Response to Multistate *Salmonella* Typhimurium Outbreak from Prepackaged Chicken Salad, United States, 2018

[Announcer] This program is presented by the Centers for Disease Control and Prevention.

[Sarah Gregory] Hello, I'm Sarah Gregory, and today I'm talking with Dr. Brad Greening, a health scientist at CDC in Atlanta. We'll be discussing a multistate foodborne outbreak of *Salmonella* Typhimurium in the United States.

Welcome, Dr. Greening.

[Brad Greening] Well, thank you for having me, Sarah.

[Sarah Gregory] How many foodborne illnesses are there in the US annually?

[Brad Greening] Well, CDC estimates that each year, about 48 million people will get sick from a foodborne illness in the United States.

[Sarah Gregory] How many related deaths?

[Brad Greening] Out of those 48 million illnesses, we estimate about 128,000 of those will require hospitalization for severe symptoms, and about 3,000 will die.

[Sarah Gregory] Besides death, what are the symptoms of foodborne illness and why do some people die from it?

[Brad Greening] That's a good question. There's a lot of different kinds of foodborne illnesses, so symptoms can vary with the different diseases. But some commonly seen symptoms include nausea, vomiting, stomach cramps and diarrhea, sometimes fever. These symptoms can take a few hours to six or seven days to develop from the time that you swallow contaminated food or drink. And while anyone can get food poisoning, most of the time these symptoms will resolve on their own without treatment. However, adults 65 and older, children five years or younger, people with weakened immune systems, and pregnant people are more likely to get sick or have a serious illness just because their body's ability to fight germs and sickness isn't as effective for a variety of reasons.

[Sarah Gregory] What are the different kinds of foodborne illnesses?

[Brad Greening] Well, there's many different kinds of disease-causing germs that can contaminate food, so there's many different kinds of foodborne infections (we also call those foodborne disease or food poisoning). Researchers have identified about 250 different kinds of foodborne diseases. Most of them are infections and caused by a variety of different bacteria, viruses, and parasites. However, there's also harmful toxins and chemicals that can contaminate food and cause foodborne illness as well.

The top five foodborne illnesses that we see here in the United States are things like norovirus, *Salmonella*, *Clostridium perfringens*, *Campylobacter*, and *Staphylococcus aureus* (which is also called staph). Some others that you may have heard of are things like botulism, *Listeria*, *E. coli*, and *Vibrio*. Most people will have heard of these because they don't cause as many instances of illness, but when they do, the illnesses are much more likely to be

serious and lead to hospitalization and death. And for those reasons, they usually get a lot more attention when outbreaks happen.

[Sarah Gregory] Of all those different kinds of foodborne illnesses, how many are caused by *Salmonella* annually?

[Brad Greening] CDC estimates that *Salmonella* bacteria cause about 1.35 million infections every year, about 26,500 hospitalizations, and 420 deaths. Food is the source for most of those *Salmonella* illnesses.

[Sarah Gregory] Are there different strains or serotypes of *Salmonella*?

[Brad Greening] Oh yes. *Salmonella* are a diverse group of bacteria. Scientists have described more than 2,500 different kinds (we usually call them strains or serotypes) of *Salmonella*. Very little is known about most of them, though, because it's quite rare that they cause illness. Only fewer than 100 of those different kinds will cause infections in humans that we know of.

[Sarah Gregory] Your article is about outbreaks. What constitutes an outbreak and how many people have to get it for it to be an outbreak?

[Brad Greening] That's a really good question. In general, we call an occurrence of disease an outbreak when the number of cases is larger than we would expect normally. And so, of course that's a generalized definition, and different diseases will have different ranges for what we consider to be normal. We base that expectation of normalcy on our general understanding of background rates of cases for different diseases, and that comes from a long history of recorded disease surveillance. For foodborne illness, we usually call an outbreak when two or more people get the same illness from consuming a contaminated food or drink.

[Sarah Gregory] And again, your article is specifically about *Salmonella* serotype Typhimurium. Apparently, cases have decreased some over the last couple of decades, but it's more severe than other types. Tell us a little bit more about that.

[Brad Greening] There's definitely been a general downward trend in the number of cases of *Salmonella* Typhimurium since about the mid-1980s. But it is still actually one of the more commonly seen Salmonella serotypes that cause disease in humans even today. Studies that directly compare things like clinical symptoms or treatment needs serotype by serotype are pretty rare, but we were able to find a couple, which was quite nice for the purpose of this study. One study we cited showed that about 25% of Typhimurium cases would require hospitalization in the outbreak (that was the focus of our own study, about 35% of reported cases needed hospitalization). Another study that we found from England showed that people with Typhimurium would spend more time away from paid work, would need someone else to take care of them for a longer time, and also spend slightly more time in-hospital, which of course drives up things like the cost of medical treatment and other things like that. So while Typhimurium is not the proverbial Chupacabra (or the monster under the bed) in terms of *Salmonella* serotypes, it’s certainly one that we want to be aware of in public health so that we are able to respond to reported outbreaks quickly and prevent as many cases and limit the damage as much as possible.

[Sarah Gregory] And this is probably a little counter-intuitive, but does any good come out of an outbreak?

[Brad Greening] Well, I mean of course, people getting sick is not something we want to see happen. And in public health, we work very hard to prevent that. But in the cases where outbreaks do happen, there's a lot of areas that we can learn lessons that can help us to prevent future outbreaks or respond more efficiently to limit cases. One good example of this is in 1993, there was a rather large outbreak in the western United States that was caused by *E. coli* in ground beef that was distributed by a large hamburger chain, and this resulted in about 700 cases, almost 200 of which needed hospitalization and four died. And a lot of the serious cases were in children. This, of course, got a lot of attention, and lessons learned from this outbreak resulted in things like new, mandated labels about safe food handling on ground beef as well as other new policies to improve the safety of food products made with ground beef all the way from the farm to the time that you actually eat that product. So while I'm still not going out and ordering my hamburgers cooked rare or anything, at least I'm not playing Russian roulette when I want to order a nice, juicy cheeseburger.

[Sarah Gregory] Tell us about the outbreak you studied and why you did the study on that particular one.

[Brad Greening] So the outbreak that we studied, as we said, it was an outbreak of *Salmonella* Typhimurium. It was identified in Iowa, and on February 5, 2018, the staff at the Iowa State Hygienic Laboratory reported an uptick in samples that were being submitted for *Salmonella* testing. And over the next four days, quite a lot of work was completed by Iowa's Foodborne Rapid Response team, which consists of laboratory staff from the State Hygienic Lab, epidemiologists from the Iowa Department of Public Health, and other technical staff from the Iowa Department of Inspections and Appeals. And this team worked furiously over that four days to do things like case interviews, which helped them to identify common food sources that might have been the source of contamination. They also collected potential food sources and environmental samples for testing. They also tested and characterized patient samples, which helps to link cases by comparing the DNA sequences of the different *Salmonella* strains that are found in those samples. And these coordinated efforts were able to identify the source of the outbreak as a pre-packaged chicken salad that was sold out of a Midwestern grocery store chain. And because of the coordinated efforts of this team, they were able to get the chicken salad removed from the grocery store shelf by February 9th, which was just four days after the lab staff noticed the unusual number of samples being submitted. And so, that's really quite amazing.

There were also a couple of unique things about this study that helped us to choose it for our study here. One of the unique things about this was that the laboratory was using whole-genome sequencing to characterize the samples from the patients and from the suspected food sources. And whole-genome sequencing basically enables the laboratory to record a DNA fingerprint, if you will, and this allows for rapid identification of outbreaks by comparing those fingerprints one against another to tell who can be a part of that outbreak. Today, we use that technology a lot more often, but in 2018, these laboratories really had only begun to bring that system online for use in identifying *Salmonella* outbreaks.

The other nice thing about this outbreak response is that it was an excellent example of multiple agencies collaborating to provide a rapid, coordinated response to an identified outbreak. And this is really, really critical in reducing the spread of disease and limiting economic damage.

[Sarah Gregory] What were some of those agencies?

[Brad Greening] Out of the Rapid Response team (the Foodborne Rapid Response team), we had laboratory staff there from Iowa State Hygienic Lab, epidemiologists from Iowa Department of Public Health, and other technical staff from Iowa Department of Inspections and Appeals. There's also interactions that happened between the state agencies there that I just mentioned, as well as CDC and USDA for things like posting the outbreak announcements and the recall announcements. And the coordination that's needed for all of those things to go off rapidly and smoothly is really quite intense.

[Sarah Gregory] And you mentioned data. What kind of data did you use?

[Brad Greening] Nearly all of the data used in this study can be obtained through publicly accessible sources, and that was really one of the nice things about this study. I don't know that I would say it's something that we started as having a goal in mind (all publicly accessible data), but it ended up being a really nice feature. For example, a lot of the data that we used regarding the quantity of chicken salad that was part of the contaminated batch and marked for recall as well as the quantities that were actually recovered, these were obtained from a public announcement that was published online by USDA's Food Safety and Inspection Service. These announcements are posted for most known outbreaks, and they contain information about things like cases, hospitalizations, and deaths. There's also a lot of additional details about this outbreak that are archived on CDC's *Salmonella* website. We used cost-of-illness data for *Salmonella* illness as well as estimates of how much purchased food is actually eaten versus wasted, and these are published online by the Economic Research Service at the USDA. A member of that team we were very fortunate to have is a coauthor on this study. One or two of our data inputs required a bit of searching to find suitable ranges, but as I said, really...ultimately one of the nice features of this study was just how accessible most of these data inputs were. And that bodes really well for replicating this methodology for future studies.

[Sarah Gregory] And I believe you used modeling. Can you tell us what modeling is?

[Brad Greening] A model is really just a simplified version of a real-world object or system. So a lot of people who are listening may have heard of things like model cars or weather models—these are all ways that we slim down/size down/simplify things that we want to learn about in the real world. And when we talk about creating a mathematical model, we're really just talking about building a series of rules that approximate the way that we believe something works, like the spread of disease. These models allow us to combine available data by describing how inputs interact to produce outputs. And the way that I like to think about most mathematical models is like a dashboard of knobs and dials—one for each input. The model allows us to twist these dials, and we can see the effect on the output in ways that might not be feasible (or really even ethical) to do in the real-world, such as raise or lower the amount of vaccination that we're performing to limit the spread of an outbreak. That might not be something we would want to do in the real world but understanding the ramifications of that is really important. And this ability to answer those "what if" questions in data-driven and well-defined ways makes modeling a really useful tool in public health. And for the record, I'm pretty sure my PhD advisor asked me that question in my qualifying exams, so I hope she thinks I did a better job answering this time.

[Sarah Gregory] Well, it's definitely seems like an amazing tool and should be used in pretty much any study, it seems to me.

On that note, how did you go about your study?

[Brad Greening] Well, the rapid response to this *Salmonella* outbreak was highlighted in a success story to CDC's ELC Cooperative Agreement. That stands for Epidemiology and Laboratory Capacity for Prevention and Control of Emerging Infectious Diseases Cooperative Agreement (we're just going to call it ELC) —that is a mouthful. So ELC staff identified that adding a quantitative impact analysis component to this success story could result in an even stronger message to be shared beyond highlighting the rapid response itself. And much like the response to the outbreak itself, our study also was completed through the efforts of a multi-agency and multi-disciplinary team. Staff from CDC, USDA, as well as the state agencies that we mentioned in Iowa, all combined expertise in epidemiology, biology, economics, and mathematics to create this modeling tool that estimates the number of cases and hospitalizations that were potentially prevented by this rapid response. And the tool also allows us to provide estimates of costs that were associated with medical treatment and lost work, both for the cases that were identified as well as the cases that we estimate were prevented.

[Sarah Gregory] Briefly, is there anything else you want to tell us about your study?

[Brad Greening] Sure. In this study, we created a modeling tool, like we said, and that allowed us to combine data about the number of reported cases, the amount of product (or the chicken salad) that was successfully recalled, and the cost of the *Salmonella* illness. And we were really interested in what might have happened if that contaminated chicken salad had not been recalled at all. So to get to that, in short, we calculated a rate of cases that was based on the amount of chicken salad that we estimated was actually eaten as opposed to just purchased and not recovered. And then, we assumed that the rate of cases seen for the non-recovered chicken salad would have been approximately the same for the rate of cases from the chicken salad that was recovered. And that allowed us to calculate a number of cases that was prevented. And then to each of those, we incorporated the costs of medical expenses and lost productivity from missed work that was associated with *Salmonella* disease, and that gave us our estimates of averted economic costs. One of the nice things we were able to do with this study was that we published that modeling tool as an appendix to our study in *Emerging Infectious Diseases* so that it is freely available for anyone who's curious about the details of the calculation or who might want to use the methodology to replicate for their own studies in the future.

[Sarah Gregory] Well, that's a nice addition.

With all this modeling, what did you discover?

[Brad Greening] Our study estimated that in addition to the 265 cases that were reported in this outbreak, the rapid recall and recovery of the chicken salad prevented an additional 94 cases due to that rapid response. It's important to note, though, that these are only the cases that would have been reported. Disease surveillance isn't perfect, and variations in things like medical care seeking, specimen submission, laboratory testing variations—these can result in underdiagnosis of *Salmonella* cases. And what that means is most people aren't going to report a *Salmonella* illness or go to see a doctor if their symptoms quickly resolve. However, if they are part of a group and they know other people who are also affected, maybe then they will report to public health officials. Usually, the biggest barrier to reporting is often having to provide a stool sample for the lab to perform *Salmonella* testing.

One study estimated, in terms of underdiagnosis, that for every case of *Salmonella* that is reported, there might actually be anywhere from 22 to 38 additional cases that don't get reported.

So that's quite a gap there. If we include that potential underdiagnosis in our results, we calculate that this response may have averted as many as 3,600 cases. And while many of these cases would not have had serious outcomes, we estimate that medical costs that were averted would have still tallied somewhere between $600,000 and $730,000 in US dollars and also cause people to miss a total of 1,024 working days, which equals an additional societal cost of about $280,000. So this rapid response to the *Salmonella* outbreak, really, we estimate, could have averted nearly one million dollars total in costs to society.

[Sarah Gregory] I've probably had food poisoning, maybe, four times in my life. And I've never reported it to anyone, even though I was terribly sick for a day or two. I think one of the barriers is people don't really even know where to report something like this. Where should people go, even if it's a mild case, I mean, that they can... it just resolved in a couple of days?

[Brad Greening] For reporting on mild symptoms, that's really a desire more than a need, I would say, because the desire is that we would be able to know about the burden of cases that happens in the United States. The need is that we would be able to know about the serious cases so that we can prevent future complications for that case and limit the possibility of death. And so, while it's important to report illnesses when you can so that we can identify potential outbreaks, if your symptoms are mild, many of us may just think of it as, "Oh, I have a stomach bug of unknown origin". And if the symptoms resolve quickly, we just go on our way. If the symptoms are more serious, though, of course you want to see your doctor or, in very cases, go to the emergency room. But if you want to report any less serious cases, there's usually instructions on your local state or local public health department for who you can contact with the report for that disease and where you can go to get tested for confirmation.

[Sarah Gregory] Why is it important for public health to know these things? It seems pretty clear, but why don't you give us a summation of it?

[Brad Greening] If public health agencies are doing a good job, that means bad things (like outbreaks) are happening less. But this can also result in a bit of a conundrum because if we're doing a good job and bad things aren't happening, it's also a lot easier to justify diverting funding and investments away from public health to other areas because do we really need to keep investing if the bad things aren't happening? And there's been a lot of news stories and peer-reviewed journal articles that are detailing the impact of underfunded public health infrastructure, especially after the onset of the global COVID-19 pandemic. Our study, even though it only examines one outbreak, it allows us to translate the value of a robust public health infrastructure that enables us to rapidly respond to these outbreaks. And we can translate that into numerical estimates of cases and dollars or costs that are averted, which are actually quite relatable to a wide audience.

[Sarah Gregory] You mentioned putting the modeling tool in the appendix with your article. How can that tool and any other information from your study be used to benefit public health in the future?

[Brad Greening] In addition to the lessons that we learned from the outbreak response itself that helped to improve food safety and handling processes, for example, the estimates of cases and costs averted that we provide in this study provide just another brick of evidence in a wall that's being built that shows that significant returns on investment in a robust public health infrastructure translates to significant returns in terms of population health. And if we can show

these returns in clear and relatable terms, that can be very useful to support things like requests for additional public health funding or when you're defending against budget cuts.

[Sarah Gregory] What kinds of future studies of this kind do you think are needed?

[Brad Greening] It's not always easy to draw a direct link between a public health action and the impact that that action has on population health. In some cases, it's downright impossible. So the nice thing about this study is we were able to draw a fairly direct link between those two things, and it's the most effective way for most people to connect a public health action to their personal life. Like, if I tell most people that a recent investment in public health has resulted in hiring five more epidemiologists and purchasing three new laboratory testing machines, most people are going to understand that our public health capabilities have increased, but they don't know how to relate to that. However, if we can show that these additional capabilities helped us to prevent 50 people from becoming ill, this has a far better chance of hitting home in a relatable way. And so, if we are able to increase our capacity to perform impact analyses (like this study) when it's possible to do so, that's really critical if we want to continue to demonstrate the importance of investing in our ability to rapidly respond to disease outbreaks.

[Sarah Gregory] Dr. Greening, tell us about your job at CDC. I believe you had a different position when you conducted this study, correct?

[Brad Greening] I did. When this study was conducted, I was working with CDC's Health Economics and Modeling Unit within the Division for Preparedness and Emerging Infections. And this is a very specialized and multidisciplinary team that functions kind of like a consulting unit inside of CDC, in that other divisions and teams from around the agency will come to that team for technical assistance on economic evaluations and mathematical modeling. So I was really fortunate to have been able to work on projects in a wide range of public health applications, not just one disease area or pathogen, and that included staffing several CDC Emergency Responses going back to the 2014 Ebola outbreak in Western Africa. So some really cool experiences that we had there. And I'd say that my favorite part of that position was that I got to learn so much from the many subject matter experts that we were working with on all these projects, and it was really great to be able to combine our unique areas of expertise to produce better public health science than any one individual group would have been able to do on their own. This study here is actually really a great example of one of those types of collaborations. Funnily enough, my current position now has me leading the Evaluation Team for the ELC Cooperative Agreement that we mentioned earlier (this is the cooperative agreement that funded Iowa for some of the public health work that was responsible in that rapid response). So I guess it's safe to say that sometimes these collaborations lead to things beyond science also.

[Sarah Gregory] Well, on a personal note, what do you like to do in your free time? It's very, very hot and humid in Atlanta right now.

[Brad Greening] It is. And my answer is probably going to surprise you, given that heat and humidity. I actually spend a lot of my free time either playing or refereeing ice hockey around Atlanta, which is great when you can be inside on top of a sheet of ice in this kind of weather. I've played since I was a kid growing up in New Jersey, but I really only started refereeing this sport about four years ago here in Atlanta. And it has not only been a great source of exercise, which is what I started doing it for, but I was a little surprised that I enjoyed it as much as I do,

because you hear all the horror stories of players and spectators wanting to tell you vehemently that you made a wrong call. But it's quite challenging and it demands a level of mental focus, and for me that outweighs the occasional confrontation.

[Sarah Gregory] Back to food for a second, here. Knowing so much about foodborne illnesses, does that put you off food? It makes me think of everything I eat now very carefully.

[Brad Greening] Well, it's certainly an understandable reaction. But for me, I'm usually hard-pressed to say no to a nice, delicious, juicy cheeseburger. I mean, I think of it like there's so many risks every time we walk outside of our front door, and food safety risks are just one of many. So I think all that we really can do is try to balance the likelihood of these risks occurring with an appropriate amount of prevention safety so that we have a good chance of making it through the day and coming back home unscathed. If we try to prevent every single thing that could conceivably happen, we'd probably spend more time on prevention and avoidance than we would actually experiencing the good things in life. So have everything in moderation and keep a good balance is how I try to think about it.

[Sarah Gregory] Well, that's certainly a very healthy, optimistic outlook.

And thank you for taking the time to talk with me today, Dr. Greening.

[Brad Greening] It's my pleasure. Thank you for having me.

[Sarah Gregory] And thanks for joining me out there. You can read the June 2022 article, Public Health Response to Multistate *Salmonella* Typhimurium Outbreak Associated with Prepackaged Chicken Salad, United States, 2018, online at cdc.gov/eid.

I'm Sarah Gregory for *Emerging Infectious Diseases*.

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