Sickness Transmitted by Food and Water

[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. Elizabeth Beshearse, a CDC epidemiologist. We'll be discussing how sickness is transmitted by food and by water.

Welcome, Dr. Beshearse.

[Elizabeth Beshearse] Hey Sarah. Thank you so much for having me today.

[Sarah Gregory] What's the magnitude of the disease burden from food and water?

[Elizabeth Beshearse] So, understanding the true magnitude of illnesses transmitted through food and water is challenging. And when we think about magnitude, it doesn't necessarily just mean the number of people who get sick. But we also want to think about hospitalizations, deaths, and healthcare costs. Some of the reasons for this are...because when people get sick with many of these different food and waterborne pathogens, they often don't actually go to the doctor. And even if they do go to the doctor, you know, they don't always get the test that would detect the pathogen that made them ill. So, what happens then is this leads to a large gap between the true burden of illness and the illness...illnesses that we have confirmed through laboratory testing.

Another complication is that many of these pathogens can make people sick through pathways that are different than food and water. So, not just food and water makes people sick, for these pathogens. Other ways include contact (direct contact) with animals, for example. And different methodologies have been applied to try and overcome these gaps between, you know, this true burden and magnitude and what we actually have laboratory-confirmed data for and getting to creating those burden estimates that are accurate. So for example, for foodborne illnesses, you know, Elaine Scallan and her colleagues estimated in 2011 that of 31 known pathogens transmitted commonly through foods, they cause approximately 94 million illnesses, 56,000 hospitalizations, and 1,350 deaths each year in the United States. And then there's also a paper by Sarah Collier that was recently published that updated estimates on the waterborne disease burden, and this estimated approximately 7.15 million waterborne illnesses that occur annually resulting in about 3.3 billion in direct healthcare costs. And this is just from 17 known waterborne infectious diseases in the United States.

So, kind of as you can see despite all these advancements to protect our food and water supply, these illnesses remain a major burden in...in the United States. So with all that said, in order to under....to get a better understanding of the ways that pathogens can be transmitted in addition to food and waterborne routes, we went ahead and did a study looking at the proportion of illnesses that are transmitted through different pathways in addition to food and water.

[Sarah Gregory] Ok. I want to just throw in here that Sarah Collier's article is also published in the EID journal in January 2021.

Why did you do this study?

[Elizabeth Beshearse] So, there are a few reasons. The methodology that we used, which is called structured expert judgment, has been used increasingly to assist with burden of illness estimates in other countries as well as globally for foodborne estimates that were performed by the WHO. But it hasn't been applied to this extent informing burden estimates in the United

States. So, we undertook this study to help inform, you know, these burden studies for here in the United States and other types of studies by providing estimates of the proportion of illnesses that are transmitted through each of a comprehensive set of five transmission pathways. The estimates from this study can then be applied in the process of creating burden estimates. So, they do this by allowing researchers to estimate, for example, the number of illnesses, hospitalizations, or deaths caused by one of the modes of transmission by specific pathogens. You know, in fact I mentioned earlier—as we mentioned earlier the paper by Sarah Collier—they have already used the results from this study to update the waterborne burden estimates in the United States. And we expect that these will be useful to CDC updating its foodborne burden estimates.

[Sarah Gregory] You used reports of estimates from what you called a structured expert judgment study. What is that?

[Elizabeth Beshearse] Structured expert judgment is a methodology that can be used to combine estimates that are produced by experts to quantify uncertainty for the purpose of risk analysis when limited or no data exists. So, there are multiple ways to approach this and we used a methodology called Cooke's classical model, which is the most mathematically rigorous. Now, there is quite a bit that goes into this. But for our study, we had 48 expert participants from across the United States and Canada who did participate. And, you know, they had to receive multiple training sessions in the methodology. They provided not only an estimate for the proportion of illness transmitted by each pathway, but also an uncertainty bound. So what that means, for example, you know you can get sick from eating food contaminated with *E. coli* but you can also get it from directly contacting an animal or consuming contaminated water. So what each expert did was estimate these kind of in this way.

So based on all the research and data available, as well as my personal professional knowledge about what the limitations of these available data are, I estimate the proportioned illness transmitted through food is 60%. But this could be as low as 40% or as high as 77%. And experts did this for each of our five transmission pathways for each pathogen that they were assigned to. Each expert does also go through a calibration and weighting process, which is also applied to their responses. And then in the end, what ends up happening is the experts' responses are combined to produce a single estimate with uncertainty bounds.

[Sarah Gregory] Why did you choose this method?

[Elizabeth Beshearse] So, structured expert judgment is really used when the ability to gather data or use other data-driven approaches is hindered by high expense, data scarcity, or just a lack of reliable data. You know, as I mentioned earlier in the case of food and waterborne illnesses, these data gaps exist and make it challenging to approach these types of research questions with strictly data-driven approaches. You know, if it were possible to use fully data-driven approaches or complete data exists, structured expert judgment would not be necessary. Structured expert judgment allows experts to apply their professional knowledge about the limitations of the data as well as combine and synthesize available data and research that we don't currently have methods that can combine that data in a mathematical way.

[Sarah Gregory] You distinguished different pathways. What are they?

[Elizabeth Beshearse] So for our study, we included five major transmission pathways. And these are considered comprehensive as well as mutually exclusive. So, they cover 100% of transmission for each pathway. Instead of just taking estimates of a single pathway, we did all 5 to cover this full comprehensive 100% of transmission. You know, these...the pathways that we included were foodborne transmission, waterborne transmission, person-to-person, animal contact, and then environmental.

In addition to these (which we consider our major pathways), we also included some nested subpathways that fit underneath those. For example, for foodborne transmission we included food handler–related. And then for waterborne, we also looked specifically at drinking water, recreational water, and then nonrecreational/nondrinking water. And for the environmental transmission pathway, we also included environmental but presumed to be person-to-person–associated and presumed to be animal contact–associated…kind of lacking that direct, clear link to make it confirmed person-to-person or confirmed animal contact–associated.

[Sarah Gregory] That's a pretty complicated process, lots of little bits to keep track of. Was there anything that surprised you?

[Elizabeth Beshearse] Yes. Well, you know, we knew going into this that the...the design and components of the study were critical. So really a great deal of time was spent just on designing these definitions for the transmission pathways that I talked about. You know, we also had to spend a great deal of time training the experts on precisely how to use these definitions when they were providing their estimates for the study. It was very interesting to me just to learn about the complexities of how transmission itself can be defined just depending on how you choose to look at it. We designed...we ended up designing questions to really probe the edge cases of disease transmission in order to really test the definitions and make sure that they can be applied in the same way by every expert. So these really in-depth discussions about how some real-life cases in these gray areas worked with our transmission pathway definitions was a very interesting process to me just because it had so much detail and so much thought put into it. And when you look at it on paper, it doesn't seem very long but there's so much that actually went into just the transmission pathway definitions.

[Sarah Gregory] How many pathogens were looked at ultimately and which were the most notable ones? I know there were a lot, as you just said.

[Elizabeth Beshearse] Yes. And that's one of the challenges with this study is just kind of the sheer size of it, you know. We looked at a total of 33 pathogens and this included 21 bacteria, 7 protozoa, and 5 viruses. In addition, we also included questions to sort of encompass multiple clinical manifestations in serotypes for certain pathogens. So, for example, due to the diversity of *Salmonella enterica* we included multiple serotypes and an additional category for children younger than five because these were some additional questions we had that needed more than just a single estimate for *Salmonella*.

In another case for *Pseudomonas*, we included three separate clinical manifestations looking at otitis externa (which is also sometimes called swimmer's ear), septicemia, and pneumonia. And because structured expert judgment looks at uncertainty, we didn't...we did not include, for example, some toxin-causing pathogens that are almost exclusively transmitted by food. Which, as I mentioned before, structured expert judgment should be used when there's uncertainty. So, when things...when these pathogens are believed to be almost exclusively transmitted by food, then we don't need to use structured expert judgment to look at those. So, ultimately this led to a total of 47 questions across 33 pathogens.

[Sarah Gregory] Alright, why don't you take a little bit of time right here to tell us briefly about your study?

[Elizabeth Beshearse] So, you know, the process for designing this type of structured expert judgment study is really kind of divided into three primary stages, and those three are the preparation, the elicitation, and then the postelicitation. So, the preparation portion is incredibly important to ensuring the data that are produced are useful. And it actually tends to take the most time with a study of this size. So what's kind of included in this preparation stage is, you know, identifying and selecting the pathogens that would be studied—you know, as I mentioned, creating those definitions for transmission pathways and the point of attribution, selecting the experts that are going to be participating in the study, assigning experts to the pathogens that they would be providing estimates for, creating calibration questions to really kind of test the experts, and then creating tools that would be used by the experts when they are actually providing their estimates. And as I mentioned before too, a great deal of training accompanies this for the experts to make sure that they're, you know, applying the transmission pathway definitions in the way that they are designed, how to use the tools that we created, how to provide these estimates. And then also before we embarked on actually performing the elicitation, you know, we tested these materials with a group of experts that weren't actually going to be participating in the elicitation to ensure that they were user-friendly. So as I mentioned, this stage tends to take the longest. But each of these steps are critical to ensure the data are usable.

So, then step two would be actual elicitation. And for us, the elicitation stage was a 2-day, in-person workshop that included 48 experts. This stage included training and it was a period in which the experts completed their calibration questions and provided estimates to the pathogens that they were assigned to. Then finally, the postelicitation phase is really when we do our data analysis. So not only for the pathogens, but also to evaluate the expert performance in the study. And in doing that data analysis, we did find excellent expert performance among our study participants.

[Sarah Gregory] I'm sure you found an enormous number of very important issues, but what do you consider the most important issues that you found? And anything different from other food and waterborne disease studies?

[Elizabeth Beshearse] So, we did find differences from previous estimates for foodborne transmission for many different pathogens. And I...I think it's important to note that these differences can also exist just simply due to changes in data availability and the analytic methods that have become available over the years. Just due to the sheer number of pathogens that we looked at, I won't go into all of them, I'll just highlight a few.

I think one example that we found pretty notable was for *Salmonella*. You know, the most recent US burden estimates that I kind of mentioned earlier that were produced in 2011 had an estimate for the proportion of illness transmitted by food at 94%, whereas our study estimated this at 66%. So, that's kind of a large difference. But that 66% that we found is much more similar to estimates done in other countries that also used structured expert judgment.

Another example would be previous estimates used for foodborne transmission of astrovirus, rotavirus, sapovirus were all considered <1%. Our study estimated astrovirus at 15% foodborne transmission, rotavirus at 5%, and sapovirus at 13%, all of which are higher than that previous estimate of <1% being attributed to foodborne transmission. So, that's just a highlight of a few, especially with the foodborne transmission route. As far as waterborne transmission, you know, this type of attribution with comprehensive pathways haven't been done before in the United States. So especially for the bacterial pathogens that we were included reflected many pathogens' estimates, suggesting that the proportion of illness linked to water may be higher than was a...was appreciated previously.

[Sarah Gregory] Is there a way to stop or slow all these transmissions? I know that's a really huge, broad question. Is there anything public health can do?

[Elizabeth Beshearse] Yes, definitely. There's been incredible progress made over the years with regard to food safety, water treatment, and sanitation. And, while it isn't possible to completely stop food and waterborne disease transmission, public health is continuously working on these issues and they continue to improve as we learn more. So, stuff that public health is...is doing really include building...you know, building capacity to improve surveillance using things like molecular technology; whole-genome sequencing; you know, collaborating with local, state, and federal partners to investigate outbreaks. You know, understanding the sources of sporadic illness. And sporadic illness is illness that's not associated with outbreak to kind of develop and implement strategies to prevent...to prevent them in the future, really using these results to help inform which pathogens cause the greatest burden so we can really target preventative efforts. And then communicating with the public about food safety risks and steps they can take to protect their health. You know, and then on the waterborne side, some of the work public health does really includes, you know, researching the health impact, tracking disease, and developing new laboratory methods and materials, and then communicating also with policymakers (so not just the public but also policymakers) and sharing that information.

[Sarah Gregory] What about individuals? What kinds of things should people be doing to protect themselves?

[Elizabeth Beshearse] A great question. So with, you know, food safety, there are four big steps, and we kind of think of them as clean, separate, cook, and chill. So I'll kind of go into a little bit more detail about each of those. So, cleaning really includes making sure that you're frequently washing your hands and cleaning off your cooking surfaces. Separate really means to keep products like raw meat, poultry, seafood, and eggs...keeping those separate from ready-to-eat foods to prevent cross-contamination. This includes not only your cutting boards, but also while those products are in the fridge. Cook—includes making sure foods are cooked to an internal temperature that will kill the pathogens that can make you sick, and the best thing to ensure that this is being done is to use a food thermometer. And then finally chill, which means to refrigerate perishable foods within two hours or one hour if outdoor temperatures are above 90. So…

And then thinking about water, you know, we come into contact with water in many different ways, which is one of the reasons it was important for this study that we look at those subdivisions—looking separately at these different sources of water—so, recreational drinking and then nonrecreational nondrinking. You know, and while waterborne germs can cause gastrointestinal illness if they are swallowed, you know they can cause illnesses in other ways too. Like for example, if they're inhaled, you can get illness in the lungs; if you have a wound that comes in contact with contaminated water, the skin in that wound can also get infected. So there...there are different ways other than gastrointestinal illness that water can cause sickness in folks. And I'll just give an example here...when, you know, we think about recreational water, this can include aquatic facilities like swimming pools or natural bodies of water...you know, kind of wherever people are using it for recreational activities. You know, for swimming, the best thing to do is to keep the germs out of the water to begin with. So, any individual with diarrheal illness in the past two weeks really shouldn't go swimming. And for those that are swimming, try to keep water out of their mouths and then ensuring that they are drying their ears out after swimming to help prevent otitis externa, which is also called swimmer's ear like I mentioned before. That's some examples of things people can do.

[Sarah Gregory] How would people dry their ears out?

[Elizabeth Beshearse] So, you know, one of the ways you can sort of keep your ears dry after swimming, you know....use a towel to dry your ears very well, be sure to tilt your head and hold the ear facing down to allow that water to escape the ear canal. You can also pull on your earlobes in different directions while the ear is facing down to help ensure that water is draining out fully.

[Sarah Gregory] You mentioned earlier that there were some challenges. Do you want to elaborate on that a little bit?

[Elizabeth Beshearse] Sure, I'd be happy to. Anyways...I sort of mentioned it before, but one of the biggest challenges is just due to the sheer size and scope of this project. You know, it was a very large project that required collaboration between many different moving parts. It was a challenging task to coordinate these efforts, which included gathering input from experts on individual pathogens, the research team at the University of Florida, our analytic team who are the experts in the structured expert judgment methodology, the 48 expert participants, and then multiple teams just within CDC as well, you know.

And then another challenge with this type of research is that public health and infectious disease epidemiology can really change rapidly. So experts can really only provide estimates considering the data that's available at that time. And after they provide those estimates, you know, what we know about the transmission can change. So, it's really important to consider kind of the context on when these estimates were given when interpreting them.

[Sarah Gregory] Are there any actions or further surveillance or research that you'd like to see done?

[Elizabeth Beshearse] You know, we've been very fortunate in that this has already been used to produce burden estimates for waterborne diseases. So, we're already getting to see how this work can be used for furthering our understanding of disease burden. One of the things I look forward to with this data is it being used to provide updated foodborne burden estimates similar to the ones that have been produced for waterborne diseases. You know, but overall, I really hope these results continue to help lead to a deepened understanding of transmission through multiple routes so that these data can be used to support how resources are really targeted to prevent infectious disease spread through all pathways.

[Sarah Gregory] Tell us about your work and what you enjoy most about it. I understand you're with CDC now, and when you wrote the article you weren't?

[Elizabeth Beshearse] Yes, that's correct. So, I was still at the University of Florida when I wrote this paper (and that was before I came to CDC). So, when I came to CDC, I'm currently an...an officer with the Epidemic Intelligence Service here at CDC. I'm now currently with the division that works primarily in healthcare-associated infections, and I've had a lot of opportunities to assist with outbreak investigations in these kinds of settings. Fieldwork and really assisting with these sort of things has really been a piece that I really enjoy, and actually my background is in nursing. So, it's been really nice to kind of get back into the healthcare setting. And kind of interestingly, you know, many of these investigations in healthcare settings often include transmission through water. So I've been able to carry over some of this work that we've been talking about into my current role.

[Sarah Gregory] Well along that same theme, what do you enjoy doing in your personal time?

[Elizabeth Beshearse] Well, I've been spending a lot of time at home in this past year, which I think many of us are familiar with. But that's given me really ample time to sort of cook and experiment with new recipes that I really enjoy. It's something that I have always enjoyed but it's given me some more opportunity to really get creative in the kitchen. I think I got three separate cookbooks as a Christmas gift this year, so it's given me even more material to work with.

[Sarah Gregory] Well thank you for taking time to talk with me today, Dr. Beshearse.

[Elizabeth Beshearse] Thank you so much for having me, Sarah. It was wonderful to talk with you.

[Sarah Gregory] And thanks for joining me out there. You can read the January 2021 article, Attribution of Illnesses Transmitted by Food and Water to Comprehensive Transmission Pathways Using Structured Expert Judgment, United States, online at cdc.gov/eid.

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

[Announcer] For the most accurate health information, visit cdc.gov or call 1-800-CDC-INFO.