Estimated Annual Numbers of Foodborne Pathogen–Associated Illnesses, Hospitalizations, and Deaths, France, 2008–2013

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Estimates of the annual numbers of foodborne illnesses and associated hospitalizations and deaths are needed to set priorities for surveillance, prevention, and control strategies. The objective of this study was to determine such estimates for 2008–2013 in France. We considered 15 major foodborne pathogens (10 bacteria, 3 viruses, and 2 parasites) and estimated that each year, the pathogens accounted for 1.28–2.23 million illnesses, 16,500–20,800 hospitalizations, and 250 deaths. *Campylobacter* spp., nontyphoidal *Salmonella* spp. and norovirus accounted for >70% of all foodborne pathogen–associated illnesses and hospitalizations; nontyphoidal *Salmonella* spp. and *Listeria monocytogenes* were the main causes of foodborne pathogen–associated deaths; and hepatitis E virus appeared to be a previously unrecognized foodborne pathogen causing ≈68,000 illnesses in France every year. The substantial annual numbers of foodborne illnesses and associated hospitalizations and deaths in France highlight the need for food-safety policymakers to prioritize foodborne disease prevention and control strategies.

Foodborne pathogens are of public health concern worldwide (*1*). Estimates of the total number of foodborne illnesses and associated hospitalizations and deaths are needed to assess their effect on health and to set priorities for surveillance, prevention, and control strategies. In 2000, the number of foodborne illnesses and associated deaths in France was estimated by using data from 1990–2000. However, for most pathogens, data were lacking to derive estimates at the population level (*2*).

Since that study, specific surveillance systems have been implemented in France for *Campylobacter* spp. (2002) (*3*), hepatitis A virus (2005), and hepatitis E virus (2002) (*4*). Additional surveys have been conducted to provide information on healthcare-seeking behavior and the incidence of acute gastroenteritis in the general population (2009–2010) (*5*) and on physician practices in requesting fecal samples for patients with acute gastroenteritis (2013–2014) (*6*). Furthermore, the quality and availability of other nonspecific data sources (e.g., hospital discharge registers and health insurance reimbursement data) have improved and are increasingly used for epidemiologic studies in France (*7–9*). Thus, recent and valid data are available to estimate the population-level health effects of several foodborne pathogens. Such estimates have recently been generated for *Campylobacter* spp. and nontyphoidal *Salmonella* spp. (hereafter referred to as *Salmonella* spp.), the 2 main causes of foodborne bacterial infections in France (*10*). Taking into account this improved knowledge and data availability, we conducted a study to estimate the annual number of illnesses, hospitalizations, and deaths associated with 15 foodborne pathogens in France.

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Methods

Using data sources from 2008–2013, we estimated the number of illnesses, hospitalizations, and deaths in France resulting from 15 foodborne pathogens: 10 bacteria (*Bacillus cereus*, *Campylobacter* spp., *Clostridium botulinum*, *Clostridium perfringens*, Shiga-toxin–producing *Escherichia coli* [STEC], *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., *Staphylococcus aureus*, *Yersinia* spp.); 3 viruses (hepatitis A virus, hepatitis E virus, norovirus); and 2 parasites (*Taenia saginata*, *Toxoplasma gondii*). We used France's 2010 census population (62,765,235 persons) for the estimates.

We used different statistical models, depending on the most suitable data available for each pathogen, with many inputs to estimate the number of illnesses, hospitalizations, and deaths (online Technical Appendix Table 1, https://wwwnc.cdc.gov/EID/article/23/9/17-0081-Techapp1.pdf). For most proportions we defined a lower and upper bound and a beta distribution with 2 parameters derived from a method of moments, assuming a mean m = (lower + upper bound)/2 and an SD = (upper bound – m)/2 (*11*). We used lognormal probability distributions for model inputs derived from a national survey on acute gastroenteritis in

France (*5*) and for the annual numbers of reported illnesses, hospitalizations, and deaths. For final estimates, we multiplied the distributions by using Monte Carlo simulation (10,000 iterations) with R version 3.3.2 (*12*). We report median values and use ranges between the 5th and 95th percentiles of the output distribution to define a 90% credible interval ($CrI_{90\%}$).

Illnesses

To estimate the numbers of illnesses, we obtained surveillance data from the mandatory notification system (*C. botulinum*, *L. monocytogenes*, hepatitis A virus, and foodborne disease outbreaks) and from national reference laboratories and their laboratory surveillance networks (*C. botulinum, Campylobacter* spp., STEC, *L. monocytogenes*, *Salmonella* spp., *Shigella* spp., *Yersinia* spp., hepatitis A virus, hepatitis E virus, and *T. gondii*). Inclusion in these surveillance systems implies that the ill person sought medical care, had laboratory testing prescribed, and had a specimen submitted for laboratory testing and that the laboratory identified the pathogen and reported the positive result to the surveillance system. These steps can be summarized into 2 multiplication factors: an underreporting factor defined as the match between the total number of laboratory-confirmed illnesses and the number of laboratory-confirmed illnesses reported to the surveillance system; and an underdiagnosis factor taking into account the proportion of cases that were not laboratory-confirmed because the patient did not seek medical advice or was misdiagnosed. We took both multiplication factors into account to estimate the number of illnesses from mandatory notification data and national reference laboratory data.

Previously published parameters for estimating the number of *Campylobacter* spp.– and *Salmonella* spp.–associated illnesses (*10*) were used as a proxy to estimate the level of underdiagnosis for *Yersinia* spp. (using *Campylobacter* spp. data) and *Shigella* spp. (using *Salmonella* spp. data). For *C. botulinum* and *L. monocytogenes,* we assumed that 80%–100% of the cases were in persons who sought medical care and had laboratory-confirmed diagnoses. To account for underreporting, we conducted ad hoc laboratory surveys for *Campylobacter* spp., *Salmonella* spp., *Shigella* spp., and *Yersinia* spp., and we conducted a capture–recapture study for *L. monocytogenes*.

In France, cases of *B. cereus*, *S. aureus,* and *C. perfringens* infection are notified only through mandatory notification of point-source foodborne disease outbreaks. For these pathogens, we assumed that the multiplier between the number of confirmed outbreak cases and the number of community cases of foodborne origin would be similar to that estimated for *Salmonella* spp. We estimated the number of illness caused by *T. gondii* and hepatitis A and E viruses from seroprevalence data and the number of illnesses caused by *T. saginata* from health insurance reimbursement data for niclosamide (a drug used to treat tapeworm infestation). We used data from the literature to estimate the number of illnesses caused by STEC. To estimate the number of norovirus cases, we applied a proportion (14%–22%) of norovirus-associated acute gastroenteritis cases to the annual number of acute gastroenteritis illnesses in France (Table 1). This proportion was based on findings from a 2008–2009 community study in the United Kingdom (*13*) and a meta-analysis of 175 studies published during 1990–2014 (*14*). Model inputs used for each pathogen are presented in online Technical Appendix Table 1.

Hospitalizations

We used the French Hospital Information System (FHIS) as the main data source for estimating the number of hospitalizations. The system is a national database of hospital records that contains sociodemographic information (age, sex, and residence area) and medical information (main cause for admission, concurrent medical conditions, modes of admission, and discharge) (*10*). Diseases are coded according to the International Classification of Diseases, 10th revision (ICD-10; http://www.who.int/classifications/icd/en/). We extracted all hospital records with a patient discharge date during January 2008–December 2013 and containing an ICD-10 code of interest as the main cause for admission or as a concurrent medical condition.

We used the number of hospital records with pathogen-specific ICD-10 codes to estimate the annual number of hospitalizations for 8 pathogens, 4 of which cause acute gastroenteritis (Table 2). We did not redistribute records with only unspecified gastroenteritis codes to the 8 pathogens, but we did correct for undercapture, taking into account the proportion of fecal samples tested for each pathogen and the sensitivity of fecal culture. When data were available, we compared trends over time and patient age

Table 1. Data sources used to estimate the number of pathogen-specific illnesses, France, 2008–2013

Pathogen	Data source
Bacillus cereus	Surveillance
Campylobacter spp.	Surveillance
Clostridium botulinum	Surveillance
Clostridium perfringens	Surveillance
Hepatitis A virus	Seroprevalence
Hepatitis E virus	Seroprevalence
Listeria monocytogenes	Surveillance
Norovirus	Literature and national telephone survey
Salmonella spp., nontyphoidal	Surveillance
Shiga toxin–producing *Escherichia coli*	Literature
Shigella spp.	Surveillance
Staphylococcus aureus	Surveillance
Taenia saginata	Health insurance reimbursement data
Toxoplasma gondii	Seroprevalence
Yersinia spp.	Surveillance

Table 2. Methods used to estimate the number of pathogen-specific hospitalizations, France, 2008–2013*

Pathogen	Method
Bacillus cereus	Proportion of hospitalizations for AG applied to annual no. of illnesses for the pathogen
Campylobacter spp.	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Clostridium botulinum	Mandatory notification data
Clostridium perfringens	Proportion of hospitalizations for AG applied to annual no. of illnesses for the pathogen
Hepatitis A virus	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Hepatitis E virus	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Listeria monocytogenes	Mandatory notification data
Norovirus	Proportion of hospitalizations for AG applied to annual no. of illnesses for the pathogen
Salmonella spp., nontyphoidal	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Shiga toxin–producing *Escherichia coli*	*Salmonella* spp. and *Campylobacter* spp. data used as a proxy
Shigella spp.	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Staphylococcus aureus	Proportion of hospitalizations for AG applied to annual no. of illnesses for the pathogen
Taenia saginata	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Toxoplasma gondii	Annual no. persons hospitalized with a specific ICD-10 code in FHIS
Yersinia spp.	Annual no. persons hospitalized with a specific ICD-10 code in FHIS

*AG, acute gastroenteritis; FHIS, French Hospital Information System; ICD-10, International Classification of Diseases, 10th Revision (http://www.who.int/classifications/icd/en/).

and sex distributions of the hospital data with surveillance data from the national reference laboratories (*Campylobacter* spp., *Salmonella* spp., *Shigella* spp., *Yersinia* spp., and hepatitis E virus) and with mandatory notification data (hepatitis A virus).

We used the number of hospital records with acute gastroenteritis–associated ICD-10 codes (A00–A06.2 and A06.9–A09.9) to estimate the annual number of persons hospitalized for acute gastroenteritis. We then divided that number by the total number of persons with acute gastroenteritis to estimate the percentage of those persons who were hospitalized (0.58%–0.75%) (online Technical Appendix Table 1). For norovirus, *B. cereus*, *C. perfringens*, and *S. aureus,* we applied the proportion of hospitalizations for acute gastroenteritis to the annual number of illnesses for each pathogen to estimate the annual number of hospitalizations. For STEC, we used the proportion of hospitalizations estimated for *Salmonella* spp. and *Campylobacter* spp. as a proxy. For *C. botulinum* and *L. monocytogenes*, we used surveillance data from the mandatory notification system (Table 2).

Deaths

We explored death certificate data from the French national mortality database (*Institut National de la Santé et de la Recherche Médicale*, CépiDc [Epidemiology Center on Medical Causes of Death]) and data from FHIS to estimate the number of foodborne illness–associated deaths. For both data sources, we extracted all records for 2008–2013 with an ICD-10 code of interest as the main cause of death or hospitalization or as a concurrent medical condition. Compared with data from FHIS, death certificates contained fewer pathogen-specific ICD-10 codes; therefore, we used the hospital information system data as the main data source for estimating the number of deaths.

To estimate the number of deaths from *Campylobacter* spp., *Salmonella* spp., *Shigella* spp., *Yersinia* spp., hepatitis A and E viruses, *T. saginata*, and *T. gondii* infections, we used the number of hospital records with a pathogen-specific ICD-10 code and death shown as the mode of discharge. To estimate the number of norovirus-associated deaths, we applied the proportion of deaths among hospitalized case-patients with an ICD-10 code associated with viral gastroenteritis (ICD-10 codes A08.0–A08.4) to the annual number of hospitalizations for norovirus (0.18%–0.30%; online Technical Appendix Table 1). This proportion was also used as a proxy to estimate the number of deaths from *B. cereus*–, *C. perfringens*–, and *S. aureus*–associated hospitalizations. For *C. botulinum* and *L. monocytogenes*, we used mandatory notification data to estimate the number of deaths (Table 3).

Foodborne Transmission

To estimate the number of foodborne illnesses and associated hospitalizations and deaths, we applied a pathogen-specific proportion of foodborne transmission (online Technical Appendix Table 2). For 11 of the 15 pathogens, we used estimates published in the United States in 2011 (*15*). For norovirus and hepatitis A virus, data from more recent studies were used (*16*,*17*). For hepatitis E virus and *T. saginata*, the proportions of foodborne transmission were estimated on the basis of discussions with experts from the French Public Health Agency.

Results

Overall, the pathogens included in our study accounted for 4.9 million cases of illness ($CrI_{90\%}$ 4.2–6.2 million), 42,500 hospitalizations ($CrI_{90\%}$ 37,242–50,526), and 368 deaths ($CrI_{90\%}$ 335–486) each year in France. Of those 4.9 million cases, 1.5 million were caused by foodborne pathogens ($CrI_{90\%}$ 1.28–2.23 million), of which 880,500 (59%) were caused by bacteria; 579,500 (38%) by viruses; and 45,000 (3%) by parasites. These foodborne illnesses led to 17,281 hospitalizations ($CrI_{90\%}$ 15,520–20,785) and 248 deaths ($CrI_{90\%}$ 223–350).

Table 3. Methods used to estimate the number of pathogen-specific deaths, France, 2008–2013*

Pathogen	Method
Bacillus cereus	Hospital discharge data with viral gastroenteritis–associated ICD-10 codes
Campylobacter spp.	Hospital discharge data with pathogen-specific ICD-10 codes
Clostridium botulinum	Mandatory notification data
Clostridium perfringens	Hospital discharge data with viral gastroenteritis–associated ICD-10 codes
Hepatitis A virus	Hospital discharge data with pathogen-specific ICD-10 codes
Hepatitis E virus	Hospital discharge data with pathogen-specific ICD-10 codes
Listeria monocytogenes	Mandatory notification data
Norovirus	Hospital discharge data with viral gastroenteritis–associated ICD-10 codes
Salmonella spp., nontyphoidal	Hospital discharge data with pathogen-specific ICD-10 codes
Shiga toxin–producing *Escherichia coli*	*Salmonella* spp. and *Campylobacter* spp. data used as a proxy
Shigella spp.	Hospital discharge data with pathogen-specific ICD-10 codes
Staphylococcus aureus	Hospital discharge data with viral gastroenteritis–associated ICD-10 codes
Taenia saginata	Hospital discharge data with pathogen-specific ICD-10 codes
Toxoplasma gondii	Hospital discharge data with pathogen-specific ICD-10 codes
Yersinia spp.	Hospital discharge data with pathogen-specific ICD-10 codes

*ICD-10, International Classification of Diseases, 10th Revision (http://www.who.int/classifications/icd/en/).

Norovirus ranked first as the cause of foodborne illnesses (34%), third as a cause for foodborne illness–associated hospitalizations (20%), and seventh as a cause of foodborne illness–associated deaths (3%). *Salmonella* spp. ranked third as the cause of foodborne illnesses (12%), second as a cause for hospitalization (24%), and first as a cause of death (27%). *L monocytogenes* ranked second (26%), before *Campylobacter* spp. (17%), as a cause of foodborne illness–associated deaths (online Technical Appendix Table 2).

Discussion

We estimated the population-level number of illnesses, hospitalizations, and deaths in France caused by 15 pathogens with the potential for foodborne transmission. *Campylobacter* spp., *Salmonella* spp., and norovirus were responsible for 73% of all foodborne illnesses and 76% of all associated hospitalizations. The pathogens that cause most foodborne illnesses or hospitalizations are not necessarily those that cause the most deaths: *L. monocytogenes* caused <0.1% of all foodborne illnesses but ranked second as a cause of foodborne illness–associated deaths, just behind S*almonella* spp.

We used different approaches, depending on the most suitable data that were available, to generate estimates. We could not easily compare our results with previous estimates from France (*2*) and other countries because of different data sources, assumptions, and methods. Nevertheless, recent estimates of the burden of foodborne illnesses in the European region also indicated that the 3 most frequent causes of foodborne illness were norovirus (ranked first), *Campylobacter* spp. (second), and *Salmonella* spp. (third) (*1*). These pathogens were also among the leading causes of foodborne illnesses and hospitalizations in North America (*15*,*18*) and Oceania (*19*,*20*). *Salmonella* spp. and *L. monocytogenes* accounted for ≈50% of all foodborne illness–associated deaths in France, and were also responsible for most foodborne illness–associated deaths in other high-income countries (*1*,*15*,*18–20*).

We estimated the number of most pathogen-specific illnesses by using laboratory-based surveillance data corrected for underreporting and underdiagnosis, and we used well-documented estimates for *Campylobacter* spp. and *Salmonella* spp. (*10*). We assumed that the parameters regarding healthcare-seeking behavior and laboratory practice for *Yersinia* spp. and *Shigella* spp. were similar to those for *Campylobacter* spp. and *Salmonella* spp., respectively. The validity of these assumptions is difficult to explore; further studies would be needed to produce more robust estimates of the true level of underdiagnosis for these 2 pathogens in France.

For *B. cereus*, *C. perfringens*, and *S. aureus*, we assumed that the multiplier between the number of outbreak cases and the number of foodborne illnesses would be similar to that for *Salmonella* spp. An alternative approach for *C. perfringens* would have been to apply a proportion of acute gastroenteritis cases by this pathogen estimated in the United Kingdom (0.3–1.7%) (*13*) to the annual number of acute gastroenteritis illnesses in France. This approach would result in an estimate ($CrI_{90\%}$ 84,450–278,964) within the range of the estimate in our study. The estimates for *B. cereus*, *C. perfringens*, and *S. aureus* indicate that the effect of these pathogens in terms of foodborne illnesses appears to be high in France. However, only foodborne illness outbreak data were available to estimate the number of illnesses for these pathogens, and more data are needed to confirm our estimates.

We included hepatitis E virus in our study because, in France, indigenous cases of hepatitis E have been shown to be associated with foodborne transmission, particularly through consumption of products containing undercooked or raw pork liver (*21*,*22*). We estimated the number of hepatitis E cases in France from a seroprevalence study conducted in 2013, and the proportion of cases caused by foodborne transmission was assumed to be between 75% and 100%. Further studies, in particular on the proportion of foodborne transmission of hepatitis E in France, are needed to confirm these estimates.

Our use of seroprevalence and health insurance drug reimbursement data to estimate the numbers of *T. gondii*– and *T. saginata*–associated foodborne illnesses was similar to methods previously used in France (*2*). Our results indicated a decrease in the number of foodborne illnesses over the past decade (from 51,600 to 12,000 cases for *T. gondii* and from 64,500 to 33,000 cases for *T. saginata*). These decreases may be explained by fewer exposures to the parasites (*23*), by changes in food habits, and by improved hygiene practices in meat production. For *T. saginata*, the number of illnesses may be underestimated because the decrease might also be explained by a shift of treatment from niclosamide to praziquantel for this infection over the past decade in France.

We estimated the number of illnesses caused by norovirus by applying a proportion of acute gastroenteritis cases caused by this pathogen to the annual number of acute gastroenteritis illnesses in France. The final estimate for France is lower than that for other countries that used a similar method (*15*,*18*), primarily because of a lower estimated incidence of acute gastroenteritis in France (*5*) but also because we used a lower proportion of foodborne norovirus transmission (12%–16%) on the basis of an extensive study published in 2015 (*16*). Despite these differences and their effect on the final estimate, norovirus ranked first in terms of foodborne illnesses in France and appears to be a key foodborne cause of acute gastroenteritis.

The FHIS was our main data source for estimating numbers of hospitalizations and deaths associated with the 15 pathogens in our study. The relevance of this data source may be questioned because of limitations in diagnosis accuracy and in consistency of disease coding. For most of the pathogens, we estimated the number of hospitalizations by using the number of hospital records with specific ICD-10 codes. We compared trends over time and age and sex distributions of the hospital data with surveillance data from the national reference laboratories and with mandatory notification data. Trends and distributions were similar between the different data sources, supporting the use of FHIS data to estimate the number of hospitalizations. For *Campylobacter* spp., *Salmonella* spp., *Yersinia* spp., and *Shigella* spp., we corrected the number of hospitalizations and deaths for underdiagnosis, taking into account a proportion of fecal samples tested for each pathogen and the sensitivity of fecal culture. However, for the other pathogens, no specific underdiagnosis multiplier could be estimated and, therefore, the estimates presented in this study are probably conservative. An overestimation is also possible if the pathogen of interest did not cause the illness that led to the hospitalization but was, nevertheless, coded as a concurrent medical condition.

A high number of hospitalizations due to acute gastroenteritis were reported in the FHIS without a specific ICD-10 code because not all hospitalized patients were systematically tested for all pathogens that cause acute gastroenteritis. We used the proportion of hospitalizations for acute gastroenteritis as a proxy to estimate the number of hospitalizations for norovirus, *B. cereus*, *C. perfringens*, and *S. aureus* because testing for these pathogens is infrequently performed in France and because these pathogens cause illnesses with similar symptoms and severity. This proportion (0.58%–0.75%) is lower than that estimated for *Campylobacter* spp. (0.9%–1.9%) and for *Salmonella* spp. (1.2%–3.6%), which is plausible considering that illness caused by *B. cereus*, *C. perfringens*, and *S. aureus* is less severe than that caused by *Campylobacter* spp. and *Salmonella* spp. Data sources described in the literature to estimate the number of hospitalizations for norovirus, *B. cereus*, *C. perfringens*, and *S. aureus* infections include hospital discharge data and data from foodborne disease outbreaks (*15*,*18*,*19*,*24*,*25*). Estimating the number of hospitalizations for these pathogens is challenging, and these different methodologic approaches have a major effect on the final estimate. For norovirus, despite differences in methodology and healthcare systems, our estimate (all modes of transmission) of the number of hospitalizations was in the same range as those estimated in North America (*24*,*25*) and in the Netherlands (*26*).

Data to estimate the number of deaths associated with foodborne illnesses are scarce and difficult to obtain. We explored death certificate data but decided not to use that source because few records contained pathogen-specific ICD-10 codes. Hospital discharge data were the only or the most reliable data source available to estimate the number of deaths for most pathogens included in this study. However, deaths may occur after hospitalization discharge or without hospitalization at all. Therefore, our estimates are uncertain and are probably underestimated, even though we did not take into account the possibility that underlying concurrent conditions, not foodborne pathogens, may have caused or contributed to death.

As pointed out in the literature, difficulties in accurately determining the proportion of foodborne pathogen transmission is a key factor contributing to the uncertainty of foodborne illness estimates (*15*,*27*). Different methodologic approaches, such as epidemiologic and microbiologic approaches, intervention studies, and expert elicitation, have been used to estimate the proportion of foodborne transmission (*15*,*28*–*32*). Overall, in high-income countries, foodborne transmission has been considered a major transmission route for several bacterial pathogens (*B. cereus*, *Campylobacter* spp., *C. perfringens*, *L. monocytogenes*, *Salmonella* spp., *S. aureus*) and a minor transmission route for norovirus and hepatitis A virus. Nevertheless, comparison of the estimates by using expert elicitation shows greater variability and higher uncertainties, depending on

how the experts were recruited, the expert panel size, or the elicitation method used (*27*,*33*). We decided to use the proportion of foodborne transmission published in the United States in 2011 (*15*) as these proportions were based on epidemiologic and microbiologic data rather than expert elicitation. It is possible that food consumption patterns and frequency and type of microbiologic contamination differ between the United States and France and may influence pathogen exposure, resulting in a different proportion of foodborne pathogen transmission in the 2 countries. Further research is needed to obtain specific source attribution estimates for France.

The 15 foodborne pathogens in our study were selected on the basis of their perceived public health significance, their occurrence in France, and the availability of a minimum of data. Other known pathogens with potential foodborne transmission exist (e.g., other non-STEC pathogenic *E.coli*, rotavirus, and *Cryptosporidium* spp.), and the total numbers of foodborne illnesses and associated hospitalizations and deaths presented in this study are likely conservative.

We took into account new data sources that allowed for accurate estimates of foodborne illnesses and associated hospitalizations and deaths at the community level in France. Our estimates entail several assumptions, and a high degree of uncertainty remains for some of them. Our estimates indicate that substantial numbers of foodborne pathogen–associated illnesses, hospitalizations, and deaths occur each year in France, necessitating the prioritization of prevention and control strategies by food safety policymakers. We did not specifically consider the effect of sequelae linked to these illnesses when generating our estimates. Thus, our findings capture only part of the overall effect of foodborne infections, and they clear the way for further research on the public health burden of foodborne pathogens in France, taking into account complications and sequelae.

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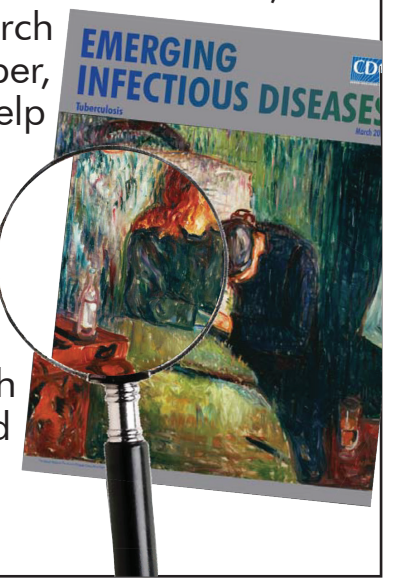

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Estimated Annual Numbers of Foodborne Disease–Associated Illnesses, Hospitalizations, and Deaths, France, 2008–2013

Technical Appendix

Technical Appendix Table 1. Model inputs to estimate the number of illnesses, hospitalizations and deaths for 15 foodborne pathogens, France, 2008–2013

Model input	Data source(s)	Distribution	Data for model input
Acute gastroenteritis (AG)			
Acute gastrointestinal illnesses	Estimated rate of acute gastrointestinal illness per person and per year based on a population-based study in 2009/2010 in France (*1*)	log normal	meanlog: -1.109, sdlog: 0.0696
Population at risk	2010 French census population estimate	Fixed	62,765,235
Acute gastrointestinal illnesses	Number estimated using the two parameters above	Outcome	5% value: 18,454,814, median value: 20,725,683, 95% value: 23,213,292
Acute gastrointestinal hospitalizations	Annual number of patients with AG related ICD-10 codes (A00 – A06.2, A06.9 – A09.9) reported in the French hospital information system (2008-2013)	log normal	meanlog: 11.824, sdlog: 0.039
Proportion hospitalized	Proportion estimated using the two parameters above	Outcome	5% value: 0.00577, median value: 0.00659, 95% value: 0.00752
Bacillus cereus			
Reported illnesses	Annual number of reported foodborne outbreak cases reported to the French national public health agency between 2008 and 2013	log normal	meanlog: 5.690, sdlog: 0.179
Underreporting	*Salmonella* spp. data used as a proxy (2008-2013) : annual number of reported foodborne outbreak cases (min 509 - max 1 066) divided by the annual number of food-related laboratory confirmed cases min 13 872 – max 15 074)	Beta	α: 25.11, β: 427.49
Test sensitivity	Sensitivity of stool culture for *Salmonella* spp. used as a proxy	Beta	α: 71.25, β: 3.75
Laboratory testing	The proportion of stool samples tested for *Salmonella* spp. used as a proxy	Beta	α: 71.25, β: 3.75
Specimen submission	Proportion of stool samples prescribed for *Salmonell*a spp. used as a proxy	Beta	α: 21.36, β: 108.08
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion of *Salmonell*a spp. cases with a duration of illness longer than 5 days used as a proxy	Beta	α: 195.43, β: 203.41
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of 3-5 days used as a proxy	Beta	α: 186.85, 210.71
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness of less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of less than 3 days used as a proxy	Beta	α: 383.96, β: 9,215.04
Proportion hospitalized	Proportion estimated for acute gastroenteritis used as a proxy (*cf*. table acute gastroenteritis in this appendix)	Beta	α: 229.15.11, β: 34,255.89
Proportion of hospitalized patients who died	Proportion estimated for norovirus used as a proxy (*cf*. table norovirus in this appendix)	Beta	α: 63.84, β: 26,537.82
Proportion foodborne	Only foodborne outbreak cases reported in France. Proportion estimated to be 100%, similar to US estimates published in 2011 (*2*)	Fixed	100%
Campylobacter spp.			
Reported illnesses	Annual number of cases of *Campylobacter* spp. reported by the national reference center between 2008 and 2013	log normal	meanlog: 8.436, sdlog: 0.157
Underreporting	Completeness of case reporting to the national reference center, estimated from a national laboratory survey carried out in 2010 (unpublished data, French national public health agency (*3*))	Beta	α: 348.34, β: 1176.13
Test sensitivity	Sensitivity of stool culture for *Campylobacter* spp., estimated by the national reference center in 2009 (*4*)	Beta	α 229.8, β: 153.2

Model input	Data source(s)	Distribution	Data for model input
Laboratory testing	Proportion of stool samples tested for *Campylobacter* spp., estimated from a national laboratory survey carried out in 2010 (unpublished data, French national public health agency (*3*))	Beta	α: 81.121, β: 44.648
Specimen submission	Proportion of stool samples prescribed for cases of *Campylobacter* spp. that consulted a general practitioner (GP), estimated from a survey among GPs carried out in 2013-2014 (*5*)	Beta	α: 17.792, β: 83.875
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (1)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion of *Campylobacter* spp. cases with a duration of illness longer than 5 days, estimated from a national case-control study (2002-2004) (*6*)	Beta	α: 118.63, β: 48.45
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion of *Campylobacter* spp. cases with a duration of illness of 3-5 days, estimated from a national case-control (2002-2004) (*6*)	Beta	A: 236.25, β: 638.75
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion of *Campylobacter* spp. cases with a duration of illness less than 3 days, estimated from a national case-control study (2002-2004) (*6*)	Beta	α: 391.98, β: 19207.02
Reported hospitalizations	Annual number of patients hospitalized with an ICD-10 code of campylobacteriosis (A04.5) reported in the French hospital information system (2008-2013)	log normal	meanlog: 8.032, sdlog: 0.168
Reported deaths	Annual number of patients hospitalized with an ICD-10 code of campylobacteriosis (A04.5) reported in the French hospital information system (2008-2013) with "death" coded as the mode of discharge	log normal	meanlog: 3.136, sdlog: 0.261
Laboratory testing: hospitalizations/deaths	Proportion of stool samples tested for *Campylobacter* spp. in hospital laboratories estimated from a national laboratory survey carried out in 2010 (unpublished data, French national public health agency)	Beta	α: 46.326, β: 16.277
Test sensitivity: hospitalizations/deaths	Sensitivity of stool culture for *Campylobacter* spp., estimated by the National Reference Center in 2009 (*4*)	Beta	α: 229.8, β: 153.2
Proportion foodborne	Estimated to be between 73 and 86% based on US estimates published in 2011 (*2*)	Beta	α: 121.78, β: 31.426
Clostridium botulinum			
Reported illnesses	Annual number of cases reported by the national reference center – mandatory notification surveillance in France between 2008 and 2013	log normal	meanlog: 2.890, sdlog: 0.3889
Underreporting	Completeness of case reporting to the national reference center – mandatory notification surveillance was assumed to be between 90 and 100%	Beta	α: 71.25, β: 3.75
Test sensitivity, laboratory testing, specimen submission, medical care seeking	Cases are reported through mandatory notification that is based on their clinical symptoms. They are reported even in absence of laboratory confirmation. Proportion assumed to be between 80 and 100%.	Beta	α: 31.5, β: 3.5
Proportion hospitalized	Proportion of hospitalization among the cases reported by mandatory notification surveillance between 2008 and 2013 (85 – 100%)	Beta	α: 44.708, β: 3.625
Deaths	Mean annual number of deaths reported by mandatory notification surveillance between 2008 and 2013	log normal	meanlog: -1.204, sdlog: 1.567
Proportion foodborne	All cases reported by mandatory notification surveillance are assumed food-related (no other mode of transmission documented). Proportion similar to US estimates published in 2011 (*2*)	Fixed	100%
Clostridium perfringens			
Reported illnesses	Annual number of reported foodborne outbreak cases reported to the French national public health agency between 2008 and 2013	log normal	meanlog: 6.240, sdlog: 0.370
Underreporting	*Salmonella* spp. data used as a proxy (2008-2013) : annual number of reported foodborne outbreak cases (min 509 - max 1 066) divided by the annual number of food-related laboratory confirmed cases min 13 872 – max 15 074)	Beta	α: 25.11, β: 427.49
Test sensitivity	Sensitivity of stool culture for *Salmonella* spp. used as a proxy	Beta	α: 71.25, β: 3.75
Laboratory testing	The proportion of stool samples tested for *Salmonella* spp. used as a proxy	Beta	α: 71.25, β: 3.75
Specimen submission	Proportion of stool samples prescribed for *Salmonella* spp. used as a proxy	Beta	α: 21.36, β: 108.08
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness longer than 5 days used as a proxy	Beta	α: 195.43, β: 203.41
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of 3-5 days used as a proxy	Beta	α: 186.85, 210.71

Model input	Data source(s)	Distribution	Data for model input
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness of less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of less than 3 days used as a proxy	Beta	α: 383.96, β: 9,215.04
Proportion hospitalized	Proportion estimated for acute gastroenteritis used as a proxy (*cf*. table acute gastroenteritis in this appendix)	Beta	α: 229.15.11, β: 34,255.89
Proportion of hospitalized patients who died	Proportion estimated for norovirus used as a proxy (*cf*. table norovirus in this appendix)	Beta	α: 63.84, β: 26,537.82
Proportion foodborne	Only foodborne outbreak cases reported in France. Proportion estimated to be 100%, similar to US estimates published in 2011 (*2*)	Fixed	100%
Escherichia coli, Shiga-toxin-producing (STEC)			
Incidence	Estimated annual rate per 100,000 from published studies in Germany (*7*), the Netherlands (*8*) and the European region (*9*)	log normal	meanlog: 3.664, sdlog: 0.462
Population at risk	2010 French census population estimate	Fixed	62,765,235
Hospitalizations	Proportion of hospitalization estimated for *Salmonella* spp. and *Campylobacter* spp. illnesses used as a proxy	Beta	α: 9.716, β: 434.958
Proportion of hospitalized patients who died	Proportion of hospitalized patients who died estimated for *Salmonella* spp. and *Campylobacter* spp. used as a proxy	Beta	α: 19.663, β: 1,675.408
Proportion foodborne	Estimated to be between 59 and 87% based on US estimates published in 2011 (*2*)	Beta	α: 28.634, β: 10.591
Hepatitis A virus (HAV)			
Reported illnesses	Annual number of domestic symptomatic cases of hepatitis A virus (HAV) reported to the French national public health agency between 2008 and 2013 (mandatory notifiable disease)	log normal	meanlog: 7.034, sdlog: 0.158
Sensibility	Sensibility the French surveillance system (6.55-7.3%), estimated from age specific incidence and seroprevalence data using a catalytic model that has been used to estimate HAV incidence in the USA (*10*) and in Canada (*11*)*	Beta	α: 1,283.548, β: 17,248.77
Hospitalizations	Annual number of patients hospitalized with an ICD-10 code related to HAV (B15.0 or B15.9) reported in the French hospital information system (2008-2013)	log normal	meanlog: 7.354, sdlog: 0.196
Deaths	Annual number of patients hospitalized with an ICD-10 code related to HAV (B15.0 or B15.9) reported in the French hospital information system (2008-2013) with "death" coded as mode of discharge	log normal	meanlog: 3.401, sdlog: 0.133
Proportion foodborne	Proportion based on a study conducted in the Netherlands (2008-2010 data) (*12*)	Fixed	16%
Hepatitis E virus (HEV)			
Number of hepatitis E virus (HEV) positive blood donors (A)	Number of blood donors RNA positive (PCR) estimated from a seroprevalence study conducted in 2013 (*13*)	log normal	meanlog: 6.670, sdlog: 0.197
Annual number of blood donors (B)	Annual number of blood donors in France (*14*)	Fixed	2,941,624
Viremia (V)	Duration of viremia of HEV assumed to be between 21 and 35 days	log normal	meanlog: 3.332, sdlog: 0.1275
Incidence	Annual incidence rate of hepatitis E virus (cases per 1,000 inhabitants) estimated using the following formula: (A)/[(B)*(V/365)]	outcome	5% value: 2.38, median value: 3.50, 95% value: 5.17
Population at risk	2010 French census population estimate	Fixed	62,765,235
Symptomatic illnesses	Proportion of symptomatic infections (29-33%) estimated from two outbreaks investigations conducted on a cruise ship in 2008 (*15*) and on a French island in 2013 (*16*)	Beta	α: 662.78, β: 1,475.22
Hospitalizations	Annual number of patients hospitalized with an ICD-10 code related to HEV (B17.2) reported in the French hospital information system (2013-2014)	log normal	meanlog: 6.303, sdlog: 0.0073
Deaths	Mean annual number of patients hospitalized with an ICD-10 code related to HEV (B17.2) reported in the French hospital information system (2013-2014) with "death" coded as mode of discharge	log normal	meanlog: 2.9957, sdlog: 0.05
Proportion foodborne	Proportion assumed to be between 75 and 100%	Beta	α: 23.625, β: 3.375
Listeria monocytogenes			
Reported illnesses	Annual number of cases reported by the national reference center – mandatory notification surveillance in France between 2008 and 2013	log normal	meanlog: 5.740, sdlog: 0.113
Underreporting	Completeness of case reporting for the 2008-2014 period estimated from a capture-recapture study using national reference center data, mandatory notification data and data from a laboratory network of six severe invasive bacterial diseases including listeriosis (unpublished data, French Public Health Agency)	Beta	α: 4,140.9, β: 674.1
Test sensitivity, laboratory testing, specimen submission, medical care seeking	Proportion assumed to be between 80 and 100%.	Beta	α: 31.5, β: 3.5
Hospitalizations	Mean annual number of hospitalizations reported by mandatory notification surveillance between 2008 and 2013	log normal	meanlog: 5.740, sdlog: 0.113
Deaths	Mean annual number of deaths reported by mandatory notification surveillance between 2008 and 2013	log normal	meanlog: 4.174, sdlog: 0.267
Proportion foodborne	All cases reported by mandatory notification surveillance are assumed food-related (no other mode of transmission documented). Proportion similar to US estimates published in 2011 (*2*)	Fixed	100%
Norovirus			

Model input	Data source(s)	Distribution	Data for model input
Acute gastrointestinal illnesses	Estimated rate of acute gastrointestinal illness per person and per year based on a population-based study in 2009/2010 in France	log normal	meanlog: -1.109, sdlog: 0.0696
Population at risk	2010 French census population estimate	Fixed	62,765,235
Norovirus illnesses	Proportion of AG due to norovirus (14-22%), estimated from a prospective population-based cohort study in the United Kingdom (*17*,*18*) and a systematic review and meta-analysis (developed countries) (*19*)	Beta	α: 66.24, β: 301.76
Proportion hospitalized	Proportion estimated for acute gastroenteritis used as a proxy (*cf*. table acute gastroenteritis in this appendix)	Beta	α: 229.15.11, β: 34,255.89
Proportion of hospitalized patients who died	Proportion of cases hospitalized with an ICD-10 code related to viral gastroenteritis (ICD-10 codes A08.0 – A08.5) in the French hospital information system (2008-2013) with "death" coded as mode of discharge	Beta	α: 63.884, β: 26,537.82
Proportion foodborne	Proportion (12-16%) based on a study published in 2015 (*20*) that used data from outbreak surveillance systems and from a systematic review of the literature to estimate the proportion of norovirus due to food	Beta	α: 168.42, β: 1,034.58
Salmonella spp.			
Reported illnesses	Annual number of cases of *Salmonella* spp. reported by the national reference center between 2008 and 2013	log normal	meanlog: 9.193, sdlog: 0.052
Underreporting	Completeness of case reporting to the national reference center, estimated from a national laboratory survey carried out in 2009 (*21*)	Beta	α: 479.94, β: 275.87
Test sensitivity	Sensitivity of stool culture for *Salmonella* spp. assumed to be between 90 and 100%	Beta	α 71.25, β: 3.75
Laboratory testing	*Salmonella* spp. is routinely tested on stool samples in France. The proportion of stool samples tested for *Salmonella* spp. is assumed to be between 90 and 100%	Beta	α 71.25, β: 3.75
Specimen submission	Proportion of stool samples prescribed for cases of *Salmonella* spp. that consulted a general practitioner (GP), estimated from a survey among GPs carried out in 2013 – 2014 (*5*)	Beta	α: 21.36, β: 108.08
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness longer than 5 days, estimated from outbreaks investigated during the 2008-2013 period (unpublished data, French national public health agency)	Beta	α: 195.43, β: 203.41
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of 3-5 days, estimated from outbreaks investigated during the 2008-2013 period (unpublished data, French national public health agency)	Beta	α: 186.85, β:210.71
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of less than 3 days, estimated from outbreaks investigated during the 2008-2013 period (unpublished data, French national public health agency	Beta	α: 383.96, β: 9,215.04
Reported hospitalizations	Annual number of patients hospitalized with an ICD-10 code of salmonellosis (A02 – A02.9) reported in the French hospital information system (2008-2013)	log normal	meanlog: 8.341, sdlog: 0.0698
Reported deaths	Annual number of patients hospitalized with an ICD-10 code of salmonellosis (A02 – A02.9) reported in the French hospital information system (2008-2013) with "death" coded as the mode of discharge	log normal	meanlog: 4.2195, sdlog: 0.088
Laboratory testing: hospitalizations/deaths	Proportion of stool samples tested for *Salmonella* spp. in hospital laboratories assumed to be 100%	Fixed	100%
Test sensitivity: hospitalizations/deaths	Sensitivity of stool culture for *Salmonella* spp., assumed to be between 90 and 100%	Beta	α 71.25, β: 3.75
Proportion foodborne	Estimated to be between 91 and 95% based on US estimates published in 2011 (*2*)	Beta	α: 604.5, β: 45.5
Shigella spp.			
Reported illnesses	Annual number of cases of *Shigella* spp. reported by the national reference center between 2008 and 2013	log normal	meanlog: 6.498, sdlog: 0.009
Underreporting	Completeness of case reporting to the national reference center, estimated from a national laboratory survey carried out in 2009	Beta	α: 452.87, β: 348.67
Test sensitivity	Sensitivity of stool culture for *Shigella* spp. assumed to be between 90 and 100%	Beta	α 71.25, β: 3.75
Laboratory testing	*Shigella* spp. is routinely tested on stool samples in France. The proportion of stool samples tested for *Shigella* spp. is assumed to be between 90 and 100%	Beta	α 71.25, β: 3.75
Specimen submission	Proportion of stool samples prescribed *Salmonella* spp. used as a proxy	Beta	α: 21.36, β: 108.08
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion of *Salmonella* spp.; cases with a duration of illness longer than 5 days used as a proxy	Beta	α: 195.43, β: 203.41

Model input	Data source(s)	Distribution	Data for model input
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of 3-5 days used as a proxy	Beta	α: 186.85, β:210.71
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness less than 5 days used as a proxy	Beta	α: 383.96, β: 9,215.04
Reported hospitalizations	Annual number of patients hospitalized with an ICD-10 code of shigellosis (A03.0 – A03.9) reported in the French hospital information system (2008-2013)	log normal	meanlog: 5.759, sdlog: 0.117
Reported deaths	Annual number of patients hospitalized with an ICD-10 code of shigellosis (A03.0 – A03.9) reported in the French hospital information system (2008-2013) with "death" coded as the mode of discharge	log normal	meanlog: 0, sdlog: 1
Laboratory testing: hospitalizations/deaths	Proportion of stool samples tested for *Shigella* spp. in hospital laboratories assumed to be 100%	Fixed	100%
Test sensitivity: hospitalizations/deaths	Sensitivity of stool culture for *Shigella* spp. assumed to be between 90 and 100%	Beta	α 71.25, β: 3.75
Proportion domestic	Proportion of cases with no travel history reported by the national reference center between 2008 and 2013 (71 – 78%)	Beta	α: 461.398, β: 157.928
Proportion foodborne	Estimated to be between 23 and 40% based on US estimates published in 2011 (*2*)	Beta	α: 37.315, β: 81.1455
Staphylococcus aureus			
Reported illnesses	Annual number of reported foodborne outbreak cases reported to the French national public health agency between 2008 and 2013	log normal	meanlog: 5.727, sdlog: 0.619
Underreporting	*Salmonella* spp. data used as a proxy (2008-2013) : annual number of reported foodborne outbreak cases (min 509 - max 1 066) divided by the annual number of food-related laboratory confirmed cases min 13 872 – max 15 074)	Beta	α: 25.11, β: 427.49
Test sensitivity	Sensitivity of stool culture for *Salmonella* spp. used as a proxy	Beta	α: 71.25, β: 3.75
Laboratory testing	The proportion of stool samples tested for *Salmonella* spp. used as a proxy	Beta	α: 71.25, β: 3.75
Specimen submission	Proportion of stool samples prescribed for *Salmonella* spp. used as a proxy	Beta	α: 21.36, β: 108.08
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness longer than 5 days used as a proxy	Beta	α: 195.43, β: 203.41
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of 3-5 days used as a proxy	Beta	α: 186.85, 210.71
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness of less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion of *Salmonella* spp. cases with a duration of illness of less than 3 days used as a proxy	Beta	α: 383.96, β: 9,215.04
Proportion hospitalized	Proportion estimated for acute gastroenteritis used as a proxy (*cf.* table acute gastroenteritis in this appendix)	Beta	α: 229.15.11, β: 34,255.89
Proportion of hospitalized patients who died	Proportion estimated for norovirus used as a proxy (*cf.* table norovirus in this appendix)	Beta	α: 63.84, β: 26,537.82
Proportion foodborne	Only foodborne outbreak cases reported in France. Proportion estimated to be 100%, similar to US estimates published in 2011 (*2*)	Fixed	100%
Taenia saginata			
Illnesses	Annual number of persons with a reimbursement of Niclosamide treatment between 2011 and 2013	log normal	meanlog: 10.405, sdlog: 0.0686
Reported hospitalizations	Annual number of cases hospitalized with an ICD-10 code related to taeniais (B68.1 - B68.9) reported in the French hospital information system (2008-2013)	log normal	meanlog: 4.920, sdlog: 0.0657
Reported deaths	Annual number of cases hospitalized with an ICD-10 code related to taeniais (B68.1 - B68.9) reported in the French hospital information system (2008-2013) with "death" coded as the mode of discharge	log normal	meanlog: 1.386, sdlog: 0.5
Proportion foodborne	Only foodborne transmission documented in France, proportion estimated to be 100%	Fixed	100%
Toxoplasma gondii (acquired and congenital)†			
Illnesses	Annual number of infections of toxoplasmosis estimated by modelling age-and time specific seroprevalence data (2010-2011)‡	log normal	meanlog: 11.983, sdlog: 0.018
Proportion symptomatic	Proportion of symptomatic illness estimated between 10 and 20% (*22*)	Beta	α: 30.45, β: 172.55
Reported hospitalizations	Annual number of cases hospitalized with a specific ICD-10 code (B58.0 - B58.9) reported in the French hospital information system (2008-2013)	log normal	meanlog: 7.092, sdlog: 0.0549
Reported deaths	Annual number of cases hospitalized with a specific ICD-10 code (B58.0 - B58.9) reported in the French hospital information system (2008-2013) with "death" coded as the mode of discharge	log normal	meanlog: 3.807, sdlog: 0.266

Model input	Data source(s)	Distribution	Data for model input
Proportion foodborne	Estimated to be between 40 and 60% based on US estimates published in 2011 (*2*)	Beta	α: 49.5, β: 49.5
Yersinia spp.			
Reported illnesses	Annual number of stool cultures reimbursed in the national health insurance database between 2010 and 2012	log normal	meanlog: 13.349, sdlog: 0.036
Underreporting	The frequency of *Yersinia* spp. isolation from stool cultures estimated from a national laboratory survey carried out in 2004-2005 (*23*)	Beta	α: 19.745, β: 5,703.455
Test sensitivity	Sensitivity of stool culture for *Yersinia* spp., assumed to be between 80 and 100%	Beta	α 31.5, β: 3.5
Laboratory testing	Proportion of stool samples tested for *Campylobacter* spp. used as a proxy	Beta	α: 81.121, β: 44.648
Specimen submission	Proportion of stool samples prescribed for *Campylobacter* spp. used as a proxy	Beta	α: 17.792, β: 83.875
Medical care seeking if long duration of illness	Proportion of cases of AG with a duration of illness longer than 5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.346, sdlog: 0.141
Proportion of cases with a long duration of illness	Proportion *Campylobacter* spp. cases with a duration of illness longer than 5 days, used as a proxy	Beta	α: 118.63, β: 48.45
Medical care seeking if medium duration of illness	Proportion of cases of AG with a duration of illness of 3-5 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -0.865, sdlog: 0.142
Proportion of cases with a medium duration of illness	Proportion *Campylobacter* spp. cases with a duration of illness of 3-5 days used as a proxy	Beta	A: 236.25, β: 638.75
Medical care seeking if short duration of illness	Proportion of cases of AG with a duration of illness less than 3 days that consulted for their illness, estimated from a national telephone survey conducted in 2009-2010 (*1*)	log normal	meanlog: -1.708, sdlog: 0.216
Proportion of cases with a short duration of illness	Proportion *Campylobacter* spp. cases with a duration of illness less than 3 days used as a proxy	Beta	α: 391.98, β: 19,207.02
Reported hospitalizations	Annual number of patients hospitalized with an ICD-10 code of yersiniosis (A04.6) reported in the French hospital information system (2008-2013)	log normal	meanlog: 5.371, sdlog: 0.093
Reported deaths	Annual number of patients hospitalized with an ICD-10 code of yersiniosis (A04.6) reported in the French hospital information system (2008-2013) with "death" coded as the mode of discharge	log normal	meanlog: 2.303, sdlog: 1.4
Laboratory testing: hospitalizations/deaths	Proportion of stool samples tested for *Campylobacter* spp. tested in hospital laboratories used as a proxy	Beta	α: 46.326, β: 16.277
Test sensitivity: hospitalizations/deaths	Sensitivity of stool culture for *Yersinia* spp. assumed between 80% and 100%	Beta	α 31.5, β: 3.5
Proportion pathogenic	Proportion of pathogenic strains of *Yersinia* spp. reported by the national reference center between 2008 and 2013 (66-71%)	Beta	α 945.273, β: 434.688
Proportion foodborne	Estimated to be between 80 and 100% based on US estimates published in 2011 (*2*)	Beta	α 31.5, β: 3.5

*We used seroprevalence data from 3 different seroprevalence surveys in France to derive age-specific seroprevalence estimates for hepatitis A virus (HAV). We used surveillance data (mandatory notification) from domestic symptomatic cases of HAV reported to the French national public health agency between 2008 and 2013 to produce age-specific incidence estimates. The incidence of HAV infection in France was then estimated using a catalytic model as published by Armstrong et al. in the United States (*10*) and Pham et al. in Canada (*11*). Using this model the sensibility of our surveillance system was estimated to be 6.92% (95% confidence interval 6.55–7.3%).
†The estimates derived from modelling the seroprevalence data and from the French hospital information system comprise both acquired and congenital toxoplasmosis. A very small proportion of these cases are congenital toxoplasmosis: in France 256 cases of congenital toxoplasmosis were annually reported by the national laboratory surveillance system (2008-2013), of which 90% were asymptomatic (*24*)
‡We estimated the incidence of *T. gondii* infection using age-and time specific seroprevalence data from 6 different seroprevalence surveys in France, following a catalytic epidemic parametric model proposed by Ades and Nokes (*25*). This model-based approach has recently been used and adapted in France to estimate the incidence and prevalence of *T. gondii* infections among women in France (*26*). We applied this model to the general population (unpublished data).

Technical Appendix Table 2. Estimates (5th, 50th, 95th percentiles of the output distribution) of the annual number of illnesses, hospitalizations and deaths caused by foodborne pathogens, France, 2008–2013*

	All modes of transmission†			Proportion foodborne	Foodborne transmission†		
Pathogen	5%	50%	95%	transmission, %	5%	50%	95%
Bacillus cereus				100			
Illnesses	32,841	69,468	164,316		32,841	69,468	164,316
Hospitalizations	216	457	1,080		216	457	1,080
Deaths	0.5	1.1	2.6		0.5	1.1	2.6
Campylobacter spp.				73–86			
Illnesses	272,669	492,705	1,078,543		215,216	392,177	862,747
Hospitalizations	5,138	6,943	9,510		4,039	5,524	7,595
Deaths	33	52	82		26	41	65
Clostridium botulinum				100			
Illnesses	11	21	41		11	21	41
Hospitalizations	10	19	37		10	19	37
Deaths	0.02	0.3	3.7		0.02	0.3	3.7
Clostridium perfringens				100			
Illnesses	47,922	119,632	332,244		47,922	119,632	332,244
Hospitalizations	317	811	2,238		317	811	2,238
Deaths	1	2	6		1	2	6
STEC				59–87			
Illnesses	11,523	24,710	52,295		8,206	17,927	38,668

Pathogen	All modes of transmission† 5%	50%	95%	Proportion foodborne transmission, %	Foodborne transmission† 5%	50%	95%
Hospitalizations	199	514	1,259		143	372	928
Deaths	2	6	16		2	4	12
Listeria monocytogenes				100			
Illnesses	328	402	497		328	402	497
Hospitalizations	258	310	375		258	310	375
Deaths	47	65	90		46	65	90
Salmonella spp.				91–95			
Illnesses	108,805	198,047	410,817		102,041	183,002	387,599
Hospitalizations	3,927	4,415	4,983		3,644	4,106	4,632
Deaths	62	72	84		57	67	78
Shigella spp.				23–40			
Illnesses	6,206	11,082	23,143		1,837	3,449	7,555
Hospitalizations	204	248	305		56	78	104
Deaths	0.2	0.8	4		0.05	0.3	1.3
Staphylococcus aureus				100			
Illnesses	21,058	73,021	271,056		21,058	73,021	271,056
Hospitalizations	141	486	1,827		141	486	1,827
Deaths	0.3	1.2	4.3		0.3	1.2	4.3
Yersinia spp.				80–100			
Illnesses	12,175	23,674	54,388		10,799	21,330	49,477
Hospitalizations	180	222	278		158	200	255
Deaths	1	10	108		1	9	96
Hepatitis A virus				16			
Illnesses	12,658	16,416	21,384		2,025	2,627	3,421
Hospitalizations	1,130	1,567	2,162		181	251	346
Deaths	24	30	37		4	5	6
Hepatitis E virus				75–100			
Illnesses	46,032	68,007	101,279		39,388	59,320	88,967
Hospitalizations	540	546	553		413	482	524
Deaths	18	20	22		15	18	20
Norovirus				12–16			
Illnesses	2,971,892	3,706,693	4,579,554		402,816	517,593	656,921
Hospitalizations	19,271	24,659	31,161		2,610	3,447	4475
Deaths	43	59	80		6	8	12
Taenia saginata				100			
Illnesses	29,487	33,006	36,946		29,487	33,006	36,946
Hospitalizations	123	137	153		123	137	153
Deaths	2	4	9		2	4	9
Toxoplasma gondii‡				40–60			
Illnesses	17,567	23,786	30,824		8,401	11,785	16,133
Hospitalizations	1,097	1,202	1,315		493	601	719
Deaths	29	45	69		14	22	35
Subtotal bacteria							
Illnesses	772,257	1,012,762	1,826,612		673,683	880,429	1,594,203
Hospitalizations	12,574	14,425	18,196		10,791	12,363	15,818
Deaths	182	210	315		166	191	288
Subtotal viruses							
Illnesses	3,073,457	3,791,116	4,682,930		463,131	579,540	723,256
Hospitalizations	21,320	26,772	33,444		3,344	4,180	5,189
Deaths	91	109	132		27	31	35
Subtotal parasites							
Illnesses	49,658	56,792	64,942		38,880	44,791	50,640
Hospitalizations	1,234	1,339	1,455		630	738	858
Deaths	33	49	73		18	31	41
Total							
Illnesses	4,175,457	4,860,670	6,155,454		1,280,977	1,504,760	2,233,664
Hospitalizations	37,242	42,536	50,526		15,520	17,281	20,785
Deaths	335	368	486		223	248	350

*STEC, Shiga-toxin–producing *Escherichia coli*.
†5%: 5th percentile; 50%: median; 95%: 95 percentile of the output distribution of estimates for illnesses, hospitalizations and deaths.
‡We considered both acquired and congenital toxoplasmosis.

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