Public Health Response to Multistate *Salmonella* Typhimurium Outbreak Associated with Prepackaged Chicken Salad, United States, 2018

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Quantifying the effect of public health actions on population health is essential when justifying sustained public health investment. Using modeling, we conservatively estimated that rapid response to a multistate foodborne outbreak of *Salmonella* Typhimurium in the United States in 2018 potentially averted 94 reported cases and $633,181 in medical costs and productivity losses.

The US Centers for Disease Control and Prevention estimates that 48 million illnesses, 128,000 hospitalizations, and 3,000 deaths are caused by foodborne illnesses each year in the United States (*1*). *Salmonella* alone accounts for 1.35 million illnesses, 26,600 hospitalizations, and 421 deaths in the United States annually (*2*). Although incidence of *Salmonella enterica* serotype Typhimurium has declined since 2000, infection with this serotype continues to pose a public health burden because it can result in higher rates of hospitalization and longer lengths of stay in a hospital relative to other serotypes (*3*–*6*). A subset of *Salmonella* illnesses are identified and reported as part of an outbreak (defined as ≥2 persons who become ill from the same exposure); 96% of *Salmonella* outbreaks are caused by foodborne transmission (*7*). Outbreaks provide an opportunity to identify implicated food vehicles, as well as root causes for contamination, which can in turn inform broader food safety prevention efforts. If a *Salmonella* outbreak is suspected, public health officials can limit further cases by quickly identifying the source and issuing a recall for the implicated product or making other recommendations for restricting exposure to it.

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DOI: https://doi.org/10.3201/eid2806.211633

The Study

On February 5, 2018, staff at the State Hygienic Laboratory (SHL) at the University of Iowa (Coralville, Iowa) observed a notable increase in the number of stool samples submitted for *Salmonella* testing. Whole-genome sequencing and serotyping revealed patterns of genetic similarity between isolates obtained from these samples. By completing epidemiologic interviews of affected persons and performing food sample testing on suspected food products, the Foodborne Rapid Response team of the Iowa Department of Public Health (IDPH) was able to identify the source of the outbreak as prepackaged chicken salad sold by a Midwest grocery store chain. By February 9, the grocery store chain voluntarily removed the product from all of its Iowa stores; on February 13, IDPH and the Iowa Department of Inspections and Appeals (DIA) issued a joint consumer advisory notification warning customers that the product was implicated in multiple cases of *Salmonella* illness.

Using the PulseNet national molecular subtyping network for foodborne illness surveillance (a national laboratory network that compares the DNA of bacteria from patient samples to find clusters of disease that might represent unrecognized outbreaks), we identified a total of 265 persons from 8 states with *Salmonella* Typhimurium illness as part of this outbreak. Of those, 240 were from Iowa. Ninety-four hospitalizations were reported (35.5% of cases), including 1 person

Table 1. Quantitative analysis of cases averted in a multistate *Salmonella enterica* serovar Typhimurium outbreak, United States, 2018

Parameter	Value	Source
Product included in recall, lb	20,630	(*9*)
Product marked as recovered, lb (%)	5,397 (26.2)	(9)
Product available for consumption, lb	15,233	Calculated
Available product consumed, %	88.5 (82.0–94.5)	(*10,11*)
Product consumed, lb	13,481 (12,491–14,395)	Calculated
Outbreak cases reported	265	(*9*)
Cases/1,000 lb consumed	19.66 (18.41–21.22)	Calculated
Cases averted	94	Calculated
Cases averted including underdiagnosis	2,751	Calculated (*7*)
Hospitalizations averted	33	Calculated

*Values are no. (range) except as indicated.

from Iowa who died. Decisive, cooperative actions undertaken between the Iowa SHL and IDPH, together with the Food and Consumer Safety Bureau within the Iowa DIA, resulted in the removal of contaminated product within 3 days from the initial identification of the genetically related samples, averting what could have been a larger outbreak.

Using a method reported by Scharff et al. (*8*), we estimated the number of cases of *Salmonella* Typhimurium averted by responding rapidly to this outbreak (Table 1). As a result of the alert raised by Iowa public health staff, the US Department of Agriculture (USDA) issued a recall for ≈20,630 pounds of potentially contaminated chicken salad from grocery stores in 8 states (*9*). According to USDA records, the manufacturer reported that 5,397 pounds (26.2%) of the product were recovered (*9*). Using estimates for product loss at the consumer level (10,11), we calculated that 13,481 pounds of the product were consumed, implying ≈20 confirmed cases of *Salmonella* Typhimurium per 1,000 pounds of product consumed. Assuming this rate of disease transmission also applied to the quantity of product that was successfully recalled, we conclude that ≈94 cases of *Salmonella* Typhimurium were averted through the expedient recall of the chicken salad (i.e., cases that would have been reported had the recalled product been consumed). Assuming this rate of disease transmission also applied to the quantity of product that was successfully recalled, we conclude that ≈106 (99–114) cases of *Salmonella* Typhimurium were averted through the expedient recall of the chicken salad (i.e., cases that would have been reported had the recalled product been consumed). This estimate also assumes that all reported cases of *Salmonella* infection in the outbreak resulted from consumption of the contaminated product (Appendix 1, https://wwwnc.cdc.gov/EID/article/28/6/21-1633-App1.pdf)

Our estimate does not account for potential underdiagnosis resulting from variations in medical care seeking, specimen submission, and laboratory testing. Scallan et al. (*7*) estimated that, for every reported case of nontyphoidal *Salmonella*, 29.3 (90% credible interval 21.8–38.4) cases are likely not reported; therefore, the number of cases averted due to the product recall, including underdiagnosed cases, is estimated as 2,751 (range 2,047–3,605). Those cases would have occurred had the recalled product been consumed; of those, 94 would have been reported and the rest underdiagnosed. Our results assume the middle estimate for the fraction of available product consumed, or 88.5% (Appendix 1 Table 4).

Using cost of illness estimates for nontyphoidal *Salmonella* generated by USDA/ERS (*12*), we estimated the economic costs to society averted by responding rapidly to this outbreak (Table 2). All costs are inflation-adjusted to 2018 US dollars. For our estimate of 94 cases averted, we calculated averted economic costs to society of $601,563 in direct medical costs and $31,618 in productivity losses resulting from missed working days in nonfatal cases. The total estimate of averted costs rises to $844,000 to $1 million when accounting for underdiagnosis. These numbers likely constitute an underestimate because we were conservative in selecting input parameters in cases where uncertainty or feasible ranges exist (Appendix 1). Furthermore, our analysis does not consider secondary effects that could provide

Table 2. Estimated economic impact of cases averted in a multistate *Salmonella enterica* serovar Typhimurium outbreak, United States, 2018*

Characteristic in underdiagnosis scenario	None	Low	Middle	High
Averted cases				
Underdiagnosis correction factor	0	21.8	29.3	38.4
No. cases averted	94	2,047	2,751	3,605
Economic impact of cases averted				
Medical costs, USD	$601,563	$673,626	$699,610	$731,137
Productivity loss, nonfatal cases				
Total lost working days	112.1	619.5	802.5	1,024.5
Total economic loss, USD	$31,618	$170,901	$221,123	$282,059
Total cost of illness, USD	$633,181	$844,526	$920,733	$1,013,196

*Data are for base case (middle) scenario for Fraction of Available Product Consumed. Appendix 1 Tables 5, 6 (https://wwwnc.cdc.gov/EID/article/26/6/21-1633-App1.pdf) show results using sensitivity analysis scenarios. USD, US dollars.

additional benefits, such as prevention of future potential outbreaks through providing industry with information by which to improve their processes.

Conclusions

Quantifying and communicating effects such as the amount of illness and economic costs prevented by response and prevention efforts to policymakers and other appropriate audiences using a clear and systematic approach helps to show the value in investing in a robust, responsive, and collaborative public health infrastructure. Although data from outbreak events may lack some of the information desired for a direct calculation of the effect of interventions on population health, methods do exist that aid in making conservative estimates. Routinely calculating and communicating these estimates using direct and relatable outcome indicators for a variety of public health actions helps demonstrate the importance of investing in the ability to respond to outbreaks when they occur and of sustained investment in measures that prevent these outbreaks from occurring. Future analyses could expand upon our approach by examining the sequence of public health actions in relationship to the rise and fall of daily case counts, which may provide additional useful insights into the value of timely information. Incorporating information about the distribution of product sales and recovery could yield specific knowledge for future studies.

Acknowledgments

We thank Elizabeth Allen for providing valuable feedback during the original write-up of this analysis.

The Centers for Disease Control and Prevention Epidemiology and Laboratory Capacity for Prevention and Control of Emerging Infectious Diseases provided partial support for the response actions we described through a cooperative agreement. The USDA Economic Research Service also supported this work.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the U.S. Department of Agriculture and should not be construed to represent any official U.S. Government determination or policy.

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Article DOI: https://doi.org/10.3201/eid2806.211633

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Appendix 1

Cases Averted

We used the product recall method described in Scharff et al. (*5*) to calculate the number of cases averted through the recall of the potentially contaminated chicken salad product. In short, this method calculates the rate of infection from the amount of product that is expected to have been consumed and applies that rate of infection to the amount of product that was successfully recovered by the recall to estimate how many cases may have been averted.

Following this method, we used the total amount of product in the batch of chicken salad that was designated for recall as well as the amount of product marked recovered by the manufacturer to calculate the amount of product that was still available for consumption. We reduced the estimate of product still available for consumption using a product consumption factor of 88.5%, i.e., that 88.5% of the product available for consumption was actually eaten by end consumers. We then calculated the rate of infection per 1,000 lbs. of product consumed and applied this rate of infection to the amount of product that was recovered to give us an estimate of the cases averted.

A search of the available data regarding food loss (that is, what quantities of various purchased food products are actually eaten by end consumers versus wasted) did not provide parameter values that were directly applicable to chicken salad. Therefore, we chose values from categories that were most closely aligned and performed a sensitivity analysis by varying the fraction of available product consumed from the base case value of 88.5% to a high scenario of 94.5% and a low scenario of 82.0% (Appendix 1 Table 2). These values are consistent with estimates of:

- Product losses of prepared foods by supermarkets (11.5% food loss = 88.5% of product consumed) (*3*)
- Product losses of deli products by supermarkets (5.5% food loss = 94.5% of product consumed) (*3*)
- Product losses of raw poultry by consumers (18.0% food loss = 82.0% of product consumed) (*2*)

Note that as the assumed fraction of available product consumed decreases (while known cases remains fixed), the cases per 1,000 lbs. of product consumed will increase (i.e., there would be a higher burden of illness per 1,000 lbs. of product consumed). The estimated number of cases averted does not change when varying the value for the fraction of available product consumed. This is because we had to assume that the rate of illness per 1,000 lbs. of product consumed for the recovered product would have been the same as the rate as calculated from the reported cases.

Underdiagnosis of Cases

Underdiagnosis of *Salmonella* Typhimurium and other foodborne illness can occur due to variations in medical care seeking, specimen submission, laboratory testing, and test sensitivity. We accounted for these variations by using underdiagnosis multipliers that were obtained from a study by Scallan et al. (*4*) Note that this study assumes that there is no underreporting for salmonellosis, but only underdiagnosis. We used the multiplier value given (29.3) and performed sensitivity analysis by using the low and high endpoints of the range provided (21.8, 38.4). This allowed us to provide a range of cases potentially averted by accounting for cases that may not have sought care (Appendix 1 Table 3). A recently released study by Collier et al. (*6*) provides a similar estimated underdiagnosis multiplier of 29.1. Note that both of these underdiagnosis multipliers were estimated using national-level data from the United States and thus may have differed from the actual underdiagnosis that occurred in the specific jurisdictions affected by this outbreak.

Cost of Illness Estimates

As the basis for our cost analysis, we used a standardized cost-of-illness tool for non-typhoidal *Salmonella* that was implemented in Microsoft Excel by USDA/ERS (available at https://www.ers.usda.gov/webdocs/DataFiles/48464/Salmonella_2018.xlsx?v = 7698.4). This tool contains national-level cost per case estimates for the United States given in 2018 US dollars. Methodological details for the estimates and calculations provided in the cost-of-illness tool can be found at https://www.ers.usda.gov/data-products/cost-estimates-of-foodborne-illnesses/documentation. For convenience, we have included the 'per case assumptions' section of this tool in our own Excel calculator tool that contains all calculations used in this analysis (Appendix 2, https://wwwnc.cdc.gov/EID/article/28/6/21-1633-App2.xls). We now describe how the cost-per-case estimates were incorporated into this analysis.

This tool divides cases into 4 categories:

1. Non-hospitalized, did not visit physician, recovered
2. Non-hospitalized, visited outpatient physician, recovered
3. Hospitalized, with post-hospitalization recovery
4. Hospitalized, died

We will now give some details on how we divided case estimates among these categories. (Methodological details on how these categorizations were converted into cost estimates can be found at the documentation link for the original ERS calculator, listed immediately above.) Steps taken and assumptions made to produce the results shown here can be found in the Excel tool provided (Appendix 2).

We began by calculating a hospitalization rate of 35.5% based on data in the ELC outbreak report / success story write-up (Appendix 3, https://wwwnc.cdc.gov/EID/article/28/6/21-1633-App3.pdf) that 94 of the 265 cases were hospitalized. The case report further noted that 1 hospitalized patient died, a death rate among hospitalized patients of 1.06% (1/94). This left 171 non-hospitalized patients, to which we applied a "physician visit rate" of 7.33%, which we derived from national case burden estimates provided in the USDA/ERS calculator tool (on the "Per Case Assumptions" tab). These same methods and derived values were applied to the case totals that were adjusted for underdiagnosis (both reported cases and averted cases), with the only additional detail being that we assumed that none of the underdiagnosed cases (those in excess of the 265 reported or 94 calculated averted cases) were hospitalized.

Summary tables were created using appropriate totals from the calculator tool (Appendix 2). Note that we did not include estimated costs of premature death in our results, since all scenarios resulted in less than 1 averted death. However, in other analyses assessing the impact of a public health response to outbreaks, it may be appropriate to include estimates of the cost of premature death. For such analyses, the ability to estimate the cost of premature death due to nontyphoidal *Salmonella* is provided by the USDA/ERS calculator tool, and questions regarding valuing mortality outcomes can be directed to Sandra Hoffmann (shoffmann@ers.usda.gov).

Caveats and Limitations

The USDA/ERS cost of illness calculator used was originally designed using nationally representative costing estimates for the U.S. for non-typhoidal *Salmonella*. Cases of *Salmonella* Typhimurium can be more serious, with both higher hospitalization rates and longer durations in hospital, on average, relative to other serotypes (*7–9*). We calculated the hospitalization rate using data taken directly from the outbreak report, but data regarding length of hospital stay for individual cases from this outbreak were not available. Additionally, despite studies indicating that *Salmonella* Typhimurium can have longer hospital stays relative to other serotypes, data were not available that allowed us to calculate how this translates to an increase in direct medical costs. The nationally representative cost estimates from the USDA/ERS calculator tool were used, with the understanding that they may be a slight underestimate of the treatment costs incurred in this outbreak. Combining all these points, we believe that the results presented here constitute a conservative cost estimate and have made every effort to list the data used as well as limitations where necessary.

Sensitivity Analysis Results

There were two inputs to this analysis for which parameter values were notably uncertain: 1) the amount of underdiagnosis of salmonellosis cases and 2) the fraction of the affected food product that was actually consumed. We performed scenario-based sensitivity analysis across a chosen range of values for these two parameters, producing results using a high, medium, and low value for each parameter. However, the estimated number of cases does not change when varying the value for the fraction of available product consumed (see above for explanation). Therefore, we present only the results from varying the underdiagnosis correction factor. Table 2 in the main text shows the estimates for cases and costs averted due to the expedient recall of the contaminated product, while Appendix 1 Table 4 below provides estimates of economic impact for cases that were reported.

There were 265 cases reported across multiple states as having been related to this contaminated food source (chicken salad). When accounting for expected underdiagnosis, we estimate that the true number of cases likely lies between 5,777–10,176 (Appendix 1 Table 4). This works out to an estimated economic impact of U.S.$1.90–2.06 million in direct medical costs and U.S.$2.38–$2.86 million when including productivity losses. This is a slight increase from the estimated economic impact without accounting for underdiagnosis, which is expected since the "missed" cases are, in general, not expected to have incurred very much in the way of direct medical costs, which comprise the bulk of the estimated economic impact.

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Appendix 1 Table 1. Parameters and values used in study of public health response to an outbreak of *Salmonella* Typhimurium from prepackaged chicken salad, 2018

Parameter	Value (sensitivity analysis values)	Source
Qty of product recalled, lbs	20,630	(*1*)
Qty of product marked as recovered, lbs	5,397	(*1*)
Fraction of available product consumed	88.5% (82.0%, 94.5%)	(*2*,*3*)
Underdiagnosis multiplier	29.3 (21.8, 38.4)	(*4*)
Total reported cases	265	Appendix 3
Hospitalizations	94	Appendix 3
Hospitalized, died	1	Appendix 3
Hospitalization rate, %	35.5	Calculated
% Hospitalized that died	1.06	Calculated
% Nonhospitalized that visited physician (outpatient visit)	7.33	*Assumption*
% Hospitalized in underdiagnosed population only	0	*Assumption*

Appendix 1 Table 2. Fraction of product consumed used for sensitivity analysis of an outbreak of *Salmonella* Typhimurium from prepackaged chicken salad, 2018

% of available product consumed	Cases averted	Source
94.5	94	(*3*)
88.5	94	(*3*)
82.0	94	(*2*)

Appendix 1 Table 3. Estimate of cases averted accounting for underdiagnosis of *Salmonella* Typhimurium from prepackaged chicken salad, 2018*

Underdiagnosis multiplier	Cases Averted
21.8	2,047
29.3	2,751
38.4	3,605

*Adjustment for under-diagnosis due to variations in medical care seeking, specimen submission, laboratory testing, and test sensitivity. Source: https://www.cdc.gov/eid/article/17/1/p1-1101-techapp3.pdf.

Appendix 1 Table 4. Estimated economic impact of reported cases in outbreak of *Salmonella* Typhimurium from prepackaged chicken salad, 2018

Description	Estimated economic impact			
Reported cases				
Underdiagnosis correction scenario	None	Low	Mid	High
Underdiagnosis correction factor	0	21.8	29.3	38.4
# of cases reported	265	5,777	7,765	10,176
	Economic impact (reported cases)			
Underdiagnosis correction scenario	None	Low	Mid	High
Medical costs	$1,697,907	$1,901,304	$1,974,645	$2,063,631
Productivity loss, nonfatal cases				
Total lost working days	316.5	1,748.6	2,265.0	2,891.6
Total economic loss ($US)	$89,242	$482,366	$624,118	$796,110
Total cost of illness	$1,787,149	$2,383,670	$2,598,762	$2,859,741

Article DOI: https://doi.org/10.3201/eid2806.211633

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Appendix 3

ELC Outbreak Report/Success Story

The analysis presented in this article was based on a success story submitted to CDC's Epidemiology and Laboratory Capacity for Prevention and Control of Emerging Infectious Diseases (ELC) Cooperative Agreement. For over 25 years, the ELC Cooperative Agreement has provided funding to US public health entities at the state, local, territorial, and other administrative levels to detect, respond to, control, and prevent outbreaks of infectious disease. We include a portion of this success story write-up to provide first-hand details not otherwise included in the main text.

Iowa Foodborne Rapid Response Team Quickly Identifies Chicken Salad as the Source of a Multistate *Salmonella* Typhimurium Outbreak

Problem or Challenge

When two or more people become ill after consuming the same food or drink, the event is considered a foodborne disease outbreak. CDC estimates 48 million people get sick from foodborne illnesses, 128,000 are hospitalized and 3,000 die from foodborne diseases each year. If an outbreak is suspected, public health officials need to quickly identify the source to control the spread of the outbreak and reduce the number of affected individuals. While most outbreaks tend to be locally confined and affect maybe only a few people, regional or national outbreaks may affect hundreds of people. This story is about a regional multistate foodborne outbreak that was first detected in Iowa.

The state of Iowa has a foodborne rapid response team (RRT) ready to take immediate action whenever there is a suspected foodborne outbreak. This multifunctional team comprises laboratory staff from the State Hygienic Lab that performs testing of both clinical and food/environmental specimens, epidemiologists from the Iowa Department of Public Health to investigate acute outbreaks, and technical staff of the Food and Consumer Safety Bureau within the Iowa Department of Inspection and Appeals that conduct food safety inspections at food establishments and processing plants and collects environmental and/or food samples for lab testing. In Iowa, the ELC program provides salary support for both IDPH epidemiology and SHL laboratory staff as well as funding for various laboratory testing areas for surveillance and disease detection.

Program Activity/Description/Strategy

During the first week of February, SHL lab staff observed a dramatic increase in the number of stool samples submitted for *Salmonella* culture. Most of these grew *Salmonella* Typhimurium isolates, which were characterized by pulsed-field gel electrophoresis (PFGE) and whole genome sequencing (WGS) as part of the CDC's PulseNet system and found to have similar patterns. IDPH epidemiologists interviewed affected individuals to identify potential food products and point sources causing the outbreak. Staff from the Iowa Department of Inspections and Appeals collected food and environmental samples from suspected sources for testing and comparison with clinical samples. Food sample testing was performed by SHL's environmental microbiology staff (Appendix 3 Figures 1 and 2). Whole-genome sequencing (WGS) was completed locally at the state level, after which CDC staff analyzed the data to show relatedness between isolates.

Within 3 days, the Iowa foodborne rapid response team was able to link the source of the outbreak to prepackaged chicken salad sold by a Midwest grocery store chain, which promptly removed all remaining product and notified consumers. Further environmental testing identified the production source of the chicken salad and a product recall was announced. A joint announcement by the Iowa Department of Public Health (IDPH) and the Iowa Department of Inspections and Appeals (DIA) was released on February 13, 2018. Steve Mandernach, Bureau Chief for Food and Consumer Safety of the Iowa Department of Inspection and Appeals praised SHL's laboratory testing efforts to quickly identify the source of the outbreak. The State

Hygienic Laboratory later developed a one-page handout to share with laboratory facilities during the joint 2018 American Society for Clinical Laboratory Science (ASCLS-IA) and Clinical Laboratory Management Association (CLMA) Iowa Meeting in April 2018.

This became a multistate outbreak when additional cases were identified via the PulseNet system from other states where the grocery store chain is located. CDC collaborated with public health and regulatory officials in several states and the U.S. Department of Agriculture's Food Safety and Inspection Service.

Outcomes/Impact/Value

The PulseNet system is a national laboratory network that connects foodborne illness cases to detect outbreaks across the country. When the PulseNet system was first established, collaborating laboratories used pulsed-field gel electrophoresis (PFGE) technology to create a DNA fingerprint of the tested organism which could then be compared to fingerprints submitted by other laboratories across the country to detect thousands of local and multistate outbreaks. The PulseNet system is currently migrating to a newer technology, whole genome sequencing, to detect and solve outbreaks faster with greater accuracy. During this outbreak, the State Hygienic Laboratory used both PFGE and DNA sequence analysis to rapidly confirm the source and reduce the spread of disease along with their partners on the Iowa foodborne rapid response team. SHL staff are truly dedicated to providing the best possible service to the citizens of Iowa. They are helping to reduce the spread of disease and performing a valuable public health mission. In this example, most of the cases were limited within the state of Iowa even though the affected grocery chain has locations in several Midwestern states. The food product was quickly removed from the shelves averting what could potentially have been a much larger outbreak. The outbreak received a lot of television, radio, and press coverage within the state as well as regionally.

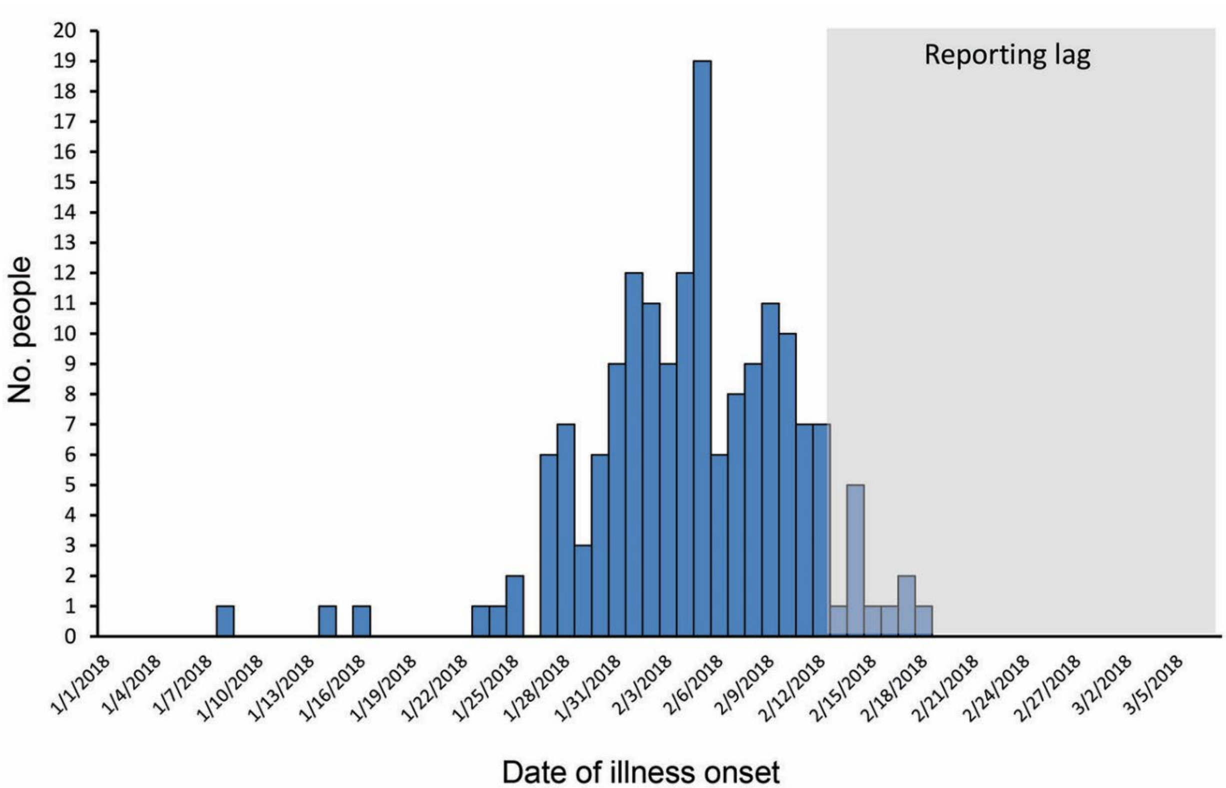
Abbreviated CDC Outbreak Summary

Epidemiologic and laboratory evidence implicated chicken salad produced by an Iowa food processing plant and sold exclusively by a Midwest grocery store chain as the likely source of this multistate outbreak. While public health officials in Iowa first detected this outbreak, the CDC searched the PulseNet database and identified a total of 265 people from 8 states with *Salmonella* Typhimurium illness as part of this outbreak (Appendix 3 Table). The majority of affected individuals (240) were from Iowa. Ninety-four hospitalizations were reported, including one person from Iowa who died.

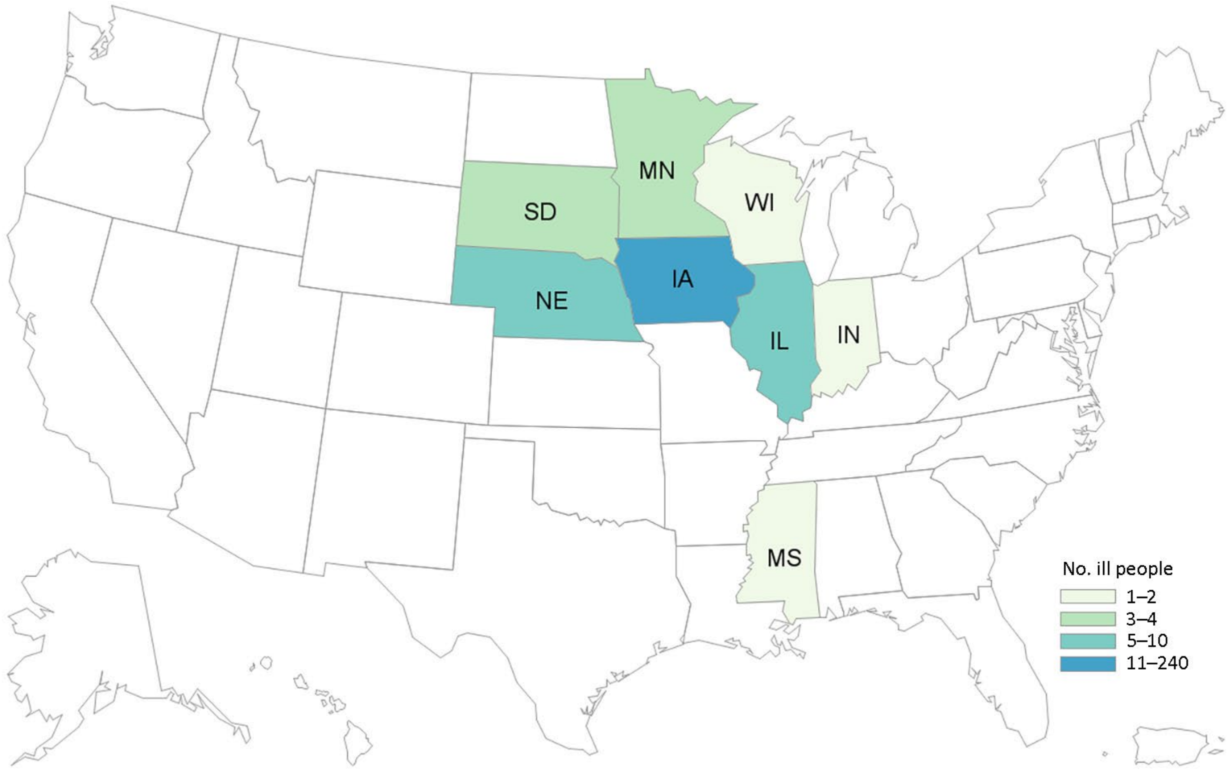
Appendix 3 Table. Number of ill persons by state of residence in study of multistate Salmonella Typhimurium outbreak, 2018.

State	Case count
Illinois	10
Indiana	1
Iowa	240
Minnesota	4
Mississippi	1
Nebraska	5
South Dakota	3
Wisconsin	1
Total	265

Source: CDC. Multistate outbreak of *Salmonella* Typhimurium linked to chicken salad (final update). 2018 Apr 16 [cited 2018 Jul 20]. https://www.cdc.gov/salmonella/typhimurium-02-18/index.html



Appendix 3 Figure 1. Persons infected with the outbreak strains of *Salmonella* Typhimurium, by date of illness onset. Information was reported for 265 persons as of April 4, 2018. Some illness onset dates have been estimated from other reported information.



Appendix 3 Figure 2. Persons infected with the outbreak strains of *Salmonella* Typhimurium, by state of residence, as of April 4, 2018 (n = 265).