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Research Paper

Cost of *Salmonella* Infections in Australia, 2015

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ABSTRACT

Gastroenteritis caused from infections with *Salmonella enterica* (salmonellosis) causes significant morbidity in Australia. In addition to acute gastroenteritis, approximately 8.8% of people develop irritable bowel syndrome (IBS) and 8.5% of people develop reactive arthritis (ReA). We estimated the economic cost of salmonellosis and associated sequel illnesses in Australia in a typical year circa 2015. We estimated incidence, hospitalizations, other health care usage, absenteeism, and premature mortality for four age groups using a variety of complementary data sets. We calculated direct costs (health care) and indirect costs (lost productivity and premature mortality) by using Monte Carlo simulation to estimate 90% credible intervals (CrI) around our point estimates. We estimated that 90,833 cases, 4,312 hospitalizations, and 19 deaths occurred from salmonellosis in Australia circa 2015 at a direct cost of AUD 23.8 million (90% CrI, 19.3 to 28.9 million) and a total cost of AUD 124.4 million (90% CrI, 107.4 to 143.1 million). When IBS and ReA were included, the estimated direct cost was 35.7 million (90% CrI, 29.9 to 42.7 million) and the total cost was AUD 146.8 million (90% CrI, 127.8 to 167.9 million). Foodborne infections were responsible for AUD 88.9 million (90% CrI, 63.9 to 112.4 million) from acute salmonellosis and AUD 104.8 million (90% CrI, 75.5 to 132.3 million) when IBS and ReA were included. Targeted interventions to prevent illness could considerably reduce costs and societal impact from *Salmonella* infections and sequel illnesses in Australia.

HIGHLIGHTS

- The rate of salmonellosis in Australia is high, but the costs have not previously been assessed.
- Salmonellosis illness and sequelae cost Australia AUD 146.8 million circa 2015.
- Foodborne *Salmonella* infections and sequelae cost AUD 104.8 million.
- Quantifying costs helps prioritize interventions across the food chain to reduce societal impact.

Key words: Cost of illness; Health care costs; Incidence; Monte Carlo methods; *Salmonella* infections

Acute gastroenteritis from nontyphoidal *Salmonella enterica* (NTS) infection (salmonellosis) causes significant morbidity. Globally, the World Health Organization has estimated that NTS is one of the highest burden foodborne pathogens, responsible for approximately 78.7 million illnesses, 59 thousand deaths, and 4 million disability adjusted life years in 2010 *(44)*. In Australia, there were an estimated 262 cases per 100,000 population circa 2010, with 72% of cases transmitted from contaminated food *(28, 43)*. The reported incidence of salmonellosis in Australia has been increasing and is higher than in the United States, Canada, the United Kingdom, and New Zealand *(7, 12, 20, 27, 35)*.

NTS illness is one of the leading causes of foodborne gastroenteritis-associated hospitalizations and deaths in Australia. In addition to salmonellosis, it has been estimated that approximately 8.8% of people infected with NTS subsequently develop irritable bowel syndrome (IBS) and 8.5% develop reactive arthritis (ReA) *(18)*. These chronic sequelae can be severe and require additional medical tests; treatments; visits to primary care, specialists, or hospitals; and time off work.

As the burden of salmonellosis and its sequelae are high, estimated costs of illness are needed to better inform food safety policy and provide inputs for calculating the cost effectiveness of new policies and interventions. Internationally, there have been several studies estimating the cost of or loss of health-related quality of life from NTS illness, demonstrating that NTS has a substantial economic burden *(25, 29, 38, 40)*. Although the overall cost of foodborne disease in Australia circa 2000 was estimated at AUD 1.2 billion *(1),* the costs were not assessed at a pathogen level. Given the burden of salmonellosis in

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Australia, our aim was to provide contemporary estimates of the cost of illness associated with NTS and resulting sequelae (IBS and ReA) in Australia circa 2015.

MATERIALS AND METHODS

We estimated costs of NTS illness and resulting sequelae illnesses in @Risk (http://www.palisade.com) by using direct health care costs, productivity loss, and the value of premature mortality for acute and ongoing illness. The estimated direct and indirect costs were based on the incidence of NTS, IBS, and ReA illness and ongoing illness from IBS and ReA in a typical year circa 2015. We estimated incidence and costs by four age groups: 0 to 4 years, 5 to 19 years, 20 to 64 years, and 65+ years. Data sources and model structure are described below with additional information in Supplemental Material S1 and S2.

Data sources for incidence burden estimates. We used data from the National Notifiable Disease Surveillance System by sex and 5-year age groups from 2013 to 2015 *(12)*. Notifications where age, sex, or both were unknown were excluded (0.16%). Denominator data were based on the Australian population provided by the Australian Bureau of Statistics for that year *(2)*. As IBS and ReA are rare in children <5 years old *(23, 39),* we used the ratio of incidence to hospitalizations for IBS and ReA in those aged 5 to 64 years to estimate incidence in children aged <5 years.

Data sources for health care usage burden estimates. For NTS, we used data from the 2008 to 2009 National Gastroenteritis Survey II, a retrospective cross-sectional survey of the population burden of infectious gastroenteritis in that year *(8),* to estimate the proportion of incident cases that consulted a general practitioner (GP), visited the emergency department, or took medication (antibiotics, diarrhea relief, pain relief, nausea relief, cramp relief). We weighted each of these proportions by the severity of diarrhea, with 1 to 2 days of diarrhea classified as mild disease, 3 to 4 days as moderate, and 5 or more days as severe (Supplemental Material S1 and S2), and we assumed that 3% of NTS cases were mild, 14% were moderate, and 83% were severe as in Hall et al. *(21)*. The number of stool microscopy, culture, and sensitivity tests, stool PCR tests, or both were estimated from the median number of notifications by age group in the National Disease Surveillance System *(12)* from 2013 to 2015, all of which were confirmed by laboratory testing (Supplemental Material S1). For IBS and ReA, we estimated the proportion of cases that see a GP, visit a specialist, receive treatment, or undergo testing from the literature or from expert clinical opinion (for details, see Supplemental Material S1 and S2). We made an a priori assumption there would be no emergency department visits for IBS or ReA following *Salmonella* infection.

We used hospital separation statistics and average length of stay data by principal diagnoses for the financial years 2011 to 2012, 2012 to 2013, and 2013 to 2014 from the Australian Institute of Health and Welfare to estimate NTS, IBS, and ReA hospitalizations *(5, 6)*. Diagnostic codes were based on the Australian modification of the 10th International Classification of Diseases and are detailed in Technical Appendix 3 of Kirk et al. *(28)* and Technical Appendix 4 of Ford et al. *(18)*. Because principal diagnosis data only are available online from the Australian Institute of Health and Welfare, we imputed the number of additional diagnoses for NTS, IBS, and ReA based on Kirk et al. *(28)* and Ford et al. *(18)*.

Data sources for lost productivity burden estimates. Days of lost paid work for illness and caring were estimated from the National Gastroenteritis Survey II for NTS. Using the same approach taken for GP and emergency department visits, we adjusted data on the number of reported days of paid work missed due to gastroenteritis illness or caring for someone with a gastroenteritis illness for the severity of diarrhea and by age group. We followed Abelson et al. *(1)* in estimating days of lost paid work as days in hospital plus 0.5 day for visiting the GP for IBS and data from Townes et al. *(42)* to estimate a distribution of 3.37 days (90% credible interval [CrI], 2.59 to 4.3) for ReA. Confidence intervals (CI) for days of lost paid work due to NTS, IBS, and ReA illness were generated using cii means with a Poisson distribution in Stata SE 14.2 (StataCorp LLC, College Station, TX).

Data sources for premature mortality burden estimates. We used data from the Australian Bureau of Statistics on underlying or contributing causes of death in males and females aged 0 to 14, 15 to 64, and 65+ years from 2001 to 2010. The diagnostic code used was A02, based on the 10th International Classification of Diseases as detailed in Technical Appendix 3 of Kirk et al. *(28)*. We estimated the number of deaths due to NTS infection for our age groups by using a statistical model with multipliers for underreporting, domestic acquisition, and foodborne proportion, as in Kirk et al. *(28)*. We assumed no premature mortality due to IBS or ReA.

Data sources for ongoing illness burden estimates. We used the literature and built on previous work *(1)* that was reviewed and updated by an expert clinician, to estimate the proportion of cases that have ongoing illness from incident IBS or ReA following *Salmonella* infection in a typical year circa 2015. For IBS, we estimated that 42.9% (95% CI, 21.8 to 66%) of cases would have continuing symptoms at 12 months *(31)*. For ReA, we estimated that 50% (95% CI, 23 to 77%) would have continuing symptoms at 3 months *(23, 30)*.

Data sources for health care usage cost estimates. We assumed costs for GP and specialist visits based on the Medicare Benefits Schedule *(9)*. We used an estimate from 2009 to 2010 in New South Wales for emergency department triage costs *(36),* and hospital cost data were extracted as Australian Refined Diagnosis Related Group costs published by the Independent Hospital Pricing Authority for 2013 to 2014 *(26)*. Because pathology costs are generally paid for through national health insurance, we calculated the costs by dividing total benefits (monetary value spent) by services (number billed) from Medicare item reports *(13)* for Medicare Benefits Schedule *(9)* for relevant item numbers. Costs were extracted from the Pharmaceutical Benefits Schedule by dividing total benefits by services (pharmaceuticals) from Pharmaceutical Benefits Schedule item reports *(14)* for Pharmaceutical Benefits Schedule item numbers *(10)* for the calendar year 2015. If the medication or treatment was not listed on the Pharmaceutical Benefits Schedule or may commonly be bought over the counter, we extracted costs from an Australian pharmaceutical store (https://www.chemistwarehouse.com.au). See Supplementary Material S2 for details.

Data sources for lost productivity cost estimates. We used a human capital approach to calculate the cost of lost productivity *(34)* and tested lost productivity in sensitivity analysis. We used the participation rate in the workforce by age group for June 2015 extracted from the Australian Bureau of Statistics (79.2% for 20 to 64 years and 12.2% for 65 years and older) *(3)* and multiplied this by the estimated days of lost paid work and by the daily wage rate. As the Australian Bureau of Statistics provided a participation rate for 15- to 19-year-olds (52.6%), we weighted this across our 5- to 19-year-old age group to produce a participation rate of 17.5%. We used the participation rate for 20- to 64-year-olds (79.2%) for days of paid work missed by carers reported in the National Gastroenteritis Survey II for the age groups 0 to 4 years, 5 to 19 years, and 20 to 64 years and the participation rate for 65 years and older (12.2%) for the age group 65+ years. To calculate the daily wage rate, we divided the average weekly earnings for May 2015 extracted from the Australian Bureau of Statistics *(4)* by 5 to estimate a daily productivity cost of AUD 227.38.

Data sources for premature mortality cost estimates. To calculate mortality costs, we used a value of statistical life: "the financial value society places on reducing the average number of deaths by one" *(24, 33)*. We used a 2014 value of statistical life from the Australian Office of Best Practice Regulation *(33),* adjusted to 2015 dollars by using the Reserve Bank of Australia inflation calculator *(37),* of AUD 4,263,351.50.

Data sources for new ongoing illness cost estimates. To calculate the health care costs of new ongoing illness over 1 year, we used medication costs and specialist visit costs as described above. To calculate lost productivity costs from ongoing illness over 1 year, we used the lost productivity cost as described above.

Burden estimates. We used the same estimation approach, distributions, and multipliers to estimate foodborne NTS, IBS, and ReA incidences, hospitalizations, and deaths as in the foodborne disease estimation study circa 2010 *(18, 28)*. We used simulation techniques in @Risk for each estimate using multiple inputs, each with a level of uncertainty for our four age groups. The final output was a distribution, from which we extracted a median estimate of incidence, hospitalizations, and deaths together with 90% CrI. Because mortality data were only available for 2000 to 2010, we added an additional step to these models that multiplied the estimated median rate of foodborne illness for NTS by the population for 2013 to 2015. This adjusted the estimate for changes in the population since 2000 to 2010, although it does not allow us to detect any change in the death rate since 2010. More information about distributions and outputs can be found in Supplemental Material S1.

Cost estimates. In @Risk, we multiplied burden estimates by costs for health care, lost productivity, and valuation of premature mortality for each age group and for all cases to calculate costs in AUD value for health care usage, the loss to productivity, and the implied value of life. From the resulting distribution, we extracted a median, mean, and 90% CrI. We used an expert elicitation of the proportion of foodborne NTS infections *(43)* to estimate the cost of NTS, IBS, and ReA due to contaminated food.

Sensitivity analyses. We used a probabilistic simulation approach by calculating 90% CrI for key parameters known to vary in our burden estimates. We also conducted a one-way sensitivity analysis by halving and doubling individually first health care usage costs and then productivity costs and finally the value of statistical life values *(15)*. In addition, because estimating the net present value of production changes is difficult *(11),* we tested the impact of removing all productivity losses from acute illness and used an alternative participation rate to model the probability that both parents of 0- to 4-year-olds and 5- to 19-year-olds are working (0.627) in calculating lost productivity due to caring. Because approximately 75% of 15- to 19-year-olds are in the labor force part-time *(2)* and a day of missed paid work may not be the equivalent of a full-time day, we also performed a sensitivity analysis of halving the daily wage rate for this group.

RESULTS

Estimated burden of NTS in Australia. We estimated 90,833 (90% CrI, 51,583 to 158,265) cases, 4,312 (90% CrI, 3,335 to 11,091) hospitalizations, and 19 (90% CrI, 15 to 22) deaths from salmonellosis in Australia circa 2015 (Table 1). Of these, 64,000 (90% CrI, 34,000 to 117,000) cases, 3,100 (90% CrI, 1,829 to 4,786) hospitalizations, and 13 (90% CrI, 10 to 17) deaths were estimated to be due to contaminated food.

Estimated costs of NTS disease. We estimate that NTS cost a median of AUD 124.4 million and a mean of 124.7 million (90% CrI, 107.4 to 143.1 million) circa 2015, with a median of 23.7 million and a mean of 23.8 million (90% CrI, 19.3 to 28.9 million) from health care usage, a median of 21.3 million and a mean of 22.0 million (90% CrI, 13.7 to 32.6 million) from lost productivity, and a median and mean of 79.0 million (90% CrI, 66.0 to 92.1 million) from premature mortality. When acute and ongoing illness from IBS and ReA following *Salmonella* infection were included, the estimated cost was a median of AUD 146.8 million and a mean of 147.2 million (90% CrI, 127.8 to 167.9 million) (Table 2 and Supplemental Material S3). NTS illness due to contaminated food was responsible for a median of AUD 88.9 million and a mean of 88.7 million (90% CrI, 63.9 to 112.4 million) of the total cost of NTS illness and a median of AUD 104.8 million and a mean of 104.6 (90% CrI, 75.5 to 132.3 million) when IBS and ReA were included. Premature mortality from NTS as the underlying or contributing cause of death was the highest contributor to the total cost, accounting for 63% of the NTS cost and 54% of the total cost. Lost productivity due to acute NTS infection accounted for 17% of the NTS cost, lost productivity due to acute and ongoing IBS accounted for 39% of the IBS cost, and lost productivity from acute and ongoing ReA accounted for 59% of the ReA cost.

The total cost of illness and the total cost per case was highest in the 65+ years age group (Tables 3 and 4; Supplemental Material S3 for means). Overall, we estimated that the cost of acute salmonellosis was a median of AUD 1,322 per case and AUD 1,559 per case when IBS and ReA were considered (Table 4; Supplemental Material S3 for means).

Sensitivity analysis. In probabilistic simulation of the burden estimate parameters, uncertainty was greatest in premature mortality, followed by estimates of lost productivity (Fig. 1).

In one-way sensitivity analyses of costs, varying value of statistical life for premature mortality costs by halving and doubling costs had the largest impact on cost values

TABLE 1. *Estimated median number of cases, hospitalizations, and deaths from NTS and resulting IBS and ReA circa 2015, Australia*

	Median no. (90% CrI)		
	NTS	IBS	ReA
Cases			
0–4 yr	20,924 (12,059–36,250)	1.46 (0.82–2.57)	341 (56–898)
5–19 yr	14,617 (8,408–25,384)	1,284 (714–2,308)	1,206 (290–3,125)
20–64 yr	44,525 (25,012–77,489)	3,906 (2,104–7,077)	3,652 (865–9,626)
65+ yr	10,767 (6,104–19,042)	942 (516–1,703)	881 (209–2,310)
Total	90,833 (51,583–158,165)	6,133 (3,335–11,091)	6,080 (1,420–15,959)
Hospitalizations			
0–4 yr	984 (661–1,346)	0.29 (0–0.23)	1.84 (1.07–3.52)
5–19 yr	607 (391–912)	16 (9–25)	4 (3–6)
20–64 yr	1,814 (1,162–2,750)	326 (186–517)	20 (13–26)
65+ yr	907 (570–1,382)	67 (39–104)	2.5 (2–4)
Total	4,312 (2,784–6,390)	409 (234–647)	28 (19–40)
Deaths			
0–4 yr	0.65 (0.5–0.82)	—[a]	—
5–19 yr	1.7 (1.34–2.07)	—	—
20–64 yr	4 (2.71–4.38)	—	—
65+ yr	13 (10–15)	—	—
Total	19 (15–22)	—	—

[a] —, not applicable.

(Fig. 2). Additional sensitivity analysis showed that removing costs associated with short-term productivity loss from acute NTS, IBS, and ReA illness resulted in an AUD 21.1 million drop in the NTS cost to 102.7 million (90% CrI, 89.0 to 116.8 million) and an AUD 26.5 million drop in the total cost estimate to 119.8 million (90% CrI, 104.7 to 135.7 million). Adjusting the participation rate of carers for 0- to 4-year-olds and for 5- to 19-year-olds, and halving the daily wage for 5- to 19-year-olds had a minimal impact on the final cost estimates, reducing the estimate by less than 2% and less than 1%, respectively.

DISCUSSION

We estimated that the burden of salmonellosis and its sequelae in Australia are substantial, costing a median of AUD 146.8 million in a typical year circa 2015. Of the total cost, 35.7 million (24%) was due to health care costs, 31.7 million (22%) was due to costs associated with lost productivity, and 79.0 million (54%) was due to premature mortality. Quantifying these costs allows the burden of NTS to be compared against other illnesses, assisting with prioritization of public health interventions for policy-making.

TABLE 2. *Estimated annual cost of illness of health care usage, lost productivity, and premature mortality, for acute and ongoing illness, circa 2015, Australia*

	Median cost in millions of AUD (90% CrI)			
	NTS	IBS	ReA	Total[a]
Health care usage				
Acute illness	23.7 (19.3–28.9)	5.6 (4.0–8.0)	1.9 (1.0–3.6)	31.4 (26.5–37.2)
Ongoing illness	—[b]	3.2 (1.8–6.9)	0.77 (0.34–1.7)	4.2 (2.7–6.5)
Lost productivity				
Acute illness	21.3 (13.7–32.6)	2.0 (1.3–3.3)	2.7 (1.0–6.5)	26.5 (18.5–38.4)
Ongoing illness	—	3.6 (1.8–6.9)	1.0 (0.37–2.8)	4.8 (2.7–8.4)
Premature mortality				
Acute illness	79.0 (66.0–92.1)	—	—	79.0 (66.0–92.1)
Total costs				
Acute illness	124.4 (107.4–143.1)	7.6 (5.3–11.3)	4.6 (2.0–10.0)	137.7 (119.7–157.0)
Ongoing illness	—	6.8 (3.9–12.3)	1.8 (0.73–4.4)	9.0 (5.5–14.8)
Total	124.7 (107.4–143.1)	14.5 (9.5–23.0)	6.5 (2.8–14.2)	146.8 (127.8–167.9)

[a] Numbers may not sum due to simulation and rounding.
[b] —, not applicable.

TABLE 3. *Estimated annual cost of acute and ongoing illness in 1 yr by age group, circa 2015, Australia*

	Median cost in millions of AUD (90% CrI)			
	NTS	IBS	ReA	Total[a]
Health care usage				
0–4 yr	4.2 (3.0–5.9)	0.004 (0.002–0.006)	0.14 (0.04–0.37)	4.4 (3.2–6.1)
5–19 yr	2.8 (2.0–4.0)	1.6 (0.90–3.0)	0.48 (0.13–1.3)	5.1 (3.7–6.9)
20–64 yr	8.6 (5.9–12.4)	5.7 (3.3–9.8)	1.5 (0.46–4.0)	16.3 (11.9–22.0)
65+ yr	7.6 (5.1–11.0)	1.4 (0.80–2.4)	0.34 (0.10–0.93)	9.4 (6.8–13.0)
Lost productivity				
0–4 yr	4.9 (2.3–10.0)	0.002 (0.001–0.004)	0.29 (0.07–0.78)	5.2 (2.6–10.3)
5–19 yr	1.5 (0.46–4.4)	0.34 (0.17–0.65)	0.23 (0.05–0.61)	2.2 (1.0–5.0)
20–64 yr	12.6 (6.7–22.8)	5.0 (2.7–9.4)	3.1 (0.73–8.4)	21.7 (13.9–33.6)
65+ yr	1.2 (0.33–3.0)	0.18 (0.10–0.35)	0.11 (0.03–0.31)	1.5 (0.64–3.3)
Premature mortality				
0–4 yr	2.8 (2.1–3.5)	—[b]	—	2.8 (2.1–3.5)
5–19 yr	7.2 (5.7–8.8)	—	—	7.2 (5.7–8.8)
20–64 yr	15.0 (11.6–18.7)	—	—	15.0 (11.6–18.7)
65+ yr	53.8 (41.6–66.3)	—	—	53.8 (41.6–66.3)
Total costs				
0–4 yr	11.9 (8.5–18.1)	0.006 (0.004–0.009)	0.43 (0.11–1.1)	12.4 (8.9–18.6)
5–19 yr	11.8 (9.4–15.3)	2.0 (1.1–3.6)	0.70 (0.09–1.9)	14.7 (11.9–18.6)
20–64 yr	36.5 (27.7–49.8)	10.7 (6.0–19.1)	4.6 (1.2–12.2)	53.3 (41.2–70.0)
65+ yr	62.9 (50.3–75.9)	1.5 (0.9–2.7)	0.46 (0.12–1.2)	65.2 (52.5–78.2)

[a] Numbers may not sum due to simulation and rounding.
[b] —, not applicable.

Because NTS is mostly transmitted through contaminated food, targeted interventions across the food chain could help to prevent acute and ongoing illness. Australia's Foodborne Illness Reduction Strategy 2018 to 2021+ aims to reduce the number of illnesses from foodborne salmonellosis *(17)*. Although the national strategy does not set a specific reduction target, a 10% reduction in acute foodborne NTS illness incidence would equate to more than AUD 8 million immediate reduction in costs, with additional reductions from sequel illnesses expected as well.

Because of the higher proportion of people aged 65+ years with salmonellosis taking medications, being admitted to the hospital, and dying compared with other age groups, the cost per case was highest in the 65+ age group. Therefore, interventions targeted at preventing illness in this age group would be most effective in reducing all costs. Our

TABLE 4. *Estimated median annual cost of acute and ongoing illness per case by age group, circa 2015, Australia*

	Median cost (AUD)			
	NTS	IBS	ReA	Total
Health care usage only				
0–4 yr	200.78	854.05	302.90	208.65
5–19 yr	190.85	434.31	287.48	344.33
20–64 yr	192.17	491.17	301.1	363.49
65+ yr	691.93	491.80	284.09	866.14
Total	250.02	476.64	293.32	377.97
Health care usage with lost productivity				
0–4 yr	443.64	1,398.50	920.24	467.78
5–19 yr	307.88	525.02	423.95	507.56
20–64 yr	480.79	930.31	916.21	845.78
65+ yr	814.92	558.66	378.88	1,020.85
Total	479.99	783.99	718.10	713.85
Health care usage, lost productivity, and premature mortality				
0–4 yr	579.88	1,398.50	920.24	603.97
5–19 yr	807.77	525.02	423.95	1,003.88
20–64 yr	818.47	930.31	916.21	1,190.35
65+ yr	5,798.29	558.66	378.88	6,003.72
Total	1,322.14	783.36	718.96	1,558.53

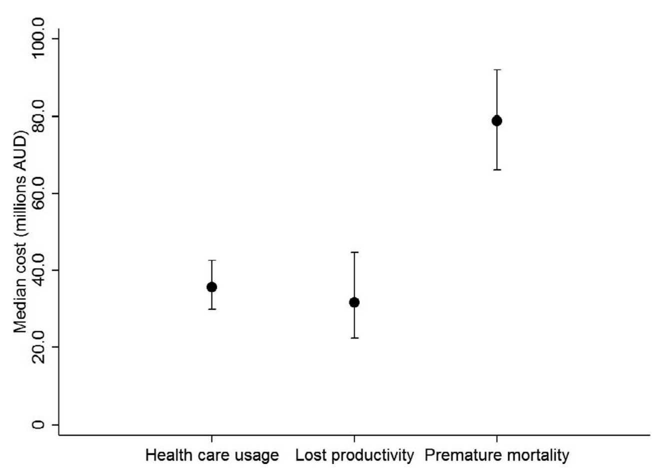

FIGURE 1. *Median cost of acute and ongoing illness from NTS, IBS, and ReA from health care usage, lost productivity, and premature mortality, circa 2015, Australia. Ranges reflect 90% credible intervals for burden estimates.*

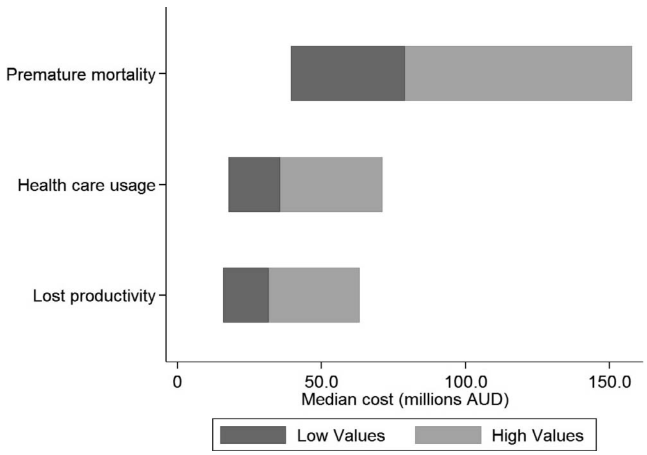

FIGURE 2. *One-way sensitivity analysis of health care usage, lost productivity, and premature mortality for NTS, IBS, and ReA cost of illness circa 2015, Australia. Low values represent when costs were halved, and high values when costs were doubled around our cost estimate.*

total cost per case for NTS of AUD 1,322 (∼USD 995) is generally lower than in studies from the United States from 2013 and 2015 (USD 3,568 *(16),* USD 5,335 *(32)*), although higher than an estimate of €691 (∼USD 765) by Sundstrom *(40)* for Sweden in 2016 dollars and the estimate of NZD 220 (∼USD 151) by Lake et al. *(29)* for New Zealand in 2006 and 2007. The estimates from these studies are not directly comparable due to differing years, variables estimated, and estimation methods.

Because premature mortality from NTS as the underlying or contributing cause of death was the largest contributor to our cost estimates, accounting for 63% of total NTS cost and 54% of NTS and sequelae cost, the method used to value a lost life is very influential. In one-way sensitivity analysis, premature mortality costs had the largest range of uncertainty, compared with health care usage and lost productivity costs. Methods and values for lost life are also influential when comparing estimates between cost-of-illness studies. For example, although the total cost per NTS case estimated by the Economic Research Service for the United States is higher than our estimate at USD 3,568, when only costs from health care usage and lost productivity are taken into account, the cost estimates are similar at USD 383.55 for the United States compared with our estimate of AUD 480 (∼USD 361) *(16)*.

Costs associated with IBS and ReA following *Salmonella* were also a large contributor to our total cost estimate of AUD 146.8 million, accounting for 14% of the total cost (10% from IBS and 4% from ReA). Although we did account for these sequelae costs in our estimates, we have not included costs of NTS to industry and public health agencies for surveillance and regulation. Because NTS can be expensive for the food industry, including costs associated with everyday prevention measures, product recalls, and liability, we have likely underestimated the costs to society.

Although we estimated lost productivity costs in line with previously published methods *(1),* these methods may overestimate costs as we have not considered that either production will be made upon return to work or that employers will have excess capacity in the labor force to cover absenteeism for short-term absences *(11)*. In addition, a weakness of the human capital approach is that it overestimates productivity loss compared with the friction cost approach *(34)*. We restricted lost productivity estimates to paid work only, not including the value of lost time for those not employed, such as unpaid carers or housework, or the loss of leisure time. One-way sensitivity analysis of removing productivity loss from acute illness resulted in a AUD 21.1 million reduction in the estimate for NTS and a AUD 26.5 million reduction for NTS, IBS, and ReA.

A limitation of this study is that due to a lack of data for IBS and ReA, we relied on expert opinion from a physician to review and update the proportion of cases receiving certain medications, pathology tests, and IBS cases seeing specialists from previous work and the literature. We used uncertainty intervals around these estimates to account for the uncertainty in the data. There is also limited data on duration of ongoing ReA symptoms, with some studies finding that symptoms had ceased in most patients in less than 12 months *(22, 23, 30),* whereas others found cases with long-lasting symptoms *(19, 41)*. We used a conservative estimate of the proportion of ReA cases with ongoing symptoms in 1 year based on Hannu et al. *(23)* and Leirisalo-Repo et al. *(30)*. Although we were not able to include the decrease in quality of life to calculate quality adjusted life years, we have captured the decrease in quantity of life through the value of statistical life. Although our cost of illness estimates provide a baseline, a full economic evaluation that compares costs and benefits of alternative policy interventions is needed to identify how effective new programs and policies would be at reducing burden. Identifying and implementing targeted prevention measures in the food supply chain could considerably reduce overall NTS costs.

In summary, the clinical and economic burden of salmonellosis and its sequelae are high. The cost of illness estimates in this article will inform food safety policy and can be used in subsequent analysis of cost effectiveness of new policies and interventions aimed at the prevention and control of NTS infection in Australia.

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SUPPLEMENTAL MATERIAL

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