
Direct healthcare costs of selected diseases primarily or partially transmitted by water

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(Accepted 7 December 2011; first published online 11 January 2012)

SUMMARY

Despite US sanitation advancements, millions of waterborne disease cases occur annually, although the precise burden of disease is not well quantified. Estimating the direct healthcare cost of specific infections would be useful in prioritizing waterborne disease prevention activities. Hospitalization and outpatient visit costs per case and total US hospitalization costs for ten waterborne diseases were calculated using large healthcare claims and hospital discharge databases. The five primarily waterborne diseases in this analysis (giardiasis, cryptosporidiosis, Legionnaires' disease, otitis externa, and non-tuberculous mycobacterial infection) were responsible for over 40 000 hospitalizations at a cost of \$970 million per year, including at least \$430 million in hospitalization costs for Medicaid and Medicare patients. An additional 50 000 hospitalizations for campylobacteriosis, salmonellosis, shigellosis, haemolytic uraemic syndrome, and toxoplasmosis cost \$860 million annually (\$390 million in payments for Medicaid and Medicare patients), a portion of which can be assumed to be due to waterborne transmission.

Key words: *Cryptosporidium*, *Giardia*, Legionnaires' disease, mycobacteria, waterborne infections.

INTRODUCTION

The use of filtration and disinfection to make clean water widely available has been recognized as one of the greatest US public health achievements of the 20th century [1, 2], and is credited with an estimated 50% of the reduction in mortality in major cities and

nearly two-thirds of the decrease in child mortality observed in the early 1900s [3]. Although classic drinking water-associated diseases such as cholera and typhoid fever have become rare, water usage in the USA has become more complex; waterborne disease is now associated with recreational, industrial, healthcare, agricultural, and medical uses. As a result, although transmission patterns have changed, waterborne illness remains a public health problem in the USA.

The magnitude of waterborne disease in the USA is thought to be substantial but is not well quantified. Almost 1400 outbreaks have been reported to the

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Centers for Disease Control and Prevention (CDC) since the current surveillance system was created in 1971 [4, 5]. Estimates of gastrointestinal illness caused by drinking water from public water systems fall between 4 and 33 million annual US cases [6, 7], but no overall estimate of the total burden from all water pathways exists. A more complete accounting would include illness from recreational water exposures, industrial exposure, and the built environment. Aerosolized mists generated in hospital and other building cooling and water distribution systems can contain pathogens such as *Legionella* [8] and non-tuberculous mycobacteria (NTM) [9, 10]. Thus, Legionnaires' disease and NTM infections are serious illnesses primarily transmitted by water although the transmission pathway differs from that of gastrointestinal infections spread through drinking water. The burden of illness due to swimming and other recreational water exposure also appears extensive. Swimmers at southern California beaches were estimated to have experienced 689 000–4 003 000 gastrointestinal illness episodes and 693 000 respiratory illness episodes associated with contaminated water annually [11], while the chlorine-tolerant parasite *Cryptosporidium* is estimated to cause 740 000 cases of diarrhoeal illness each year [12].

A more precise quantification of the costs of US waterborne disease would be useful in prioritizing waterborne disease prevention activities and allocating limited resources, and is a key building block for determining the overall burden of waterborne disease in the USA. To begin to quantify the costs of waterborne diseases, the hospitalization costs of specific waterborne infections were estimated. This study summarizes data from three large health insurance claims databases to estimate the inpatient and outpatient cost per episode of selected waterborne diseases in the privately insured, Medicare-, and Medicaid-eligible populations and gives a national estimate of the total hospitalization costs. In a landscape of diminishing public health resources, these estimates are necessary components of any plan developed by policy-makers working to prioritize waterborne disease prevention efforts.

METHODS

Data sources for cost estimates

This analysis used data from the MarketScan[®] 2006 and 2007 Commercial Claims, Medicare

Supplemental, and 2004 and 2005 Multi-State Medicaid databases from Thomson Reuters, the two most recent years of each database that were available at CDC. The commercial and Medicare databases contain anonymized medical and pharmaceutical insurance claim information for over 20 million employees, dependants, and retirees enrolled in primary or Medicare Supplemental insurance coverage through employers across the USA. The Medicaid database contains anonymized medical and prescription drug claims for seven million people enrolled in Medicaid programmes in eight states.

Inclusion criteria

All inpatients and outpatients in the databases whose record included an eligible diagnosis for five infections or syndromes considered to be primarily (> 50%) transmitted by water were included: International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes 007.1 for giardiasis, 007.4 for cryptosporidiosis, 482.84 for Legionnaires' disease, 380.10, 380.12, and 380.14 for acute or malignant otitis externa, and 031.0–031.9 for non-tuberculous pulmonary mycobacterial infection. NTM infections were further subdivided into pulmonary (031.0) and disseminated (031.2) infections. Hospitalizations and outpatient visits with ICD-9-CM code 031.0 were classified as pulmonary NTM infections and hospitalizations and visits with code 031.2 were classified as disseminated NTM infections. Because chronic otitis externa (particularly chronic otitis externa associated with suppurative otitis media) may be less likely to be waterborne, only acute (380.10 and 380.12) and malignant (380.14) otitis externa codes were included. Furthermore, for otitis externa hospitalizations, only cases with a primary diagnosis of otitis externa and no concurrent diagnosis of otitis media were included. For otitis externa outpatient visits, visits with a first or second diagnosis of otitis externa and no concurrent diagnosis of otitis media were included. Five infections or syndromes considered to be partially (< 50%) transmitted by water were also included: ICD-9-CM codes 008.43 for campylobacteriosis, 003 for salmonellosis, 004 for shigellosis, 283.11 for haemolytic uraemic syndrome (HUS), and 130 for toxoplasmosis. Outpatient visits associated with an inpatient admission within 7 days were excluded from the outpatient set and included with inpatient costs.

Cost-per-case estimates

Using the Marketscan databases, the cost paid by the insurer, the out-of-pocket cost, and the sum of total payments from any source for each hospital or outpatient visit was calculated. Cost estimates included payments for prescription medication. The insurer cost for Medicare, Medicaid, and privately insured patients is the total amount paid by the insurer to the healthcare provider and excludes out-of-pocket payments (deductibles, co-payments, or co-insurance). The sum of total payments from any source is the sum of insurer payments and out-of-pocket payments. Because all enrollees in the Marketscan Medicare Supplemental database have a Medicare Supplemental insurance plan through their employer, payments from three sources (Medicare, the employer-provided supplemental plan, and out-of-pocket payments) are reported. To avoid calculating cost estimates based on a very small sample, cost estimates were not calculated for any disease with less than five patients from any payment source. Any hospitalized patient with a diagnosis code included in the list of immunocompromising conditions in the Prevention Quality Indicators Technical Specifications published by the Agency for Health Research and Quality was considered to be immunocompromised [13]. Because only two diagnosis codes were reported for outpatients, immune status was not determined. All costs were adjusted to 2007 US dollars using the Medical Care Consumer Price Index (Bureau of Labor Statistics, US Department of Labor).

National hospitalization cost estimates

To begin to quantify total waterborne disease costs, an estimate of the annual national cost of hospitalization for each disease was calculated. Because no single national surveillance system for the diseases included in this analysis exists, multiple sources were used to estimate the total cost of hospitalizations per year for each disease. The total number of hospitalizations per year for each disease was obtained from published estimates. For giardiasis, cryptosporidiosis, campylobacteriosis, salmonellosis, shigellosis, and toxoplasmosis, the estimates of Scallan *et al.* were used [12]. For Legionnaires' disease, the midpoint (13 000 hospitalizations per year) of the range (8000–18 000) estimated by Marston *et al.* was used [14]. For otitis externa, NTM infections, and HUS, the 2006 and 2007 Healthcare Utilization Project Nationwide Inpatient Sample (NIS) was used. The

NIS was also used to estimate the distribution of payers (commercial, Medicare, Medicaid, uninsured, other) for each diagnosis. The NIS is the largest all-payer database of US hospital inpatient stays. To obtain the average cost per case for all payers, the cost per case for each payer was multiplied by the corresponding proportion of payers in the NIS. The commercially insured cost per case was used for uninsured cases and cases with others types of insurance (e.g. Tricare, the military health plan).

RESULTS

This analysis included 3684 hospitalizations and 341 157 outpatient visits. Among primarily waterborne diseases, cryptosporidiosis (24%) and NTM infections (21%) had the highest proportion of immunocompromised patients; hospitalized patients with NTM infections (10.5 days) and Legionnaire's disease (10.2 days) had the longest average length of stay. The average length of hospitalization for giardiasis and otitis externa was 3 days; length of stay for cryptosporidiosis was more than twice as long (6.5 days).

Among diseases partially transmitted by water, HUS (24%) and toxoplasmosis (44%) had the highest proportion of immunocompromised patients. Average length of hospitalization for the diarrhoeal diseases campylobacteriosis, salmonellosis, and shigellosis was 4 days, while the average length of stay was greater for toxoplasmosis and HUS, infections with systemic effects (10 and 13 days, respectively).

Both hospitalization and outpatient costs per case varied by disease and by payer (Table 1). The majority of outpatient visits were for otitis externa (334 201 visits, average cost per visit \$192). The most expensive primarily waterborne disease per outpatient visit was pulmonary NTM infection (\$1649 per visit, commercially insured patients); the most expensive partially waterborne disease was HUS (\$2591).

Over 40 000 hospitalizations for primarily waterborne diseases were estimated to occur annually (Table 2). Legionnaires' disease (\$33 366) and NTMs (\$25 985) had the highest cost per episode of primarily waterborne diseases. The cost of hospitalization for cryptosporidiosis was nearly twice the cost of giardiasis or otitis externa. Nationally, insurers paid an estimated \$434 million in hospitalization claims annually for Legionnaires' disease alone. Over \$250 million in annual hospitalization costs for Medicare patients were due to Legionnaires' disease and pulmonary NTM infection, two diseases that

Table 1. *Estimates of the cost (in US\$) of illness per episode for selected waterborne diseases in the USA, by type of insurance*

	<i>N</i> (% immuno-compromised)	Average length of stay (range in days)	Insurer cost ^a (\$)	Supplemental cost ^b (\$)	Out-of-pocket cost ^c (\$)	Total cost per episode (\$)
PRIMARILY WATERBORNE						
Giardiasis						
<i>Inpatients</i>						
Medicaid hospitalized cases	38 (7.9)	4.4 (1–10)	\$3863	n.a.	\$0	\$3863
Medicare Supplemental hospitalized cases	15 (6.7)	4.2 (2–9)	\$9773	\$1283	\$786	\$11 842
Commercial hospitalized cases	101 (0.0)	3.9 (1–32)	\$9803	n.a.	\$785	\$10 588
<i>Outpatients^d</i>						
Medicaid outpatient cases	307	n.a.	\$121	n.a.	\$0	\$121
Medicare Supplemental outpatient cases	45	n.a.	\$88	\$132	\$53	\$273
Commercial outpatient cases	732	n.a.	\$188	n.a.	\$65	\$253
Cryptosporidiosis						
<i>Inpatients</i>						
Medicaid hospitalized cases	18 (50.0)	7.4 (1–25)	\$16 203	n.a.	\$0	\$16 203
Medicare Supplemental hospitalized cases	8 (12.5)	5.8 (1–11)	\$7217	\$1954	\$190	\$9361
Commercial hospitalized cases	118 (21.2)	5.7 (1–70)	\$19 266	n.a.	\$807	\$20 073
<i>Outpatients^d</i>						
Medicaid outpatient cases	18	n.a.	\$267	n.a.	\$0	\$267
Medicare Supplemental outpatient cases	16	n.a.	\$432	\$270	\$55	\$757
Commercial outpatient cases	96	n.a.	\$457	n.a.	\$134	\$591
Legionnaires' disease						
<i>Inpatients</i>						
Medicaid hospitalized cases	3	— ^e	— ^e	— ^e	— ^e	— ^e
Medicare Supplemental hospitalized cases	84 (2.4)	10.3 (1–75)	\$22 680	\$3807	\$254	\$26 741
Commercial hospitalized cases	187 (10.2)	10.2 (1–84)	\$37 295	n.a.	\$1068	\$38 363
<i>Outpatients^d</i>						
Medicaid outpatient cases	2	n.a.	— ^e	— ^e	— ^e	— ^e
Medicare Supplemental outpatient cases	24	n.a.	\$95	\$434	\$58	\$587
Commercial outpatient cases	73	n.a.	\$451	n.a.	\$110	\$561
Otitis externa						
<i>Inpatients</i>						
Medicaid hospitalized cases	84 (4.8)	3.1 (1–40)	\$4741	n.a.	\$0	\$4741
Medicare Supplemental hospitalized cases	49 (2.0)	6.8 (1–125)	\$5966	\$1702	\$235	\$7903
Commercial hospitalized cases	387 (4.1)	2.5 (1–10)	\$5167	n.a.	\$743	\$5910
<i>Outpatients^d</i>						
Medicaid outpatient cases	63 863	n.a.	\$145	n.a.	\$0	\$145
Medicare Supplemental outpatient cases	21 612	n.a.	\$55	\$151	\$53	\$259
Commercial outpatient cases	248 726	n.a.	\$136	n.a.	\$62	\$198
NTM infection						
<i>Inpatients</i>						
Medicaid hospitalized cases	29 (31.0)	12.1 (1–83)	\$21 041	n.a.	\$0	\$21 041
Medicare Supplemental hospitalized cases	226 (4.0)	10.4 (1–204)	\$16 960	\$3487	\$340	\$20 787
Commercial hospitalized cases	426 (29.6)	10.5 (1–108)	\$37 197	n.a.	\$1235	\$38 432
<i>Outpatients^d</i>						
Medicaid outpatient cases	81	n.a.	\$1073	n.a.	\$0	\$1073
Medicare Supplemental outpatient cases	1292	n.a.	\$275	\$680	\$114	\$1069
Commercial outpatient cases	1521	n.a.	\$1335	n.a.	\$183	\$1518
Pulmonary NTM infection						
<i>Inpatients</i>						
Medicaid hospitalized cases	5 (40.0)	13.2 (2–22)	\$12 725	n.a.	\$0	\$12 725
Medicare Supplemental hospitalized cases	152 (2.0)	10.7 (1–204)	\$20 472	\$2606	\$324	\$23 402
Commercial hospitalized cases	209 (23.0)	10.4 (1–108)	\$36 570	n.a.	\$1009	\$37 579

Table 1 (cont.)

	<i>N</i> (% immuno-compromised)	Average length of stay (range in days)	Insurer cost ^a (\$)	Supplemental cost ^b (\$)	Out-of-pocket cost ^c (\$)	Total cost per episode (\$)
Outpatients^d						
Medicaid outpatient cases	27	n.a.	\$311	n.a.	\$0	\$311
Medicare Supplemental outpatient cases	754	n.a.	\$286	\$729	\$120	\$1136
Commercial outpatient cases	674	n.a.	\$1415	n.a.	\$199	\$1649
Disseminated NTM infection						
Inpatients						
Medicaid hospitalized cases	3	— ^e	— ^e	— ^e	— ^e	— ^e
Medicare Supplemental hospitalized cases	45 (0·0)	9 (1–73)	\$9564	\$2331	\$415	\$12 310
Commercial hospitalized cases	120 (55·8)	12·1 (1–56)	\$46 081	n.a.	\$1042	\$47 123
Outpatients^d						
Medicaid outpatient cases	6	n.a.	\$1295	n.a.	\$0	\$1295
Medicare Supplemental outpatient cases	180	n.a.	\$271	\$592	\$97	\$960
Commercial outpatient cases	196	n.a.	\$1326	n.a.	\$186	\$1512
PARTIALLY WATERBORNE						
Campylobacteriosis						
Inpatients						
Medicaid hospitalized cases	35 (5·7)	3·0 (1–26)	\$4328	n.a.	\$0	\$4328
Medicare Supplemental hospitalized cases	65 (4·6)	4·3 (1–19)	\$6037	\$1570	\$354	\$7961
Commercial hospitalized cases	246 (5·7)	3·8 (1–57)	\$9945	n.a.	\$861	\$10 806
Outpatients^d						
Medicaid outpatient cases	37	n.a.	\$288	n.a.	\$0	\$288
Medicare Supplemental outpatient cases	26	n.a.	\$121	\$175	\$43	\$339
Commercial outpatient cases	184	n.a.	\$606	n.a.	\$110	\$716
Salmonellosis						
Inpatients						
Medicaid hospitalized cases	234 (0·4)	3·5 (1–27)	\$4036	n.a.	\$0	\$4036
Medicare Supplemental hospitalized cases	111 (3·6)	5·4 (1–25)	\$6706	\$1610	\$289	\$8605
Commercial hospitalized cases	661 (2·7)	3·9 (1–39)	\$7757	n.a.	\$930	\$8687
Outpatients^d						
Medicaid outpatient cases	132	n.a.	\$235	n.a.	\$0	\$235
Medicare Supplemental outpatient cases	50	n.a.	\$445	\$351	\$111	\$907
Commercial outpatient cases	382	n.a.	\$348	n.a.	\$69	\$417
Shigellosis						
Inpatients						
Medicaid hospitalized cases	80 (2·5)	3·0 (1–15)	\$3510	n.a.	\$0	\$3510
Medicare Supplemental hospitalized cases	18 (5·6)	11·6 (1–89)	\$11 857	\$5727	\$257	\$17 841
Commercial hospitalized cases	151 (4·0)	3·6 (1–19)	\$8720	n.a.	\$955	\$9675
Outpatients^d						
Medicaid outpatient cases	204	n.a.	\$134	n.a.	\$0	\$134
Medicare Supplemental outpatient cases	101	n.a.	\$56	\$201	\$61	\$318
Commercial outpatient cases	579	n.a.	\$221	n.a.	\$77	\$298
Haemolytic uraemic syndrome						
Inpatients						
Medicaid hospitalized cases	48 (27·1)	14·4 (1–150)	\$29 968	n.a.	\$0	\$29 968
Medicare Supplemental hospitalized cases	7 (28·6)	22·9 (9–69)	\$28 134	\$13 640	\$1029	\$42 803
Commercial hospitalized cases	177 (22·6)	11·1 (1–78)	\$62 158	n.a.	\$1447	\$63 605
Outpatients^d						
Medicaid outpatient cases	98	n.a.	\$585	n.a.	\$0	\$585
Medicare Supplemental outpatient cases	52	n.a.	\$215	\$533	\$93	\$841
Commercial outpatient cases	220	n.a.	\$2425	n.a.	\$166	\$2591

Table 1 (cont.)

	<i>N</i> (% immuno-compromised)	Average length of stay (range in days)	Insurer cost ^a (\$)	Supplemental cost ^b (\$)	Out-of-pocket cost ^c (\$)	Total cost per episode (\$)
Toxoplasmosis						
Inpatients						
Medicaid hospitalized cases	10 (20·0)	10·1 (3–34)	\$19 647	n.a.	\$19 647	\$39 294
Medicare Supplemental hospitalized cases	7 (0·0)	8 (1–20)	\$21 177	\$14 594	\$211	\$35 982
Commercial hospitalized cases	76 (51·3)	10·5 (1–138)	\$53 634	n.a.	\$1149	\$54 783
Outpatients^d						
Medicaid outpatient cases	61	n.a.	\$1127	n.a.	\$0	\$1127
Medicare Supplemental outpatient cases	86	n.a.	\$96	\$253	\$63	\$412
Commercial outpatient cases	541	n.a.	\$536	n.a.	\$114	\$650

NTM, Non-tuberculous mycobacteria; n.a., not applicable.

Data sources: Marketscan 2004–2005 Multistate Medicaid and 2006–2007 Medicare Supplemental and Commercial Claims databases. All costs in 2007 US dollars.

^a Insurer cost: total amount paid by the insurer to the healthcare provider.

^b Supplemental cost: for Medicare enrollees, this amount includes payments from the employer-provided supplemental plan. All patients in the Marketscan Medicare Supplemental database are enrolled in an employer-provided supplemental plan. For persons without a supplemental plan, this would most likely represent an out-of-pocket cost.

^c Out-of-pocket cost: total amount paid by the insured person, including deductibles, co-payments, and co-insurance.

^d Outpatient visits associated with an inpatient admission within 7 days were excluded from the outpatient set and included with inpatient costs.

^e Costs were not reported for groups of <5 cases.

disproportionately affect the elderly. Among partially waterborne diseases, hospitalization for HUS (\$51 261) and toxoplasmosis (\$44 705) were the most costly. Average hospitalization costs for campylobacteriosis (\$8915), salmonellosis (\$7687), and shigellosis (\$8721) were lower.

Over 40 000 hospitalizations for Legionnaires' disease, otitis externa, and NTM infection, diseases entirely or primarily transmitted by water, were estimated to occur each year and cost \$970 million annually, including at least \$430 million in costs for Medicare and Medicaid patients (because of small numbers of patients in the database, costs for Medicaid patients with Legionnaires' disease could not be calculated). An additional 50 000 hospitalizations for campylobacteriosis, salmonellosis, shigellosis, HUS, and toxoplasmosis cost \$860 million annually (\$390 million in payments for Medicaid and Medicare patients), an unknown portion of which can be assumed to be due to waterborne transmission.

DISCUSSION

Waterborne disease in the USA involves a complex mixture of pathogens, transmission routes, and water uses. The five primarily waterborne diseases in this

analysis were responsible for over 40 000 hospitalizations at a cost of \$970 million per year, and included at least \$430 million in hospitalization costs for Medicaid and Medicare patients. These costs probably represent only a fraction of the overall cost of US waterborne disease and underscore the need for further investment in waterborne disease monitoring, economic analyses, and burden estimates.

Average costs for outpatient visits were also reported in this analysis. Although annual national costs for outpatient visits were desired, no nationally representative outpatient visit data source evaluated contained the pathogen-specific diagnosis codes used in this analysis, perhaps because the diagnoses reflect laboratory testing completed after the visit records are submitted to the outpatient databases. An exception is otitis externa, which is frequently readily apparent without diagnostic testing.

In the USA, there were 2·4 million ambulatory care visits for otitis externa in 2007 [15], and a UK report estimated the prevalence of otitis externa in general practice patients to be more than 1·2% in a 12-month period [16]. The average cost per otitis externa visit in this analysis was \$192, implying that outpatient visits might add an additional \$0·5 billion to the cost of this preventable waterborne disease.

Table 2. Estimates of the annual prevalence and total cost (in US\$) of hospitalizations for selected waterborne diseases in the USA

	Medicaid	Medicare	Commercial	Uninsured	Total
PRIMARILY WATERBORNE					
Giardiasis					
Mean total cost/hospitalization	\$3863	\$11 842	\$10 588	— ^a	\$9607
Proportion of hospitalizations with type of insurance	20 %	29 %	39 %	9 %	
Number of hospitalizations/year	716	1038	1397	306	3581
Total hospitalization cost	\$2 766 681	\$12 297 799	\$14 787 095	— ^a	\$34 401 449 ^b
Cryptosporidiosis					
Mean total cost/hospitalization	\$16 203	\$9361	\$20 073		\$16 797
Proportion of hospitalizations with type of insurance	21 %	23 %	47 %	9 %	
Number of hospitalizations/year	572	627	1281	233	2725
Total hospitalization cost	\$9 272 167	\$5 867 007	\$25 708 495	— ^a	\$45 770 572 ^b
Legionnaires' disease					
Mean total cost/hospitalization	— ^c	\$26 741	\$38 363	— ^a	\$33 366
Proportion of hospitalizations with type of insurance	8 %	43 %	39 %	6 %	
Number of hospitalizations/year	1040	5590	5070	795	13 000
Total hospitalization cost	— ^c	\$149 482 190	\$194 500 410	— ^a	\$433 752 020 ^b
Otitis externa					
Mean total cost/hospitalization	\$4741	\$7903	\$5910	— ^a	\$6293
Proportion of hospitalizations with type of insurance	15 %	28 %	45 %	7 %	
Number of hospitalizations/year	664	1239	1992	316	4426
Total hospitalization cost	\$3 147 550	\$9 794 030	\$11 770 947	— ^a	\$27 851 446
NTM infection					
Mean total cost/hospitalization	\$21 041	\$20 787	\$38 432	— ^a	\$25 985
Proportion of hospitalizations with type of insurance	22 %	48 %	21 %	5 %	
Number of hospitalizations/year	3679	7933	3416	750	16 386
Total hospitalization cost	\$77 402 622	\$164 909 131	\$131 270 710	— ^a	\$425 788 469 ^b
Pulmonary NTM infection^d					
Mean total cost/hospitalization	\$12 725	\$23 402	\$37 579	— ^a	\$25 409
Proportion of hospitalizations	16 %	57 %	20 %	4 %	
Number of hospitalizations/year	1248	4386	1510	290	7659
Total hospitalization cost	\$15 885 069	\$102 632 748	\$56 753 918	— ^a	\$194 597 422 ^b
Disseminated NTM infection^d					
Mean total cost/hospitalization	\$21 080	\$12 310	\$47 123	— ^a	\$23 388
Proportion of hospitalizations with type of insurance	31 %	40 %	19 %	6 %	
Number of hospitalizations/year	2008	2573	1221	360	6447
Total hospitalization cost	\$42 337 221	\$31 675 113	\$57 535 633	— ^a	\$161 895 431 ^b
Primarily waterborne total hospitalizations/year	6671	16 428	13 155	2400	40 118
Primarily waterborne total cost^d	\$92 589 019 ^e	\$342 350 156	\$378 037 657	— ^a	\$967 563 956 ^b
PARTIALLY WATERBORNE					
Campylobacteriosis					
Mean total cost/hospitalization	\$4328	\$7961	\$10 806	— ^a	\$8915
Proportion of hospitalizations with type of insurance	16 %	30 %	45 %	6 %	
Number of hospitalizations/year	2118	3972	5958	753	13 240
Total hospitalization cost	\$9 168 435	\$31 621 092	\$64 382 148	— ^a	\$118 048 105 ^b

Table 2 (cont.)

	Medicaid	Medicare	Commercial	Uninsured	Total
Salmonellosis					
Mean total cost/hospitalization	\$4036	\$8605	\$8687	— ^a	\$7687
Proportion of hospitalizations with type of insurance	21 %	28 %	41 %	6 %	
Number of hospitalizations/year	4857	6476	9482	1426	23 128
Total hospitalization cost	\$19 602 368	\$55 724 603	\$82 374 304	— ^a	\$177 792 568 ^b
Shigellosis					
Mean total cost/hospitalization	\$3510	\$17 841	\$9675	— ^a	\$8721
Proportion of hospitalizations with type of insurance	38 %	17 %	32 %	10 %	
Number of hospitalizations/year	2087	933	1757	542	5491
Total hospitalization cost	\$7 323 896	\$16 654 038	\$17 000 136	— ^a	\$47 884 375 ^b
Haemolytic uraemic syndrome					
Mean total cost/hospitalization	\$29 968	\$42 803	\$63 605	— ^a	\$51 261
Proportion of hospitalizations with type of insurance	20 %	27 %	46 %	4 %	
Number of hospitalizations/year	475	641	1092	99	2373
Total hospitalization cost	\$14 222 813	\$27 424 310	\$69 429 946	— ^a	\$121 642 495 ^b
Toxoplasmosis					
Mean total cost/hospitalization	\$39 294	\$35 982	\$54 783	— ^a	\$44 705
Proportion of hospitalizations with type of insurance	42 %	19 %	17 %	14 %	
Number of hospitalizations/year	3733	1689	1511	1286	8889
Total hospitalization cost	\$146 699 434	\$60 770 360	\$82 784 235	— ^a	\$397 386 567 ^b
Partially waterborne total hospitalizations/year	13 270	13 711	19 800	4106	53 121
Partially waterborne total cost	\$197 016 945	\$192 194 403	\$315 970 768	— ^a	\$862 754 111 ^b

NTM, Non-tuberculous mycobacteria.

Data sources: 2006–2007 Nationwide Inpatient Sample; Marketscan 2004–2005 Multistate Medicaid and 2006–2007 Medicare Supplemental and Commercial Claims databases. All costs in 2007 US dollars.

^a Costs for uninsured patients could not be estimated from the insurance claims-based Marketscan databases.

^b Totals are higher than the sum of Medicaid, Medicare, and Commercial columns because the total includes the uninsured and other insurance sources (e.g. Tricare).

^c The number of cases of Legionnaires' disease in the Marketscan Medicaid database was too small (<5 cases) to calculate cost estimates.

^d Pulmonary and disseminated NTM infections were a subset of all NTM infections and are not included in total cost calculations.

^e Not including Legionnaires' disease costs.

A complete estimate of the true cost of waterborne illness would also include the cost of mortality and disability, work and time loss, and chronic sequelae, which could be substantial. As an example, salmonellosis was estimated to cost \$2.5 billion per year in 2007 US dollars when productivity loss and mortality (but not chronic sequelae, childcare or travel expenses) were accounted for [17].

The near-universal exposure to drinking water can lead to extraordinary costs in a community-wide outbreak. The massive 1993 outbreak of cryptosporidiosis in Milwaukee sickened 400 000 and was estimated to cost \$96.2 million in medical costs and lost

productivity [18]. For illness associated with recreational water, the popularity of swimming implies a large population of exposed people and a high potential economic cost of illness or beach closure. Dwight *et al.* estimated that nearly 75 000 excess cases of illness were due to water pollution at just two beaches in Orange County, California [19], while an economic analysis of closures at a single Lake Michigan beach found a net economic loss of \$1274–37 030 per day (depending on the method used to assign values for health and recreation costs) [20].

Previous publications have estimated healthcare costs for some of the diseases included in this analysis.

A study by Ballarino and co-workers [21] of 27 hospitalized pulmonary NTM patients reported a median cost of \$19 876 (range \$398–70 917), slightly lower than the mean cost of \$25 409 for the 366 episodes observed in this analysis. In an analysis by the Economic Research Service of the US Department of Agriculture, salmonellosis was estimated to cost \$512 per outpatient visit and \$10 412 per hospitalization (2007 US dollars), similar to the \$418 (outpatient visit) and \$7687 (hospitalization) observed in this analysis [17, 22]. A study that addressed salmonellosis in California between 1990 and 1999 estimated an average cost of \$9054 per hospitalized case, similar to the \$7687 observed in this analysis [23].

A limitation of these estimates is their reliance on ICD-9 codes from billing records. Because a conservative estimate was desired, no adjustments for under-diagnosis were made. In particular, the estimates of hospitalization derived from the NIS instead of literature estimates (NTMs, HUS and otitis externa) are almost certainly lower than the actual number of hospitalizations because patients could have been hospitalized and treated for their symptoms without receiving a pathogen-specific diagnosis. The otitis externa total might also be lower since only hospitalized patients with a primary diagnosis of otitis externa and no concurrent diagnosis of otitis media were included.

A second limitation of this analysis in estimating the true cost of waterborne disease is the unknown proportion of disease transmission that is waterborne. Legionnaires' disease [24], NTM infection [25], and otitis externa [26–28] are believed to be almost entirely transmitted by water, while water is thought to be the primary vehicle for transmission of giardiasis [29] and cryptosporidiosis [30, 31]. Campylobacteriosis, salmonellosis, shigellosis, HUS, and toxoplasmosis are transmitted via multiple routes (foodborne, waterborne, person-to-person, and zoonotic transmission have all been documented) with non-water-related routes thought to be the primary mode of transmission. The fraction of cases acquired through water has not been precisely quantified, although some attempts at describing transmission sources have been made [12, 32–39]. Denno *et al.* [33] reported that recreational water exposure was responsible for 44% of *E. coli* O157 infections (the primary infectious agent of HUS) and 23% of campylobacteriosis cases in children, while 17% of salmonellosis cases were associated with septic tank use and 11% with well water use, but risk factors could differ for adult cases.

Scallan *et al.* [12] estimated the foodborne percentage for campylobacteriosis (80%), salmonellosis (94%), shigellosis (31%), Shiga-toxin producing *E. coli* O157 (68%), and toxoplasmosis (50%). The proportions of these diseases that are transmitted via person-to-person, zoonotic or other routes have also not been fully quantified, further obscuring the overall attribution picture.

Future studies are needed to more fully describe the burden of waterborne disease in the USA beyond the costs of hospitalizations. The national hospitalization cost estimates reported here represent nearly a billion dollars or more in healthcare costs for preventable waterborne diseases. However, these are underestimates since they do not include the substantial cost of outpatient care, work and time losses, and mortality associated with waterborne infections (e.g. *Legionella*, NTM infections). With millions of waterborne infections estimated to occur each year, the large healthcare expenditures for hospitalizations reported here underscore the likelihood of a large and hidden toll of waterborne disease and demonstrate a need for investment in future waterborne disease surveillance and prevention programmes.

ACKNOWLEDGEMENTS

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

DECLARATION OF INTEREST

None.

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