CDC Ebola Response Oral History Project

The Reminiscences of

Barbara M. Knust

David J. Sencer CDC Museum

Centers for Disease Control and Prevention

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Barbara M. Knust

Interviewed by Samuel Robson
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Interview 1 of 1

CDC Ebola Response Oral History Project

Q: This is Sam Robson, here today with Barbara Knust. Today's date is April 8th, 2016, and we're here in the audio recording studio at CDC's [United States Centers for Disease Control and Prevention] Roybal Campus in Atlanta, Georgia. I'm interviewing Barbara as part of our CDC Ebola [Response] Oral History Project. Barbara, thank you for being here with me.

Knust: Thank you for inviting me.

Q: Of course. It's a pleasure. For the record, could you please state your full name, and your current position with CDC?

Knust: My name is Barbara Marie Knust. I am an epidemiologist in the Viral Special Pathogens Branch, and I've been in that position since 2009.

Q: Great. Thank you. Can you tell me when and where you were born?

Knust: I was born in Michigan, in 1978.

Q: And where did you grow up?

Knust: I grew up in Michigan. I went to school there for both my bachelor's degree and for my veterinary degree. Then I went to New York State and worked in New York State in a veterinary practice for a few years after that point. I was very interested in working in public health, however. Got into some different research projects and public health projects when I was in veterinary school as a student. I wanted that clinical background, though, because the veterinary degree really covers the clinical side of veterinary medicine so much. I worked in practice for a few years, but I knew that it was something that I really wanted, to eventually go into public health. I went to University of Minnesota after about two and a half years in practice and did a veterinary public health residency at the vet school. And also worked on my master's of public health at the same time.

Q: That's a great outline of your education. I'm just going to back us up just quickly.

Knust: Okay, no problem.

Q: Can you tell me about growing up in Michigan—

Knust: Yeah, sure.

Q: —and, like, what your parents did?

Knust: Sure, yeah. I grew up in a semi-rural area, I guess you would say. We had horses, and when I was little, we raised dairy steers, as well for beef. So, had a little bit of an agricultural interest, or background. But we weren't, like, real farmers. You know, real farmers make money off of all of their farming activities, and it was more like a hobby than really an economic endeavor. My parents both had master's degrees. My mom stayed home with me and my brother, and my dad was working as a statistician for the state of Michigan. They both were very interested in other cultures. So I grew up learning about other cultures. Neither one of them had much of a medical interest, or medical background, and I think that I got interested in veterinary medicine just from the exposures of being around the animals that I grew up with—the horses and everything—and then having veterinarians come to the farm and seeing what they did. Thought that it was very interesting.

Q: When you graduated high school, were you already pretty set on going that route?

Knust: Oh, yeah, yeah. I wanted to be a veterinarian from about twelve years of age on. So yeah, it was a pretty early interest. I grew up riding horses and doing a lot of outdoor activities. I didn't travel internationally all that much until I graduated from high school and I went to Germany for like six weeks. That really got me interested in working and living—doing things overseas more. An interest in overseas work, an interest in veterinary medicine, and then later, got an interest in infectious diseases, and especially diseases that can transmit between animals and people. That really was very fascinating

to me. So public health, and especially international public health, really started to look quite appealing.

Q: Where did that other interest in infectious diseases come from?

Knust: Before I went to veterinary school, one of the requirements of being accepted into veterinary school is that you have to have some experiences with veterinarians, working with veterinarians. I had worked in a small animal clinic, just walking dogs and giving baths and doing whatever they needed somebody in the back room to do. That was fine, but I wanted to get a different experience as well. I had learned about a research project that was going on at the veterinary school that was looking at a disease that affects horses, that's a parasite. The host of the parasite is opossums, and then they were looking to try and understand what other hosts there might be, and how horses get infected, and what kind of control measures there might be. I wound up working in this research lab for a summer while I was still thinking about going to veterinary school, and got just an amazing experience working in a lab. This great exposure of understanding that a disease—in order for an animal to get infected with a disease, that it can be multiple different species interactions that can go into that and have the effect there. Also it was a diagnostic lab, so I got to do a lot of work on running different diagnostic assays. I just really found it to be very interesting. It was a little bit of everything, in terms of—and then the epi [epidemiology] side of things was definitely in there, too. I really liked it a lot. That definitely translated in later studies, too, and to other things that I got involved in.

Q: Right on. Thank you. And so, I think—and you've described, you went to New York, you came back to Minnesota, went to master's in public health school. Was there a direction that you started to drift to in public health school that—I don't know.

Knust: I really already had a very strong interest in zoonotic diseases, or those diseases that can be transmitted from animals to humans. That definitely was a focus of my studies when I was doing my MPH [master of public health degree]. As part of the veterinary public health residency that I was doing, I was working on some different projects that had a zoonotic disease component. At the time, there was an outbreak of bovine tuberculosis that was in cattle. Bovine TB can be transmitted to people. As a result—it's actually a disease that really hardly exists in the United States anymore in people because the Department of Agriculture had a big eradication effort. Things like, everybody drinks pasteurized milk unless it's a very small subset of people. Those kind of efforts really help to reduce the infectious disease burden in people. Then they also eradicated it mostly from the cattle herds.

There's a few places where there still is bovine TB. Up in Minnesota, when it was discovered, first of all, they basically killed, or culled all of the cattle that were in those herds to get rid of the infected cattle there. But they found that the white-tailed deer that lived right in the same area had also become infected because they were coming into contact with the cattle through the feed that was being put out for the cattle. So my master's project was really looking at those deer-cattle interactions and trying to give

advice to the farmers about how they can cut down on deer coming in and eating the cattle feed sources and reducing that potential for transmission of TB between those two species, and getting it under control. In Minnesota, they were actually quite successful, and they were able to eradicate it from both the wild animal population and from the cattle, which is great.

A similar situation in Michigan. It's basically endemic in the deer, and so in this one particular area, where they have white-tailed deer that are infected, they can't get rid of it in the cattle. It's just always there.

It's those kind of things that I find to be very interesting. So I applied to the EIS [Epidemic Intelligence Service] program here at CDC, and got into that. I started EIS in 2009. In the different areas that I was looking at getting an EIS position, I was very interested in zoonotic diseases, so Viral Special Pathogens Branch had an opening. And especially I was very interested in the ecological components because they have things like hantavirus and Nipah virus, and also, there's a lot of international work. Ebola was also there on the list, but it wasn't—I think a lot of people sort of assumed that, oh, the people who work in Ebola, they're just adrenaline junkies, and they just want to do Ebola outbreaks. For me, it wasn't like I thought, oh, these guys do Ebola outbreaks, that's totally what I want to do. It was more just another thing—another disease that was very interesting, but it wasn't the only disease.

Q: Can you talk about some of the outbreaks, while you were in EIS, that you were a part of responding to?

Knust: Oddly enough, I didn't have any actual, true outbreaks that happened while I was in EIS. [laughs]

Q: Okay. Sorry, that was a silly question to ask.

Knust: It's kind of a funny—

Q: Right after you say that—

Knust: [laughs] Well, it was sort of a funny situation, but we had a very quiet period from 2009 to 2010, when I was—or to 2011, when I was an EIS officer, that we didn't have a ton of things going on. There had been outbreaks previously. I got involved in a lot of surveillance work and different things. I helped with some hantavirus field ecology studies, where we went out to a cattle ranch in Montana and trapped deer mice and collected blood, to test them for hantavirus. Then went to the Philippines. It was sort of some after-action activities. They had discovered Ebola Reston in some swine in the Philippines. We went there to help with the diagnostic testing and talk about further surveillance activities they could do to better understand how widespread Ebola Reston infection might be within the swine in the Philippines. No human cases with that, by the way. It was—it doesn't cause—Ebola Reston doesn't cause disease in people. But it

still—it's closely related to the other Ebolas that do cause disease. So, we certainly watch it very closely and want to better understand why that is, and also make sure that at some point, it doesn't become a disease that affects people.

I also went to Saudi Arabia. They thought they had a Rift Valley fever outbreak. It wound up not being the case, but I did some discussions about surveillance there for both Rift Valley fever, and for another tick-borne disease that they have there, called Alkhurma virus. I got to be involved in a really interesting vaccine project that we did on Rift Valley fever, which is a disease that's both in livestock and people. It's an opportunity, kind of similar to rabies, that if you vaccinate livestock, you could stop an outbreak from happening in livestock so that people don't become infected. There was a vaccine that was developed by some members of Viral Special Pathogens for sheep. We vaccinated the sheep, and then actually challenged them with the virus to see if they were protected from it or not. As a veterinarian, that was a really fun thing to participate in.

Q: How did the sheep fare?

Knust: Oh, they did great, actually. The vaccine works very well. I also went to Kazakhstan for some Crimean-Congo hemorrhagic fever work, after they had some cases there. So, yeah, lots of different viruses. Very interesting stuff. The only Ebola case that occurred while I was an EIS officer was a single case that was in Uganda. I was actually pregnant at the time, and just past the point where I was a little too far along to be able to travel anywhere. So I didn't wind up being able to participate in that.

Q: Right. But I believe—but you did go to Uganda again, for the first time I suppose—

Knust: Yes, indeed, yes. So—

Q: —in 2012. After EIS.

Knust: The year of outbreaks was 2012. We had a number of outbreaks go on in that year. It all started in May of 2012, when I got a call from a physician that was in Indiana who said that he had this person who said that he works on a rat farm, and he had meningitis, and his girlfriend also had meningitis. It wound up being an outbreak of lymphocytic choriomeningitis virus. You probably have not heard of that one before. [laughs] It's a virus that's carried in mice. In people, it can cause meningitis. In pregnant women, it can infect the fetus and cause some pretty severe birth defects, not similar to Zika virus, but the same kind of concept. In some people, it can cause some very severe disease. That was the first outbreak, and it was a multi-state outbreak. There were twenty-one states that these infected mice had gone to—been sold to. There were a lot of people that were working at the mouse breeding facilities that these mice were living in originally who got infected. That was a big outbreak investigation. It was very interesting in terms of trying to figure out how to measure the disease, both in the animals and in the people, and correlate them to each other.

Just as we were working on that, notifying all the states that had mice that had been sold to them, we found out about the first Ebola outbreak in Uganda. We just had an EIS officer coming on to join our branch, and I was her supervisor. She was just finishing up with orientation and basically had to leave a couple days early to go to her first Ebola response. Also traveling along with us was Richard [E.] Besser from ABC News, who was going as an embedded journalist to document the CDC activities relating to this Ebola response. It was a little bit stressful, just because of having—I didn't have a ton of media training before that. Having a TV camera over my shoulder was a little bit nerve-wracking. But it turned out very well. Every Ebola outbreak is extremely complex, and every Ebola outbreak has its issues. But in comparison, it was like a dream come true. [laughs] The issues were very minor, and it was actually wrapped very quickly. It was a good response. The ABC News piece was very nice, and everything turned out well.

But we didn't have much time to bask in that, because just as I was coming back from that, we found out about an outbreak of hantavirus in Yosemite National Park. There were a total of ten cases of hantavirus, and it was in people who—most of the people had stayed in a particular kind of housing at Yosemite National Park. The housing had to be destroyed, and since it's such a popular park with so many visitors, there was a lot of public concern, so that was a very intense time. Then we also, at the very same time, had another Ebola outbreak in Democratic Republic of Congo. There was a team responding to that outbreak there. It was a complex outbreak. There was a lot of resistance in the community, and a lot of chains of transmission that didn't necessarily link to each other, and so it was difficult to be absolutely sure that it was under control. It sounded very

similar—like now, thinking back on it, it was a very similar situation to what we had in West Africa. But fortunately, it was in an area where people weren't traveling very far and wide. But it did get under control, eventually.

And then, just as that was quieting down, we had a Marburg outbreak in Uganda. So we went back to Uganda again. Marburg is very similar to Ebola, similar kind of outbreaks that are transmitted the same way, similar disease picture. So we investigated that outbreak. Then, just as we were finishing that up, there was another Ebola outbreak that was diagnosed in Uganda. Fortunately, that one was just a handful of cases. It was, like, seven cases, and that was the end of it. That one got wrapped up pretty quickly, but yeah, it was a very intense several months there.

Q: Sounds like it. I have a few questions, if that's okay.

Knust: Yeah, sure.

Q: When you're responding to Ebola and Marburg in Africa, what aspects of the response are you most heavily invested in?

Knust: So, I guess I'll talk about the older Ebola responses, versus the—

Q: Versus 2014?

Knust: —one that we had—yeah, yeah. 2014 and 2015 were a completely different ballgame. Although, in many ways it's the same elements that get involved. It's just the scale of magnitude and what you can be involved in is different. A typical Ebola outbreak, the kind of things that we would get involved in is investigating the cases, going to the places where cases had been diagnosed, trying to list contacts, and interview people to understand who might have had contact with the Ebola patient while they had symptoms. Also, trying to trace back the outbreak, and trying to understand how this person got Ebola. Trying to figure out who the original person in the whole outbreak chain of transmission was.

For example, in the Marburg outbreak in 2012, there were a couple Ebola cases—or not Ebola. I'm sorry. There were a couple Marburg cases that were found that both had Marburg in the same place at around the same time, but they didn't know each other. There was no connection between the two. We thought that was pretty strange, so we wanted to try and figure out, okay, there must be other cases there. The sequence of the two—they looked in the lab, and the genetic sequence of the two was the same. So it was the same outbreak. It wasn't two different outbreaks going on in the same place at the same time.

Ilana [J.] Schafer, who was an EIS officer, and I, and Luke Nyakarahuka, who was an epidemiologist that works in Uganda; we went, and we interviewed—there was this one case, it was a taxi driver. He survived. So we went to interview him, and he—first of all, he had a machete in his hand. He's a farmer. It's very common for farmers in Uganda to

just have a machete. It's a very normal tool that they have. But he's sort of absently whacking at a tree, or something, with his machete, as he's talking to us. [laughs] And we're asking him these questions about, "What do you do in the month before you got Marburg?" And he's saying, "All these people come, and they ask me these same questions. And here you are, you're just asking me the same questions as the other people did." He was very frustrated, we could tell, with us, because we were just asking him all these questions that a whole bunch of other people asked.

But we asked him, and basically, he had been a motorcycle taxi driver, and we asked him, "Did you take anybody around who was sick? Or did you take anybody to a funeral?" And he said, "I did take somebody to a funeral. But she's healthy. She didn't get Marburg." We asked, "Can we get her phone number?" So he gave us her phone number. We call her up, and we go and interview her. We are asking her all these questions, and just don't seem to be going anywhere. Then, somehow, we just asked the right question, in the right way, about the funeral that she went to. We asked, "Were there a lot of people who died in that family, or a lot of people who were sick in that family?" And then, all of a sudden, it was like the lightbulb went on, and she started telling us about all these people in that family who had died. And we thought, okay. Maybe she never got Marburg, but somehow, these people are connected to each other. We wound up interviewing more people that were within that family. Driving all over the countryside to interview anyone and collect blood from anyone who had been sick at that time. And sure enough, they had been Marburg cases. We wound up finding another ten cases in that process. That's the kind of thing that a lot of time, epidemiologists do.

Working on the data management is another big part of it. There's forms that are filled out, getting all those forms entered, making sure that they all are clean enough to be able to analyze the data, and trying to understand later what the risk factors were for infection and everything. We do a lot of that kind of work. A lot of times, it's a little bit of wearing several hats, too. Sometimes, you're also trying to figure out how to get blood tubes and packaging materials to a clinic so that they can collect a specimen on somebody who looks like they have symptoms. Sometimes you just are running around, doing a lot of different things. And sometimes, because you're in a situation, and you're the only person who knows anything about Ebola, you're answering a lot of odd questions about it, too.

Q: Like what?

Knust: Can mosquitoes carry Ebola? Or, can Ebola be in the water? Those kind of questions, because people will be very scared, and there's often a lot of rumors that circulate. That's a lot of times the kind of things that you do when you're out in the field. It's always a response that calls for a lot of different players. There's clinical groups, like Doctors Without Borders, and then there's the World Health Organization, and then the local ministry of health. A lot of times, these groups have never worked together before. Or sometimes they have, but trying to bring everyone together and organize in a way that maximizes the activity and the people that are there, it's a complex thing. It's really exhausting but rewarding. I'm sure that a lot of people that have worked in the field for

the Ebola response say the same thing. But for this Ebola response, I wasn't working in the field so much, so it was a little different working back in the EOC [Emergency Operations Center] instead.

Q: No doubt. Well, we'll get into that. I am interested, actually—I'm sorry, I'm rewinding again, a little bit. In EIS, you ended up staying on at Viral Special Pathogens.

Knust: Mm-hmm.

Q: Can you talk about that?

Knust: Yeah. I really enjoyed working in the branch. It's a branch that has a lot of laboratorians. So you're very close to the real science and the bench-top work that's being done. I really enjoyed that. I really enjoyed that we have ecologists and veterinarians, and then the diseases themselves are so fascinating. So I wanted to stay. And I was able to. I felt really excited about that opportunity.

Q: Right on. Can you talk about some of the people who you worked with, who are, I don't know, important to you, or influences on you?

Knust: Yeah, so going back to—I guess, are you asking for people that are within CDC? Or also before that as well?

Q: I—actually, yeah. Within just—let's do all.

Knust: Okay.

Q: Let's do it all. [laughter]

Knust: Okay, so, when I was working at Michigan State University, Linda [S.] Mansfield was the veterinarian that I worked with in the parasite project that was studying equine protozoal myeloencephalitis. She was a really great mentor for helping me understand how scientific research is done and giving me a lot of really great opportunities. I also worked with John [B.] Kaneene at the veterinary school, too, who was an epidemiologist and very excited about epidemiology. He was a great mentor for that. And at University of Minnesota, I worked with Scott [J.] Wells on the bovine TB project.

Since I've been at CDC, Pierre Rollin has been my boss. Hopefully, he's on your list of people to interview. Has to be, really. He's just a wonderful person to work for. Such a wealth of knowledge, and then just really has a lot of perspective and great ideas on how to respond to things. Also, I really appreciate being able—he gives you room to develop your own methods, and he just has a great way of letting you explore things. I really enjoyed that a lot. Then, also, other people—Stuart [T.] Nichol is the branch chief. He has really a lot of amazing experience as well, and Ute Stroeher is also really, really knowledgeable. They're all subject matter experts in an amazing way. Far beyond me. I'm an epidemiologist, which means I'm kind of like a Swiss Army knife. I can

understand a lot about different things, and do a lot of different things, but they have a depth of understanding that's just—the true virologist, that's really comprehensive.

Q: Gotcha. Okay. That was a wonderful analysis. It's almost as if you had written it before. [laughter] You're really good at this.

Knust: Oh, thank you.

Q: Yeah. So, we've talked mostly about the career, and that makes sense, because we're talking about your response. But can you talk a little bit about personal life, too, about starting a family, for instance?

Knust: Yeah, sure. I married my husband just before starting EIS, actually. He and I met when I was working in practice in upstate New York. He was working there and living there as well. When I went to Minnesota, we were a long-distance relationship. When I got the job in Atlanta with EIS, we decided we'll go there together. And so we have two kids. Our daughter, she is four-and-a-half years old, and she was born in July of 2011. And our son was born in May of 2014.

Q: Thank you for that. I like to have a little balance between the two. So, what are you doing immediately before getting involved in the Ebola epidemic of 2014?

Knust: We were doing a variety of different things. Because our branch has a lot of different diseases, a lot of times, we'll be involved in a lot of various little projects. Especially after all of the epidemics that we had in 2012, 2013 kind of served as a year to get caught up from all of that. We had a few small-scale other things that went on in the meantime, but yeah. In 2014, when we first found out about the Ebola response, or the Ebola epidemic—I guess setting the stage for it, I was eight months pregnant. We had a [veterinary] student with us, and then our EIS officer was just finishing up. Ilana Schafer was just finishing up as well, with her EIS experience.

We got a call initially from MSF [Médecins Sans Frontières]—or maybe it was an email from MSF that basically said, "Can you call us?" [laughs] They had some news, and we'd heard that there was some specimen that was being tested in Institut Pasteur, and so, we assumed that it was probably the results. We gave a call, and they told us about it. And we said, okay, what are we going to do? Because I was in advanced gestation, I wasn't going to be able to travel anywhere. Pierre and Ilana immediately made some plans, and then we also looked around to see who else was French-speaking that could go. We came up very quickly with Craig Manning, who's a communicator within our branch, and then Andrea [M.] McCollum, who I think you already interviewed. She went as well. There might have been one or two additional people that went in that very first team, but that was the first team to go to Guinea.

It was interesting. I actually remember, when we first hear about it, we hear that the European lab was going, and Stuart Nichol actually said, "Oh, well, forget it. We don't

need to send anybody. We can sit this one out." The idea, with the information that we had at the time, was that it was a small outbreak, there was a lab that was already covered, WHO [World Health Organization] seemed to have a team of people that were going. So maybe our help wasn't really needed. And then we talked about it a little bit more, and we said, well, maybe at least an epi team. We should send an epi team. And so, that's who we sent.

It really appeared in some ways to be like a typical Ebola epidemic. I mean, especially the first month of the response, it didn't appear to be that unusual, from what we had seen before. I think that there were some assumptions made that it was going to wrap up like a typical Ebola epidemic, and no, it wouldn't be absolutely perfect and pretty, but it would stop. And then, obviously, that wasn't the case.

Q: Right. So, when did you become much more involved in the response?

Knust: Oh, I mean, I was much—I was very involved, from—

Q: You were already involved—

Knust: —yeah, from that point. So—

Q: Just, in Atlanta.

Knust: Yes. Being in Atlanta, just to better clarify that. First of all, there was a piece of making sure that the people who we were organizing—so we pretty soon realized that, okay, we need to send some people to Liberia. Then we also need to send more people to Guinea. And we quickly realized that there was some training that we had to do for people. I was involved in sharing a lot of materials and helping the people who were getting ready to respond get up-to-speed on Ebola. And then also get up-to-speed on the data management system that we were introducing, as well, because there was some training required for that. Then also, getting in touch with the embassies, and any points of contact that I could, to try to understand what was going on in the other countries. We pretty immediately got requests from Côte D'Ivoire, from Mali, to test specimens or to send information about Ebola. Because this part of the country really didn't have any materials or training to deal with this virus. A lot of it was compiling things, trying to scrounge things together, in both English and French. And then also helping in Liberia, too, and trying to understand who to even talk to in Sierra Leone. Because, as you might be aware, the CDC presence in these countries was very small. In Liberia, there was one health officer there. In Guinea, there was one health officer there. In Sierra Leone, there was no one who was actually a CDC employee, or any kind of health-related embassy position there. We really didn't have a firm point of contact for several months. We were reaching out to whoever we could find, to send some materials and say, here's the case report form, in case you see cases. That was a big job, just trying to keep tabs on that kind of a thing.

Pretty soon after the outbreak was described in Liberia, we got a call from Minnesota, and they said, "We have this patient who just came from Liberia, and he's got hemorrhagic symptoms and a fever. We think it might be Ebola." Reviewing his symptoms, it didn't sound—I mean, it could have been Ebola, or it could have been Lassa fever, but he didn't have any risk factors and the outbreak wasn't widespread in Liberia. So we thought, maybe it's Lassa. Anyway, a specimen came down, we tested it. Sure enough, he had Lassa fever. So we were dealing with that patient and making sure that we were providing good guidance for the hospital and for the state health department in working with that patient as well, while the Ebola outbreak was going on. We kind of had the three-person EOC, [laughs] and then a few other things—

Q: Who were the three of you?

Knust: —going on. Yeah. [laughs] So—

Q: So the three of you would consist of?

Knust: —the three of me—oh yeah, the three of us were Stuart Nichol, Elizabeth Ervin, and myself. Elizabeth Ervin, she is an MPH epi [epidemiologist] in our group. She came a few years—or maybe one year before the Ebola outbreak hit, and she's still with us, too. She would be a great person to interview, if you want to add her to your list.

Q: I always appreciate suggestions. Yeah, absolutely.

Knust: Yeah, so yeah. We were running around, trying to be a central switchboard as much as we could, just with a small number of people.

Q: No doubt. And are you also communicating with Tom [Thomas R.] Frieden, and with—

Knust: Yeah, so we were communicating up our chain. Our chain eventually did reach the director. However, we weren't really in direct communication with him at that point in time. He did stop by, however. It caught me completely by surprise one day. [laughter] Because my office was over in Building 15. I don't know if you know where that building even is—

Q: I honestly don't. I'm sorry.

Knust: That's exactly it. Nobody ever comes through, is really the point. [laughs] So to have anybody come through, much less the director, is—was really quite a surprise. But good to see him, anyway. That was probably toward the end of April of 2014.

Q: Mm-hmm. And he was just looking for updates, or—

Knust: No, he came by basically to thank us for a job well done, I think, just to say hi. He had a few minutes free in his schedule or something.

Q: Yeah, that makes sense. Because I suppose, by the end of April, when people pull out of Guinea, you're thinking, job well done. Right? There's no idea that this is going to erupt into what it eventually did.

Knust: You know, there were a few indications that things weren't going perfectly. Especially in the eastern part of Guinea, where the outbreak had started, there were reports coming from the EIS officers who were out there that they weren't necessarily reporting every single suspect case that they had, and that there was some doctoring of the sit-reps [situation reports] that was happening. There was some concern that they were maybe masking things and making them look a little bit more rosy than they actually were. I think that it was a very dangerous period because there was a sense that things were going well, and so people were dropping their guards.

But yeah, in the end of April, we were at least optimistic that things were going to be getting better. And then I had maternity leave starting in early May. While I was on maternity leave, I was still checking in to see what was going on with the outbreak. In the end of May, when things really started to go bad, I thought, oh no. When I get back from maternity leave, it's going to be really busy. Not really necessarily thinking that it was going to be anything to this extent, but just—you know, we'd be back to a bigger response, but especially that it was back in Sierra Leone and in Liberia. I really was concerned and thinking that I'm not hearing a lot of information that this is a big response

that a lot of people are running out to, other international organizations and stuff. That did concern me.

When I came back from maternity leave, it was the first week of July, and that was the week that we opened the EOC. By that point, it was almost a foregone conclusion that, yes, this needed to be an EOC response. There was no doubt about it.

Q: You didn't get a whole lot of maternity leave.

Knust: No. [laughs] No, I did not. I had intended for there to be more time, to be a little bit more relaxed. But there was just no way. It was very clear that this was a critical situation and a time where I needed to be heavily involved. Not that I was excited about that [laughs]—that fact. But I could see that taking a more passive role was not going to be beneficial to the agency.

In general, it's not been—it's not been wonderful, from the perspective of missing my kids and not getting to spend tons of time with them all the time. I do hope that—fortunately for them, I think that they're so young that they don't necessarily understand that. This is just taken for granted that that's part of what life is, at the moment. But yeah, it was definitely difficult in those first few months to try and balance anything. But I did feel at least fortunate that I was based in Atlanta, and able to come home and see them, at least for a few hours, before they had to go to sleep at night. Just being around for that was good. It was very good. But exhausting. [laughs]

Q: So when you come back, you said it's the same week that the EOC was opening?

Knust: Yeah.

Q: Wow.

Knust: Yeah, it was. Fortunately, also, it was my second kid. I was a little bit more accustomed to being a mother at that point than I would have been with my first. [laughs]

In terms of the three-person EOC—Stuart, Beth, and me, plus a few other people, Ute as well—we were trying to figure out what all this EOC business was because there's a lot of very specific terms and specific roles that people play, and we really weren't well-accustomed to it. Learning all of that was a big process. There was a lot of other activity as well, and just getting in touch. At that point, there was one team in Guinea. We hadn't sent a team back to Liberia, and so there had been nobody in Liberia since the end of April. There had never been a team in Sierra Leone.

In Liberia, we had some points of contact with Samaritan's Purse in particular, and we got in touch with them to try and understand—they were involved in the ETU [Ebola treatment unit] that was in Monrovia, ELWA [Eternal Love Winning Africa] 2 and ELWA 1. They were working up in the northern part of the country as well. Talking to them, they were very concerned, and they didn't have a lot of really concrete information

because basically nobody had concrete information. They basically were saying, "There's a lot of rumors of cases. We don't know what's true." And it really was very—it was concerning and confusing.

In preparing the first team that went to Liberia, we did our best to brief them as much as we could about the situation. But it was like, basically, there's no surveillance, and people are hearing about a lot of cases that aren't being reported, and things are not well organized. It was a little bit difficult sending them out, and then also, when they got there, they were basically saying the same thing that we'd heard from other people about Liberia. And then a lot of things started happening really fast with that first team that went there.

Satish [K.] Pillai was one person who was in that team, and so was Ilana Schafer. And there was one EIS officer who was up along the border who had to flee the area because of resistance, and had to flee across into Guinea with Doctors Without Borders personnel. There was a fire that was set by an arsonist at the Ministry of Health [and Social Welfare] building like the next day, because the person was frustrated about the Ebola response. There were just some really wild things that were going on, and our team had some very imminent problems. After a few more weeks, that was when there was the diagnosis of Kent Brantly and Nancy Writebol, and that was really—I mean, in some ways, it was the watershed moment that made the United States wake up and pay attention. But it was clearly a sentinel for all of the really disastrous activity related to the response, and just

that the—not disastrous. I'm sorry. The disaster that was forming as a result of this outbreak.

A lot of people were talking about tribal unrest rising up, and different groups using the outbreak as a way to pit one tribe against another, and that was—those kind of things were really quite concerning to think about. I'm so happy that it didn't happen, but to think about civil unrest that was in a direction toward war, on top of an Ebola outbreak, that possibility was very concerning. It almost looked like it was going to happen. Fortunately, the president of Liberia was able to quell that, somehow. But it was a very heated time, in July, August, September in Liberia.

Q: Was that situation with—was that kind of unique, in your experience?

Knust: Yes. I mean, so resistance is not a unique situation for Ebola responses. Resistance is quite common—denial is very, very common. We've definitely experienced that before. Stuart can tell you about situations in previous outbreaks where an angry mob will form and run everybody out of the ETU because they want to come and collect the body of their loved one, or they were upset about how somebody was buried, or didn't trust what the responders were doing, for one reason or another. And that's pretty understandable because it's really—what we do is unusual, in terms of these outbreak response efforts. Forcing somebody to go to a place where they're cared for with people that are wearing really scary-looking costumes that are—we think of it as protective gear, but they think of it as really some kind of bizarre ritual. Then the person winds up dying,

and they don't get to necessarily see the body or see all of the body because of the protection that's needed to protect the other people from becoming infected. People don't trust that. They're very suspicious of that. And I can understand why. And so resistance is normal. I don't know about civil unrest being in that as well, but certainly, there can be a lot of economic effects and health effects from even a normal-sized Ebola outbreak—what we would consider to be normal, it's a few dozen cases—because people don't want to go to the hospital afterwards. They know that that hospital was where there were Ebola patients, and so sometimes, women wind up giving birth outside of the hospital when they should have gone and gotten medical care. That can have adverse effects. Or people don't go to get treatment, and that can have adverse effects. I imagine that there's economic effects as well that can happen, on the personal level, for people who are survivors. And if it's a particular village that's affected, that people would also want to avoid it. So those definitely can have effects, but never on such a large scale. That, I think, was really the difference, and that this was happening not in one place but in multiple places at once, was really—

Q: Gotcha. So you hadn't seen the same kind of ethnic conflict aspect of it before.

Knust: Not that I recall, although my memory isn't as long as maybe some other people's.

Q: Sure. Okay, gotcha. So tell me what happens next. Things are really heating up?

Knust: Yeah. In some ways, yeah, when Kent Brantly came to Emory [University], first of all, it was on a Saturday, and we were at the EOC, working on a number of different things. It was really surreal to be watching the ambulance driving down I-85 and taking the Druid Hills exit, and then driving up Briarcliff [Avenue], and then driving up Clifton Road. We walk over to the stairwell, and we see the ambulance driving right by. [laughs] This was what we were working on. This was what we were dealing with, and it was driving right by our door. Just amazing. And hearing all the helicopters that were getting all the footage coming by, too. And just thinking, this is the disease that I've been studying for a number of years now. It was very hard to completely process and completely believe that it was a real situation. [laughs] That first week of August, to me, it was almost one of the most stressful weeks that we had in the response. Because not necessarily the domestic situation— and when we had domestic cases was, of course, a really unbelievable situation, too. But that particular time, we were barraged, in some ways, with a lot of different questions. There were very few people at CDC who had known much about Ebola at that time who were prepared to answer those questions. Then, also, there was a lot of unknown situation in West Africa. They were trying to suss out. We were having conversations that were somewhat sensitive. Then you'd turn around, and there would be CNN's camera. You kind of felt like you couldn't have a conversation without somebody listening in, even in the EOC. It was a really very crazy week. [laughs]

That month of August was really—there was a lot of interest, and we would have a call, a conference call, and it would be a record-breaking conference call. We had a call for all

of the US clinicians, with an update about Ebola. It was the biggest call that they'd ever had. It was seven thousand people or something that called in. And everything was like that. Everything was like a blockbuster situation, record turnouts for various different events. And realizing that we had a lot of unknowns. There were a lot of things in the science that we had some picture of, but it wasn't like a definitive answer for everything. And people wanted definitive answers. Especially for something that has as much consequences as Ebola, if you get ill, people don't want to just be told, transmission is low-risk if you're not having contact with blood and body fluids. They wanted to know, how low of a risk, exactly? And can you guarantee that this person won't get Ebola? It's very difficult to try and navigate, and then figure out how many different ways that you can say we don't know, for all of the different questions that come up.

Q: Were there interactions with the media that stand out to you, when you look back on them?

Knust: Not necessarily. I was pretty fortunate. I had what I would say were decent interactions with media. I'd never felt like anything was hostile or particularly heated or anything. I felt like it was pretty good. I think most of the—if they knew that it was going to be difficult, they gave it to somebody else. [laughs] I think I just was given an easier hand than some other people might have.

Q: Oh, I don't know. So, what do you—I know that you were putting teams together, for instance. What are you doing, throughout August?

Knust: We had an epi team that was in the EOC. And the epi team was doing a little bit of everything. They were taking clinical enquiries of potential Ebola patients that might need testing within the United States. They were putting together updated data and trying to present new maps and new summaries of the case counts. And also, trying to develop recommendations for various topics. Then working with a lot of other groups to provide my subject-matter expertise for things like healthcare worker recommendations. Recommendations for transporting bodies, or specimens, or whatever. So a lot of input on different things across the board. I wound up working with a lot of different groups, just in all of the different things that came up, as we were working through.

And a lot of the things like making guidance. The sort of previous assumption, before this outbreak happened, was that if we had a domestic Ebola case, that our branch would just go to wherever that case was and provide a lot of very intense situation-specific information, and we'd work through it because it would be one isolated case. And then when this happened, when we had a big outbreak, and we had a lot of people that were in the field, and then a big need to have a lot of support within the EOC, that quickly changed. There was a need to develop general guidance documents that could be provided to clinicians who—we couldn't just directly reach out and touch them. We had to just post things on the website and stuff. That was a very different situation.

And so, really thinking in those terms, and then also thinking about how to be very clear with what we were communicating, when there was so much nuance. Part of it is, you

can squeeze a message into a bumper sticker, but "is that message correct" is the issue. Making sure that what we were saying was scientifically correct and still had enough of the uncertainty built into it, because we didn't necessarily know absolutely 100% for everything, either.

Q: What were some of those nuances that it was sometimes hard to communicate?

Knust: I think a lot of the nuances that were about how Ebola is transmitted were really difficult to communicate. And it continues to be difficult to communicate. For example, there was a lot of discussion at the time about—"could Ebola be airborne" was a big topic of discussion. What airborne means is different to different people. The sort of formal sense of airborne means that something could be—a passage down a hallway, and across a building, and it's a stable infectious particle for a very long period of time. You could walk into a room hours later, and you could still become infected. And that's very true for something like measles or flu [influenza]. But it really—or not flu, actually. But something like measles can be like that, or TB can be like that. But for Ebola, Ebola can be—if somebody has Ebola, and they have the virus in their saliva, and they're sneezing, yes, the virus can be present in that droplet, and that droplet can be in the air, but it's not going to be in the air for hours. So, figuring out how to communicate that in five words is very difficult. [laughs] And we're trying to boil things down, and explain things so that people can understand them easily, but you need to make sure that you don't lose that nuance in the same time.

Q: Right. I think you probably need a drink.

Knust: Yeah.

Q: Probably a break. Do you want to take a quick break? Or are you good to continue?

Knust: I'm fine. Yeah.

Q: Okay. Cool. I don't know, so is the next big thing that happens Dallas? Or—

Knust: Yeah. The next big thing—I mean, I guess the next big thing that happened was that the president came to visit.

Q: Oh, yeah, there we go.

Knust: I was in a meeting, and somebody said, "POTUS [president of the United States] is coming next week." And I said, "POTUS, what's POTUS?" Everyone looked at me like I was completely stupid, and said, "Uh, the president?" I said, "Oh!" And I told my family that I was going to get to meet the president, and they were all excited about it. And I was thinking, I don't know if I'm really so happy to be meeting the president. Not because—I mean, meeting the president is an amazing honor. But the fact that the president was coming here meant that things were not going well. And that was the part that I didn't like.

It really—it took a long time for me—in general, just because I went from the point of being the person who was training everyone who was going overseas, to obviously this response had increased in size by humungous magnitudes, but still in my mind, I still felt a lot of care for the people who were going overseas and a lot of personal responsibility for the response. To me, it was almost like I didn't do my job well enough because we have this outbreak that isn't under control, and now the president has to come, and—you know. [laughs]

It seems kind of silly, but at the same time, it's an important—I really just felt that it was a symbol that we needed—we needed the President to be behind us, to get enough resources to do this thing. That was an amazing thing to see what the process is when a president comes to town, and what the level of resources that go into that visit takes. But it was amazing to meet him, and it was an amazing thing to—an honor to be in the briefing room. I didn't have to give a briefing. I just sat there and was available to answer questions, if he had a random question. And I didn't have to even answer any questions, but that was just fine.

He really had some great questions. He actually had a great comment that I took to heart when he was talking about—we were talking about some of the issues that had to do with the response, and how difficult it was to have enough healthcare facilities and enough healthcare workers caring for these Ebola patients, because a lot of times, just the limitations of the protective equipment that the healthcare workers have to wear, that they

can only be in for a short period of time before they start to become heat-exhausted, and lose too much body fluid from perspiration. He really fixated on that, and he said, "This issue you're talking about, it seems like technology could overcome this if you had enough resources. This is just one example, but think about all the other shortcomings or issues that are blocking your ability to really effectively respond to this outbreak, and think about how you can overcome them with enough resources. I want you to work on that." I thought it was such a great example and such a great thing for him to point out.

Q: Sounds like it might have also been an origin, if this is a later challenge, to create—

Knust: Oh, it certainly was.

Q: —to create the PPE [personal protective equipment].

Knust: Yeah. Yeah, it certainly was. Yeah. I really thought of that as an important turning point, to have him really standing behind CDC and committing resources. The Department of Defense got involved after that point. He went to the UN [United Nations] summit the next week and really rallied to the UN, and a lot of other countries stepped up to the plate. In addition to a number of nongovernmental organizations who stepped up to the plate. There were resources that were now being available. I really felt like that was a very important process, and point, in the response, that we were really getting a lot of help behind this effort.

Q: Good. Okay, so what happens after the president?

Knust: After the president, I was pretty exhausted at that point and I wanted to have a few days off while I had some family visiting. Just as they were coming into town, one of the members of the epi team got a call from Dallas, and he sent an email with a little quick summary about this patient. I emailed him back very quickly, and I said, make sure to get in touch with this person, this person, this person, just to let them know, and make sure that they're getting enough education and guidance on what to do and that they're covering all the bases that need to be covered. Because to me, even from that first little brief description about the patient, I thought this looks like an Ebola case. This looks like it could be real.

That week, I was watching things very closely and I was spending time with my family, but ready to go back to the EOC. I didn't wind up going to Dallas, which at the time I felt incredibly guilty about, but they assured me that they had plenty of people that were doing everything that they could and that I needed to take a break. So I took that time, and then when I came back, things were going well in Dallas, at the time. And then the first nurse became infected.

Actually, one of the little sidebar things was that the whole situation with her dog, [laughs] we had heard that she had a dog. We very quickly started to put together a response plan for what to do with this dog, just in case—it was while she was being

tested, before she even was confirmed. Sure enough, the dog had to undergo an observation period.

Just as that was slowing down a little bit, we found out about the second Dallas nurse. That day, I decided to sit out on the EOC main floor because there was so much going on. It was like—there weren't any meetings. It was just people running around and talking to each other. It was incredibly chaotic. I was out on the main floor, and Dr. Frieden came by. First of all, he was standing there, and he looked over at me and made eye contact with me, and smiled, and said, "Hi, Barbara." At first, I thought, oh no, he knows my name! [laughter] And then I saw his eyes, and he was smiling. But I could see in his eyes, he was really thinking very hard about what was going to happen next. And just a few days later, he was testifying [before Congress].

That night, I was on an airplane flying to Ohio. So I was involved in the response that was in Ohio. We had Chris [Christopher R.] Braden, Matt [Mateusz P.] Karwowski, Colin [A.] Basler, and Carolyn McCarty there, and Kristen Nordlund on the team. It was a great team. We did not have a shard of Ebola virus anywhere in the whole state of Ohio, but we still had a very good outbreak response for it. [laughs] It was very intense, though, because the second Dallas nurse, of course, had been on two airplanes, and it was decided that both airplanes were going to be treated as if she had had symptomatic Ebola while she was on the airplanes. That was a very intense investigation. Then there was also a very intense investigation of everywhere that she had been in the town in Ohio. A lot of community concern—people were thinking that the contact of a contact was a risk of

having Ebola. A lot of discrimination was happening as well, as a result. Discrimination against the known contacts and discrimination against people who even knew them.

Q: Can you give some examples of that?

Knust: For example, there were some children who were—the children of a friend of hers. And they were asked not to attend school. And the friend of hers was completely healthy. The children were completely healthy. But people were just so afraid. The bridal shop where she had worked—or not worked, where she had gone to look at different bridesmaid gowns because she had a wedding coming up, the shop closed its doors. They did a complete cleaning of the shop. The shop still wound up going out of business just a few months later because people were afraid. I'm sure that that's just an example of—I'm sure that there were a lot of other examples in Dallas, as well, of just—people had a lot of fear about it. It was really great working with the county and the state health departments there in Ohio, though. Especially the folks of the county really knew their people well. I think that they were very well-connected, and they did a great job of working to reduce the hysteria and focus on what was really important. They really stood up very well and performed, delivered very, very well. It was really rewarding to work with them.

It was nice to get out of the EOC for a little while, too, and be working and actually doing something instead of—the EOC, it's good. There's a lot of very important functions. But sometimes I like to be a little bit more right on the very front edge and really be

interacting directly with the people. It was a very intense week, but nice to have a little change of pace.

Q: No doubt. So, Ohio. You're in Ohio. You come back.

Knust: Yup. Just as I was coming back—I think I was in the airport, getting ready to board the flight back. There was an email that I was cc'd on from an epidemiologist in New York City that said, "This is not a drill. Ebola suspect patient." I thought, oh no, and read through it, and sure enough, it was an MSF doctor who had recently come back from Guinea. He had a good variety of symptoms, and he was being tested, and indeed, that was our next case.

Mary Choi, who is another person that you should interview, she was actually out in Dallas working with Pierre and working with the crew that were caring for the nurses in the hospital there. She had just come back from Dallas and then was asked to go to New York City. I saw her in the EOC just dropping off some equipment and picking up some equipment because she was immediately being turned around from one situation and going into the other. She looked so tired. I said, "Mary, are you ready? Are you up for this?" And she's like, "Ready or not, here I go!"

Things went very well in New York City. But just as New York City and the response to that was happening, I got a call from Doctors Without Borders, and they said, we have this nurse, and she just got back from overseas, and she's at the airport in Newark, and

they won't let her leave. Sure enough, that was Kaci Hickox. They were asking me what to do. I called around and basically, there was very little that I could do about it. That was the end of October, was that situation where she had a lot of issues and really was very vocal about the way that she was treated. There was a lot of work that we were doing to really clarify what people should be—what states and what kind of follow-up there should be done for healthcare workers and for people that were coming back from overseas.

By the end of October, beginning of November, that was when we really started something that was thought of as maybe unthinkable a few months before, but the process of entry screening, which we wound up carrying out for several months. In many situations with the Ebola response, there was—I remember this conversation that we had with Travelers' Health where there were sort of—there's different levels of advisories that happen as a situation gets worse and worse. The very first was an advisory, where you basically say, there's an Ebola outbreak going on. We were talking about the next steps in the advisories, where first you just make an advisory to say there's an outbreak going on. Then the next step, you actually say, "You should limit your travel to particular areas." Or, "Practice enhanced precautions." Then the last step, you advise not to travel there. I remember thinking at the time, we're not going to need to deal with advising against somebody traveling to a particular place. Then, like two weeks later, we were doing that. It was amazing how some of these things would happen. We'd talk in sort of theoretical terms about doing—it was like, "Exit-screening in the countries. That makes sense. But entry screening doesn't make any sense." And then, of course, a few months

later, it was really happening. It was amazing, some of these things that you think, it's important to think about this, but we won't really need to use it. And then we did. [laughs]

Q: Can you talk more about that, though, because it sounds like "we won't need to do this" comes from that experienced, scientific viewpoint. And then you have to do it. Is it just the political environment that forces it? Is it the hysteria? The fear? What's going on there?

Knust: I think to some extent, some things were fueled by politics. Some of that is unavoidable. I think that it's very difficult to not let politics drive the bus, and to try and keep something that's at least somewhat science-based. On that front, I think that we actually did a good job of holding up at least some pieces of scientific evidence. There was definitely a period of time where we were using the term "out of an abundance of caution" a lot because there were a number of things that we were doing that were possibly over the top, but we kind of had to. I think we still tried to maintain some level of scientific understanding to underpin it. For example, with the entry screening that was occurring, in some ways, for people that had no known exposure—with all of the entry screening that happened, there wasn't a single Ebola case that was diagnosed from entry screening. There was a lot of malaria that was diagnosed. There was also a Lassa fever patient who actually was completely missed by entry screening. But that was because the Lassa fever patient lied and denied having any symptoms at all. But I think entry screening was an important step. I think that it was important, first of all, for airlines to

continue to allow people to travel. And it was important for countries to continue to allow people to travel from the—there were a few countries that did restrict people coming from the Ebola-affected countries, but for the most part, the travel stayed open, even with this outbreak going on. There were airlines that did stop their routes for a while, but there were still ways to get in and out of the countries. It wasn't like they just threw barbed wire around the whole area and let it do its own thing, which would have been a true disaster.

Q: I'm hearing what you're saying. It's like, although scientifically, "out of an abundance of caution" might seem over the top, it has practical effects, which ultimately are useful.

Knust: Yeah. Yeah. I think we really needed especially to not have the situation where somebody was sick for a long time and showed up at a St. Elsewhere kind of hospital that wasn't prepared with advanced Ebola. There was a real need for that to not happen. I think from that perspective that it was a valuable thing. But it was incredibly expensive, and any local health department will tell you that it was incredibly time- and resource-intensive in order to carry that out. I wasn't directly involved in much of any of that part. I was mostly involved in making some recommendations and giving a few advice pieces. But the people who really carried that load, they really worked very hard. I was very appreciative that they dealt with that as graciously as they did. I'm sure that it was very difficult, and there were other programs that suffered in the process because of that.

Q: Okay. Do you need to take a break, or—

Knust: I'm fine.

Q: You're good?

Knust: Yup.

Q: Okay. We'll keep going. What else is going on during this time, or what happens next?

Knust: I wouldn't say that things were completely quiet on the outbreak front, but we did get a little bit of breathing room in November of 2014 and start to think about these screaming scientific questions that were coming up again and again that this outbreak afforded an opportunity to try and answer. My role really started to turn more toward addressing those scientific questions as the outbreak went on. I started to work on making some lists of different activities that could be prioritized and putting together teams to address them. So, a couple of things. There were a number of things that got started. A couple of things that I was more heavily involved with include a Household Transmission Study that was carried out in Sierra Leone. And the Virus Persistence Study in Sierra Leone. And then, helping with some of the elements of the semen testing program in Liberia, too.

Q: What are some of those questions, then, that are animating those—

Knust: The particular questions with the Household Transmission Study had to do with, how is Ebola transmitted in a household? A lot of that was based on these questions of, this outbreak is spreading so fast and so quickly, are there other modes of transmission that we just aren't paying attention to or didn't notice before? Is it really just close contact with people, or are people in wider areas around Ebola cases also getting infected somehow? We had a team who worked—we worked in the Western District of Sierra Leone, so right around Freetown. When there was an Ebola case diagnosed, there was a team that would go and, for all of the contacts, they would interview them and ask them about the kind of contact that they had with the case. After they had all finished their contact follow-up, check again and assess who had developed Ebola within that household. That was a very complex activity. It was over one hundred fifty households that were—no, I'm sorry. I'm losing my numbers here. It was over one hundred households that were included. And over a thousand contacts that were interviewed as a result of this study. It was very important in terms of building that understanding. Right now, we're still in the process of doing the analysis for that project because it was such a complex amount of data. Just trying to suss out—because a lot of times, if you are living with a particular person, it's not like you only share a meal with them. I mean, you share a meal. You share a bathroom. You might share a bed with them, if they are your partner. While they were sick, you probably were the one who was changing their bedsheets. And so trying epidemiologically to suss out all of these different potential risk factors and be able to describe them is a challenge.

One of the things that was very important to understand, though: was this different from what had been found with other outbreaks? Also, with more cases, were we able to detect things that were not able to be detected when there was a more limited number of cases? That was a very important thing. It was also very helpful—in our preliminary data, we're seeing that really, direct contact is what rules the day. It wasn't necessarily that far of a difference from what we've seen before, but it's still very helpful to have much better numbers behind it and a better, more specific description of a lot of the different kinds of contact that people could have. People who were living right within the same area, they're at much greater risk of getting Ebola—that are living in the same essential apartment, or living quarters—than people who are just living in the same building as the Ebola case. Which is what we thought. But it's very important to have that information because again, there was a period of time where people weren't necessarily believing that Ebola was still transmitted the same ways that we thought that it had been transmitted for decades before.

Q: Right. Can I ask what your role was in the study?

Knust: In that study in particular, I was mostly involved in developing the protocol and the questionnaire and then giving advice on interpretation of data. I did not do the data collection in the field at that point because I was also trying to get some other things underway.

Early in January of 2015 was when I first went to the field. I traveled there with Jordan [W.] Tappero, and the purpose of the trip was to get a sense of what the level of interest in scientific activities were in the different countries, get to know who some of the players would be, work with the CDC field teams, and then also meet the people that were in the Ministry of Health and understand what their priorities were. And that was a very helpful visit. Very clear early on, there was a large amount of interest in the persistence of Ebola in survivors. This was something that we knew had potential from previous Ebola outbreaks. It had been described that virus can persist in the semen of Ebola survivors. There had never been a proven sexually-transmitted Ebola case, but there had been of Marburg. And we certainly had recommendations for survivors that they should abstain from sex or use condoms for three months after they were discharged. But that three-month number was based on very, very small numbers of people that had provided semen samples for testing. So there were a lot of questions about whether that was adequate guidance. Especially thinking about the number of male survivors present in West Africa, and knowing that condom use was really not very common, there was a lot of speculation that this could be a problem in the future, and that it was really important to have better information.

On top of that, there was also very little that was known about persistence of virus in other body fluids as well. There was some indication that at least shortly after recovery, virus might be present in some other body fluids in small amounts. Again, with a large number of people surviving, you have the opportunity to collect much more information and really much better answer that. We really wanted to pursue that further. So we started

to develop a protocol to look at the persistence of Ebola virus in body fluids. This work wound up being a collaboration between the Ministry of Health [and Sanitation] in Sierra Leone, the World Health Organization, US CDC, and then eventually later, China CDC. It's an interesting process, from the perspective of just—when you're dreaming things up in a protocol, sometimes it seems complex, but it's never nearly as complex as actually carrying it out. Especially carrying it out in a time frame that you're trying to do as quickly as possible, and also while resources are definitely directed toward the outbreak response that's also going on at the same time. I really want to emphasize that when an outbreak is going on, the first priority has to be outbreak response. Scientific questions are nice, but that's not the most important thing. The most important thing is—the way that you're saving lives primarily is by stopping ongoing transmission. And so, with that in mind, I mean, it's very important to be able to—the study was important, but it also had to be pushed ahead, while this other very important task and primarily important task was going on.

I guess also to say at that point, the reason that I had the space to be able to look at these was because there were a lot of other people at CDC who had spent so much time and had learned so much about Ebola that I was able to—you know, there were a lot of functions that were set up, and I was able to stop bouncing around all over the place and be able to really focus on some of these more specific things. That was really key, and really—I appreciated that, from the perspective of so many people that just gave up whatever they were working on before for many months and gave so much of their time

in order to help stop this outbreak. That was tremendous, in terms of a lot of sacrifice that so many people gave. What time is it? Three fifteen.

Q: Do you have to be out of here at—

Knust: I'm just going to check my time, real quick, because—

Q: Sure, yeah, please do.

Knust: I'm not sure what's going on at three thirty. [pause] Okay. Nothing. That's good. All right.

Q: Good for me. [laughter]

Knust: Let's see here. I guess the other thing that was interesting was working on a scientific protocol, which normally—for a study where you're collecting specimens every two weeks from survivors until they test negative, and looking at a very large number of survivors, and it's a human subjects research study, this is the kind of thing that would take a year to set up. We set it up in a matter of a couple of months. That was pretty amazing. Working with collaborators, with the World Health Organization, many of whom I'd never met before. They'd also been to Sierra Leone, and we'd been talking on the phone. We didn't actually meet until we were launching the study, literally. It was very challenging trying to make sure that everyone was aligned. Then also dealing with

the fact that CDC and WHO both are incredibly bureaucratic, and bureaucratic in very different ways [with regard to funding and ethical approvals]. Making that come together was quite challenging, too.

Q: How did you do it? I imagine with the IRB [institutional review board], etcetera, things get dragged out, as you said.

Knust: Yeah. Yeah. To some extent, a lot of it just had to do with some incredible determination and prioritization on both sides to really move things forward. It was really amazing. We had some great people who were involved and really dedicated a lot of time to working on this. We started talking about the study in the beginning of February, and it was the end of May when we actually launched and started enrolling people. So it was a very quick process.

Q: To do that, were there some rules that you bent or went around, or did you just do everything the same but much, much faster?

Knust: I think it was mostly just that it was quite an expedited process. Yeah, yeah. Although there were a lot of things that I think would have been done more thoroughly if we'd had more time to set it up. For example, things like registering a clinical trial, even though it wasn't a clinical trial. There are still things that you can do to register something and post the protocol in different places. There's a lot of those pieces that we just didn't have time to do before we were live. It was a very intense period.

It wasn't like we were doing something that we had an absolute protocol for. The priority specimen was semen. Semen specimens. First of all, we go, and we're trying to assess from other sexually transmitted disease experts, what other research studies have you collected semen specimens for? No answer. Nobody had ever done that in any kind of real, comprehensive, and large-scale way. Of course, because it's Ebola, you have to not just collect a semen specimen, but you also have to treat it as if it has Ebola in it. That calls for appropriate precautions. We really had to develop this way to, first of all, educate the staff. The staff were already well-educated. They were staff from [34 Military Hospital] in Freetown that had worked in an Ebola treatment unit and really understood very well how to care for Ebola patients. And also were very good about learning the protocols that were required for a research study. But we were also blazing some ground in terms of, okay, we have to collect the specimen, and we have to keep it appropriately cold and package it safely, and then get it out to the lab in Sierra Leone—the lab in Bo. The lab in Bo, it was a field lab, and field conditions, and they had to figure out how to test semen in a way that we were getting consistent results. Semen is not blood. It's a different body fluid. Then also, just the unusual situation of collecting semen specimens. You're asking somebody to do something that's uncomfortable to ask them to do, from the perspective of being awkward and taboo in many cultures. There were a lot of really challenging issues that were wrapped up in that. We had some amazing people who were willing to take on these issues and help provide expertise. We had some really great people that had sexually transmitted disease expertise. Then the other part was, we felt very strongly that it was important to give the results back to the participants and counsel

them on what to do, so that they wouldn't just be a research subject, but that they were getting a service in response. So we developed a counseling program that told them about their result, and we told them if it meant that they had to wear condoms. We told them if [it was negative,] it meant that they may not need to wear condoms for Ebola prevention. Then we also told them if the results were not conclusive, that we didn't know what they needed, and that we needed them to continue providing specimens, too.

We developed all of this in a very short time frame. This information and these techniques were also immediately being used for programs in other places. We immediately turned around and developed a semen-testing program in Liberia, because by this time, there had been the first case of sexually transmitted Ebola that had happened in Liberia that had the best evidence to date. It was a very important political situation there that the president was asking for this program to be started as soon as possible. That case was in March, and they started their program in early July. They turned around also very quickly to be able to do that service. We really were working against the clock to try and be able to answer this. Not only because it was important for the response, but also with a situation where we didn't know exactly when the outbreak was going to end. Things were tailing off. We had a situation where we were trying to measure persistence of virus in body fluids that we expected was going to be something that was fleeting and that would tail off eventually. We wanted to be able to describe that and get enough people enrolled so that we could describe that well before we got to a point where everybody was either negative or we couldn't describe what had happened earlier on in the process.

When we got our first results, we were expecting that we would have some people that were positive, but we were completely flabbergasted when we saw how many of the participants actually had positive results and for how long. Before that point, the understanding was that virus would be present up to around one hundred days after the onset of illness, so for about three months or so, they'd have virus present—virus RNA [ribonucleic acid] detectable by PCR [polymerase chain reaction] present. Then it would taper off after that point. Then this guy in Liberia, he was about six months afterwards, and we thought maybe he's some kind of outlier. Then we test these guys and we see there's plenty of guys that are still positive at six months, or even beyond that, there can still be a significant portion that are positive by PCR. That was a shocker. It was a surprising result. It was very important that we get even that preliminary view out. We did a lot of work to publish the first paper, and that first came out in October.

Also, along the way, just a lot of work to get—we got the semen testing part started, but then we wanted to test other body fluids too. Getting that up and running, and figuring out, what's our guidance going to be for saliva and sweat? What are we doing to do if somebody tests positive? And breast milk? What recommendation are we going to make if somebody has positive breast milk, and they're nursing a baby? It was a lot of work to really suss out and think these things out, but still try to get something launched in a meaningful time frame, that we'd still be able to potentially detect something. We launched the study in November of last year, for the other body fluids as well.

Q: Can I ask the names of all of these studies? Do they have names?

Knust: This is the Ebola Virus Persistence Study in Sierra Leone.

Q: And in Liberia? Does that also have a name?

Knust: In Liberia, it's a program—a semen testing program, and it's called the Men's Health Screening Program.

Q: Right. Okay. And the newer one, which is all the other fluids?

Knust: Yeah, that's also part of the Virus Persistence Study.

Q: Gotcha. Gotcha.

Knust: It's been interesting. Especially the piece of—if you had asked me or told me a few years ago that you're going to be an Ebola sexually transmitted diseases expert, and you're going to be talking about semen all the time, I would have thought, no way. No way, that's totally not what I do. No, not at all. And so, here I am. Come to find out, it's become a very important issue, as we're getting to the tail end of this outbreak. There have been several clusters in the past few months. In all three countries, we've stopped the ongoing human-to-human transmission, and there's surveillance that's set up to detect new cases. There will be no new cases, and then suddenly, there will be a new case in an

area where there's been no transmission. It clearly is not just something that we weren't aware of, it's a new case. Because it's very difficult to investigate cases of sexual transmission because of taboos and people not necessarily being willing to reveal a lot of information about their sexual activity, it's hard to prove all the time exactly where these clusters start from. But in many of these situations, there is some link to communities that do have a lot of survivors. It's really become very important to better understand and then figure out how to take it, just from a scientific understanding to a recommendation and some action, so that survivors know what the potential risks are and that they're taking the appropriate precautions and that they have support to do that.

Survivors in general have so many challenges. They have health challenges that we're still just learning about. They have social challenges because people are afraid of them. They are afraid that there's still a risk of transmitting Ebola. Figuring out how to communicate this information in a way that doesn't further stigmatize them is very difficult, and it's a real thing that we struggle with. But we also feel like it's very important for us to fully eradicate Ebola, that we figure out a way so that these survivors can go on with their lives and live their lives, and that the communities can become free of Ebola. Also, that these survivors aren't—that people don't just decide, we'll throw them in jail. There have been a lot of terrible things that have been thought of, when I think that we can mitigate this risk with some very close work with the survivor community instead.

Q: Have you met survivors in West Africa?

Knust: Oh, yes. Yes, absolutely. At the study site where we started the pilot study that was testing the one hundred male survivors, the first few weeks, I didn't—I was shy to talk to the survivors directly at first because I didn't want to interfere too much. But then you start to see them more and know them more. And yeah, there are some people, and I definitely understand—I've heard a lot of their stories about the real things that they struggle with.

Ebola is such a devastating disease because number one, people who are at the greatest risk are the people who are caregivers. Frequently, whole families will be wiped out because they're caring for a sick loved one or preparing a dead person's body for a funeral. Many of these guys, they lost their wife, they lost their girlfriend. A lot of times, they're thinking about—maybe they lost several children as well. They're thinking about wanting to start a family again and move on with their lives and find a new wife, or—and having children again is very important to them, and having a family is very important to them. Having this issue of virus being present in their body is a very discouraging thing. A lot of them lost their jobs while they were sick because frequently people—they're sick with Ebola. It takes a long time for them for them to recover, and even when they're out of the hospital, they're still very weak and they have a lot of sequelae afterward. It takes a long time for them to really get to a point where they can work again. It really has economic and emotional tolls on them that are really quite devastating.

Q: Has most of your work, then, in 2015 and now into 2016, been with the survivors?

Knust: Yeah. That's been a very large focus, mm-hmm. I'm just trying to think of other things that we've been doing. Yeah, that definitely has been a very large focus. Then also just trying to pick up the pieces of everything else that—[laughs]. Like I said, our branch—we have a number of other viruses that we study. Trying to make sure that we didn't completely neglect the rest of them has also been important. We're in the process of rebuilding that.

Fortunately, we have a number of new additions to the team now. In addition to Beth and Pierre and Craig and me, who have been around since all of this started, on our epi team, we also have a couple of EIS officers, and Mary Choi is now in our team as well. It's really great to have them. We're trying to move past Ebola, and obviously there's still plenty to do with Ebola, too. Just in a process of trying to think about, okay, where are we now? And then, what are we doing for the next thing? I think that it's very important for West Africa in terms of them having some better public health infrastructure. I'm so happy that there's a real amount of attention that's being paid to this area now. The impression that I really had was that it was just an area that there was very little activity before. I hope that the investments that are there will continue to be invested in. There's a large cadre of people who broke their teeth on this Ebola response, and now they can really be harnessed to tackle a number of other very important health concerns that are present in that area. I really hope that we can leave them in a better place than they were when they started. I really have appreciated the opportunity to work with a number of them who, they really are shining stars, and—

Q: Are there some in particular you could mention?

Knust: Yeah. In Sierra Leone, I've really enjoyed working with Dr. [Amara] Jambai and Dr. [James] Bangura, in particular. They both are very, very smart. Dr. Gibrilla [F.] Deen is also the principal investigator for the Virus Persistence Study. A very keen clinician, and very good at educating people about scientific issues. And then, at [34 Military], we have a couple of young doctors who are military doctors, Dr. Foday Sesay and Dr. Thomas Massaquoi, who have dedicated a lot of time to really building up the study. I think their futures are very bright. I think that they have a lot of capacity that they now can bring to the country in terms of tackling a lot of other public health problems.

Q: Absolutely. Well, I have kept you captive here for a very long time. I know it's probably getting hard to speak [laughter] to some extent. But I guess I'll just ask you now: is there anything that we haven't talked about that you think, this really should be on the record, I want to make sure that this gets into the oral history?

Knust: I think I've got a lot of things. [laughter]

Q: No, I think so, too.

Knust: I think I covered most of the things that I can think about. There's probably something else. But that's all right.

Q: Okay.

Knust: Yeah, I think I feel like I covered a pretty good swath.

Q: You did. This is going to be a great gift to the archive. And should you consider another thing, I'm always open to doing another interview. This is what I'm doing full-time.

Knust: Wow, that's great.

Q: I know. [laughter]

Knust: That's really great.

Q: I know. [laughs] Okay. Well, thank you so much for being here with me, Barbara. It's been a pleasure.

Knust: Oh, yeah. Well, I really appreciate the opportunity. I'm really glad that the CDC Museum is doing this.

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