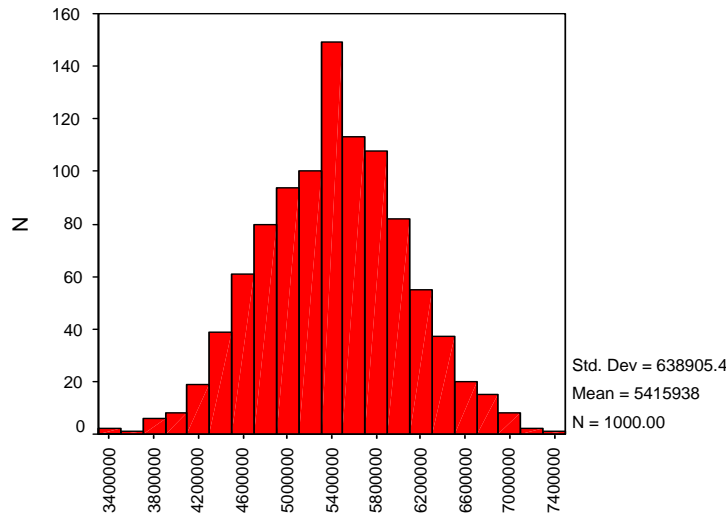


Table 8 Number and incidence of all cases of gastroenteritis¹ and of foodborne gastroenteritis in Australia in a 'typical' year~2000

	Estimate	Credible Interval
Known pathogen		
Total cases among 'known' pathogens	4.6	3.7 -5.5 million
Foodborne cases among 'known' pathogens	1.5	1.0-1.9 million
Unknown pathogen		
Total cases with 'unknown' pathogens	12.6	10.6-14.8 million
Foodborne cases with 'unknown' pathogen	4.0	3.0-5.2 million
Total		
Total cases gastroenteritis	17.2	14.5-19.9 million
Foodborne cases gastroenteritis	5.4	4.0-6.9 million
Incidence: Cases per person per year		
All gastroenteritis	0.92	0.77-1.06
Foodborne gastroenteritis	0.29	0.23-0.35

¹ Gastroenteritis: non-infectious excluded, stools \geq 3 OR vomit \geq 2 in 24 hrs, if resp symptoms then stools \geq 4 OR vomit \geq 3

4. Discussion of the estimation study

Summary of main findings

Of the 17 million episodes of gastroenteritis identified in a year in the gastroenteritis survey, it is estimated that about 32%, or 5.4 (4.0-6.9) million cases, are due to foodborne transmission. This equates to an incidence of 0.29 episodes per person per year which means that on average, every Australian can expect to experience an episode of foodborne illness every three to four years.

Using the methodology described in this report for estimating the number of foodborne cases, the estimate of the *incidence of all gastroenteritis* is crucial for final estimate of foodborne disease. The definition of gastroenteritis in this study was 3 loose stools or 2 vomits in 24 hours, with adjustment for those with respiratory symptoms to account for diarrhoea and vomiting secondary to a primary respiratory system. The decision to use this definition was a collective outcome of the Delphi process, involving ten foodborne disease experts in Australia. This definition includes “mild to moderate illness” as well as more “serious illness”. It should be borne in mind that if the focus had been on more severe gastroenteritis, such as illness that interferes with daily activities, or duration of 3 days or more, or some other criteria, then we would have considerably less cases of gastroenteritis due to foodborne disease.

Across countries, different case definitions of gastroenteritis and different methodologies of collecting data make comparisons of the estimate of gastroenteritis very problematic.

Other similar studies of the amount of foodborne gastroenteritis have been done recently in US [1] and UK [2]. The Australian estimate is remarkably similar to that reported for the United States of America, but higher than in the United Kingdom. In America, 36% of all gastroenteritis was estimated to be due to foodborne transmission and the incidence estimate is 0.28 cases per person per year.

In the UK in 1995, the total amount of gastroenteritis in the community was much lower than Australia or US at only 0.2 cases per person per year. [8]. Some possible methodological reasons that may have influenced the estimate of a lower incidence of total gastroenteritis

from the UK survey compared with the US and Australia were discussed at the end of the working paper titled “Results from the National Gastroenteritis Survey 2001-2002”.

The proportion of gastroenteritis estimated to be due to foodborne transmission was also lower in the UK. In 1995, there were an estimated 2.37 million infections due to foodborne gastroenteritis which is only 26% of the total estimate of all gastroenteritis of nearly 10.5 million [2]. One of the key influential estimates among ‘known’ pathogens is for Calicivirus; this was assessed as contributing a very high number of gastroenteritis cases in all three countries. Only 10% of NLV (Caliciviruses) gastroenteritis was ascribed to foodborne transmission in the UK study, compared with 40% in the US, and 20% in Australia[1, 2]. Both the UK and Australian estimates were based on outbreak data. In the UK, the low total estimate of community gastroenteritis (0.2 cases per person per year) combined with a low proportion thought to be foodborne (26%) leads to a very low estimate of foodborne gastroenteritis of 0.04 cases per person per year in the UK in 1995.

The UK study also compared estimates between 1992 and 2000, using adjusted annual General Practitioner surveillance data for the total estimate of gastroenteritis, and adjusted laboratory data for the individual pathogens. The number of laboratory reports for all infectious gastroenteritis was about 123,000 in 1992 and 117,000 in 2000, suggesting a stable situation. However, the estimate for foodborne gastroenteritis decreased from 2.9 to 1.3 million cases.

The change in the estimates for foodborne gastroenteritis suggest that the number of people reported as visiting GPs and/or the proportion of gastroenteritis that is foodborne must have changed over the ten years, although these numbers are not given. A change in GP visits for gastroenteritis seems unexpected given the stable number of reports from laboratories.

In the UK calculations it is not clear whether the same ‘proportion due to food ‘ was applied at different times (that is, using the 1995 estimate of 26% for 1992 and 2000) or whether different proportions were estimated at the different time points. If the estimates were based on data at each time point, the influence of changed reporting must be borne in mind. The number of infections reported to laboratories due to ‘unknown’, *Yersinia* and *Clostridium perfringens* and *Salmonella* declined over the period 1992 to 2000, but the number due to Norwalk Like Virus increased. The decline for the bacterial pathogens is presumably real, but

the increase in NLV is likely to be related to increased and improved laboratory testing. As the UK authors themselves point out, the potential influence of Norwalk Like Virus on the calculations is considerable, and so the possible influence of changed laboratory practices on the proportion foodborne needs to be carefully assessed.

The need for Improved and Standardised Methodology

The importance of a standardised methodology when comparing results of the amount of foodborne gastroenteritis across countries or times cannot be overemphasised. Not only the study design is likely to be influential, but also the definition of gastroenteritis. In this Australian study, the definition took some account of those with concurrent respiratory symptoms but most studies estimating the amount of gastroenteritis have not considered this. The US study [1] adjusted for those with respiratory illness, by excluding a proportion of cases that were thought likely to have symptoms secondary to respiratory infections rather than a primary gastro-intestinal infection. The UK definition of gastroenteritis was different from the Australian definition in several ways. While there are differing arguments that can be raised about the 'best definition' of gastroenteritis, the main concern is to have a consistent, reasonable definition for comparative purposes.

The studies in the US and UK did not account for uncertainty, which is inherent in the type of calculations used for estimation of the foodborne component. The simulation method used in this Australian estimation to account for uncertainty has an interpretation akin to Bayesian inference and is simple to use. It is important to emphasise that there is a range of plausible values rather than one single point value, and this technique is a means for interpreting the available data in a reasonable way. In this Australian calculation overseas-acquired infections were accounted for and not included.

Strengths and limitations of the data

In this study, as in others overseas, each of the data sources had strengths and weaknesses and data gaps remain. Notification data and outbreak data are likely to be subject to reporting variation across jurisdictions, over times and by illness, which can affect the estimate of the amount of foodborne gastroenteritis. The National Gastroenteritis Survey provided useful information for estimating the level of under-reporting to surveillance, and other data were also used to gain insight into this, including data from outbreak investigations. Outbreak data represents only those episodes of illness that are ultimately recognised as linked, and as such

is possibly more likely to be 'serious' illness and biased towards a smaller under-reporting factor. Both the under-reporting factor and outbreak factor used in the calculations were largely based on reports of *Salmonella*, but the factors are likely to be illness specific. Further work to improve the estimates of under-reporting would be very beneficial to improve the calculations, and in addition, to provide more insight into the surveillance systems in Australia.

The Melbourne longitudinal study represents the best data of its kind in Australia [3]. However, it should be remembered that it was based on families with children in one locality, and bias of the pathogen estimates is possible due to the age distribution of the sample, clustering by person and household, and especially the constrained locality. About one third (795 of 2669) of gastroenteritis cases actually submitted a stool, so this may represent more severe cases, or cases early in the study when enthusiasm was higher, which could lead to differences due to seasonality of illness caused by different pathogens. While a wide range of pathogens were sought, there were still some 'known' pathogens that were not tested for. Only 17% of the stools examined had a pathogen identified.

Two important issues regarding the National Gastroenteritis Survey that would benefit from further enquiry are recall bias and the influence of the case definition.

Future estimations

Monitoring of foodborne disease is necessary to evaluate improvements or otherwise in the control of foodborne disease. The study in the UK [2] suggests that the level of foodborne gastroenteritis has declined in the last decade and it would be worthwhile repeating the current study in 5-10 years time to identify any trends in Australia.

Improved data are needed in order to improve estimations. In particular, these include:

- Data to allow better estimates of the under-reporting fraction. This includes not only further analysis of available data, but collection of new data from laboratories
- Further longitudinal studies with pathogen identification
- Enhanced outbreak data collection

In order to compare estimations, a standardised methodology is needed. In particular, the major issues are:

- standardised definition of gastroenteritis
- standardised data collection method for the gastroenteritis survey
- standardised method of estimating the foodborne component

APPENDICES

Appendix 1 Under-reporting factors

Factors for moderate, bloody and serious illness

The factor for *moderate illness* was derived from several data sources. Data on outbreaks in Victoria due to *Salmonella*, indicated that about one case of Salmonellosis in six was reported to surveillance. The Melbourne longitudinal study [3] provided data that suggested under-reporting factors for *Salmonella* of 23, and *Campylobacter* of 21, when extrapolated rates were compared with the number of notifications in Australia. The gastroenteritis survey results regarding duration of illness being an important predictor for visiting a doctor and having a stool sample taken was combined with information about the duration of *Salmonella* infections from a case-control study in the Hunter region of NSW. This indicated an under-reporting factor of 11 for *Salmonella* [6].

Given this information, a distribution of the Moderate Illness Reporting Factor was simulated to be a normal distribution, with one reported illness in every 15 illnesses in the community, with a credible interval of 5 to 25.

The factor for *bloody diarrhoea* was derived from the national gastroenteritis survey. Twelve cases had bloody diarrhoea and of these, three saw a doctor and two of these had a stool taken. Although the number of cases is extremely small, similar results were found in the US gastroenteritis surveys, which lends some validity to the results [9]. The fraction of bloody stools that had a stool test was 0.17(95%CI: 0.07,0.32), or conversely, for 3-14 cases of bloody stool in the community, one had a stool test. Given this information, and allowing for further uncertainty about the sensitivity of the laboratory test and reporting to surveillance, a plausible distribution of the Bloody Diarrhoea Reporting Factor was simulated to be a normal distribution, with one reported illness in every 9 illnesses in the community, with a credible interval of 1 to 17.

The under-reporting factor for *serious disease* was taken as one in every two illnesses in the community, the same as the US estimate [1], with credible interval 1 to 3.

Appendix 2. Delphi process

Estimation of the proportion of gastroenteritis that is foodborne

As there are little data on how much of the illnesses are due to foodborne transmission, foodborne disease experts were asked for their opinion to supplement opinion in the literature (most of which are not based in strong evidence).

Ten foodborne disease experts (epidemiologists and clinicians) were sent a survey to estimate the proportion of illnesses of 26 pathogens that cause gastroenteritis that were due to foodborne transmission. The results were collated and other information was provided from the literature and outbreak data. A meeting was held to discuss the results and the 26 pathogens were either considered not relevant to foodborne gastroenteritis in Australia, or a plausible distribution of the proportion foodborne was agreed upon.

Experts asked about pathogens causing foodborne gastroenteritis, 2002
Dr Craig Dalton, Director, Hunter Public Health Unit
Martyn Kirk, Co-ordinating Epidemiologist, OzFoodNet
Scott Crerar, ANZFA
Geoff Millard, OzFoodNet Epidemiologist, ACT
Dr Mark Veitch, Public Health Physician, MDU, Victoria
Dr Rod Givney, Epidemiologist Communicable Diseases, SA
Russell Stafford, OzFoodNet Epidemiologist, Queensland
Leanne Unicomb, OzFoodNet Epidemiologist, Hunter Region NSW
Joy Gregory, OzFoodNet Epidemiologist, Victoria
Dr Scott Cameron, Public Health Physician, SA

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