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A Peek Behind the Curtain: How National Foodborne Disease Estimates are Developed

Elaine Scallan Walter, PhD | Professor, Co-Director Colorado Food Safety CoE

AFDO Healthy People 2030 Workgroup | March 26, 2024

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Centers for Disease Control and Prevention
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Preliminary Incidence and Trends of Infections Caused by Pathogens Transmitted Commonly Through Food — Foodborne Diseases Active Surveillance Network, 10 U.S. Sites, 2022

Miranda J. Delahoy, PhD[1]; Hazel J. Shah, MPH[1]; Daniel Lowell Weller, PhD[1]; Logan C. Ray, MPH[1]; Kirk Smith, DVM, PhD[2]; Suzanne McGuire, MPH[3]; Rosalie T. Trevejo, DVM, PhD[4]; Elaine Scallan Walter, PhD[5]; Katie Wymore, MPH[6]; Tamara Rissman, MPH[7]; Marcy McMillian, MPH[8]; Sarah Lathrop, DVM, PhD[9]; Bethany LaClair, MPH[10]; Michelle M. Boyle, MPH[11]; Stic Harris, DVM[12]; Joanna Zablotsky-Kufel, PhD[13]; Kennedy Houck, MPH[1]; Carey J. Devine, MPH[1]; Carey E. Lau[1]; Robert V. Tauxe, MD[1]; Beau B. Bruce, MD, PhD[1]; Patricia M. Griffin, MD[1]; Daniel C. Payne, PhD[1]

Each year, infections from major foodborne pathogens are responsible for an estimated 9.4 million illnesses, 56,000 hospitalizations, and 1,350 deaths in the United States (*1*). To evaluate progress toward prevention of enteric infections in the United States, the Foodborne Diseases Active Surveillance Network (FoodNet) conducts surveillance for laboratory-diagnosed infections caused by eight pathogens transmitted commonly through food at 10 U.S. sites. During 2020–2021, FoodNet detected decreases in many infections that were due to behavioral modifications, public health interventions, and changes in health care–seeking and testing practices during the COVID-19 pandemic. This report presents preliminary estimates of pathogen-specific annual incidences during 2022, compared with average annual incidences during 2016–2018, the reference period for the U.S. Department of Health and Human Services' Healthy People 2030 targets (*2*). Many pandemic interventions ended by 2022, resulting in a resumption of outbreaks, international travel, and other factors leading to enteric infections. During 2022, annual incidences of illnesses caused by the pathogens *Campylobacter*, *Salmonella*, *Shigella*, and *Listeria* were similar to average annual incidences during 2016–2018; however, incidences of Shiga toxin-producing *Escherichia coli* (STEC), *Yersinia*, *Vibrio*, and *Cyclospora* illnesses were higher. Increasing culture-independent diagnostic test (CIDT) usage likely contributed to increased detection by identifying infections that would have remained undetected before widespread CIDT usage. Reducing pathogen contamination during poultry slaughter and processing of leafy greens requires collaboration among food growers and processors, retail stores, restaurants, and regulators.

CDC, 10 state health departments, the U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS), and the Food and Drug Administration (FDA) collaborate to conduct active population-based surveillance of the FoodNet catchment area,* which included an estimated 51 million

* The FoodNet catchment includes Connecticut, Georgia, Maryland, Minnesota, New Mexico, Oregon, Tennessee, and selected counties in California, Colorado, and New York.

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U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

TABLE 1. Number of laboratory-diagnosed bacterial and parasitic infections, hospitalizations, deaths, outbreak-associated infections, crude incidence, and incidence rate ratios compared with 2016–2018 average annual incidence, domestic incidence, and Healthy People 2030 incidence targets,* by pathogen — Foodborne Diseases Active Surveillance Network, 10 U.S. sites,† 2022§

Pathogen	Infections,¶ no.	No. (%) Hospitalizations**	No. (%) Deaths††	No. (%) Outbreak-associated infections§§	Crude average incidence 2016–2018	Crude incidence 2022¶¶	IRR (95% CrI)***	Domestic incidence†††	Healthy People 2030 (domestic) incidence target
Bacteria									
Campylobacter	9,751	1,938 (19.9)	42 (0.4)	59 (0.6)	18.8	19.2	1.02 (0.96–1.08)	17.4	10.9
Salmonella	8,285	2,228 (26.9)	62 (0.7)	756 (9.1)	17.0	16.3	0.95 (0.89–1.02)	14.5	11.5
STEC§§§	2,882	582 (20.2)	11 (0.4)	78 (2.7)	5.3	5.7	1.18 (1.02–1.36)	4.6	3.7
STEC O157¶¶¶	301	—****	—****	—****	0.9	0.6	0.76 (0.65–0.86)	—****	NA††††
STEC non-O157¶¶¶	992	—****	—****	—****	2.1	2.0	0.92 (0.77–1.13)	—****	NA††††
Shigella	2,478	758 (30.6)	6 (0.2)	136 (5.5)	5.1	4.9	0.95 (0.75–1.18)	3.9	NA††††
Yersinia	1,003	200 (19.9)	5 (0.5)	6 (0.6)	0.9	2.0	2.41 (2.03–2.88)	1.9	NA††††
Vibrio	504	117 (23.2)	13 (2.6)	0 (—)	0.8	1.0	1.57 (1.37–1.81)	0.9	NA††††
Listeria§§§§	136	128 (94.1)	30 (22.1)	7 (5.1)	0.3	0.3	1.06 (0.93–1.22)	0.26	0.22
Parasite									
Cyclospora	440	30 (6.8)	1 (0.2)	54 (12.3)	0.4	0.9	4.77 (2.60–10.7)	0.6	NA††††
Total	**25,479**	**5,981 (23.5)**	**170 (0.7)**	**1,096 (4.3)**	—****	—****	—****	—****	—****

Abbreviations: CIDT = culture-independent diagnostic test; CrI = credible interval; HHS = U.S. Department of Health and Human Services; IRR = incidence rate ratio;

FoodNet

https://www.cdc.gov/foodnet/reports/preliminary-data.html

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FoodNet Surveillance

Foodborne Diseases Active Surveillance Network (FoodNet)

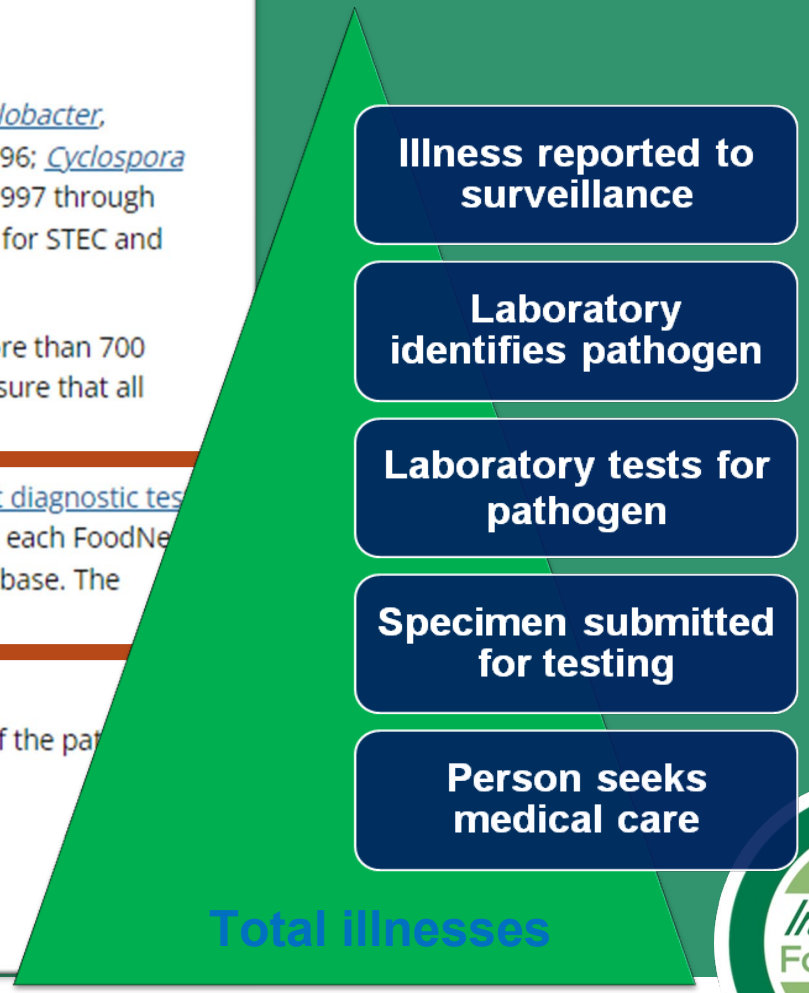
Active Laboratory Surveillance

FoodNet has conducted population-based surveillance for laboratory-diagnosed infections caused by *Campylobacter*, *Listeria*, *Salmonella*, Shiga toxin-producing *Escherichia coli* (STEC) O157, *Shigella*, *Vibrio*, and *Yersinia* since 1996; *Cyclospora* since 1997; and STEC non-O157 since 2000. FoodNet also conducted surveillance for *Cryptosporidium* from 1997 through 2017. FoodNet began to collect information on infections identified by culture-independent methods in 2009 for STEC and *Campylobacter* and in 2011 for *Listeria*, *Salmonella*, *Shigella*, *Yersinia*, and *Vibrio*.

FoodNet is an active surveillance system, meaning that public health officials routinely communicate with more than 700 clinical laboratories serving the surveillance area to identify new infections and conduct periodic audits to ensure that all infections are reported.

FoodNet collects information on laboratory-diagnosed infections identified by culture or culture-independent diagnostic tes (CIDT) for bacterial pathogens and microscopy or polymerase chain reaction (PCR) for parasites. Personnel at each FoodNe site collect information about cases of infection and share that information with CDC through FoodNet's database. The information includes

- hospitalizations occurring within 7 days of the specimen collection date,
- the patient's status (alive or dead) at hospital discharge (or at 7 days after the specimen collection date if the pat not hospitalized),
- whether the patient traveled abroad in the 7 days before illness began, and
- selected food and environmental exposures.



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Why estimate foodborne illnesses?

- Surveillance data only represents tip of the iceberg
  - Many illnesses not reported to surveillance
- “Foodborne” pathogens can be transmitted via other routes
  - Estimate illnesses transmitted through food

Why estimate foodborne illnesses?

- Foodborne illness estimates inform:
  - Prioritization of policies and programs
  - Allocation of resources
  - Targeted educational initiatives
  - Risk ranking, cost estimates etc.

Approaches used to estimate illnesses

- Illnesses estimated using variety of data sources
- Four approaches used to estimate illnesses

Surveillance data scaled-up

Direct

Syndrome or population data scaled-down

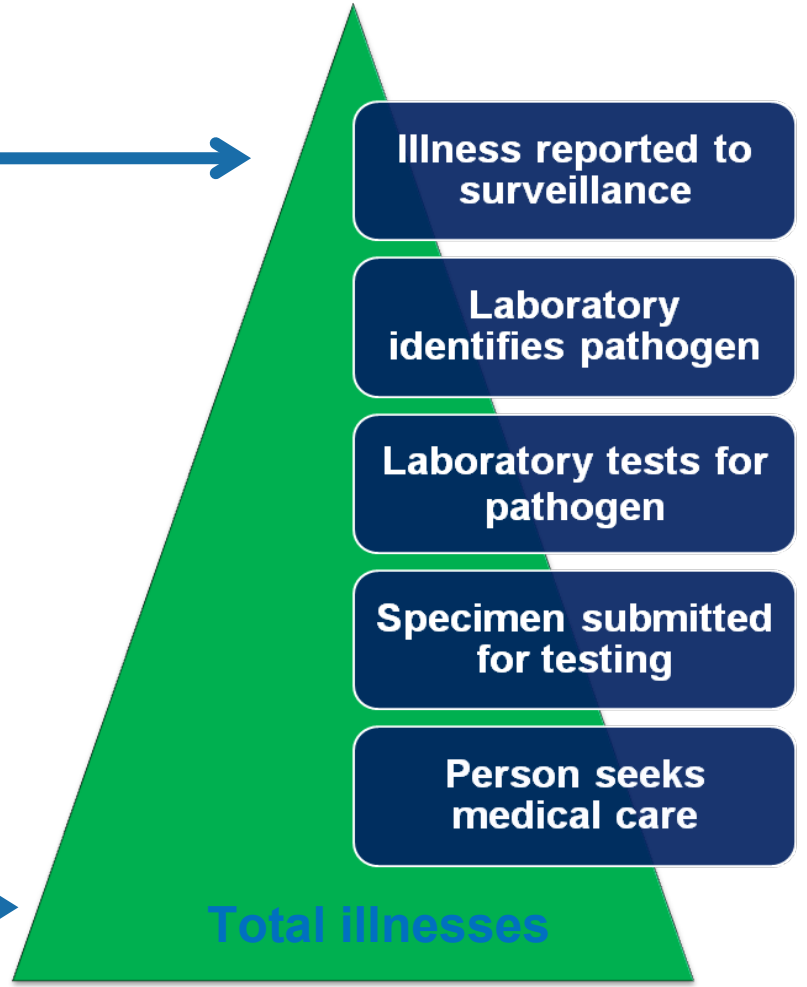
Inferred

Scallan Walter et al. Estimating the Number of Illnesses *Foodborne Pathog Dis.* 2021 Dec;18(12):841-858.

Surveillance scaled-up approach

We know the number of reported illnesses

We want to estimate total domestically acquired foodborne illnesses



Surveillance scaled-up approach

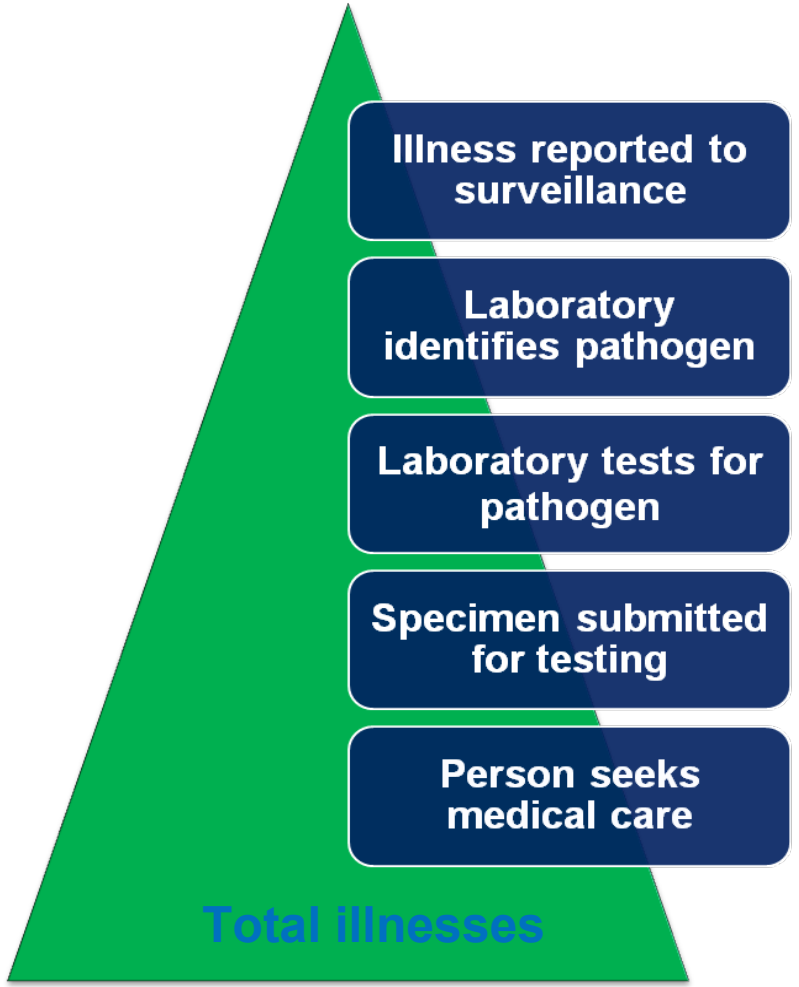
Reported illnesses

Under-diagnosis

Adjusted for:

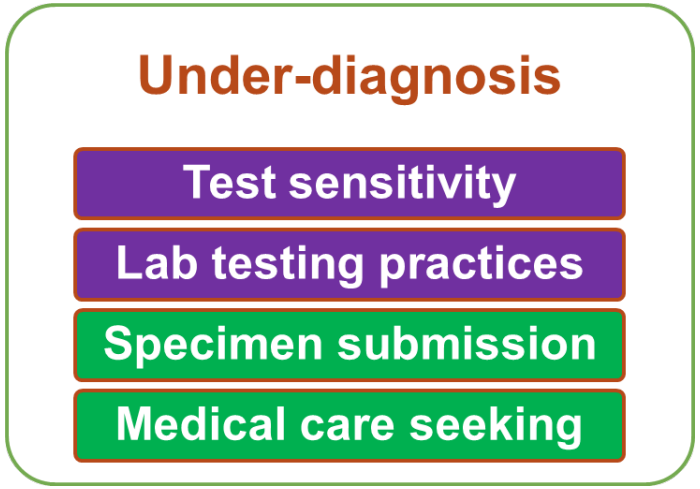
Under-diagnosis

- Test sensitivity
- Lab testing practices
- Specimen submission
- Medical care seeking



Adjusting for under-diagnosis

- Variety of data sources used, including expert opinion
- Medical care-seeking & specimen submission
  - Population surveys asking about diarrheal illness and related medical care visits
- Laboratory testing and test sensitivity
  - Surveys of laboratory practices, literature



Direct Approach

- Measures all relevant illnesses in defined source population
  - Prospective **cohort studies** of people in the community
  - **Serological surveys** (e.g., *Toxoplasma*) or **cross-sectional surveys** (e.g., ciguatera fish poisoning)

Syndrome/population data scaled-down

Syndrome

- Begins with the number of illnesses manifested by a specific syndrome and estimates % caused by a specific agent
  - E.g., % acute gastroenteritis illnesses caused by norovirus

Population data

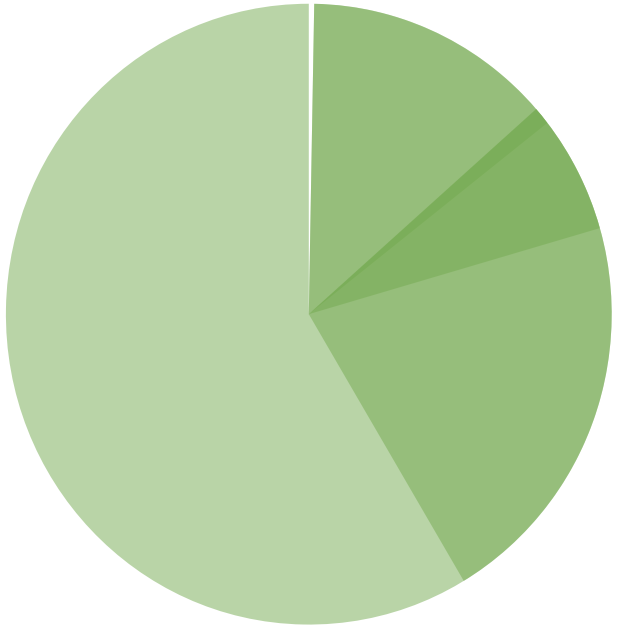
- Begins with the number of people in a population and estimates the proportion who became ill
  - E.g., % of children <5 year who experience an episode of rotavirus

Inferred

- Data from another pathogen, a syndrome, a treatment for a specific infection, or from another location used to inform the number of illnesses caused by that pathogen
  - E.g., a drug used to treat tapeworm infestation, STEC illnesses extrapolated from data on HUS

Estimating “foodborne” illnesses

- Determine for pathogen % proportion attributable to food
  - Outbreak data
  - Epidemiological studies
  - Expert elicitation



Burden assessment **not "exact science"**

- Driven by availability and quality of data
  - in that country or region, at that time
- Many ad hoc choices are made along the way
- End result is a set of "best estimates"

Estimating foodborne burden **is an "art"**

- Requires contextual knowledge, clinical knowledge, and a broad epidemiological toolbox
  - Relies on a **network of experts**
- Precision but not 'uncertainty-induced' paralysis
- Creativity and plausibility

Comparing burden estimates (don't!)

- Methods and approaches do (and should change)
  - more refined methods and
  - improved and new data sources
- Because of changes, cannot compare the new and old estimates for the purpose of assessing trends
  - comparing apples and oranges

Foodborne Trends

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INSIDE

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Foodborne Burden

Foodborne Illness Acquired in the United States—Major Pathogens

Elaine Scallan,[1] Robert M. Hoekstra, Frederick J. Angulo, Robert V. Tauxe, Marc-Alain Widdowson, Sharon L. Roy, Jeffery L. Jones, and Patricia M. Griffin

Estimates of foodborne illness can be used to direct food safety policy and interventions. We used data from active and passive surveillance and other sources to estimate that each year 31 major pathogens acquired in the United States caused 9.4 million episodes of foodborne illness (90% credible interval [CrI] 6.6–12.7 million), 55,961 hospitalizations (90% CrI 39,534–75,741), and 1,351 deaths (90% CrI 712–2,268). Most (58%) illnesses were caused by norovirus, followed by nontyphoidal *Salmonella* spp. (11%), *Clostridium perfringens* (10%), and *Campylobacter* spp. (9%). Leading causes of hospitalization were nontyphoidal *Salmonella* spp. (35%), norovirus (26%), *Campylobacter* spp. (15%), and *Toxoplasma gondii* (8%). Leading causes of death were nontyphoidal *Salmonella* spp. (28%), *T. gondii* (24%), *Listeria monocytogenes* (19%), and norovirus (11%). These estimates cannot be compared with prior (1999) estimates to assess trends because different methods were used. Additional data and more refined methods can improve future estimates.

Estimates of the overall number of episodes of foodborne illness are helpful for allocating resources and prioritizing interventions. However, arriving at these estimates is challenging because food may become contaminated by many agents (e.g., a variety of bacteria, viruses, parasites, and chemicals), transmission can occur by nonfood mechanisms (e.g., contact with animals or consumption of contaminated water), the proportion of disease transmitted by food differs by pathogen and by host factors (e.g. age and immunity), and only a small proportion of illnesses are confirmed by laboratory testing and reported to public health agencies.

Laboratory-based surveillance provides crucial information for assessing foodborne disease trends. However, because only a small proportion of illnesses are diagnosed and reported, periodic assessments of total episodes of illness are also needed. (Hereafter, episodes of illness are referred to as illnesses.) Several countries have conducted prospective population-based or cross-sectional studies to supplement surveillance and estimate the overall number of foodborne illnesses (*1*). In 2007, the World Health Organization launched an initiative to estimate the global burden of foodborne diseases (*2*).

In 1999, the Centers for Disease Control and Prevention provided comprehensive estimates of foodborne illnesses, hospitalizations, and deaths in the United States caused by known and unknown agents (*3*). This effort identified many data gaps and methodologic limitations. Since then, new data and methods have become available. This article is 1 of 2 reporting new estimates of foodborne diseases acquired in the United States (hereafter referred to as domestically acquired). This article provides estimates of major known pathogens; the other provides estimates for agents of acute gastroenteritis not specified in this article (*4*).

Methods

Adequate data for preparing national estimates were available for 31 pathogens. We estimated the number of foodborne illnesses, hospitalizations, and deaths caused by these 31 domestically acquired pathogens by using data shown in the online Appendix Table (www.cdc.gov/EID/content/17/1/7-appT.htm) and online Technical Appendix 1 (www.cdc.gov/EID/content/17/1/7-Techapp1.pdf).

Data were mostly from 2000–2008, and all estimates were based on the US population in 2006 (299 million persons). Estimates were derived from statistical models with many inputs, each with some measure of uncertainty (*5*). To reflect this uncertainty, we used probability distributions to describe a range of plausible values for all model

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DOI: 10.3201/eid1701.P11101

https://www.cdc.gov/foodnet/reports/preliminary-data.html

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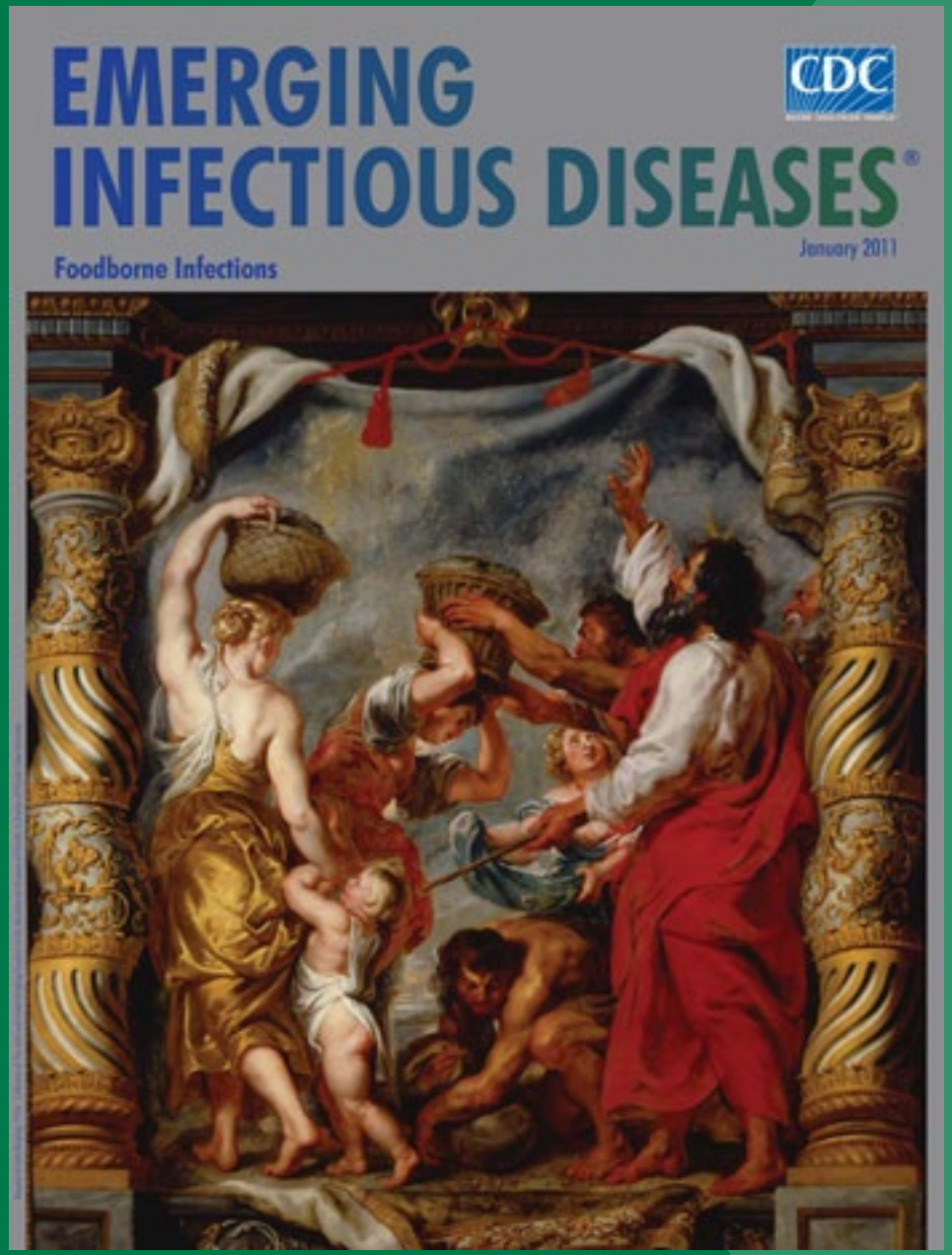

Foodborne Illness Acquired in the United States—Major Pathogens

Elaine Scallan,[1] Robert M. Hoekstra, Frederick J. Angulo, Robert V. Tauxe, Marc-Alain Widdowson, Sharon L. Roy, Jeffery L. Jones, and Patricia M. Griffin

Scallan et al. *Emerg Infect Dis*. 2011;17(1):7-15.

RESEARCH

Foodborne Illness Acquired in the United States—Unspecified Agents

Elaine Scallan,[1] Patricia M. Griffin, Frederick J. Angulo, Robert V. Tauxe, and Robert M. Hoekstra

Scallan et al. *Emerg Infect Dis*. 2011;17(1):16-22.

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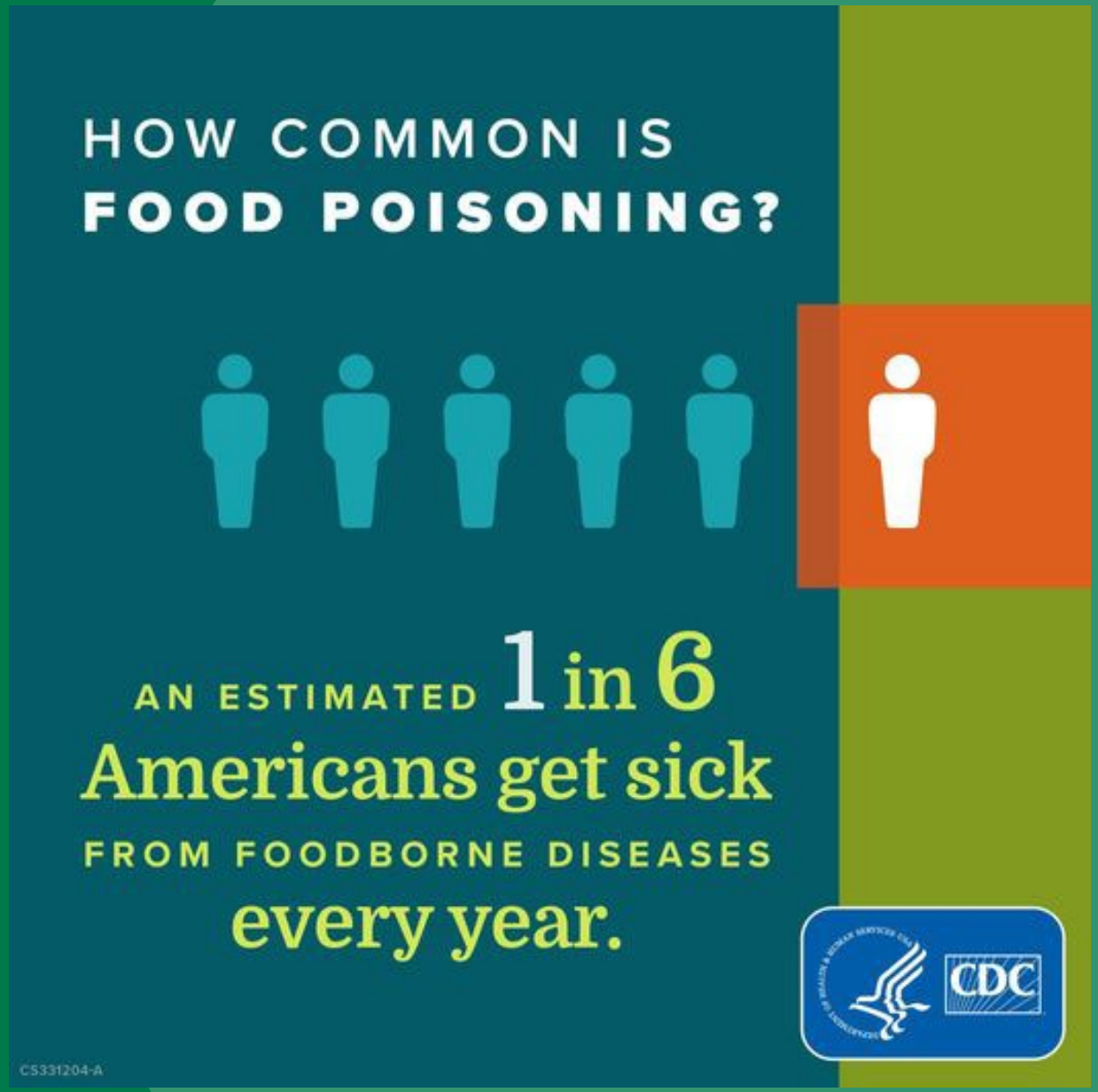
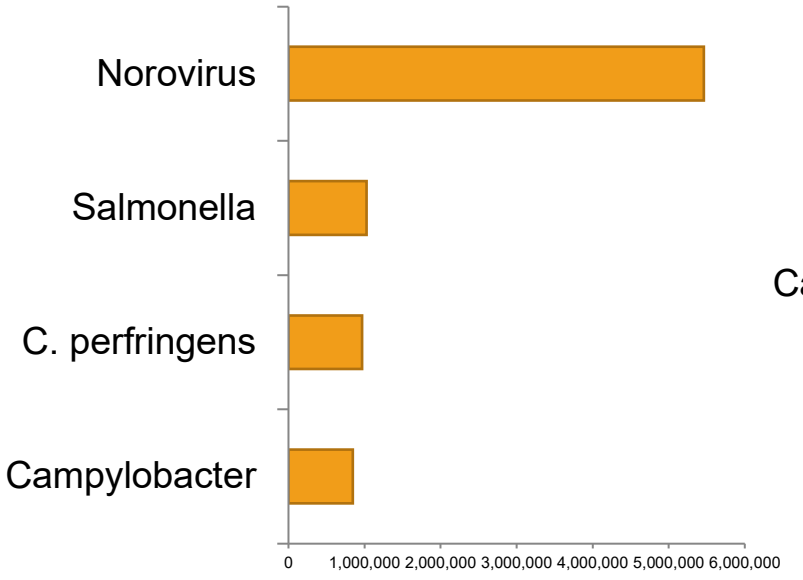
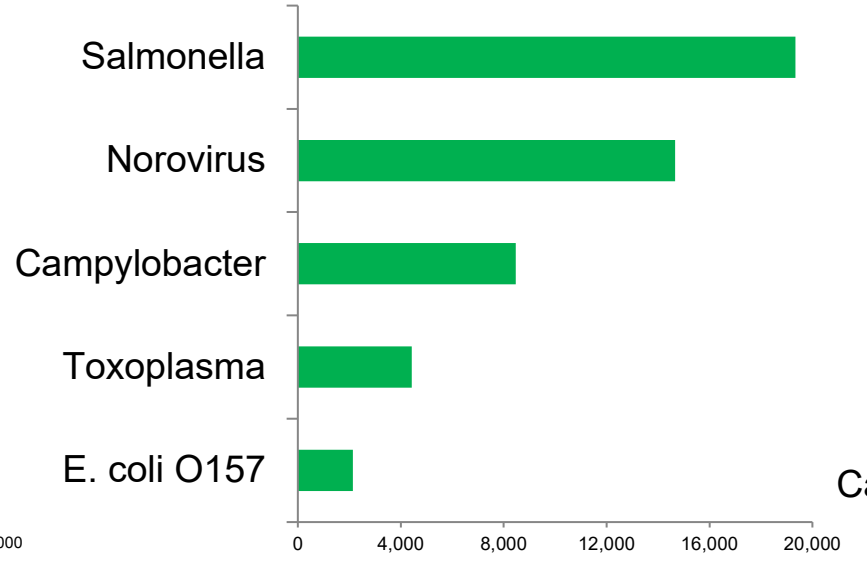

HOW COMMON IS
FOOD POISONING?
AN ESTIMATED 1 in 6
Americans get sick
FROM FOODBORNE DISEASES
every year.
CDC
CS331204-A

Major pathogens causing illness, hospitalization and death, 2006

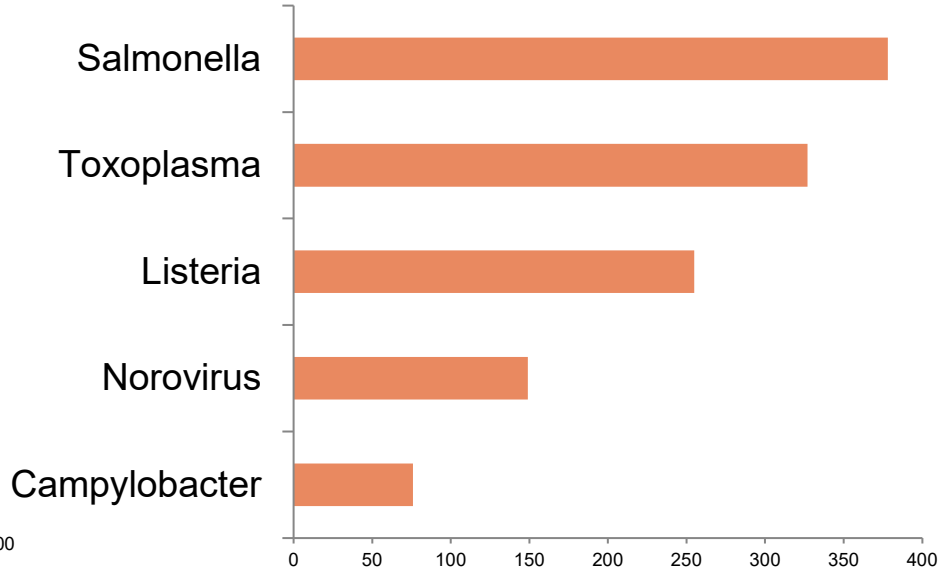
Salmonella (non-typhoidal), norovirus, *Campylobacter spp.*, *Toxoplasma gondii, E. coli* O157, *Listeria, Clostridium perfringens*



Illnesses



Hospitalizations



Deaths

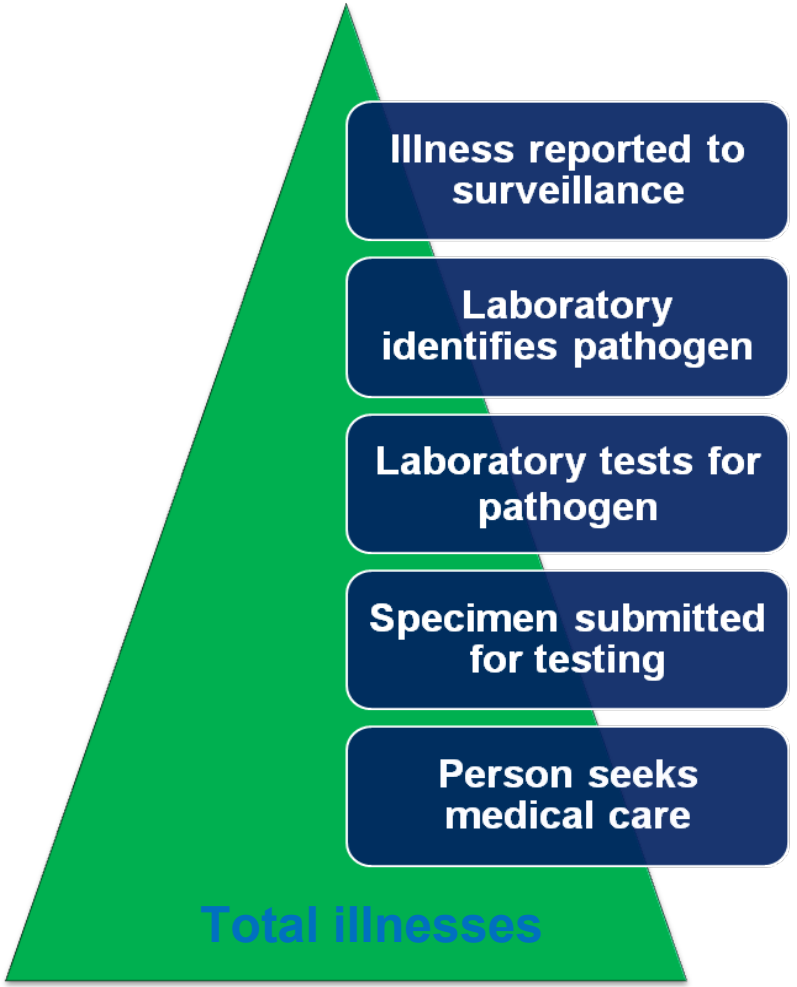
Table 1

Modeling approaches used to estimate the total number of illnesses for different types of data, United States*

Pathogens for which laboratory-confirmed illnesses were scaled up			
Active surveillance data	**Passive surveillance data**	**Outbreak surveillance data**	**Pathogens for which US population was scaled down**
Campylobacter spp.	*Brucella* spp.	*Bacillus cereus*	Astrovirus
Cryptosporidium spp.	*Clostridium botulinum*	*Clostridium perfringens*	Norovirus
Cyclospora cayetanensis	*Giardia intestinalis*	ETEC†	Rotavirus
STEC O157	Hepatitis A virus	*Staphylococcus aureus*	Sapovirus
STEC non-O157	*Mycobacterium bovis*	*Streptococcus* spp. group A	*Toxoplasma gondii*
Listeria monocytogenes	*Trichinella* spp.		
Salmonella spp., nontyphoidal‡	*Vibrio cholerae*, toxigenic		
S. enterica serotype Typhi	*Vibrio parahaemolyticus*		
Shigella spp.	*Vibrio vulnificus*		
Yersinia enterocolitica	*Vibrio* spp., other		

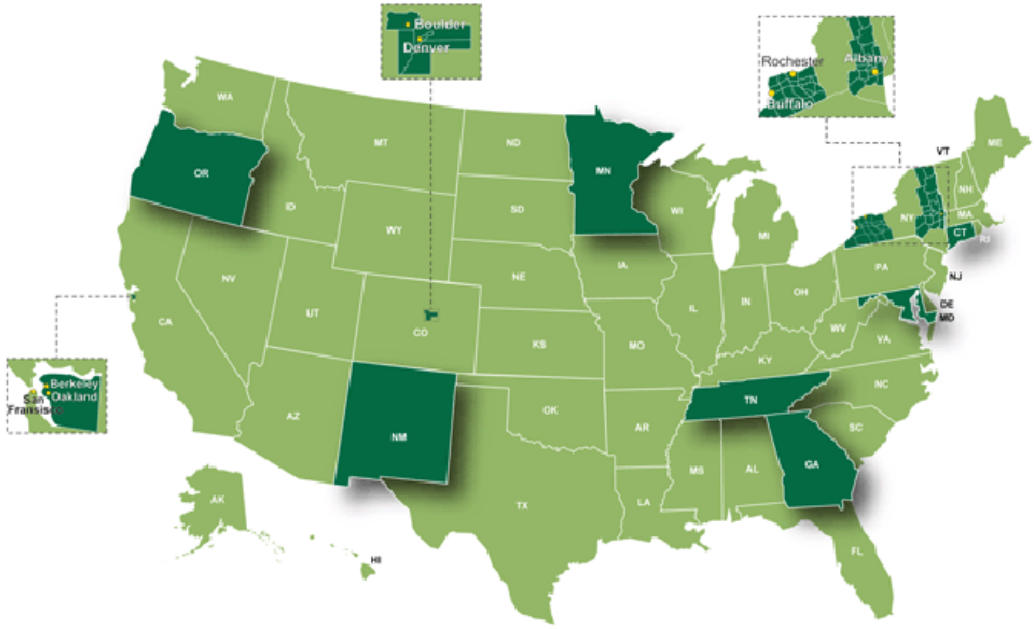
Health People 2030 Pathogens

- *Campylobacter*, *Listeria*, STEC, and *Salmonella* infections
- Relied heavily on FoodNet data
  - FoodNet Surveillance
  - FoodNet Population Survey data
  - FoodNet Laboratory Surveys



Campylobacter spp., *Listeria*, *Salmonella*, STEC illnesses

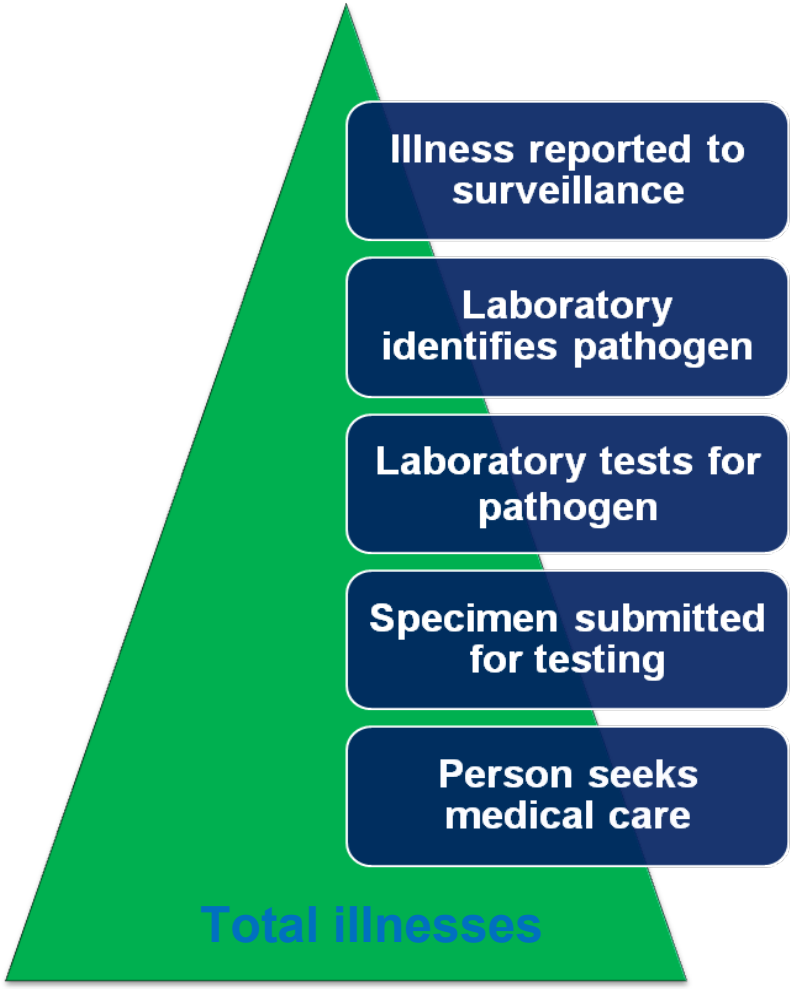
- Number of cases reported to FoodNet
- Estimated number of **laboratory-confirmed cases in the U.S.**
  - Cases in FoodNet (by year and site) applied to U.S. population
- Assumed no **under-reporting**



Surveillance area includes 15% of US population (~51 million people)

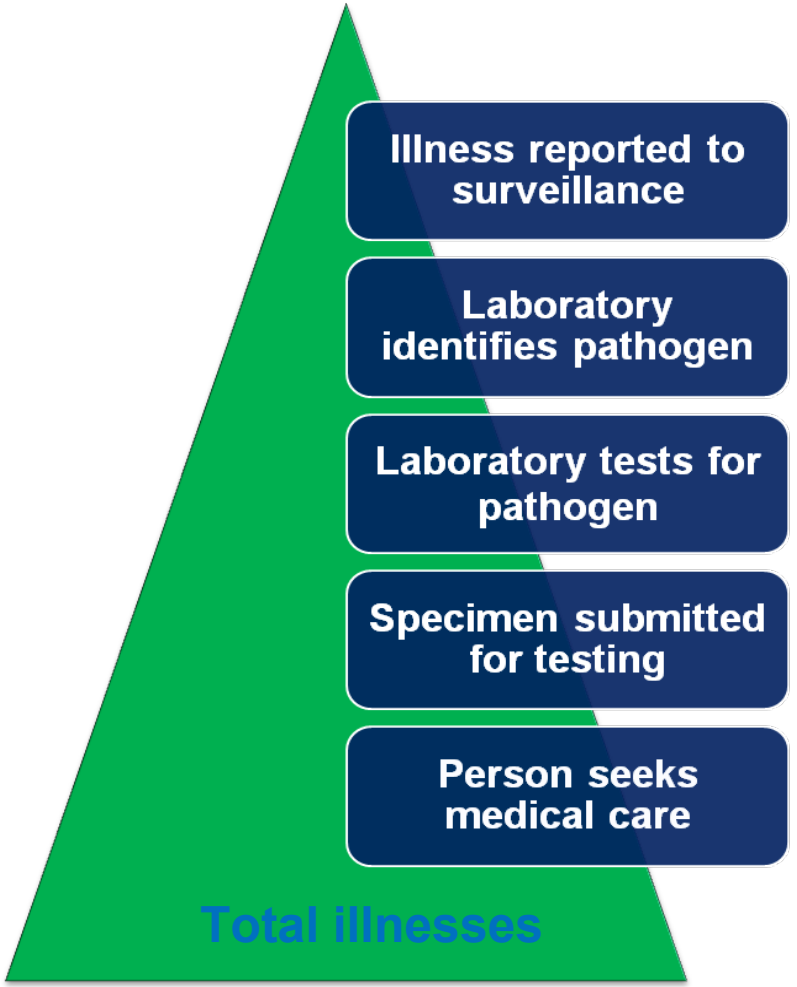
Campylobacter spp., *Listeria*, *Salmonella*, STEC illnesses

- **Test sensitivity**
  - Based on data from the literature
- **Laboratory testing**
  - Frequency based on FoodNet Laboratory Surveys
  - SME opinions (*Listeria*)



Campylobacter spp., *Listeria*, *Salmonella*, STEC illnesses

- Probability of **medical care-seeking and stool sample submission** from FoodNet Population Survey
  - Separately for people with bloody (severe) and non-bloody diarrhea (mild)
- Assumed to have high rates of medical care seeking (*Listeria*)



Domestically Acquired, Foodborne

- % illnesses acquired while traveling outside U.S. determined from FoodNet
  - Remaining proportion considered domestically acquired
- % foodborne based on a variety of sources
  - Including outbreak data, case-control studies

Campylobacter spp., *Listeria*, *Salmonella*, STEC hospitalizations and deaths

- % of laboratory-confirmed cases hospitalized or died (year and FoodNet site)
  - applied to estimated number of laboratory-confirmed illnesses
- **Underdiagnosis:**
  - Doubled to account for under-diagnosis

Complications and Sequelae
from foodborne pathogens

- National foodborne estimates published in 1999 and 2011, do not include complications and sequelae
- The burden of which is substantial, and includes:
  - Acute complications (e.g., HUS, sepsis)
  - Autoimmune and inflammatory responses (e.g., GBS, ReA)
  - Chronic gastroenteric disease (e.g., IBS)
  - Chronic consequences of toxoplasmosis
  - Chronic outcomes of listeriosis

Hoffmann, Scallan Walter *Foodborne Pathog Dis.* 2020 Mar;17(3):172-177.

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Incidence of *Campylobacter*-Associated Guillain-Barré Syndrome Estimated from Health Insurance Data

Elaine J. Scallan Walter,[1] Stacy M. Crim,[2] Beau B. Bruce,[2] and Patricia M. Griffin[2]

Abstract

Guillain-Barré syndrome (GBS) is sometimes preceded by *Campylobacter* infection. We estimated the cumulative incidence of *Campylobacter*-associated GBS in the United States using a retrospective cohort design. We identified a cohort of patients with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code of "intestinal infection due to *Campylobacter*" (008.43) using MarketScan Research Databases for 2004–2013. *Campylobacter* patients with an encounter for "acute infective polyneuritis" (AIP; ICD-9-CM 357.0) were identified. Patients with an inpatient encounter having AIP as the principal diagnosis were considered probable GBS cases. Patients with probable GBS ≤8 weeks after the *Campylobacter* encounter were considered probable *Campylobacter*-associated GBS cases. For comparison, we repeated this analysis for patients with "other *Salmonella* infections" (ICD-9-CM: 003). Among 9315 *Campylobacter* patients, 16 met the case definition for probable GBS. Two were hospitalized with probable GBS ≤8 weeks after the encounter listing a *Campylobacter* diagnosis (9 and 54 days) and were considered probable cases of *Campylobacter*-associated GBS; this results in an estimated cumulative incidence of 21.5 per 100,000 *Campylobacter* patients (95% confidence interval [CI]: 3.7–86.6), or 5% of all estimated GBS cases. The remaining 14 patients were diagnosed with probable GBS on the same encounter ($n=12$) or 1–3 days ($n=2$), before the encounter listing the *Campylobacter* diagnosis. Including these cases increased the cumulative incidence to 172 per 100,000 *Campylobacter* cases (95% CI: 101.7–285.5), 41% of estimated GBS cases. This study, using a method not previously applied to United States data, supports other data that *Campylobacter* is an important contributor to GBS, accounting for at least 5% and possibly as many as 41% of all GBS cases. These data can be used to inform estimates of the burden of *Campylobacter* infections, including economic cost.

Keywords: *Campylobacter*, Guillain-Barré syndrome, health insurance data

Introduction

Guillain-Barré syndrome (GBS) is an autoimmune disorder of the peripheral nervous system and the most common cause of acute flaccid paralysis worldwide (Hughes and Rees, 1997). The neuropathy affects the motor, sensory, and autonomic nerves, causing numbness and tingling, mild to severe muscle weakness, and autonomic dysfunction. The annual incidence in the United States is about 1.8 per 100,000 population and 3–5% of patients die (Frenzen, 2007; Alshekhlee *et al.*, 2008). The estimated United States economic cost is $1.7 billion annually (Frenzen, 2007, 2008; Alshekhlee *et al.*, 2008). Many GBS cases are preceded by an acute infectious illness, mainly upper respiratory and gastrointestinal infections (McGrogan *et al.*, 2009). In particular, strong evidence supports a link between GBS and *Campylobacter*, a common foodborne pathogen estimated to cause 1.3 million episodes of gastroenteritis annually in the United States (Allos, 1997; Scallan *et al.*, 2011).

Estimating the incidence of *Campylobacter*-associated GBS is challenging because patients have often recovered from the infection by the time they develop GBS. United States estimates have been derived from case–control studies that compared the odds of *Campylobacter* infection among GBS and non-GBS patients, based on serologic evidence of *Campylobacter* infection (Mishu and Blaser, 1993; Mishu *et al.*, 1993; Vriesendorp *et al.*, 1993; Allos, 1997) or a diarrheal illness consistent with campylobacteriosis (Halpin *et al.*, 2018). These studies have estimated cumulative incidences ranging from 33 to 95 cases of GBS per 100,000 *Campylobacter* infections (Allos, 1997; Halpin *et al.*, 2018). European studies have used a cohort design that linked

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ARTICLE

Postinfectious Irritable Bowel Syndrome After *Campylobacter* Infection

Elaine J. Scallan Walter, MA, PhD[1], Stacy M. Crim, MPH[2], Beau B. Bruce, MD, PhD[2] and Patricia M. Griffin, MD[2]

OBJECTIVES: **Postinfectious irritable bowel syndrome (PI-IBS) is an important sequela of *Campylobacter* infecti Our goal is to estimate the incidence of *Campylobacter*-associated PI-IBS in the United States.**

METHODS: **Data from January 1, 2010 to December 31, 2014, were obtained from the MarketScan Researc Commercial Claims and Encounters Database. We identified patients with an encounter that incl an *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis cod "intestinal infection due to *Campylobacter*" (008.43) and individually matched them (on age sex, and length of enrollment) to a group of persons without a diagnosed *Campylobacter* infectio cases). The primary outcome of interest was a new diagnosis of IBS (*International Classificati Diseases, Ninth Revision, Clinical Modification* 564.1).**

RESULTS: **Our final matched cohort included 4,143 cases and 20,491 non-cases. At 1 year, the incidenc IBS was 33.1 and 5.9 per 1,000 among cases and non-cases, respectively, with an unadjuste of 5.6 (95% confidence interval [CI]: 4.3–7.3). After adjusting for healthcare utilization, th proportional hazard ratio was 4.6 (95% CI: 3.5–6.1). Excluding those who received an IBS within 90 days, the 1-year incidence rate of IBS was 16.7 and 3.9 per 1,000 among case cases, respectively, with an unadjusted risk ratio of 4.3 (95% CI: 3.0–6.2).**

DISCUSSION: **Persons with a *Campylobacter* infection have a much higher risk of developing IBS compare not diagnosed with *Campylobacter* infection. The burden of *Campylobacter*-associated P be considered when assessing the overall impact of *Campylobacter* infections.**

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INTRODUCTION

Campylobacter is an important cause of bacterial gastroenteritis in the United States, causing an estimated 44,000 laboratory-confirmed and 1.3 million total illnesses each year, most of which are foodborne (1). Although most episodes of illness are self-limited, the infection can result in long-term complications and sequelae, with substantial burden (2,3). An important sequela of *Campylobacter* is postinfectious irritable bowel syndrome (PI-IBS) (4–7). IBS is a functional gastrointestinal disorder characterized by altered bowel habits and recurrent episodes of abdominal discomfort and pain; PI-I gastroenteritis episode (8–11). IBS ty tion; however, studies have observe among PI-IBS cases in the years after t (12,13). The mechanism by which the not fully understood (10).

Risk factors for developing PI-IBS includ psychosocial factors (e.g., stress, anxiety, and d ing, bacterial infections, antibiotics, female sex (10). The cumulative incidence of PI-IBS after intestinal infection, such as with *Campylobact* to 46% depending on the criteria used to d ogen, and the duration of follow-up (8,14).I PI-IBS has been estimated to account for overall human health burden of *Campylob* in terms of Disability Adjusted Life Yea

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Clinical Infectious Diseases

MAJOR ARTICLE

Identifying Sepsis From Foodborne Hospitalization: Incidence and Hospitalization Cost by Pathogen

Jae-Wan Ahn,[1] Elaine Scallan Walter,[2] Alice E. White,[2] R. Brett McQueen,[3] and Sandra Hoffmann[4]

[1]Economic Research Service, US Department of Agriculture, Kansas City, Missouri, USA; [2]Department of Epidemiology, Colorado School of Public Health, Aurora, Colorado, USA; [3]Department of Clinical Pharmacy, University of Colorado Anschutz Medical Campus, Aurora, Colorado, USA; and [4]Economic Research Service, US Department of Agriculture, Washington D.C., USA

Background. Sepsis causes a major health burden in the United States. To better understand the role of sepsis as a driver of the burden and cost of foodborne illness in the United States, we estimated the frequency and treatment cost of sepsis among US patients hospitalized with 31 pathogens commonly transmitted through food or with unspecified acute gastrointestinal illness (AGI).

Methods. Using data from the National Inpatient Sample from 2012 to 2015, we identified sepsis hospitalizations using 2 approaches—explicit ICD-9-CM codes for sepsis and a coding scheme developed by Angus that identifies sepsis using specific ICD-9-CM diagnosis codes indicating an infection plus organ failure. We examined differences in the frequency and the per-case cost of sepsis across pathogens and AGI and estimated total hospitalization costs using prior estimates of foodborne hospitalizations.

Results. Using Explicit Sepsis Codes, sepsis hospitalizations accounted for 4.6% of hospitalizations with a pathogen commonly transmitted through food or unspecified AGI listed as a diagnosis; this was 33.2% using Angus Sepsis Codes. The average per-case cost was $35 891 and $20 018, respectively. Applying the proportions of hospitalizations with sepsis from this study to prior estimates of the number foodborne hospitalizations, the total annual cost was $248 million annually using Explicit Sepsis Codes and $889 million using Angus Sepsis Codes.

Conclusions. Sepsis is a serious complication among patients hospitalized with a foodborne pathogen infection or AGI resulting in a large burden of illness. Hospitalizations that are diagnosed using explicit sepsis codes are more severe and costly, but likely underestimate the burden of foodborne sepsis.

Keywords. sepsis; foodborne illness; organ failure; hospitalization cost; NIS.

Sepsis imposes a major health burden in the United States. In 2017, it was the most expensive condition treated in US hospitals, accounting for 5.8% of hospital stays and 8.8% of aggregate hospital costs [1]. Research increasingly shows many sepsis survivors experience serious long-term health impacts, increasing treatment costs [2–5].

Globally, diarrheal diseases, including many foodborne pathogens, have been the leading cause of sepsis since the 1990s [6]. In the United States, annually there are an estimated 48 million domestically acquired foodborne illnesses, resulting in 127 839 hospitalizations and 3040 deaths, resulting in society over $17.6 billion [6]

pathogens) or from unspecified acute gastrointestinal illness (AGI). We look at per-case and total hospit- pathogen and in aggregat-

Identifying Sepsis

Identifying cases complicate matte over time. Since Consensus sepsi-

FoodNet FAST

Hemolytic Uremic Syndrome (HUS)

Cases

1,624

cases

0.6

incidence per 100,000 children

Hospitalizations

11 days

median days of hospitalization

0 to 372

range of hospitalization days

Deaths

38

deaths

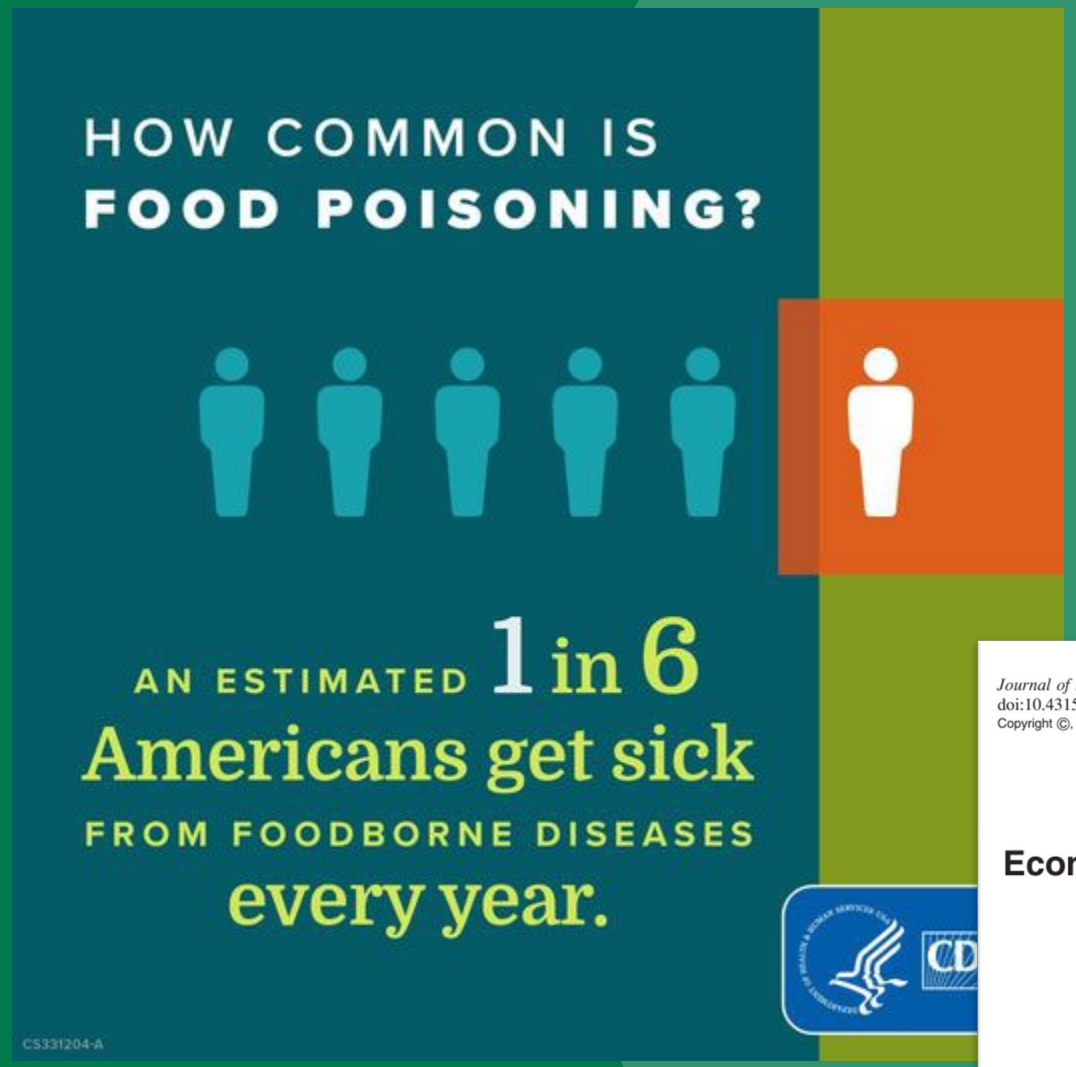
2.3%

of HUS patients died

Which disease is most important?

Number of cases, **number** of deaths

- ⇔ **Severity** of case: duration, reduction quality of life
- ⇔ **Severity** of death: residual life expectancy


HOW COMMON IS
FOOD POISONING?
AN ESTIMATED 1 in 6
Americans get sick
FROM FOODBORNE DISEASES
every year.
CS331204-A


WHO ESTIMATES OF THE GLOBAL BURDEN OF FOODBORNE DISEASES
The burden of foodborne diseases is substantial
Every year foodborne diseases cause:
almost
in 10
people to fall ill
33 million
healthy life years lost
Foodborne diseases can be
especially in children <5
420 000
deaths
FOODBORNE DIS
EVERYONE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Life Year Losses in the
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Economic Burden from Health Losses Due to Foodborne Illness in the United States
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The Ohio State University, Columbus, Ohio 43210, USA
MS 11-058: Received 4 February 2011/Accepted 26 September 2011


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ated
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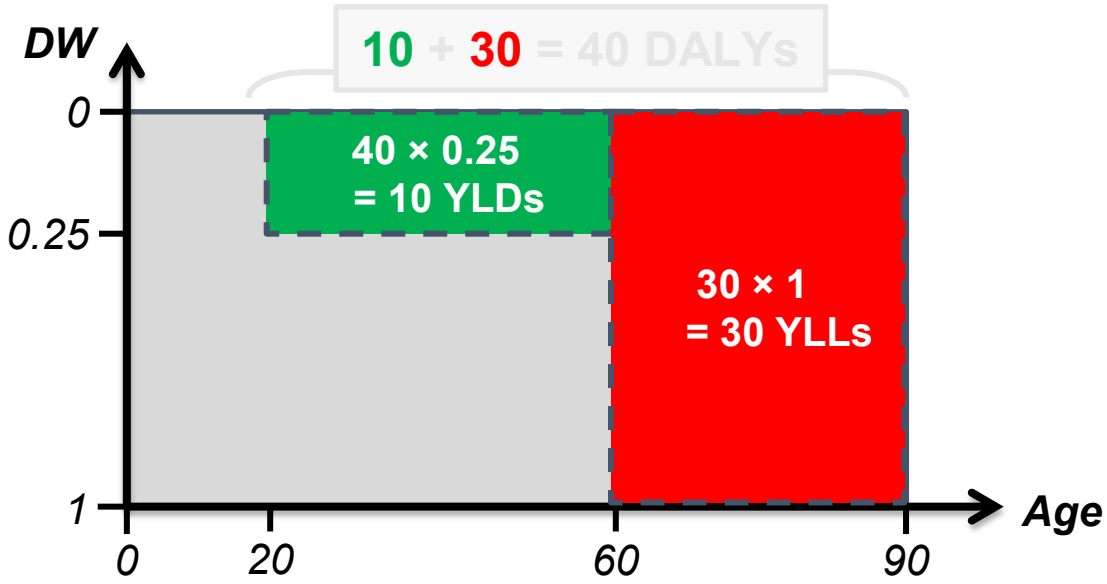
Summary Measures of Population Health (e.g., DALYS) and Cost-of-Illness Estimates

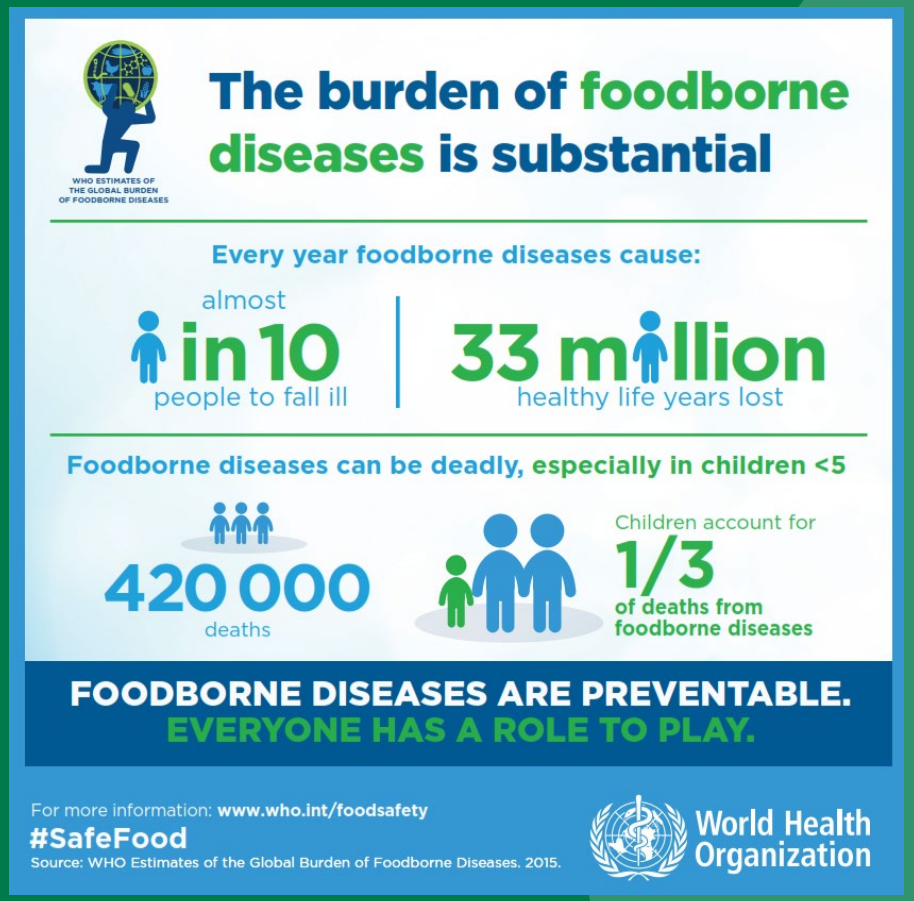
- Often based on illness estimates **+** estimates of complications and sequelea
- Provide an aggregate measure of the impact of a disease across outcomes
  - can be used to compare impact of disease with diverse health outcomes

Disability-Adjusted Life Years (DALYs)



DALY = YLD + YLL = healthy life years lost

- YLD = Years Lived with Disability = Incidence × Duration × Disability Weight (DW)
- YLL = Years of Life Lost = Mortality × Residual Life Expectancy



PLOS | MEDICINE

COLLECTION REVIEW

World Health Organization Global Estimates and Regional Comparisons of the Burden of Foodborne Disease in 2010

Arie H. Havelaar[1,2,3]*, Martyn D. Kirk[4], Paul R. Torgerson[5], Herman J. Gibb[6], Tine Hald[7], Robin J. Lake[8], Nicolas Praet[9], David C. Bellinger[10], Nilanthi R. de Silva[11], Neyla Gargouri[12], Niko Speybroeck[13], Amy Cawthorne[14], Colin Mathers[14], Claudia Stein[15], Frederick J. Angulo[16], Brecht Devleesschauwer[2,9,13,17], on behalf of World Health Organization Foodborne Disease Burden Epidemiology Reference Group¶

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¶ Membership of the World Health Organization Foodborne Disease Burden Epidemiology Reference Group is provided in the Acknowledgments.

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Havelaar et al. World Health Organization Global Estimates and Regional Comparisons of the Burden of Foodborne Disease in 2010. PLoS Med. 2015 Dec 3;12(12):e1001923.

Epidemiol. Infect. (2015), **143**, 2795–2804.
doi:10.1017/S0950268814003185

An assessment of the human health impact of seven leading foodborne pathogens in the United States using disability adjusted life years

E. SCALLAN[1]*, R. M. HOEKS
P. M. GRIFFIN[3]

Table 3. *Estimated disability adjusted life years (DALYs) from domestically acquired foodborne illnesses, by pathogen, including the number of years lived with disability (YLD) and the number of years of life lost (YLL) due to mortality, United States**

	Domestically acquired foodborne illnesses					
	YLD		YLL		DALY	
Pathogen (estimated % foodborne†)	Mean	90% CrI	Mean	90% CrI	Mean	90% CrI
Campylobacter (80%)	20 100	8800–36 100	2300	200–6800	22 500	10 400-38 600
Acute gastroenteritis	3600	1100–7300	2,200	90–6,700	5800	2000–11 600
Reactive arthritis	960	220–2100	–	–	960	220–2100
PI irritable bowel syndrome‡	15 500	5200–30 900	–	–	15 500	5200–30 900
Guillain–Barré syndrome	50	20–110	100	20–210	150	40–310
Clostridium perfringens (100%)	3000	550–7200	900	30–2700	4000	1100–8400
Escherichia coli O157 (68%)	430	280–590	800	150–2200	1200	540–2600
Acute gastroenteritis	370	230–530	400	0–1800	760	80–2100
Hemolytic uremic syndrome	60	30–100	400	300–510	460	350–580
Listeria monocytogenes (100%)						
Pregnancy-associated	100	30–220	4,300	1500–8200	4400	1500–8400
Not associated with pregnancy	80	30–150	4,300	210–13 000	4400	300–13 100
Salmonella, non-typhoidal (94%)‡	24 300	15 500–35 400	8600	430–25 700	32 900	19 200–52 800
Acute gastroenteritis	4200	3000–5700	8,600	430–25 700	12 800	4400–29 900
Reactive arthritis	1200	620–1900	–	–	1200	620–1900
PI irritable bowel syndrome	18 900	10 300–29 900	–	–	18 900	10 300–29 900
Norovirus (26%)	7500	5700–9500	2400	630–5000	9900	7200–13 000
Toxoplamsa gondii (50%)						
Congenital	3900	1000–6900	630	160–1200	4500	1200–8100
Acquired	15 900	8400–25 700	12 300	7500–18 000	28 200	18 900–39 600

CrI, Credible interval; PI, post-infectious.

Scallan et al. Epidemiol Infect. 2015 Oct;143(13):2795-804.

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ERS Cost of Foodborne Illness Research

- 1989 Roberts estimates cost for 16 pathogens
  - Limited evidence on incidence
  - Treatment cost and lost wages from illness and deaths
- 2000 Crutchfield and Roberts 4 priority pathogens
  - Based on Mead et al. 1999 CDC incidence estimates
  - Introduce use of VSL to value deaths
- 2000-2010 multiple studies
  - updating estimates and
  - improve sequelae modeling on 4 pathogens
  - Create online cost of illness calculator
- 2012 Hoffmann et al. combine ERS estimates with new estimates
  - 15 priority pathogens
  - Based on Scallan et al. 2011 incidence estimates
  - Disease modeling of multiple vintages (ERS and new)
  - Cost of treatment, wage loss for morbidity, VSL for death
- 2015 New ERS Cost of Foodborne Illness data produ
  - Present 2012 estimates in publicly useable form
- 2018 ERS estimates updated for inflation and incom

USDA Economic Research Service
www.ers.usda.gov

ELSEVIER

Journal of Food Protection
Volume 75, Issue 7, 1 July 2012, Pages 1292-1302

Annual Cost of Illness and Quality-Adjusted Life Year Losses in the United States Due to 14 Foodborne Pathogens †

Sandra Hoffmann [1], Michael B. Batz [2], J. Glenn Morris JR. [2]

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Economic Burden from Health Losses Due to Foodborne Illness in the United States

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MS 11-058: Received 4 February 2011/Accepted 26 September 2011

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New ERS estimates, circa 2023

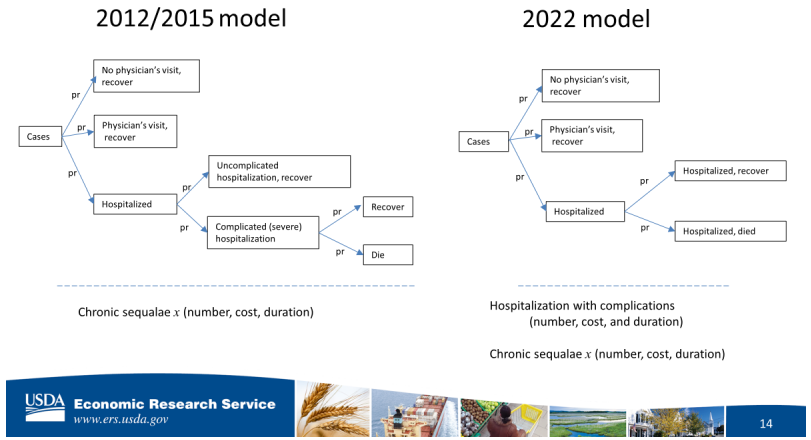
- Expanded pathogen coverage to parallel CDC estimates
  - 31 major pathogens and unspecified agents
- Expand inclusion of complications and chronic sequelae
  - ReA (*Campylobacter, Salmonella, Shigella, Yersinia*), IBS (*Campylobacter, Salmonella, Shigella*)
- Update disease modeling, cost estimates, and enhanced uncertainty modeling

Hoffmann et al. Economic burden of foodborne illnesses acquired in the United States. *Foodborne Pathogens and Disease*, In press

New ERS cost estimates

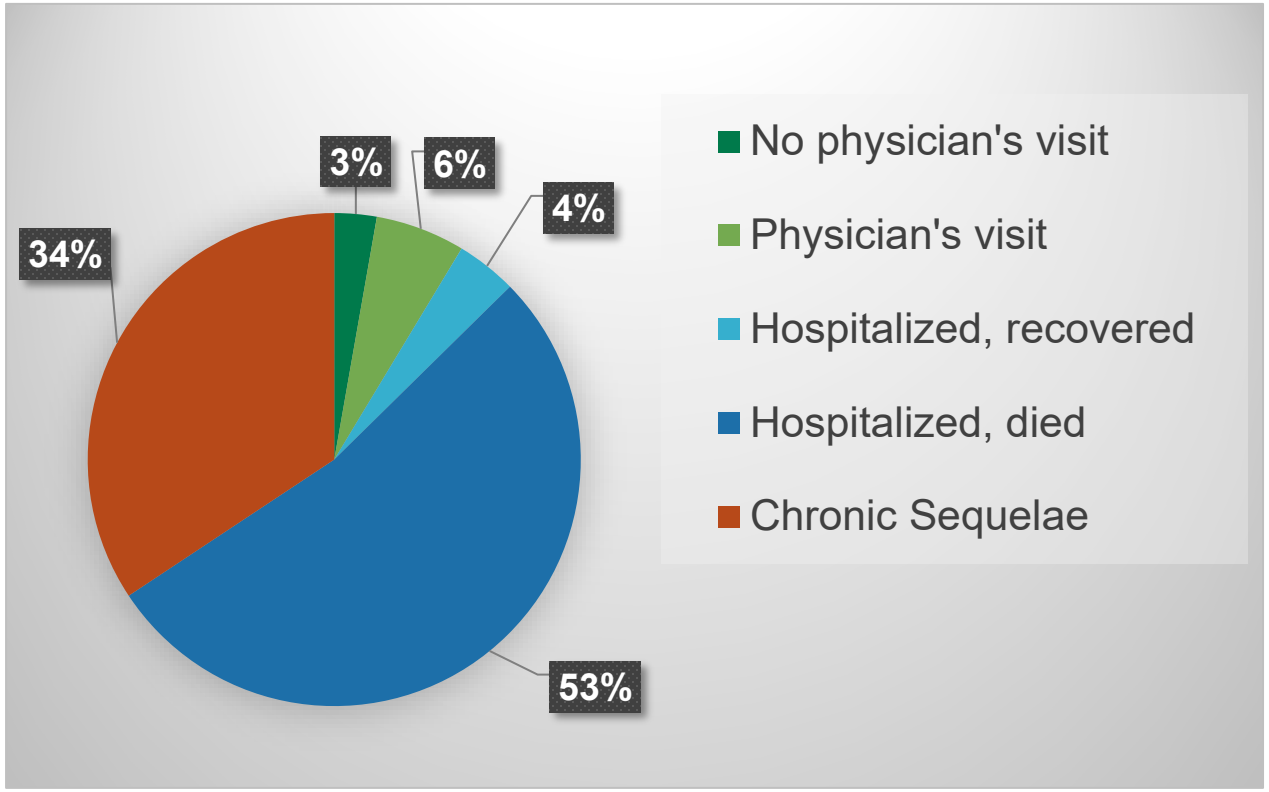
- Cost of medical treatment
  - Outpatient
  - Hospitalizations
  - Chronic outcomes
- Lost wages for all outcomes
  - Duration of illness + time recovering from hospitalization
  - (adjusted for employment rate)
- Deaths valued using U.S. VSL
  - Stillbirths and miscarriages: sensitivity analysis on range value (0-VSL)

Disease Outcome Tree Structure



Hoffmann et al. Economic burden of foodborne illnesses acquired in the United States. *Foodborne Pathogens and Disease*, In press

Total Cost: $58 billion

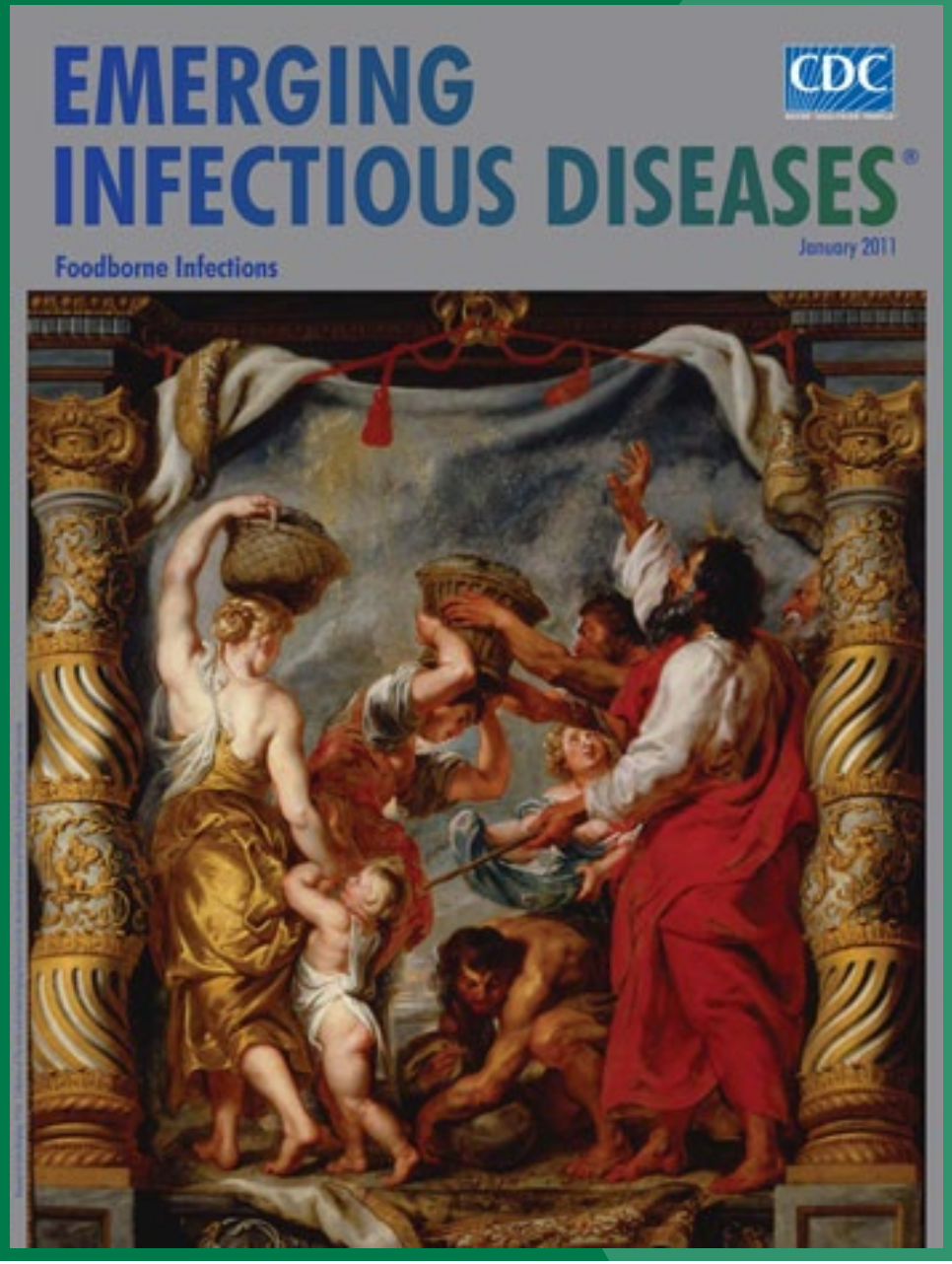


	Mean cost	Mean cases
31 known pathogens	$36 billion	9.4 million
Unspecified agents	$22 billion	38.4 million
Total	$58 billion	47.8 million

Hoffmann et al. Economic burden of foodborne illnesses acquired in the United States. *Foodborne Pathogens and Disease*, In press

Summary

- Foodborne illness estimates aim to assess true number of foodborne illnesses
  - "Art" than reflects advances in methods and data sources
  - Should not be used to assess trend
- Foundation for other metrics providing aggregate measures of the impact of a disease across outcomes
  - Summary measures of health (DALYs)
  - Cost-of-illness estimates



Peter Paul Rubens (1577–1640)

The Gathering of the Manna (c. 1625)

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Thank you!

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