Estimated community costs of an outbreak of campylobacteriosis resulting from contamination of a public water supply in Darfield, New Zealand

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Abstract

Aim To estimate the economic costs to the community of an outbreak of campylobacteriosis in August 2012 resulting from contamination of a public water supply in Darfield, New Zealand.

Method Probable incidence of waterborne disease was estimated. Reported cases were scrutinised to identify symptoms, duration, hospital admissions and those in the paid workforce. Extra public health and local authority costs were calculated. Estimated time off work was multiplied by the average wage to obtain a conservative estimate of lost production. Sensitivity analysis was used to estimate unreported cases and their associated costs.

Results There were 138 cases of confirmed or probable campylobacter, of whom 46 sought a medical consultation. Taking into account the usual pyramid of non-notified cases, estimates of the population infected range between approximately 828 and 1987. The dominant societal cost is lost production from time off paid work. Forty-six per cent were in the paid workforce, indicating a total estimated economic cost of at least $714,527 but it could have been as high as $1.26 million, depending on estimates of unreported cases.

Conclusion The likely cause of the Darfield outbreak was faecal contamination of the water supply, which with a multi-barrier approach would have been entirely preventable. The results provide economic evidence to support upgrading of water supplies to provide safe water and prevent waterborne disease.

In August 2012, there was an outbreak of gastrointestinal disease in Darfield, New Zealand (NZ) which evolved into one of the largest outbreaks of waterborne disease ever recorded in NZ. The majority of infections were confirmed or probable campylobacteriosis.

The outbreak occurred in a context of concern that there are unsafe water supplies in a number of NZ communities, compounded by a lack of action by local authorities, as the drinking water suppliers, who are responsible by law to provide safe water.

In the Darfield outbreak, elevated levels of faecal indicator bacteria Escherichia coli (E. coli) were confirmed in the water supply by laboratory testing. Before the outbreak, the Selwyn District Council had reverted to a river water source because of problems with its deep bore water source, then failure of a chlorination system allowed the survival of Campylobacter in the Darfield water supply, causing infection.
In the 4-year period before August 2012, the background population incidence of notified campylobacter in the Darfield area averaged between 1–2 cases per month. In August the number of confirmed and probable cases dramatically increased, as shown in Figure 1.

**Figure 1. Onset dates of probable and laboratory confirmed campylobacteriosis cases associated with the Darfield water contamination**

The Selwyn District Council contracted independent consultants to review their water system. They have subsequently working through a number of recommendations including providing an additional deep bore source of water, continuous chlorination of any surface water used as back-up, and updating of hygiene systems.

Darfield is a small town, which in 2012 had an estimated resident population of 1790. It is located on a major highway approximately 40 km west of the Christchurch urban area.

Campylobacteriosis is a well-recognised issue in NZ, which has been most commonly associated with consumption of undercooked chicken.\(^1,2\) Considerable economic costs of foodborne campylobacteriosis and other gastrointestinal illness have been documented in NZ.\(^2,3\) Public health action has achieved much improved recognition of the risks of under-cooked chicken and of foodborne disease.

Although there have been ongoing attempts to increase awareness of the risks of unsafe water supplies, there remain a number of communities where significant concern exists about the safety of drinking water. Failure to take remedial action to address this is often accompanied by debates about its costs, but there is a relative lack of evidence on the potential economic costs of unsafe water supplies.

This paper aims to estimate the economic costs to the community of an outbreak of disease resulting from the contamination of a public water supply in Darfield in
August 2012. This data should help to inform debates about investment in safer water supplies.

**Methods**

Costs to the community were estimated from cases of confirmed as well as probable campylobacteriosis reported to the Canterbury District Health Board in August and September 2012 (n=138). The case definitions were as follows:

A person who had been in Darfield between 14 July and 30 August 2012, who was not overseas during the 10 days before the onset of symptoms and for whom there was no medical or other likely explanation for their symptoms and who either had:

- Diarrhoea and/or abdominal pain with fever—for at least 1 day (probable case of campylobacteriosis); or
- Laboratory confirmed campylobacteriosis (confirmed case).

Previous international research has shown that reported cases of infectious gastrointestinal illness represent the tip of the iceberg as most cases remain unreported to health authorities. Recent relevant research in the UK found that for every case of campylobacteriosis reported to national surveillance there were approximately 9.3 cases in the community (95% confidence intervals 6.0 to 14.4) that were unreported. Lake et al estimated that for every reported case of acute gastrointestinal illness in NZ, there were 222 cases that were not reported (95% CIs 199–247). However, the majority of this unreported disease pyramid is viral in origin and the UK studies indicate that ratios for unreported campylobacteriosis are likely to be considerably lower.

Therefore, the UK estimates by Tam et al were used to estimate the number of unreported cases of campylobacteriosis associated with the Darfield 2012 outbreak. The numbers of laboratory confirmed and probable cases were multiplied by the 95% confidence interval estimates of the number of unreported cases (based on Tam et al).

Uncertainty exists around this estimate of unreported cases, therefore the results include sensitivity analysis to indicate possible costs if the ratio in Canterbury was greater than the unreported to reported case ratio of 9.3:1. Possible reasons for this uncertainty are explored in the discussion section below.

The Community and Public Health Division of the Canterbury District Health Board provided a database of the 138 confirmed and probable cases, which included data on age, gender, occupational status, use of health services, laboratory testing, and type and duration of symptoms.

Costs of laboratory testing ($36.62 per faecal test) were as supplied by the Canterbury District Health Board in 2012. Costs of the primary care visit included the patient fee (as advertised for Darfield Medical Centre) plus the government capitation subsidy (total cost per visit $56.34), apportioned assuming an average of four GP consultations per person per year, which has been found in NZ Health Surveys.

The average age of reported cases was 30 years (range 0 to 89). Therefore the capitation subsidy for 25–44 year olds (averaged for males and females) was used for the purposes of these estimates. In the Darfield outbreak, the proportion of men and women was approximately equal among reported cases.

Our estimates included an allowance for transport costs to and from a medical centre. For this we assumed a conservative distance of six kilometres per person at the average vehicle mileage paid by the Canterbury District Health Board in 2012 (70 cents per km).

We followed the assumption of Scott et al (2000) who received advice that approximately 10% of infected individuals would either receive a prescription for or buy an electrolyte replacement over the counter (OTC). For the purposes of this project, the OTC cost for Gastrolyte™ was used ($19.99).

To estimate losses from time off work (lost production), people who reported being in the active paid workforce were included, while preschoolers, school children, students and retired people were excluded.

Sixty-three confirmed and probable cases were currently in the workforce (46%). For the purposes of this analysis, we followed the assumption by Scott et al that each non-hospitalised case would have 5 days off normal work. This is conservative in view of the duration of symptoms reported in Table 1.
The average weekly wage ($922) for salaries and wages before tax in NZ published by Statistics NZ was used to calculate lost production.

Intangible costs were not included in this analysis. In their analysis of the costs of foodborne acute gastrointestinal illness in NZ, Scott et al included an estimate for intangible costs, by calculating time off usual activities associated with the illness, and then multiplying by the average wage. While there are undoubtedly intangible costs of such illness, we have not included any in our estimates because of the problems in quantifying them. Hence, our estimates could be viewed as conservative. Similarly, we have not included any potential damage to tourism and the “clean, green image” that is often promoted for NZ.

Inpatient costs of admissions to Christchurch Hospital were estimated from the average cost per bed day in 2012, supplied by the Canterbury District Health Board ($920 per day for an acute medical bed), multiplied by the length of stay (in days).

Extra work hours spent by District Health Board public health staff in containing the outbreak were multiplied by the relevant wage rates to obtain a cost estimate of the staff time directly attributable to investigating the outbreak and the Darfield water contamination. This method provides a conservative estimate of the opportunity costs of work time spent by staff who would otherwise have been working on other important public health issues.

Our estimates do not include any work time, operating or capital costs for the Selwyn District Council to repair and/or upgrade any of the local water reticulation and storage system. This is based on the assumption that providing clean water is part of a District Council’s legal responsibility, as the drinking water supplier, so that in theory all water reticulation and treatment systems should be maintained routinely, despite this outbreak. However, we have included the costs of a consultant’s report (Opus), which was commissioned by the District Council.

We have also included an allowance for costs of additional staff time (personal communication, 2013) by District Council staff involved in responding to enquiries, issuing boil water notices and responding to the outbreak.

Results

There were a total of 138 cases of confirmed and probable campylobacteriosis reported during the August 2012 outbreak (Table 1). Forty-six people reported seeking a formal medical consultation (either doctor or nurse), and laboratory testing was undertaken for 35 people.

Thirty-five cases submitted stool samples of which 29 were positive for campylobacter. Twenty-three of these were C. coli, three of which also had C. jejuni isolated and one Giardia. Three cases were positive for C. jejuni only, and for three cases no further subtyping was done. All specimens (where tested) were negative for Salmonella, Shigella, Yersinia, rotavirus, norovirus and E. coli 0157.

Water samples taken from the well, residential water tank and Waimakariri River were all negative for Campylobacter. Sixteen sheep stool samples were taken, of which 25% were positive for C. jejuni and one was positive for C. coli. The C. coli strain was very closely related to the strain isolated in human cases.

The mean age of cases was 30 years, ranging from infants to 89 years of age. Men and women were affected equally. Cases commonly reported diarrhoea, stomach pain, vomiting and nausea (Table 1).

On average, symptoms lasted for approximately 5 days before they were cleared (range 1–28 days). One hospital admission directly related to campylobacteriosis was reported, requiring admission to an acute medical bed in Christchurch Hospital for 5 days, followed by discharge home with no further medical treatment required.
Table 1. Estimated costs to the economy of the reported* cases of campylobacteriosis August 2012 outbreak in Darfield

<table>
<thead>
<tr>
<th>Reported cases of confirmed &amp; probable campylobacter*</th>
<th>N</th>
<th>138</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases who sought medical consultations</td>
<td>N</td>
<td>46</td>
</tr>
<tr>
<td>Mean age (range) years</td>
<td></td>
<td>30 (0.9–89)</td>
</tr>
<tr>
<td>Female %</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>Notified cases in the active workforce N (%)</td>
<td></td>
<td>63 (46%)</td>
</tr>
<tr>
<td>Reporting diarrhoea % (range in days)</td>
<td>%</td>
<td>97% (1–14)</td>
</tr>
<tr>
<td>Reporting stomach pain % (range in days)</td>
<td>%</td>
<td>96% (1–28)</td>
</tr>
<tr>
<td>Reporting vomiting % (range in days)</td>
<td>%</td>
<td>26% (1–14)</td>
</tr>
<tr>
<td>Reporting nausea % (range in days)</td>
<td>%</td>
<td>60% (1–28)</td>
</tr>
<tr>
<td>Costs of primary care consultations $</td>
<td></td>
<td>2592</td>
</tr>
<tr>
<td>Costs of laboratory tests and electrolytes $</td>
<td></td>
<td>1558</td>
</tr>
<tr>
<td>Costs of hospital admission $</td>
<td></td>
<td>6440</td>
</tr>
<tr>
<td>Extra public health staff time costs $</td>
<td></td>
<td>7712</td>
</tr>
<tr>
<td>Costs of lost work $</td>
<td></td>
<td>58,086</td>
</tr>
<tr>
<td>Total economic costs for reported cases $</td>
<td></td>
<td>75,212</td>
</tr>
<tr>
<td>Estimated extra costs incurred by local authority $</td>
<td></td>
<td>95,000</td>
</tr>
</tbody>
</table>

Notes: $ are in 2012 NZ$ values; *reported cases includes both confirmed and probable cases.

The majority of people with campylobacteriosis endure the condition in the community, with limited input from formal health services. The estimated costs of primary care consultations, laboratory tests and of the hospital admission are shown in Table 1.

Together with lost production from lost work, the direct economic costs of notified cases are estimated at $75,212. Approximately 77% of these are costs of lost production from time off work. Forty-six percent of confirmed and probable cases were people in the paid workforce (Table 1), so just over half were preschoolers, students, retired people or those not in paid work.

The district council incurred additional direct costs of approximately $95,000, comprising an expert report from an engineering consultancy, as well as additional staff time for dealing with enquiries and issuing boil-water notices.

Research has established that in gastrointestinal disease outbreaks, reported cases represent only the tip of the iceberg and there is usually an underlying disease pyramid of unreported cases, of people who endure the symptoms without seeking consultations from formal primary health care services.4,5,7

If we use the best published evidence that there are an estimated 9.3 cases of unreported campylobacteriosis for every one reported case,5 the “best estimate” economic costs total approximately $714,528, which includes $170,212 of costs directly attributed to reported cases, plus $544,316 estimated costs of lost production from time off work (Table 2). However, the 95% confidence intervals reported by Tam et al5 indicate a possible range from $521,383 to $938,000, including estimated lost production in Table 2.
Table 2 shows that applying the Tam et al’s ratio of unreported to reported cases (i.e. 9.3:1), provides an estimate of the population affected by the Darfield outbreak of 1283.

Tam et al’s estimate was obtained from a UK study, which could potentially underestimate unreported campylobacteriosis in NZ, when it is considered that there are considerable general practice co-payments which provide a deterrent to primary care consultations in this country. Such co-payments do not exist in the UK. Also, cases are likely to include non-residents travelling through and/or working in the area—i.e. not restricted to residents of Darfield.

Hence a sensitivity analysis investigated costs if the ratio of unreported to reported cases was twice the level reported by Tam et al, i.e. 18.6:1, indicating that the costs of lost production could be as high as $1.09 million (Table 2). Adding the costs of directly reported cases from Table 1, would give an upper plausible total cost estimate of $1.184 million.

Table 2. Total estimated cases and economic costs, including unreported campylobacteriosis associated with the August 2012 outbreak in Darfield

<table>
<thead>
<tr>
<th>Variables</th>
<th>Using estimate by Tam et al* (9.3 for every 1 reported case)</th>
<th>Lower 95% CI* (6.0:1)</th>
<th>Upper 95% CI* (14.4:1)</th>
<th>Sensitivity analysis – if the ratio was twice that estimated by Tam et al (18.6:1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cases</td>
<td>N 1283</td>
<td>828 1987</td>
<td>2567</td>
<td></td>
</tr>
<tr>
<td>In active workforce</td>
<td>N 590</td>
<td>381 914</td>
<td>1181</td>
<td></td>
</tr>
<tr>
<td>Costs of lost production</td>
<td>S 544,316</td>
<td>351,171 842,811</td>
<td>1,088,631</td>
<td></td>
</tr>
</tbody>
</table>

Notes: *From Tam et al

Discussion

These estimates indicate that the majority of economic costs to the community of this outbreak were from lost work time from people in the paid workforce taking time off work. This is similar to the conclusions of Scott et al, reporting on societal costs of foodborne disease.

These estimates should be viewed as conservative when it is considered that they do not include any allowance for non-paid work such as voluntary work, caring for others, lost school days, lost leisure time or social events. Also, our estimates do not include costs that employers may have incurred if they had to replace sick employees—e.g. those who may be teachers, in the health workforce or in industries needing replacement staff.

This study did not attempt to include any value for intangible costs such as suffering, pain, or lost social or leisure opportunities. These are valid costs, but methods for valuing them are subjective, controversial and may be open to criticism. In excluding intangible costs, we are not avoiding them—rather it indicates that our cost estimates are conservative.
This study has used the best published international evidence on the ratio of unreported to reported cases of campylobacteriosis (the Tam et al\(^5\) estimate of 9.3:1).

The most relevant NZ study is by Lake et al\(^7\) who estimated that there were 222 unreported cases in the community for every reported case of acute gastrointestinal illness. This estimate was made from the number of reported cases throughout NZ in 2006, from a nationwide telephone survey, and from a survey of community and hospital laboratories.\(^7,9\) They found that 22\% of all people with acute gastrointestinal illness (AGI) had consulted their general practitioner (GP). However, only approximately 0.4\% of community cases ultimately result in reporting of a case of notifiable disease to public health authorities.

Other research in the UK found that the majority of community cases of AGI are due to viruses and that the probable incidence of unreported cases of bacterial illness is smaller: for campylobacteriosis, it was estimated at 9.3 unreported cases for every reported case.\(^5\) An earlier UK study drew similar conclusions.\(^6\)

The Lake et al\(^7\) estimates are of a similar order of magnitude to other international studies, for example Majowicz et al\(^4\) for Ontario, Canada, and Tam et al\(^5\) for the UK. However, Tam et al\(^5\) found that the unreported disease pyramid for viral illness was much greater than for bacterial illness, of which Campylobacter is the most common.

Accordingly, in this study we have used the ratio reported by Tam et al\(^5\) (9.3 unreported cases for every reported one) as the most relevant to the Darfield water contamination.

Another possible reason for uncertainty as to the validity of applying UK estimates to a NZ situation is the possibility of the primary care co-payment as a potential barrier to seeking medical advice, especially when there might be public advice that a watchful waiting approach might be preferable to active medical intervention.

In the UK, there are no GP co-payments to provide such potential financial deterrents. This ratio of unreported to reported cases is the greatest potential source of uncertainty to our estimates, therefore we have included a sensitivity analysis that showed that if the ratio of unreported to reported cases was twice that found by Tam et al,\(^5\) i.e. if it was 18.6 cases for every reported case, the total estimated economic costs of the Darfield water contamination would have been $1.26 million.

There is yet another reason why our costs are probably conservative. We took into account only cases of campylobacteriosis and we made no allowance for infection with multiple pathogens. Waterborne outbreaks commonly involve more than one pathogen, as the three cases in this outbreak who were infected with more than one subtype of *Campylobacter* and the one who also had *Giardia* illustrate. The costs of treatment and the risks of complications, including need for hospitalisation, will vary for different diseases.

This estimate does not include any allowance for the Selwyn District Council to upgrade its water supply. This was not included because it is a statutory requirement for local authorities, as drinking water suppliers, to provide a safe water supply—i.e. there should have been a safe water supply to prevent any such outbreak.

A further point to note is that Darfield is a small town, but it is located on a significant highway, close to the Christchurch urban area and there is a large travelling public
who may not necessarily reside in Darfield, but who travel through there for work, study and leisure. Therefore, it is likely that those affected by the outbreak in Darfield will have included non-residents. There is some evidence to support this contention.

There was a rise in reported cases of campylobacteriosis in other parts of Canterbury (mostly in Christchurch city) that was coincident with the rise in reported cases from the Selwyn District (Community and Public Health Surveillance Unit data). This increased regional incidence lasted until mid-September and differed from the usual seasonal pattern of a “spring peak” in incidence of campylobacteriosis, which usually begins later.

The combination of events strongly suggests that contamination of the water supply was the source of the outbreak. Immediately before the outbreak, there were periods of heavy rainfall, run-off and flooding in the river (Figure 1). Without any filtration or chlorination, pathogenic organisms would have been able to enter and survive in the drinking water supply.

A common risk exposure amongst reported cases was having drunk unboiled water from the local water supply. Although it does not appear to have occurred in this case, the possibility that contaminated water could be used in commercial food preparation, thereby contaminating foodstuffs and subsequently resulting in foodborne infection of an even larger group of people, could have significant and widespread economic and commercial impacts.

There is continuing concern, publicity and debate about potentially unsafe water supplies in a number of NZ communities. This situation is compounded by relative inertia and reluctance to address these problems, at least in part because of the costs of upgrading and protecting water supplies.

Lessons should be learned from the 2012 Darfield outbreak, which was costly to the community as a whole and which was entirely preventable. We also note that the water contamination in Darfield was contained within a tight timeframe, with reported campylobacteriosis cases peaking in mid-August and a safer water source restored before the end of August.

Other communities with unsafe water supplies elsewhere sometimes experience much longer periods before adequate preventive measures are instituted and such longer periods of water contamination are likely to incur greater costs to these communities.

The cost estimates from our study provide evidence to inform decisions about upgrading water supplies and decreasing risks to public health.

**Competing interests:** Dr Sheerin was involved in peer reviewing a consultant’s report on the Darfield outbreak by Sapere Research Group who were contracted independently by the Ministry of Health to undertake a similar costing analysis.

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Acknowledgements: The authors thank the staff of the Community and Public Health Division of the Canterbury District Health Board as well as Selwyn District Council staff for discussion and information; Sapere Research Group for their involvement in research, discussion and feedback; and the Canterbury District Health Board for their permission to publish this article.

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