Prevalence and direct costs of emergency department visits and hospitalizations for selected diseases that can be transmitted by water, United States

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ABSTRACT

National emergency department (ED) visit prevalence and costs for selected diseases that can be transmitted by water were estimated using large healthcare databases (acute otitis externa, campylobacteriosis, cryptosporidiosis, *Escherichia coli* infection, free-living ameba infection, giardiasis, hepatitis A virus (HAV) infection, Legionnaires' disease, nontuberculous mycobacterial (NTM) infection, *Pseudomonas*-related pneumonia or septicemia, salmonellosis, shigellosis, and vibriosis or cholera). An estimated 477,000 annual ED visits (95% CI: 459,000–494,000) were documented, with 21% ($n = 101,000$, 95% CI: 97,000–105,000) resulting in immediate hospital admission. The remaining 376,000 annual treat-and-release ED visits (95% CI: 361,000–390,000) resulted in $194 million in annual direct costs. Most treat-and-release ED visits (97%) and costs ($178 million/year) were associated with acute otitis externa. HAV ($5.5 million), NTM ($2.3 million), and salmonellosis ($2.2 million) were associated with next highest total costs. Cryptosporidiosis ($2,035), campylobacteriosis ($1,783), and NTM ($1,709) had the highest mean costs per treat-and-release ED visit. Overall, the annual hospitalization and treat-and-release ED visit costs associated with the selected diseases totaled $3.8 billion. As most of these diseases are not solely transmitted by water, an attribution process is needed as a next step to determine the proportion of these visits and costs attributable to waterborne transmission.

Key words | costs, disease, emergency departments, infections, insurance, waterborne

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INTRODUCTION

Emergency departments (EDs) are unique outpatient care settings whose vital role includes coordinating pre-hospital emergency medicine, administering rapid diagnostics and treatments, as well as providing unrestricted access to care and a round-the-clock gateway to inpatient care (Tang *et al.* 2010; Schuur & Venkatesh 2012). In the United States, nearly 100 million annual outpatient acute care visits occur in EDs, with two-thirds occurring on weekends or after physician office hours (Pitts *et al.* 2010). The number of ED visits in the United States increased from 1997 to 2001 at twice the rate that would be expected from population growth alone, largely driven by adult Medicaid patients (Tang *et al.* 2010). Additionally, the proportion of inpatients admitted from EDs increased nationally from 1993 to 2006, highlighting the growing role of these facilities as a gateway to inpatient care (Schuur & Venkatesh 2012). Treat-and-release ED visits also comprise an estimated 40% of acute care encounters occurring within 30 days of hospital discharge (Vashi *et al.* 2013). Although EDs play an important role in managing illnesses in the United States, characteristics of ED visits associated with specific pathogen and infectious disease diagnoses have not been well described.

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Previously, Collier *et al.* (2012) found nearly 82,000 hospitalizations occur annually at a cost of $1.3 billion each year for eight diseases that can be associated with water exposures – acute otitis externa (swimmer's ear), campylobacteriosis, cryptosporidiosis, giardiasis, Legionnaires' disease, nontuberculous mycobacterial (NTM) infection, salmonellosis, and shigellosis. An analysis examining deaths associated with these diseases and an additional five that can be transmitted by water (*Escherichia coli* (*E. coli*) infection, free-living ameba infection, hepatitis A virus (HAV) infection, *Pseudomonas* infection, and vibriosis/cholera) documented the occurrence of 6,939 deaths each year, with 91% associated with Legionnaires' disease, NTM infection, and *Pseudomonas*-related pneumonia or septicemia (Gargano *et al.* 2017). To better describe outpatient ED care for diseases that can be transmitted by water in the United States, national ED visit prevalence, direct costs, visit characteristics, and payer-breakdowns were quantified. To tabulate total ED visit and hospitalization costs for the selected diseases, the number of national hospitalizations and associated direct costs for the diseases not previously published were calculated and then totaled with the published hospitalization estimates and ED visit analyses described here.

METHODS

US waterborne disease and outbreak surveillance data and existing literature were used to identify 13 diseases that can be transmitted by water (Craun *et al.* 2010; Collier *et al.* 2012; Gargano *et al.* 2013, 2017; Beer *et al.* 2015; Hlavsa *et al.* 2015). International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes were grouped to create disease definitions. Diseases included the following: acute otitis externa (380.10, 380.12, and 380.14), campylobacteriosis (008.43), cryptosporidiosis (007.4), *E. coli* infection (008.0, 041.41–041.43), free-living ameba infection (136.2), giardiasis (007.1), HAV infection (070.0 and 070.1), Legionnaires' disease (482.84), NTM infection (031), *Pseudomonas*-related pneumonia (482.1) or septicemia (038.43), salmonellosis (003), shigellosis (004), and vibriosis or cholera (001.0, 001.1, 001.9, 005.4, and 005.81). Concurrent cases of otitis media (381 and 382) were excluded from the acute otitis externa category. NTM infections were further divided into pulmonary (031.0), disseminated infection (031.2), and other (031.1, 031.8, and 031.9). Enterohemorrhagic *E. coli* and Shiga toxin-producing *E. coli* (EHEC/STEC) diagnoses (008.04, 041.41–041.43) were tabulated separately from the overall *E. coli* category. Several of the selected diseases are transmitted more commonly by other pathways, such as through food or contact with infected people. We aimed to summarize total visit and cost estimates for the diseases, and thus did not apply attribution estimates (proportions of disease attributable to specific transmission pathways) to the results.

Healthcare visits and costs for the 13 diseases were characterized using large, nationally representative administrative databases, including the US Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) Nationwide Emergency Department Sample (NEDS), HCUP Nationwide Inpatient Sample (NIS), and Truven Health MarketScan Commercial Claims and Encounters, Medicare Supplemental, and Medicaid Databases. The NEDS is the largest all-payer ED database in the United States and includes discharge data from a 20% stratified sample of all US hospital-based EDs that is weighted to yield national estimates (HCUP 2016a). Similarly, the NIS is the largest publicly available all-payer inpatient database in the United States and includes discharge data from a 20% stratified sample from US community hospitals that is weighted to yield national hospitalization estimates (HCUP 2016b). The MarketScan databases provide longitudinal patient-level expenditures and healthcare encounters data for a large sample of inpatient, outpatient, and prescription drug services across providers and healthcare facilities (Truven Health Analytics 2013a, 2013b, 2014a, 2014b). The Commercial Claims and Encounters (i.e. private insurance) and Medicare Supplemental databases provide anonymized payment records for insurance claims incurred by employees, dependents, and retirees enrolled in primary or Medicare-supplemental employer-based insurance plans (Truven Health Analytics 2013b, 2014b). The Medicaid databases provide anonymized payment records for claims incurred by approximately seven million Medicaid enrollees from several states (Truven Health Analytics 2013a, 2014a).

National annual numbers of ED visits for each disease were estimated using HCUP NEDS data from 2008 to 2012. Records that indicated that the patient was treated and released from the ED or admitted were used for analyses. Visits with all-listed diagnoses that included the diseases defined above were analyzed. SAS survey procedures were used to apply sampling weights to account for the complex sampling design and to yield annual national estimates of ED visits and measures of uncertainty for the selected diseases (SAS Institute Inc., USA). The weighted proportions of the total visits attributed to private insurance, Medicare, Medicaid, and other types of payment, including self-pay and military Tricare plans, were also calculated for each disease.

Next, direct costs for treat-and-release ED visits for each disease were calculated by insurance type using the MarketScan 2012 and 2013 Commercial Claims and Encounters, Medicare Supplemental, and Medicaid Databases. This analysis included outpatient services claims that took place in an ED and counted all costs incurred on a day when a visit involving a selected diagnosis occurred. Because a small number of records in the MarketScan outpatient services databases represent inpatient services (e.g. claim not incorporated into inpatient admission because room and board charge not found) (Truven Health Analytics 2014b), ED visits associated with an inpatient admission on the same day were excluded. To provide a full accounting of costs including costs for prescription drugs, only visits by individuals with pharmaceutical insurance coverage were examined. Outpatient pharmaceutical claims were added to the visit costs when prescriptions were filled on the same day as the visit. The mean insurer costs, patient out-of-pocket costs, and total costs per ED visit were calculated in 2014 US dollars by disease and insurance source, using healthcare commodity price conversion rates (Bureau of Labor Services 2015). To account for outliers that could skew mean cost calculations, ED visits were excluded if they resulted in zero total cost or the log of the total cost for that ED visit was at least three standard deviations from the log mean total cost (Bhattarai 2013). Cost estimates based on very small sample sizes – that is, less than five patients per disease and insurance source – were not reported. The overall mean cost per ED visit for each disease was calculated by multiplying the mean cost per visit for each insurance type derived from MarketScan by the corresponding proportion of visits with that insurance type from NEDS. Similarly, overall median, 25th percentile, and 75th percentile costs per ED visits were calculated for each disease. Private insurance mean costs per visit were used for the other payer category. Using the 2012 and 2013 MarketScan Commercial Claims and Encounters inpatient admissions and outpatient services databases, the proportion of patients with an associated hospital admission 1–14 days after the treat-and-release ED visit and the numbers of repeat ED visits per person in a one year period (2013) were characterized for each disease. The overall mean cost per ED visit was multiplied by the annual number of treat-and-release ED visits to calculate the total annual direct costs of treat-and-release ED visits for the selected diseases.

Hospitalizations for eight of the 13 diseases have been previously described (Scallan *et al.* 2011; Collier *et al.* 2012); for the five diseases that were not included in published analyses (*E. coli* infection, free-living ameba infection, HAV infection, *Pseudomonas* infection, and vibriosis/cholera), 2008–2012 HCUP NIS data were used to estimate national annual numbers of hospitalizations, and MarketScan 2012 and 2013 Commercial Claims and Encounters, Medicare Supplemental, and Medicaid inpatient admissions databases were used to calculate direct hospitalization costs. Survey procedures were used to calculate the national number of hospitalizations for each disease and the proportions of visits by payer type from the NIS data (SAS Institute Inc., USA). Following methods outlined previously (Collier *et al.* 2012), mean costs per hospital stay were calculated from the MarketScan databases in 2014 US dollars by disease and insurance source, using healthcare commodity price conversion rates (Bureau of Labor Services 2015). If patients had more than one associated hospital stay within a 365-day period, costs were aggregated to represent one hospitalization episode. Hospitalization costs also included costs for prescription medications and ED visits related to the hospitalization stay (i.e. ED visits that were not 'treat-and-release'). Cost estimates based on less than five patients per disease and insurance source were not reported. The overall mean cost per hospitalization episode was multiplied by the annual number of hospitalizations to calculate a total annual direct hospitalization cost for each disease. Finally, total costs of hospitalization episodes for the 13 selected diseases

were added to the total annual costs of treat-and-release ED visits to summarize overall annual costs.

RESULTS

An estimated 476,543 annual total ED visits (95% CI: 459,295–493,791) were documented for the 13 selected diseases (Table 1). Most of these ($n = 375,021$ (79%)) resulted from acute otitis externa. After acute otitis externa, the next most common diagnosis groups were *Pseudomonas*-related pneumonia or septicemia ($n = 54,211$ (11%)), NTM infection ($n = 14,122$ (3%)), and salmonellosis ($n = 9,574$ (2%)). Most *Pseudomonas* visits were associated with pneumonia ($n = 39,864$ (74%)), followed by septicemia ($n = 16,357$ (30%)). Visits for NTM infections were most often

Table 1 | Annual numbers of US ED visits for 13 selected diseases, by discharge status

	All ED visits		ED visits that resulted in immediate hospital admission			Treat-and-release ED visits	
Diagnosis [ICD-9-CM]	N[a]	95% CI	Percent admitted	N	95% CI	N	95% CI
Acute otitis externa[b] [380.10, 380.12, 380.14]	375,021	(360,894–389,147)	3	10,564	(10,052–11,076)	364,457	(350,656–378,258)
Campylobacteriosis [008.43]	4,609	(4,218–5,000)	81	3,739	(3,406–4,071)	870	(759–981)
Cryptosporidiosis [007.4]	1,809	(1,645–1,973)	73	1,314	(1,188–1,440)	495	(426–565)
E. coli infection [008.0, 041.41–041.43]	1,971	(1,778–2,165)	74	1,450	(1,308–1,592)	521	(411–632)
EHEC/STEC infection[c] *[008.04, 041.41- 041.43]*	*826*	*(698–955)*	*81*	*668*	*(553–783)*	*158*	*(113–203)*
Free-living ameba infection [136.2]	31	(19–43)	58	18	(9–27)	13[d]	(4–21)
Giardiasis [007.1]	1,918	(1,756–2,079)	65	1,252	(1,132–1,371)	666	(594–737)
HAV infection [070.0, 070.1]	8,484	(8,009–8,959)	59	5,009	(4,699–5,319)	3,475	(3,206–3,744)
Legionnaires' disease [482.84]	3,359	(3,096–3,622)	91	3,063	(2,818–3,309)	295	(248–343)
NTM infection [031]	14,122[e]	(13,171–15,074)	91	12,781[e]	(11,906–13,656)	1,341[e]	(1,182–1,499)
Disseminated NTM infection [031.2]	*5,922*	*(5,420–6,424)*	*91*	*5,391*	*(4,937–5,845)*	*531*	*(435–628)*
Pulmonary NTM infection [031.0]	*6,583*	*(6,096–7,070)*	*91*	*6,013*	*(5,556–6,471)*	*570*	*(493–646)*
Other NTM infection [031.1, 031.8, 031.9]	*1,742*	*(1,586–1,897)*	*86*	*1,496*	*(1,354–1,638)*	*246*	*(211–280)*
Pseudomonas infection [482.1, 038.43]	54,211[f]	(51,604–56,818)	98	53,373[f]	(50,818–55,929)	838[f]	(587–1,088)
Pseudomonas pneumonia [482.1]	*39,864*	*(37,781–41,946)*	*98*	*39,203*	*(37,161–41,245)*	*660*	*(461–860)*
Pseudomonas septicemia [038.43]	*16,357*	*(15,551–17,163)*	*99*	*16,156*	*(15,361–16,950)*	*201*	*(136–267)*
Shigellosis [004]	2,043	(1,612–2,475)	62	1,267	(1,121–1,413)	777	(458–1,095)
Salmonellosis [003]	9,574	(9,000–10,148)	83	7,925	(7,450–8,400)	1,649	(1,487–1,812)
Vibriosis/cholera [001.0, 001.1, 001.9, 005.4, 005.81]	239	(181–297)	31	73	(54–91)	166	(112–221)
Total[g]	476,543	(459,295–493,791)		101,029	(96,587–105,471)	375,514	(361,426–389,602)

[a]Total number of visits calculated using survey procedures and might not equal the sum of admitted and treat-and-release visits because of rounding.
[b]Excludes concurrent otitis media (ICD-9-CM = 381, 382).
[c]Estimates based on HCUP NEDS 2011–2012 because STEC ICD-9-CM codes (041.41–041.43) added in 2011.
[d]Unstable weighted estimate (relative standard error >30%) using HCUP NEDS 2008–2012 databases.
[e]Sub-categories do not total to overall NTM category because 86 visit records had concurrent disseminated NTM and pulmonary NTM diagnoses, 26 records had concurrent pulmonary NTM and other NTM diagnoses, 11 visit records had concurrent disseminated NTM and other NTM, and one visit record had all three sub-categories.
[f]Sub-categories do not total to overall *Pseudomonas* category because 2,010 records had concurrent *Pseudomonas* pneumonia and *Pseudomonas* septicemia diagnoses.
[g]Total numbers of visits do not equal totals of the diseases listed in the table because 49 treat-and-release visit records and 799 records of admitted patients had concurrent diagnoses of more than one disease.

associated with the pulmonary infection code ($n = 6,583$ (47%)), followed by the code for disseminated infection ($n = 5,922$ (42%)). Overall, 21% ($n = 101,029$, 95% CI: 96,587–105,471) of the ED visits resulted in admission to the hospital, although this proportion varied widely by disease, from over 90% for *Pseudomonas* infection, Legionnaires' disease, and NTM infection, to 3% for acute otitis externa. An estimated 375,514 annual treat-and-release ED visits (95% CI: 361,426–389,602) were documented; 97% of these were associated with acute otitis externa. The next three most common diagnosis groups for annual treat-and-release ED visits were HAV infection ($n = 3,475$ (0.9%)), salmonellosis ($n = 1,649$ (0.4%)), and NTM infection ($n = 1,341$ (0.4%)).

Costs-per-visit for patients treated-and-released from the ED varied by diagnosis (Table 2). Cryptosporidiosis resulted in the highest overall costs per ED visit (mean = $2,035/ED visit, median = $1,197/ED visit); 5% of the cryptosporidiosis patients had a co-diagnosis of human immunodeficiency virus (not shown). Campylobacteriosis (mean = $1,783/ED visit, median = $1,148/ED visit), NTM infection (mean = $1,709/ED visit, median = $932/ED visit), and giardiasis (mean = $1,634/ED visit, median = $1,065/ED visit) resulted in the next highest costs per visit. Acute otitis externa resulted

Table 2 | Mean costs per US treat-and-release ED visits for 13 selected diseases, by type of insurance

	Overall total cost per ED visit (2014 $)		Private insurance mean cost per ED visit (2014 $)			Medicare mean cost per ED visit (2014 $)				Medicaid mean cost per ED visit (2014 $)		
Diagnosis	Mean	Median (Q1, Q3)	Insurer	Out-of-pocket	Total	Medicare	Supplemental insurer	Out-of-pocket	Total	Insurer	Out-of-pocket	Total
Acute otitis externa[a]	487	362 (217, 608)	452	217	670	284	162	62	508	185	1	187
Campylobacteriosis	1,783	1,148 (583, 2,352)	2,092	383	2,475	689	506	60	1,255	426	1	427
Cryptosporidiosis	2,035	1,197 (542, 2,653)	1,890	405	2,295	3,461	366	55	3,882	521	1	521
E. coli infection	1,059	761 (414, 1,267)	1,384	278	1,662	538	208	29	775	223	1	224
EHEC/STEC infection	1,213	812 (414, 1,652)	1,704	317	2,021	463	206	17	686	181	0	181
Free-living ameba infection	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Giardiasis	1,634	1,065 (563, 2,052)	1,765	339	2,104	935	273	44	1,252	501	0	501
HAV infection	1,579	922 (469, 1,898)	1,989	326	2,316	651	367	86	1,104	621	1	621
Legionnaires' disease	1,056	872 (631, 1,420)	1,173	136	1,310	580	383	41	1,004	[b]	[b]	[b]
NTM infection	1,709	932 (360, 1,885)	1,468	145	1,614	1,579	392	61	2,032	756	1	757
Disseminated NTM infection	1,716	990 (378, 1,991)	1,658	172	1,830	1,409	450	36	1,895	1,023	1	1,024
Pulmonary NTM infection	1,671	853 (328, 1,773)	1,168	127	1,295	1,644	292	86	2,021	646	1	647
Other NTM infection	1,541	805 (220, 2,640)	1,561	130	1,691	1,623	447	31	2,101	401	1	402
Pseudomonas infection	840	360 (159, 988)	1,671	138	1,808	295	222	19	536	322	1	322
Pseudomonas pneumonia	842	330 (152, 1,027)	1,534	146	1,680	336	242	22	599	291	1	292
Pseudomonas septicemia	922	487 (138, 797)	2,589	80	2,669	159	144	9	312	532	0	532
Salmonellosis	1,328	732 (352, 1,635)	1,511	314	1,825	1,136	321	43	1,499	412	2	414
Shigellosis	975	611 (290, 1,166)	1,827	305	2,132	248	146	24	417	289	0	289
Vibriosis/cholera	1,028	808 (505, 1,251)	1,162	205	1,366	149	433	44	626	172	1	173

[a]Excludes concurrent otitis media (ICD-9-CM = 381, 382).

[b]Costs were not reported when $n < 5$ patients in MarketScan databases.

in the lowest cost per ED visit (mean = $487/ED visit, median = $362/ED visit). For patients with private insurance, the highest average out-of-pocket costs were associated with cryptosporidiosis ($405), campylobacteriosis ($383), giardiasis ($339), and HAV infection ($326). For Medicare patients, cryptosporidiosis had the highest mean cost per ED visit ($3,882), with a mean out-of-pocket cost of $55 per ED visit. For Medicaid patients, NTM infection resulted in the highest mean cost per ED visit ($757), with disseminated infection costing a mean of $1,024/ED visit.

Most patients had one treat-and-release ED visit in 2013 but some had additional visits associated with their diagnosis (Table 3); 15% or more of patients with shigellosis (23.5%), EHEC/STEC infection (18.8%), NTM infection (15.8%), and campylobacteriosis (15.0%) had more than one ED visit with that diagnosis in the one year period. Five percent of patients with pulmonary NTM infection and 6% of patients with disseminated NTM infections had four or more associated treat-and-release ED visits in the one year period. Over half of the *Pseudomonas* septicemia patients (57.1%) had an associated hospital admission 1–14 days after the treat-and-release ED visit. Over 7% of patients with cryptosporidiosis (8.4%), pulmonary NTM infection (7.1%), and EHEC/STEC (7.1%) diagnoses had an associated hospital admission 1–14 days after the treat-and-release ED visit.

The total cost of the 375,514 annual treat-and-release ED visits associated with the 13 selected diseases was $194 million, with $79 million in costs for patients with private insurance, $18 million in costs for Medicare patients, $25 million in costs for Medicaid patients, and $71 million for uninsured patients or those with other types of insurance (e.g. Tricare) (Table 4). Most of the total costs ($178 million (92%)) were associated with acute otitis externa. Although acute otitis externa had the lowest overall mean cost per visit, the high prevalence of visits contributed to this disease

Table 3 | Treat-and-release ED visit characteristics among patients with private insurance (2013)

Diagnosis	Median no. ED visits/year (min-max)	Median no. days between ED visits (min-max)	% Patients with more than one ED visit/year	% Patients with at least four ED visits/year	% Admitted 1–14 days after treat-and-release ED visit
Acute otitis externa	1 (1–6)	1 (1–295)	5.8	0.1	0.6
Campylobacteriosis	1 (1–5)	1 (1–8)	15.0	1.8	3.6
Cryptosporidiosis	1 (1–3)	1 (1–57)	13.8	0.0	8.4
E. coli infection	1 (1–3)	1 (1–3)	9.4	0.0	4.4
EHEC/STEC infection	1 (1–3)	1 (1–3)	18.8	0.0	7.1
Free-living ameba infection	[a]	[a]	[a]	[a]	[a]
Giardiasis	1 (1–3)	1 (1–18)	3.9	0.0	2.8
HAV infection	1 (1–7)	1 (1–103)	10.4	1.7	3
Legionnaires disease	1 (1–2)	1 (1–2)	12.5	0.0	4.5
NTM infection	1 (1–5)	1 (1–235)	15.8	3.5	6.7
Disseminated NTM infection	1 (1–5)	1 (1–5)	17.6	5.9	4.8
Pulmonary NTM infection	1 (1–5)	1 (1–235)	23.8	4.8	7.1
Other NTM infection	1 (1–2)	1 (1–22)	5.3	0.0	2.1
Pseudomonas infection	1 (1–1)	1 (1–1)	0.0	0.0	15.4
Pseudomonas pneumonia	1 (1–1)	1 (1–1)	0.0	0.0	4
Pseudomonas septicemia	1 (1–1)	1 (1–1)	0.0	0.0	57.1
Salmonellosis	1 (1–4)	1 (1–5)	10.8	1.7	6.5
Shigellosis	1 (1–4)	1 (1–4)	23.5	2.9	2.3
Vibriosis/cholera	1 (1–3)	1 (1–3)	5.6	0.0	0

[a]Not reported because $n < 5$ patients in 2012/2013 MarketScan Commercial Claims and Encounters dataset.

incurring the majority of the overall costs. Following acute otitis externa, the highest total costs were incurred for visits with diagnoses of HAV infection ($5.5 million), NTM infection ($2.3 million), and salmonellosis ($2.2 million). Giardiasis ($1.1 million) and campylobacteriosis ($1.6 million) were associated with total annual costs over $1 million.

Hospitalizations and costs for *Pseudomonas*-associated pneumonia and septicemia, HAV infection, *E. coli* infection, vibriosis and cholera, and free-living ameba infection are shown in Table 5. Supplemental Table 5A (available with the online version of this paper) provides a breakdown of these costs by insurance type. *Pseudomonas* infections were associated with over 30,000 hospitalizations annually at a cost of $2.1 billion, while over 7,700 hospitalizations for HAV infection were documented at a cost of $165 million. Over 2,100 hospitalizations associated with *E. coli* infection were documented at a cost of $48 million each year. Hospitalizations for the eight diseases published previously (Collier *et al.* 2012) – acute otitis externa, campylobacteriosis, cryptosporidiosis, giardiasis, Legionnaires' disease, NTM infection, salmonellosis, shigellosis – and the five diseases added here total 122,018 annual hospitalizations at a cost of $3.6 billion each year (Table 6). Thus, the treat-and-release ED visit (375,514) and hospitalization estimates (122,018) for these 13 selected diseases total an estimated 497,532 US healthcare interactions annually costing $3.8 billion in direct costs.

DISCUSSION

This descriptive analysis of national ED visits and costs highlights the importance of US outpatient ED settings in managing illnesses from the selected diseases that can be transmitted by water. Approximately 480,000 ED visits associated with the 13 diseases occur each year, which comprise

Table 4 | Estimated total annual costs of US treat-and-release ED visits for 13 selected diseases, by insurance type

Diagnosis	Total cost (2014 $)[a]	Private insurance (2014 $)	Medicare (2014 $)	Medicaid (2014 $)	Other (2014 $)
Acute otitis externa[b]	177,629,526	71,766,321	14,237,586	24,010,464	67,615,156
Campylobacteriosis	1,551,637	983,820	175,133	89,938	302,747
Cryptosporidiosis	1,007,433	528,820	226,748	64,990	186,876
E. coli infection	551,907	304,624	144,269	23,177	79,836
EHEC/STEC infection	*191,629*	*125,396*	*30,836*	*6,658*	*28,739*
Free-living ameba infection	[c]	[c]	[c]	[c]	[c]
Giardiasis	1,088,485	599,040	111,817	73,974	303,654
HAV infection	5,488,332	2,172,182	942,603	558,700	1,814,847
Legionnaires' disease	287,622	115,510	127,979	[c]	44,133
NTM infection	2,291,126	467,938	1,505,514	161,407	156,268
Disseminated NTM infection	*911,347*	*169,761*	*575,371*	*101,789*	*64,426*
Pulmonary NTM infection	*952,370*	*170,144*	*699,361*	*36,953*	*45,913*
Other NTM infection	*379,143*	*114,812*	*195,058*	*23,348*	*45,925*
Pseudomonas infection	703,862	311,202	261,236	39,153	92,270
Pseudomonas pneumonia	*555,934*	*227,748*	*232,697*	*27,964*	*67,526*
Pseudomonas septicemia	*185,338*	*110,513*	*39,985*	*12,201*	*22,639*
Salmonellosis	2,189,580	1,211,294	301,566	221,395	455,326
Shigellosis	757,793	397,078	15,261	131,094	214,359
Vibriosis/cholera	170,566	97,936	11,348	6,203	55,079
Total	193,717,869	78,955,765	18,061,060	25,380,495	71,320,551

[a]Total cost is weighted average of all payers and might not equal sum of payer totals because of rounding.
[b]Excludes concurrent otitis media (ICD-9-CM = 381, 382).
[c]Costs were not reported when $n < 5$ in MarketScan databases.

Table 5 | Estimated annual numbers of US hospitalizations, overall mean costs per episode, and total annual costs of hospitalizations for five selected diseases

Diagnoses	Annual no. of hospitalizations[a]	Overall mean cost/episode[b] (2014 $)	Total cost in millions[c] (2014 $)
E. coli infection [008.0, 041.41–041.43]	2,133	22,439	47.9
EHEC/STEC infection [008.04, 041.41–041.43]	*730*[d]	*17,466*	*12.8*
Free-living ameba infection [136.2]	<11	44,149[e]	[e]
HAV infection [070.0, 070.1]	7,760	21,261	165.0
Pseudomonas infection [482.1, 038.43][f]	30,050	69,837	2,098.6
Pseudomonas pneumonia [482.1]	*19,248*	*74,298*	*1,430.1*
Pseudomonas septicemia [038.43]	*10,803*	*64,162*	*693.1*
Vibriosis/cholera [001.0, 001.1, 001.9, 005.4, 005.81]	98	14,762	1.4

[a]Estimates from HCUP NIS 2008–2012; weighted estimates less than 11 are unreliable and are suppressed.
[b]Estimates from MarketScan 2012 and 2013 Commercial Claims and Encounters, Medicare and Coordination of Benefits, and Medicaid databases; costs converted to 2014 US dollars; 365 day episode length assumed.
[c]Total cost is a weighted average of all payers.
[d]Estimates from HCUP NIS 2011–2012 because STEC ICD-9-CM codes (041.41–041.43) added in 2011.
[e]Reported mean cost per episode for private insurance only because $n < 5$ patients in the MarketScan Medicare and Medicaid databases; did not report total cost.
[f]Principal diagnosis used for *Pseudomonas* infection.

Table 6 | Estimated total annual visits and costs of treat-and-release ED visits and hospitalizations for 13 selected diseases

Healthcare interaction	Number of visits	Total cost (2014 $)
Hospitalizations[a]		
Previously published (8 diseases)[b]	81,977	$1,311,289,005
Table 5 analyses (4 diseases)[c]	40,041	$2,312,906,468
Total hospitalizations	122,018	$3,624,195,473
Total treat-and-release ED visits (Tables 1 and 4)[d]	375,514	$193,717,869
TOTAL	497,532	$3,817,913,342

[a]Includes ED visits in which patient was admitted to the hospital.
[b]Includes acute otitis externa, campylobacteriosis, cryptosporidiosis, giardiasis, Legionnaires' disease, NTM infection, salmonellosis, and shigellosis.
[c]Includes *E. coli*, HAV infection, *Pseudomonas* infection, and vibriosis/cholera. Hospitalizations and costs for free-living ameba could not be calculated because of small sample sizes in the HCUP NIS and MarketScan databases.
[d]Estimated in Tables 1 and 4; includes acute otitis externa, campylobacteriosis, cryptosporidiosis, *E. coli* infection, free-living ameba, giardiasis, HAV infection, Legionnaires' disease, NTM infection, *Pseudomonas* infection, salmonellosis, shigellosis, and vibriosis/cholera; Costs for free-living ameba were not reported because $n < 5$ in MarketScan databases.

approximately 0.4% of all ED visits in the United States (HCUPnet 2015). Of these, an estimated 376,000 annual treat-and-release ED visits result in $194 million in annual direct costs. Together, treat-and-release ED visits and hospitalizations for the 13 diseases result in an estimated 500,000 US healthcare interactions annually at a cost of nearly $4 billion each year.

A substantial number of national ED visits ($n =$ 375,021 (79% of 13 diseases)) and high total direct costs were associated with acute otitis externa, despite the low mean costs per visit associated with this condition. An estimated 25% of ED visits for acute otitis externa result in an opioid pain reliever prescription, although topical antimicrobials are recommended for treatment in the absence of complicating factors, which could indicate that higher pain levels motivate patients to seek urgent care in an ED (Collier *et al.* 2013). An estimated 2.4 million combined office and ED visits occur each year for acute otitis externa, at a cost of nearly $0.5 billion US dollars, 600,000 hours of clinicians' time (Piercefield *et al.* 2011), and 770,000 systemic antimicrobial prescriptions (Collier *et al.* 2013). Acute otitis externa is usually caused by an infectious agent – often *Pseudomonas aeruginosa* or *Staphylococcus aureus* (Roland & Stroman 2002; Ninkovic *et al.* 2008) – results from moisture or water in the ear canal, and is preventable; prevention strategies focus on keeping water away from the ears, either by using ear plugs, drying the ear canal with a hair dryer, or using alcohol-based drops (Beers & Abramo 2004). Reducing the prevalence of this preventable disease could reduce ED health-care spending up to $178 million annually as well as the concurrent demand on EDs.

The next highest numbers of ED visits overall were seen in illnesses from *Pseudomonas* and NTM infections; these pathogens are found in the environment and can grow and multiply in biofilms within water distribution system pipes

and building water systems (i.e. premise plumbing) and can cause infections through contact with water or inhalation of water aerosols (Falkinham *et al.* 2015a, 2015b). However, because *Pseudomonas* is ubiquitous in the environment, water is a natural reservoir, and people can be colonized without disease, the percentage of transmission attributable to various routes (e.g. water or person-to-person) is unknown (Mena & Gerba 2009). Studies of NTM patients, however, have established relationships between household plumbing and pulmonary infections (Falkinham 2011). NTM are resistant to chlorination and have been detected in water systems that meet federal drinking water quality standards (Hilborn *et al.* 2006). Changes in the flow of water within the distribution system can allow NTM to be released from biofilms and enter the drinking water (Norton *et al.* 2004), where they can multiply within premise plumbing systems and come in contact with people through aerosolization through showers and other fixtures. Biofilm-associated pathogens represent a challenge to waterborne disease prevention efforts, because of their resistance to current methods of water treatment and prevalence in building or household plumbing, which are not subject to US Environmental Protection Agency (EPA) microbial regulations (Gargano *et al.* 2013).

ED visits involving *Pseudomonas* infection, Legionnaires' disease, and NTM infection had high proportions of patients who required hospital admission, perhaps indicating more serious illness. In contrast, diagnosis groups including acute otitis externa, HAV infection, and salmonellosis were associated with high numbers of treat-and-release ED visits. More than 15% of patients with shigellosis, EHEC/STEC infection, NTM infection, and campylobacteriosis had more than one associated ED visit in a one year period, and about 5% of patients with NTM infections had four or more associated ED visits in a one year period. Repeated visits to the ED for the same diagnosis over the one year period potentially indicates that these illnesses are being managed in the ED. Drawbacks of managing illnesses in the ED include difficulties in coordination of care, potential duplication of services, and high costs and patient turnover (Coleman 2003; Pitts *et al.* 2010). Many considerations, including access to EDs, socio-economic factors, and health insurance coverage can influence patient care-seeking behaviors (DeFelice *et al.* 2016).

This analysis is subject to several limitations. These findings only capture disease diagnoses that were present on billing records in administrative databases, and these might not fully represent patient medical records because codes are prioritized for remuneration, rather than clinical significance (Schoenman *et al.* 2007; Jhung & Banerjee 2009; Pine *et al.* 2012). To address this limitation, multiple ICD-9-CM codes were combined to create disease definitions, data from multiple years and databases were used to yield more robust estimates, and ranges of estimates were reported when possible. The MarketScan and HCUP databases used in this analysis are nationally representative and reliable (Schoenman *et al.* 2007; Adamson *et al.* 2008) although not a census of US healthcare interactions. Because this study aimed to produce conservative estimates, the visit and cost estimates were not adjusted for underdiagnosis. For some diseases (e.g. salmonellosis or campylobacteriosis), presumptive treatment in the ED for diarrhea and dehydration without identification of a specific pathogen might occur, resulting in an underestimation of the number of ED visits, since this analysis used pathogen-specific diagnosis codes or groupings of codes to capture enteric illnesses. Laboratory results were not available in the administrative databases used here, and thus these data might have had low sensitivity for capturing pathogen-specific diagnostic codes. Similarly, it is plausible that diseases such as acute otitis externa, which can be diagnosed relatively easily based on clinical presentation and without laboratory testing, were better captured by the administrative data. ED visits in which the selected diagnosis was anywhere on the record were included, instead of limiting the analysis to records with only a first-listed diagnosis of the disease of interest. This might have allowed the inclusion of rule-out diagnoses that were recorded. However, the order of the diagnoses listed in the HCUP NEDS databases does not necessarily indicate clinical significance (HCUP 2015), and all-listed diagnoses were included to give a more complete indexing of patients. For the MarketScan analyses, the mean cost per visit for private insurance was used to approximate the visit cost for the other insurance and self-pay category. Lastly, the proportions of these selected diseases that are transmitted by water – that is, the attributable fraction of these diseases transmitted through water – is not known, and published estimates

vary by pathogen, from 1 to 6% for HAV (0–27% CI range) (Vally *et al*. 2014; Butler *et al*. 2015; WHO 2015), 2–8% for *Salmonella* (0–35% CI range) (Vally *et al*. 2014; Butler *et al*. 2015; WHO 2015), 6–11% for *Campylobacter* (0–32% CI range) (Vally *et al*. 2014; Butler *et al*. 2015; WHO 2015), 37% for *Cryptosporidium* (8–72% CI range) (Butler *et al*. 2015; WHO 2015), and 42–48% for *Giardia* (5–75% CI range) (Butler *et al*. 2015; WHO 2015).

CONCLUSIONS

The diseases studied here contribute to 500,000 US treat-and-release ED visits and hospitalizations annually at a cost of nearly $4 billion each year. EDs play an important role in managing illnesses in the United States, but national costs and characteristics of ED visits associated with diseases that can be transmitted by water have not been previously well described. These findings highlight the importance of tabulating national healthcare outcomes and costs as an initial step towards better understanding the epidemiology of these diseases in the United States.

DISCLAIMER

The findings and conclusions in this article are those of the authors, and do not necessarily represent the official position of the US CDC.

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