Oral History with Andy Smith, June 24, 2020
Interview by Benjamin Spohn for Hagley Museum and Library
Hologic oral histories project

Q: Just an audio version. Okay, so today is June 24th, 2020. I am interviewing Doctor Andy Smith of Hologic about his role in the medical imaging business and his personal history in the business as it pertains to Hologic. So, just to get us started off a bit, can you tell us a bit about your early life and education?

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A: Sure. So, I went to university as an undergraduate. I ended up in physics as my degree and stayed with that for my graduate work, PhD, which was also in physics. I was in the field of nuclear physics, which involves basically smashing small particles against other small particles and seeing what happens. And that was quite an interesting subject for me because it combined mathematics and quantum mechanics and other analytical things with a really hands on education. I would go to Brookhaven National Labs where they had particle accelerators where we could do these experiments.

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And as part of those experiments, I would be building detectors which would detect volumetric particles and x-rays and gamma rays and radiation of various types. And so, it combined also, you know, my interest in electronics, and there's a lot of software, yeah, [00:01:44] But it was a good combination for the interests that I had. Also when I was in graduate school, to earn a little money, I worked as a consultant for Boston University Medical Center for some researchers there that were developing a machine to image the human body. I'm going to close my door. Excuse me.

Q: Sure.

[00:02:20]
A: Okay, the room is sealed. So, following my graduation, I ended up starting a company with one of the researchers that I was involved with at Boston University Medical Center. And we

designed and built a machine to do neuroimaging, imaging of the brain using gamma rays. That sort of was a good combination of again, the skills that I had gathered in terms of building detectors which detected radiation and electronics and programming. And I did that for a while. And then I left that company and joined Hologic, which I had heard of. It had a very good reputation in the area. I had sort of just known about them serendipitously because we happened to – because Hologic happened to share the same dealer in Europe of their equipment that my company sold also.

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So, that's how I came to know Hologic. I met Jay Stein, a cofounder, and Dave Ellenbogen, both great guys. And Dave Ellenbogen has passed away. But Jay Stein is still active in the company, and he's been really a great inspiration. He's a very prolific inventor. So, that's how I ended up at Hologic. When I joined Hologic, Hologic had started making machines to image bone density. Had been successful financially. And when I joined, I was given a mandate to sort of not get involved in that. They were at that point – they knew they needed to expand into other product areas.

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And one of the things that I did for some early time at Hologic was sort of investigate other fields to get into – develop products. In the end, we ended up purchasing a company directly, a corporation which originally was an offshoot originally of DuPont. You probably heard that story from others who know more about it than I do. But they had a very interesting technology. At that time – that was around the year 2000, I think – they were developing a method of imaging x-rays, critical for medical imaging, using digital technologies. Prior to that, all the imaging had be done using x-ray film. And the digital technologies had certain technical advantages. And DRC Corporation had some very unique technology related to that.

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And their detectors were extremely high resolution. And we ended up realizing fairly early on that, in fact, that technology was explicitly suited to mammography. Talk about some of the requirements for mammographic imaging. And so, we ended up purchasing the company

LowRad, which was based in Danbury, Connecticut, which for many years had been building systems to do breast imaging using film imaging. And we took the shell of their system, which did the film imaging, and replaced the film imaging component with a digital detector. And that digital detector really had very specific requirements that suited mammographic imaging very, very well. And mammographic imaging was actually a very demanding technology. So, that's kind of, very briefly, my start.

Q: Okay. So, what was it like making the decision to leave a company that you had started to go to work for someone else?

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A: Well, when you work for a small company and you're working with cofounders and your visions deviate from their visions, then sometimes you have no choice but to move on. It's not something that I've ever regretted. I've never regretted having gotten involved in a startup. I was very glad I did it right out of graduate school because I wouldn't have had the guts to do it after I had a wife and two children, et cetera, and I was in the suburbs. So, it was a good time to do it. But I also have never regretted moving on to Hologic, which is a company that I think prides itself on very sophisticated technology solutions. Very open company. I mentioned the founder is a very smart guy, very open guy, very inventive and creative guy. And I've certainly learned a lot about other fields and other areas by making that transition. So, I'm happy wherever I've been.

Q: Great. Yes, I have an interview with Jay on Friday, too.

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A: Yeah, he's quite an interesting, special character, actually. He watches this video [00:07:48]. I'm not just sucking up, Jay.

Q: So, Jim told me ahead of our interview that you were probably the best person I could talk to to explain some of the technology behind this imaging in layman's terms for somebody 50 to 100 years from now. So, can you maybe start by explaining why is digital so much better than film?

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A: Well, it's not necessarily so much better than film. I think perhaps a better way to answer your question would be to back off a little bit and talk about the medical imaging requirements and talk a little bit about breast cancer and how that works and how you might image it, and then sort of lead into the requirements and how the digital technologies fits with those requirements. Good way to proceed if you're okay with that.

Q: Sure.

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A: So, as we all know, breast cancer is a very prevalent disease in the US and around the world. And if you can detect it early before it's grown and become invasive and spread throughout the body, then there are treatments that are quite effective in reducing breast cancer mortality. In order to do that, you really have to do what's known as screening, which is imaging – I have to stop because my screen just went blank. Sorry. There we go, okay. You really have to do what's known as screening.

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So, in the US, we do mammography screening. And every year, women aged 40 and older are invited to come in for imaging. Now, these are women that don't have any suspicion of disease. They're what you might call asymptomatic. But some small number of those women do in fact have breast cancer. Maybe about five in every thousand women. And those breast cancers – because there's no symptom of it, they're very, very small. And so, if you can image them in screening and you can get them when they're still small, that's when the treatments are very effective. And that's known as screening image paradigm. Most of medical imaging is diagnostic.

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You break your leg and you go in and get an x-ray of your leg and they go, "What's wrong?" or you have a pain in your abdomen. You come in and you might get a CT scan or MRI scan, various types of imaging. Then a radiologist will look at those images. And they pretty much –

they know the area generally often where there's a problem. So, they know where to focus their attention. And they also know there is a problem. Screening is quite different in the sense that when a radiologist looks at imaging in screening, almost none of the women do have disease. And so, it's a very, very challenging task for a radiologist because day in and day out, you're looking at images and you have no idea whether there's something wrong with that patient or not. And that actually is an extremely challenging situation.

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The other thing that's challenging is you're trying to detect these breast cancers when they're very small. If you wait until a woman has a pain in her breast or feels a lump, then that cancer is much further along and is much larger. And that's when the treatments become less effective. So, by definition when you're doing screening for breast cancer, you're looking for something very, very small. So, if I sat down and tried to make a list of the requirements for a system to do breast imaging, one requirement is the resolution, and the resolution is the measure of how small you can see something in an image. And you have to be able to see something very, very small in a breast cancer image to find the cancers early. And in fact, compared to all the other diagnostic imaging that's commonly used, the requirements are quite a bit more stringent.

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Some of the imaging, like x-ray imaging, uses radiation dose, which in large quantities is harmful to people. And because most of the women that you're subjecting this exam to do not have disease, you have to keep the radiation dose, if it uses it, to a very low level. And I could say in addition to dose, the safety of the product. It has to be a safe system. If it involves the injection of a chemical, a pharmaceutical or something, that has to be safe. These requirements are not quite as stringent. When you go in and you're in a car accident, you get a CT scan. A CT scan has radiation, but it's considered to be a good use of radiation because the person generally has a problem. That's not the case for breast cancer imaging.

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Another important requirement is the speed of imaging. You have to be able to do the exam in a very rapid length of time, or short length of time. And the reason for that is because when you're

screening, there might be 15 million women in the US that you want to screen. So, you can't be spending a lot of time on any one of them because then, the healthcare costs just become exorbitant. So, speed and therefore cost are important. Cost of the machine is also important because you have to have a lot of machines to be able to service this many women.

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Another requirement for breast cancer screening would be sort of the operator independence. What I mean by that is when you go in for any diagnostic procedure, there's some type of technologist or person who's operating the machine. You have to be able to get good results sort of independent of the skill level, let's say, of the operators. It has to work well. Has to be easily worked. If you're doing breast cancer screening and you want to be effective, you have to image all types of cancers. Turns out that breast cancer is a very heterogeneous disease, and there are many different types of breast cancers. They fall into a number of sort of general characteristics. One of them, in the very earliest stages, they appear as what are known as micro-calcifications, which are tiny specks of calcium that distribute in the milk ducts in the breast. And those are very tiny.

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So, you have to be able to image those. Once they grow, they can be what you might think of as a more classic cancer, which is a sort of a lesion, a lump which might be a few millimeters to two centimeters in diameter. And you can also have ones which have spiculations, where the cancer is sort of supported by surrounding tissue, by little fingers of tissue known as spiculations. You can have cancers which can't be seen directly but which cause distortions in the breast. So, you see an area of the breast which looks abnormal, even though you're not necessarily seeing the underlying thing which represents the cancer. So, if you're going to be doing breast cancer screening effectively, you have to find an imaging method which images all that.

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You have to image small cancers. I did mention that. You have to be able to cover all regions of the breast because breast cancers can happen anywhere in the breast. So, if you had an imaging modality which didn't capture far enough back in the breast or something, that might not be an

effective screening method. You have to be able to image all women, and women's breast sizes vary enormously, very enormously. And the individual breasts look quite different. Breast tissue – a normal breast is composed mostly of two different types of components. One are the structures that hold the breast up – fibro-glandular structures which are both a supporting tissue and the milk ducts. And then in between all that is fat. But every woman's breast is completely unique. This is actually quite different than other body parts.

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If you looked at 100 brain scans of a [00:17:14], their brains would like by and large the same, whereas every woman's breast looks quite different. So, those are some of the challenges. You also have to think about what's going to happen when you get a suspicion of breast cancer. So, if you do imaging on a person and then you decide that there's something suspicious enough for cancer, you can't make a diagnosis just from that alone. You have to take a tissue sample to the biopsy center from the region that you've identified as normal. And so, you have to have a method of doing a biopsy. And often, the best way to do that is to use the same imaging that saw that cancer, that lesion to perform the biopsy because if you switch to another imaging modality, the cancer might be occult [?], and might not be visible using that technology.

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So, that, in a nutshell, are the breast imaging requirements. And there have been a very large number of technologies that have been used or proposed, let's say, for breast cancer screening throughout the years. I can talk about some of them. Until about 20 years or so ago, people used film imaging. They would put a piece of x-ray film and an intensifying screen, which is something that amplifies the signal, underneath the breast. Find x-rays through the breast, and then develop the film. And when you look through the film, you would be able to see areas of greater and lesser density. The areas of lesser density represent the fatty tissue and the areas of greater density represent the fibro-glandular structures. And it turns out that breast cancers also are dense.

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And so, they stop x-rays efficiently if using x-rays. And you have to be able to image both of those. Film does that. It has very high resolution requirements. It meets actually most of those requirements for breast imaging that I described. But digital imaging actually works better than film imaging. And that came out about 20 years ago. There's a number of different technologies that were promoted to try that out. And the major advantages of digital imaging is that for one thing, it allows the accumulation of the generation of an image with a lower radiation dose that it was needed for film imaging. And that was very important, as I mentioned, for screening. And also with a film image, when you generate a film image, you have a physical piece of film.

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And so, if the radiologist wants to look at it, he has to go and get that film. And then when you're done, somebody has to take that piece of film and put it in a file holder somewhere. So, you end up accumulating rooms full of films. It's difficult to quickly pull up films from a patient who came in and you're curious about what the image looked like last year. It's not so quick. Whereas once you have a digital image, then you can move it around much more easily. So, the advantages of digital – it was originally introduced primarily for the advantages of remote display and remote transmission and storage.

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But it's turned out to be a very good technology as it's progressed over the years. When digital imaging was first introduced, it used a radiation detection material known as cesium iodide. This was a material that was used in digital x-rays for a number of years. And if you go into a hospital again for just a standard x-ray like a chest x-ray or again, like a broken bone or something, you would be imaged on a detector which almost certainly used cesium iodide as the radiation detection. And the first digital systems that were developed were based on that technology because people understood it well.

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What Direct Ray Corporation had been developing was a detector based on selenium. Selenium is a metal. And if you deposit it in a non-crystalline form, in an amorphous form, and you put an electric field across it, it turns out when an x-ray hits it, you will get a current of electrons. And

you can detect those and image those. And compared to cesium iodide, the resolution characteristics of selenium were higher than that of cesium iodide. And like I mentioned, the resolution requirements were very important. Another important advantage of selenium over cesium iodide is that the x-rays that are used in mammography differ from the x-ray energies that are used in regular radiography. In regular radiography, each one of those x-rays is a very high energy x-ray. And they're much lower energy in mammography.

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And it turns out that cesium iodide does not stop those low energy x-rays as efficiently as selenium. And you need to stop the x-rays. That's the way that you get something which is very dose efficient. If you build a detector and most of the radiation goes through the detector without being absorbed, then you need to deliver more radiation to the patient to get a reasonable image. So, selenium was, as we realized, a very good material for building a system out of digital mammography. And that's what we built around the system that was being sold by LowRad corporation. It worked very, very well. There are other methods of imaging breast cancer.

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I described x-ray. That is by no means the only one. A very common method is using ultrasound imaging. And ultrasound uses acoustic waves. You can't hear them because they're too high in frequency. And you can get an image using that. But the ultrasound typically does not meet some of those requirements that I mentioned. It takes a long time to do the exam. It uses a skilled operator to control an ultrasound probe, which is moved over the breast. So, it doesn't have what I called that operator independence characteristic. The quality of the image that you get is very dependent on the quality of the user. It's also perhaps not as good at finding all types of breast cancers. Cancers that appear as micro-calcifications, for example, don't appear very well in ultrasound.

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But it is used and it has a place in breast cancer imaging. People also use MRI, magnetic resonance imaging systems, for looking for breast cancer. It also does not meet, let's say, all those requirements that I listed. And it's poorer resolution in mammography. It takes a very long

time for an exam. Up to an hour, maybe, compared to just two minutes for an entire breast exam with mammography. Those machines are extremely expensive. And so, thinking about screening a large fraction of the population with MRIs is a challenging thing. There are other, I would say, less common methods of doing imaging which have been proposed. There are nuclear medicine methods, PET, and single photon imaging, which have higher radiation doses than mammography, quite a bit higher.

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And take a very long time for those exams. And so, don't meet some of the requirements that I mentioned. Those imaging technologies are poorer resolution than mammography. So, they won't be finding the smaller cancers. People have proposed using thermography. Thermography is looking for the area of your breast which is warmer than another area, the idea being that if you have a cancer growing, you'll get increased regional blood flow which will cause a slight temperature increase in that region. And you can build very – sensitive, let's say, thermal imaging systems to look for that.

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And that does work for finding cancers. One of the major problems with that is that it only finds very, very large cancers, which are not really the ones that you're looking for. So, that's why mammography has turned out to be the method of choice for breast cancer screening in the United States. And originally film imaging, and now digital imaging has completely supplanted that. I'm not going to say that mammography is perfect. It certainly has some limitations. One of the limitations is that as I mentioned, breast cancers can appear very similar on a mammogram to normal breast tissue.

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And that problem is exacerbated in women with dense breasts. And women's density varies from women to women. It also varies on younger to older women. Younger women tend to have denser breasts. And if you have a breast which is comprised of a lot of dense tissue, it becomes extraordinarily difficult to see a small cancer because it can be hiding underneath a normal dense tissue. And that again comes back to the problem in screening where you're imaging women that

– most women don’t have disease. So, if you're a radiologist looking at a mammogram which is from a woman with dense breasts, it just can become very challenging. So, much clutter in the way.

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So, I've been talking about screening. There actually are two methods of doing breast imaging. Screening is the method by which you image women that are asymptomatic every year. If a woman comes in and has a screening mammogram and then the radiologist sees something suspicious, then she's given additional imaging to see if they can either rule out breast cancer or generate enough suspicion for breast cancer to want to take a biopsy sample. So, that is called a diagnostic exam. And in a diagnostic exam, we typically use more than just x-ray mammography.

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A woman may very well have additional x-rays, but she may well have other imaging. And ultrasound is a very common method, and also MRI imaging. So, you know, the fact that ultrasound takes longer to perform than mammography is not as important in a woman that is symptomatic and has some problem that you have to diagnose. So, that’s the history of breast cancer imaging. I can take you up now to where we were a few years ago in terms of the invention that we did for 3D mammography. [00:29:16]. So, I mentioned that mammography, x-ray imaging performs less well in women with dense breasts. MRI works very well in women with dense breasts. And ultrasound works very well in imaging with dense breasts.

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And those might be reasonable alternatives to mammography in women with dense breasts, except for the problem that in screening, those other imaging modalities would not be the first choice. So, we realized - we were not the first to realize it. A group at Mass General Hospital led by a physicist, Loren Nikelson, were really the original creators of it. But they realized that you could do 3D imaging. Mammography is a 2D imaging. It’s just a simple picture of a breast. That if you took multiple x-ray images around the breast, just as you do with a CT scanner, you can

get a three-dimensional representation of the breast. And that would likely not be as affected by breast density as a standard mammogram.

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And we were the first company to commercialize that technology. It's known as breast tomosynthesis, or 3D mammography. And it's actually worked very well. I would say better than my wildest dreams in some ways. And what I mean by that is it's shown to find cancers earlier and with – and it finds more cancers than regular digital mammography and it finds them earlier. So, what I mean by earlier is a woman comes in every year and she gets a mammogram. And then a radiologist doesn't see a cancer and she goes home. And then a year or two later, she comes back for her next screening exam, and then you see the cancer. Well, if you're able to find more cancers during that first screening that would've been missed, then you're actually finding it a year or two earlier than if you have to wait for her to come back again. And that's what tomosynthesis [00:31:30]. It finds about 40% more cancers on average.

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It finds cancers that are not seen in digital mammography, would not have been seen for at least the next three rounds. And tomosynthesis shares all those very nice features that are requirements for breast cancer screening. It operates at the same radiation dose as mammography. It has the same resolution. It costs basically the same. It's a very fast exam – just two seconds. Basically the same time as a regular mammogram. Works on all women, it works on all regions of the breast. You can do a biopsy using that technology. It finds all types of cancers. It also is something which a radiologist is completely comfortable with because these images, even though they're three-dimensional, look quite a bit like a regular mammogram.

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And of course, radiologists nowadays are very comfortable reading 3D images because that's what they do all day long. So, that's the technology that we introduced almost ten years ago, if I'm remembering correctly. Maybe it's more than ten years. And I'm very proud to have been involved in the development of that. We're the first company to have developed that technology.

At the moment, now there are three other companies that have US FDA approval for – we'll say similar approaches to breast tomosynthesis.

Q: So, the 3D – is it literally a 3D scan?

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A: It is literally a 3D scan. So, you end up with the ability to – when I was talking about the difficulty of seeing a cancer in a dense breast, an imperfect analogy would be to walk into a forest full of trees and try to see – let's say it's an oak forest. And then somewhere in that forest was a maple tree. Well, you probably couldn't see that maple tree very easily because all the oak trees are in the way. Similarly, if you're looking at a woman who has a cancer in a dense breast, you've got all those trees. Those are the normal breast structures for hiding. And in a 3D image of a breast, it's sort of like you can cut down those trees, or you don't have to see the trees that are between you and the breast cancer. So, it does allow greater visibility and boosts performance in women that have dense breasts. Any type of mammography, even film mammography works quite well in finding small cancers in women with very, very fatty breasts.

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But it's the younger women that tend to have denser breasts where it's more of a challenge. And those are the women, in fact, that you want to find those cancers because they're younger and they have a longer [00:34:54]. Really going to make a big difference in society. You have to address that population. And breast tomosynthesis does that quite effectively.

Q: So, about how early is the earliest that you can detect a cancer?

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A: Nobody knows the answer to that. I mean, it might be that – I'm going to make a guess here – that everybody's walking around with breast cancer cells in their body. But just having one or two – it doesn't make a clinical situation. It has to grow to a certain size before it becomes relevant. So, you can detect using modern mammography systems breast cancers on the order of just a few millimeters in size. Very, very small. And those breast cancers almost invariably are

not invasive. They have not grown and spread into the breast or beyond the breast. So, in terms of size, we know what we're detecting. We don't know how long it was lying indolent in the breast or it's been growing. That, I think, is an unknown feature right now. We can talk about – go ahead. I'm sorry.

Q: No, please keep going with your point.

[00:36:29]
A: Yeah, so people talk about maybe developing explicitly sensitive methods of detecting breast cancer. And one can think about genetic testing where you might be able to, from a sample of a person like blood or saliva or something – you might be able to detect a single cell of breast cancer. And whether that would be a good idea or a bad idea, I don't actually even know. So, there's a limit to how sensitive you want to make a detection system. If it was true that everybody was walking around with a cell of breast cancer, you wouldn't want to have a test where everybody was coming up positive because you wouldn't be able to do anything about it.

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You wouldn't know where it was and you wouldn't know how to act on it. So, there's a lower limit to detection where you just don't want to detect it if you can't do something about it. It may well be that these breast cancers or other cancers or other diseases in the body sort of come and go. And most of them don't end up killing you. It's always a quandary for a screening in general.

Q: I feel like for someone with different temperament than us might be able to have a heck of a philosophical debate about whether or not we're ever actually well.

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A: Well, there's that. And then there's also the limitations of imaging. I mean, people propose going in for whole body scans every year. Healthy people. And if you do those, there absolutely are situations where you would find something which otherwise was – nobody knew you had, and maybe you're glad that you found it. It might also find things which would never end up resulting in a problem for you. But the big problem with these very, very sensitive tests,

especially in screening, is they have what's known as false positives. So, they can find things which, in fact, are not true. And those become big problems if you're imaging people that are basically healthy because you have to do something about those. But you don't know that they're a false positive.

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All you know is you see something which is suspicious and you have to act on it. And that might involve surgery or other interventions. So, we're sort of diverting a little bit. But these are questions about screening which are important. And there are no good answers for them.

Q: No, I never thought about it in those terms. Excuse me. Does blood testing play a role in early cancer detection, too?

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A: Well, it's out of my area of expertise. But when I did look at it a couple years ago, there were a number of people that were proposing it. And it was not ready for primetime in the sense of – I'm not sure that all breast cancers go into the blood. And so, if not all breast cancers go into the blood, then it fails the first requirement of imaging all breast cancers. And then they also didn't have a very good sense – they didn't have the right amount of cancer detection without false positives. Again, it's been a couple of years. To my knowledge, there are no commercially available, FDA approval blood tests for breast cancer. But it's certainly an interesting and attractive area and people are looking at it.

Q: So, you talked earlier when you were describing imaging and managing a lifetime radiation dose for women. Are these written down regulations that you have to deal with, or is it just something that you, as someone who's designed equipment, have to keep in mind?

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A: Well, there are regulatory limits. There are laws in the United States and elsewhere that the equipment cannot exceed those limits. Those limits are quite low. Talk about what I mean by that in a minute. And all modern mammography equipment is a fraction of those limits. People have

no trouble being under those limits with a modern digital system. And those limits are really quite low. Every person in the world gets exposed to radiation every day. There's radiation all around you. There's radiation coming in from outer space. There's radiation coming from the earth. And if you sum up all that radiation, that's known as normal background radiation. And it's not known actually if radiation at that level causes harm or not. That's how low it is.

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And the medical limits for mammography are well below that limit. And so, if you're doing a mammogram, you're doing it every year, you're not subjecting yourself to a significantly increased amount of radiation relative to that natural background radiation, which has never been shown to cause diseases. So, I don't think that these systems are unsafe. People hear the word "radiation" and they get very, very scared. But they should not be scared. And I think it's a mistake to be dissuaded from getting an annual mammogram if you're afraid of radiation because A) all mammography systems are well below these regulatory limits. Those regulatory limits, even if you were at them, are below what you're getting every day and which people don't worry about.

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And so, these levels are not something worth worrying about. And the natural background radiation varies across the United States. People are not even aware of that. The higher the elevation, for example, the more radiation you get because you're closer to outer space. And if you're living in New York City and move to Denver, you're actually getting twice as much natural background radiation as you were getting when you were living in New York. And people move from New York to Denver and back and forth and they don't think about the radiation. And they shouldn't think about the radiation because if you said, "I'm not going to move to Denver because I'm worried about getting breast cancer because of the increased radiation," well, that would be illogical because in fact, the breast cancer fatality rate is lower for Denver than it is for New York.

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So, clearly, radiation is not playing a significant role in – natural background radiation is not causing a significant role in the incidence of breast cancer. So, that's the – and yet, people are scared. I get that. And one of my pet peeves is that a breast clinic will put up a billboard saying, "We have lower radiation in our system than another system across town." They're being competitive, and that's what businesses do, and I'm okay with that. But I'm afraid that when a woman reads that billboard and thinks, oh, this system is low radiation. I guess radiation is bad for me. Maybe I should just not go get a mammogram at all. Well in fact, that's going to present you with a much greater risk of harm by not getting a mammogram than anything else. So, radiation is not well understood. But these levels are safe.

Q: So, maybe – I guess you don't have to answer if you think this is a silly question. But which would give you a higher dose of radiation – a really long flight, or a mammogram?

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A: I believe that a mammogram is more than one flight. But it's less than two flights. So, that's kind of the relative – but you have to take risks into perspective. The greatest risk of the mammogram is driving to the mammogram, getting into a car. That is well known. You have to be rational about things.

Q: Right. Actually, you brought up something there that I would like to talk a little bit more about. You used the word "risk." I'm curious how you've dealt with risk throughout your career in developing and creating new technologies and as well as any business decisions that you've been involved in.

[00:46:18]
A: So, you don't mean risk to a patient. You mean personal risks. Is that what you mean?

Q: Yeah. Like if you were pursuing something new with no guarantee of success, how would you have weighed your options, whether or not it was a good idea to forge on and see what happens?

[00:46:47]

A: Well, when I got out of graduate school, then I needed a job. This is a classic thing when you graduate from any college. And I interviewed a number of companies, three or four companies. And I didn't get the impression from these interviewees that they had the same understanding of my brilliance that my mother always talked about that I had. And it was kind of depressing, frankly. How come all these people aren't saying that I have some value to give? So, that's when I decided to start a company with this professor at Boston University. And honestly, fresh out of graduate school, I didn't evaluate the risks very carefully. It was undoubtedly an extremely risky thing to do from a career point of view because we had no money.

[00:47:46]

We had to go try to raise money, and that's a very difficult thing, and that takes you away from the stuff that I was kind of into, which was building things and testing them. So, I didn't think about the risks of that very carefully, I would say. And we built a system that worked – in its day was extremely good at neuroimaging. It was the highest resolution brain imaging system. And it was clear that it helped people. And I caught that bug of trying to get involved with things that help people. It was used for diagnosing Parkinson's and Alzheimer's and brain cancers, and other neurological things. It was very important for research to try to look for interventions.

[00:48:40]

I just got a very nice feeling about being involved in that. After we had done that for a while, we decided to try building a breast imaging system using the same technology. But we had to sort of invent a new type of detector to do that. And we worked on it for a number of years. And it never really kind of worked. And that's when I started to become aware of risk in terms of my own career. And that's why I decided to move to Hologic. And there are so many advantages of big companies and so many advantages of small companies. At that time, I guess Hologic was a medium-sized company. But I didn't have to worry about meeting payroll. I didn't have to worry about doing everything in the company, which is one of the things that I found very attractive with a small company when we started it.

[00:49:38]

And I could do electronic design. I could do software development, mathematics, building things, interacting with customers, giving scientific presentations. It was a lot of things I liked to do. And with Hologic being a much bigger company, they had a whole engineering department. They didn't want to let me design electronics. So, I had resources behind me, but I was more specialized. So, there's a tradeoff. But I never looked back on that because it's been such a great ride in terms of the technology we've developed. A huge number of patents have come out of this digital mammography and the 3D tomosynthesis. Hologic became enormously successful commercially in the breast field.

[00:50:29]
We were up against very big competitors. Nobody listening to this probably even knows what Hologic is. But our competitors were Siemens and General Electric and Fuji and other – Hitachi and other companies that were quite big. And to try and compete against those companies is scary. But we developed actually what was a better technology, and the field recognized it. And it was based in large part on that selenium technology, which is really very high quality. And there were other features that we had that our competitors that were also developing digital mammography didn't have. So, we became very, very successful in digital mammography. And as a result of that success, that business success and getting the lion share of the market in the US, we were able to develop the breast tomosynthesis.

[00:51:31]
And I know that all those other big companies were also developing it. But they weren't developing it with the same – they didn't have the fire under their butt in the same sense that Hologic did to come out with a product quickly. So, also, we were the first company to get FDA approval for 3D mammography and [00:51:53] clinical results have been very satisfying for that. So, coming back, looping around to the sort of career satisfaction, I got it with digital mammography, but especially with tomosynthesis. Because we were finding all these cancers, I was getting calls day and night from radiologists who had just put in our technology and saying, "Oh my god, thank you very much. This is the most unbelievable thing. You've made my day. Look at these images. We can find cancers."

[00:52:26]
All they want to do is help the women that they're serving, and they want to be able to sleep at night without thinking that they've missed a breast cancer somewhere. We worked on a technology which is helping save lives, really. Has been a very gratifying career arc. It's been great.

Q: Would you say that that helping people has been your favorite part of your career?

[00:53:00]
A: I think it's one of the favorite parts. I think it's working on interesting technologies that work. I think it's being innovative. That's exciting. I think it's getting an audience worked up about the things that we're developing, getting them excited. A lot of things.

Q: So, earlier, you talked about being the first company to get approval from the FDA. What's working with the FDA been like?

[00:53:34]
A: We were the first to get approval for 3D mammography, not digital mammography. There were two companies that preceded us in digital mammography. The FDA is a conservative organization, and they're rightly so to be conservative. And what I mean by that is when they receive an application for a new technology, they scrutinize it. And that makes sense to do, okay? And when people were making a transition from film imaging, film mammography imaging to digital imaging, the FDA was very concerned about this new technology. They didn't want to approve it and find out five years later it's missing all these breast cancers and women are dying.

[00:54:21]
And so, they were very, very careful to scrutinize it. And they scrutinized the companies that got approval before us and they scrutinized our application also carefully. With breast tomosynthesis, because we were the first, we were extra scrutinized. And we had to just be very, very careful. They are somebody that if you present the scientific evidence correctly which

shows that this product is safe and that it's effective, that it does something, they will approve it. And sometimes it's frustrating because you just want to get it approved. But the fact that they make you do things formally and correctly is a good thing. So, you know, the FDA is comprised of human beings.

[00:55:11]
Sometimes it doesn't always feel that way. But they might feel like they're just bureaucrats that try to give you a hard time. But they want to, by and large, do the right thing for people. And so, we do have a mutual goal, which is get safe and effective products designed and approved and on the market.

Q: Have you worked with any international regulatory agencies?

[00:55:44]
A: Well, I work with the ones in Europe and Asia. I am the technical director on IEC, which is an international organization for standards for brain documents which describe how systems should be designed. And I'm the technical director on the committee that's involved in breast tomosynthesis. So, we're trying to come up with quality control and performance metrics that will allow the better introduction of this breast tomosynthesis to the rest of the world [00:56:24] for me.

Q: And I know that more recently, Hologic has been involved in producing some biopsy equipment. Specialized for doing biopsies.

[00:56:43]
A: Yeah. So, as I mentioned, it's not just enough to find what looks like a suspicious cancer. You have to develop the technology to take a biopsy sample. And we have had a number of products in that space when we were involved in digital mammography and film mammography also. We had an imaging system which could direct a biopsy needle to a suspicious area seen in the mammogram, on a 2D mammogram. And then when we developed the breast tomosynthesis, we needed to sort of upgrade that to be able to direct a breast biopsy based on the 3D imaging. So,

we introduced that product. And we had a number of different systems that use that technology for either having the patient in an upright position or in a prone, on the table.

[00:57:48]
And we were also the first company to develop the biopsy based on breast tomosynthesis. Again, it's important to be able to find the lesion in the same technology, to be able to biopsy the lesion in the same technology [00:58:04]. We have a number of other biopsy products that we're producing. One is called [00:58:13]. And that's designed to try to speed up the procedure. So, in a normal biopsy procedure, they would insert a needle into the breast to the desired location. You would take some breast tissue. Then you would image it using x-rays to see whether in fact you were taking the tissue from the correct location. So, that involves taking that tissue sample and moving it to some type of imaging system, which takes time.

[00:58:43]
And the woman is sitting in the equipment typically with a needle in her breast. So, what the [00:58:49] system is designed to do is it takes that breast tissue sample and then it immediately directs it, funnels it into an imaging system automatically. So, you can get that imaging confirmation in seconds really, rather than minutes. So, it shortens that procedure. Shortening that procedure is not just a great thing from a patient's view, but it also reduces the risk of bleeding during the procedure if you can shorten the procedure. But that's biopsy. We've developed some other technologies which I just remembered which I ought to mention which are kind of an offshoot of our digital mammography and tomosynthesis. And that's known as contrast imaging.

[00:59:38]
In normal mammography, you're just imaging a breast as it is. In contrast imaging, before you do the imaging, you inject a pharmaceutical – in this case, it uses iodine – and you inject it into the vein of the person, and then it goes into the breast and the rest of the body. And it turns out it pools preferentially in areas where there's a large amount of blood flow, which is often associated with a growing cancer. And then you can image the presence of that iodine in the breast. And it turns out that's an alternative method of looking for breast cancers, which can find

many more breast cancers than conventional mammography. And it has the other benefit of not being affected by breast density at all. That's a new technology that we've introduced in the past couple of years that we think is pretty exciting.

Q: So, how do you balance something like patient comfort with efficacy and the need to, I guess, be a little bit uncomfortable to get the procedure done and get it done properly?

[01:01:01]
A: Good question. So, the primary goal is efficacy. That's the purpose of mammography, is to find breast cancers. And if making the procedure more comfortable sacrifices that, I don't know of any of our users that would want that product, honestly. And I don't even think most women who had thought about it very long would want that. Yes, they'd say the current mammography is uncomfortable because you compress the breast. It turns out, there's a lot of good reasons to compress the breast. And some of them are historical and aren't needed anymore. They date back to film mammography.

[01:01:46]
But you still need to immobilize the breast to make it so it doesn't move during the exam so you can find small breast cancers. You still need to compress it so you can hold the breast tissue out and image as much of the breast as possible. That's important for finding all breast cancers. Those are the major requirements which still exist. In original film imaging, you had to make the breast very, very thin, which requires very intense compression, pressure, which made it more uncomfortable. You don't need to do that for digital systems. You don't need to do that for [01:02:24]. So, we've realized in the past couple of years that many of those requirements which resulted in an unpleasant exam for women were obsolete.

[01:02:36]
So, we've embarked on products and research programs to develop methods of doing breast imaging which maintain the cancer detection, which maintain the efficacy, but also lower the discomfort which [01:02:51]. And we have a product now called Smart Curve, which is a normal – the historical, old compression paddles, which are basically one or two pieces of hard plastic,

flat plastic which would squish the breast. The Smart Curve is something which curves and sort of hugs the breast around. And to some extent, avoids pinching the breast. When you have two flat paddles pinching down, you can get a pinching area right at the chest wall. So, we have this curved paddle, which increases the comfort. And we were able to demonstrate in some studies that the mammograms that were generated using this more comfortable paddle did not suffer in clinical performance.

[01:03:42]
And so, we were very happy about that and we embarked on long term projects to see if we can further making more comfortable mammogram without affecting clinical efficacy. The clinical efficacy – that is the name of the game. That is why you do screenings for breast cancers. If you don't want to have any discomfort and you don't want to have any radiation, you should just stay home, okay? I don't recommend that. But that's the way to get no harm from the mammogram. But you're not going to get any of the benefits.

Q: So, you mentioned staying home. And I know we're kind of looking just barely over our shoulder and into something that's still very, very much ongoing. But has the current COVID-19 pandemic had any impact on screening and people's willingness to keep going and to keep getting screened right now?

[01:04:44]
A: Well to my knowledge, in the world, screenings stopped actually, after this COVID crisis. And that all – what we call collective procedures. Our hospitals were not performing them. And fortunately now, we're almost at July 1st. We are – hospitals are slowly opening up again. And you know, each hospital has dealt with this in a different way. They have to deal with both a method of making women safe. They have to deal with making the hospital professionals safe from the women that are coming in. And they have to deal with making everybody feel safe, which is not necessarily exactly the same thing, okay?

[01:05:39]

The system can be very, very safe. You could have sterilized the heck out of it, for example, after the previous patient. But unless you have a sticker hanging saying it was cleaned, the woman won't feel safe. So, they're really kind of addressing both of these issues. They're opening up. I think they are doing a number of things trying to reduce the amount of waiting of women in waiting rooms so you're not in an environment where you're around a lot of other people. There may be spacing exams further apart, give everybody time to clean systems between exams. The technologists may well be wearing personal protective equipment now. Maybe face shields, gloves, and other things.

[01:06:28]
And so again, what I heard – and I'm only just starting to hear about things opening up, and I think each hospital is dealing with this in their own way – but screening exams went to zero. It was kind of an awful thing. Now there's a backlog of three or so months of women that have not been screened. We may well see a small uptick in breast cancer diagnoses because there's been this three months when people have not been getting them. Unfortunate. But I think things are slowly returning to normal.

Q: Great. So, to shift back around again a little bit, I know that before getting into women's – something that was more specifically related to women's health with mammography, Hologic had also dealt with several products involved with bone density. Did you ever work on any of those?

[01:07:33]
A: I've never directly worked on them because when I was hired, we were desperate to find something else. And so, I was always assigned something other than those bone density products. But I know a little bit about them. Jay Stein is the person to ask about those when you interview him. That's another product area where you can feel good about it because that is designed to detect osteoporosis, which can be a devastating disease for elderly people. I know the physics behind it. I don't know specifically what questions you might like to ask.

Q: Sorry, I'm looking back over my notes now.

[01:08:42]
A: I mean, that's another example of imaging women that are asymptomatic, that don't have a known problem, try to identify the signs that they have osteoporosis before they have a catastrophic fracture. And there are certain drug regimens and other things you can do to try to reduce the risk of a fracture.

Q: So, do you know if from the start, Hologic has always viewed itself as a women's health company, or is that just something that made sense at one time and they've been running with ever since?

[01:09:22]
A: Well, I wasn't around from the beginning, and I'm not actually sure we were a women's health company in the very, very beginning. That's a question for the founder of Hologic. But for many years, we were doing mostly the bone density. And I don't know if we necessarily thought of ourselves as a women's health company at that time. I think maybe that moniker came about after we got into breast imaging and then our two main product lines were products which focused on women. Women are not the only people that get breast cancer. Men get breast cancer, but they just get it at a greatly reduced instance. And when we [01:10:12] at Hologic, we ended up purchasing another company which has a number of other women's health type products or gynecological products. So, that's how we've ended up being known as a women's health company.

Q: Okay. Actually, oh, right, way back, way early in our interview, you talked about the – when we were talking about the switch from film to digital, you talked about storing the digital images. What sort of unique challenges did that present?

[01:10:52]
A: Well, if you think back 20 years ago, if you take a digital image today, like a photo on your camera, and you want to store it on the cloud, there's nothing easier. You pull up your phone and you get the Wi-Fi working on your phone and you click send. And it goes over the Wi-Fi into the

router sitting in your house somewhere. And then it gets transferred over some high speed internet line to some magical computer or computers somewhere in the world, we hope. And that's the way that it works today. But 20 years ago, that infrastructure was much more elementary and rudimentary than it is today. These medical – these mammographic images are large relative – for example, relative to a digital camera for sure.

[01:11:54]
And back then, they were enormous. And so, you had to deal with developing hospital networks, which were fast enough that they could support the number of megabytes per second needed to transmit these images without the slowdown of taking images. And then you had to build computer storage networks that were capable of storing large numbers of these images. And again, the mammographic images were quite large compared to many medical images. There's a lot of them. So, those are some of the challenges. In fact, there was not even a language that was defined when we first started as to how to encode the images.

[01:12:39]
Right now, when you take a picture on your phone, it's stored as a JPG image. Well, somebody had to invent what the word JPG meant. And until that was developed or similar type things, it was difficult to create an image which could be understood by computers around the world. Well, it took a while for the organization – it's called DICOM – to create the dictionary and the language by which we could store mammographic images and it would be understood. So, there were a lot of challenges.

Q: Can you say about how large an image would be?

[01:13:20]
A: Yes. So, in a typical mammographic exam, they take two views of each breast. So, there's typically four views that are taken through a women. There's one known as the CC, the cranial coddle, so the image is taken vertically. And the other is known as a medial lateral oblique, where they take it actually at an angle through the breast. And each one of those digital images is

about 20 megabytes in size. And on your digital camera, it might be half a megabyte or less even – resolution of your camera and other details.

[01:14:11]
Now, that was just digital mammography. And back in around the year 2000, those were significant challenges, storing and transmitting those. You also have to display them. And the computer monitors actually, the number of pixels in your monitor – they were much coarser back then. So, it was difficult finding a monitor that displayed those very large images. Now with breast tomosynthesis which we introduced, the images are much bigger than digital mammography, and they might be 1000 megabytes, or it may be 50 times bigger than a standard digital mammogram. So, we're kind of back to that challenge again of network speeds and digital storage capabilities of storing large quantities of images.

Q: That's almost a gigabyte per image then if it's that big. Wow. What would the resolution for that type of image be?

[01:15:26]
A: So, for our system, the images are 70 microns by 70 microns. That's .07 millimeters, if you can think in millimeters. And it's small. Quite small. And you need resolution like that to find the smallest cancers.

Q: Have advancements in displays and that sort of thing made the imaging equipment cheaper over time, or has that gotten more expensive, or is it about the same, all things equal?

[01:16:18]
A: Well, having never bought one of them, I don't know. They've gotten better for sure. I don't know if they've gotten cheaper. Maybe they just upped the performance and kept the price – I don't even actually know what the price is. But the monitors, they're enormous monitors with super high resolution and I suppose the requirements for a monitor for viewing a mammographic image – they are pretty stringent. You need to have not only a lot of pixels, but you need to have very good greyscale definition in a way that you can go to your electronics store and buy an

enormous TV. It just costs a thousand bucks or $2000 dollars or something. And the resolution of those is very, very high. But the ability to display very, very fine shades of grey in those TVs are not of medical grade typically. So, those medical grade monitors tend to be more expensive.

Q: So, with the changing storage concerns, are there also changing security concerns?

[01:17:50]
A: Well, yeah. Well, there's two types of security. One is just being hacked, and I guess the hospitals themselves deal with that. But there's also regulations regarding patient confidentiality. I think it's the Health Insurance Portability and Accountability Act, which essentially says that when you're storing patient information, it must be treated confidentially. So, doing that, a manufacturer has to provide methods for encrypting images so that if they happen to be intercepted, they can't be viewed inadvertently. And it also has to be able to provide an ability to transmit images, and yet at the receiving end, to have a radiologist or some healthcare professional who is allowed to see that patient information to get access to it.

[01:18:55]
And so, we have to deal with that. It's very important to know that if you're looking at a mammogram, you're looking at it for the right patient, for example. And yet if a hospital calls up Hologic and says, "We have a system and took this image and we're not sure it looks right," they have to be able to send that image to us for us to look at it. But they have to be able to remove the patient information from it when there's anonymization. And we have to provide software that performs that functionality. And then you have installing all of our equipment is based on computers. And when you buy a computer, Microsoft every day it seems is coming out with another security update for their operating system.

[01:19:49]
I guess all the computer systems are doing that. And that's a challenge on systems that are in hospitals because the FDA approval process is just a long process. If you buy a PC today and then you go back a month later, that same model you can't buy anymore, you know? They've made a new model. So, computers evolve so quickly. And yet, computers that are controlling

medical equipment must move much more slowly because it probably takes a year to get FDA approval. And the equipment's going to be put in a hospital and it may have a life of ten years. These are not things that I'm involved with, but there are surely challenges in maintaining security in what could be ten year old electronics. So, it's a big concern.

Q: Alright. So, you'd also talked about patents. Do you hold any patents? Can you walk me through a few things that you've worked on?

[01:20:55]
A: Well as part of a group at Hologic, we had a lot of patents. I don't actually know the numbers of them. We have fundamental patents on methods of doing digital mammography, on methods of doing digital mammography using the selenium detectors. Because we were the first really to work on a commercial breast tomosynthesis system, we developed a huge number of patents around that technology which talk about not just methods of requiring three-dimensional image, methods of doing the mathematical algorithms to generate a three-dimensional image from the scan, methods of displaying the three-dimensional images, methods of doing a biopsy based on three-dimensional localization. So, there's a wide range of disparate patents based around our technologies that we worked on. These are both US and worldwide patents. It's been an educational experience for me.

[01:22:06]
For sure in the patent – I've seen the differences in the patent offices from the US and Europe and elsewhere. To get a patent, it must be considered novel. And the patent has to reach certain requirements. You have to [01:22:25] the patent how to do something. And you can send a patent to the US patent office and get it approved. And then you can send the same patent to a European patent office and they say, "Well, somebody did this 15 years ago. How come the US patent office didn't find that," and vice versa. And so, there's a lot of regional differences in the way patents work. That's part of the development process, is making the patents. They're protective of what you're doing. You put a lot of money into developing a product. They slow down a competitor from copying you if you're the first. So, they have their values. But suing is always a risky thing because you never know [01:23:20] trial exactly what the results are going to be.

Q: So, there's different standards of novelty depending on where you are in the world.

[01:23:37]
A: Not really. I think there's different – the patent examiners – everyone's a different human being. And you just have different ones that might be more or less probing, would be the way that I would put it. I think that everybody's standard is probably the same. Must be novel, but maybe what one person thinks is novel differs from what another person thinks.

Q: So, that could really come down to the individual then rather than the system.

[01:24:08]
A: Yes, definitely.

Q: So, maybe this is time to start some more – well no, before we get into the more philosophical stuff, did you ever have to interact with any insurance companies to explain the efficacy or necessity of mammography with a new technique or a new imaging equipment?

[01:24:46]
A: Yes, I've been involved. My screen just went blank again, excuse me. I've been involved in insurance companies, payers, hospital administrators. I do get involved in that. And I would say one of my roles at Hologic has been to sort of explain technologies to our customers. And in the very beginning, I'll just use breast tomosynthesis as an example. In the very beginning of the development of that technology, I would say my audience was primarily radiologists who wanted to understand how it worked, wanted to see whether they were going to buy into it. And it's morphed, who I speak to over the years. And then it turned into hospital administrators, explaining how it works.

[01:25:39]
And the radiologists are brought in, but now you've got to convince somebody who's writing the check for the equipment that it really does something. And then it graduates to health insurance

payers, the people who are going to be paying the bills for this new technology. And these people are all conservative. Payer doesn't want to pay for a new technology which is often more expensive than an older technology unless you can demonstrate that it's better. Why should they? Develop a new drug to help headaches which costs $50 dollars a pill, then why is I, a payer, will be willing to reimburse the hospital or patient at $50 dollars a pill when maybe aspirin is just as good?

[01:26:26]
So, unless you can convince the payer that this new drug is better than the aspirin, they don't have an interest in increasing any payments. And when we introduce new technologies, the equipment's more expensive [01:26:42]. So, I have been involved in discussing with various interested parties how to develop models for and demonstrating [01:26:55]. And sometimes it's a nonlinear process for sure. I mean, to a woman, saying you're going to find cancers earlier and your mortality from breast cancer might go down – that's kind of an obvious thing. You tell a radiologist, yeah, you're going to be able to find cancers more easily. Especially in breasts that you have trouble with [01:27:20]. But then when you come to the administrator, yeah, the equipment costs them an extra $100,000 dollars per system.

[01:27:30]
Then it becomes a different type of equation. And they want to know whether – maybe it's not going to save them money. Maybe they're doing it for other reasons. Maybe they're doing it because they want to provide better healthcare than another hospital. Maybe they're going to do it because they want to attract patients to their hospital because people will know that they're a leading institution. So, there's lots of different motivations that people have. Payers, they're more than happy to pay more money for a procedure if it's going to save them money for sure. And even if it's not going to save them money, if it somehow provides better healthcare, they often will sign onto giving reimbursements.

Q: Excuse me. Have you ever been a part of any trade organizations?

[01:28:38]

A: No.

Q: Have you done any philanthropy related to your work?

[01:28:52]
A: I haven't personally. I know my company is involved. They would be the right person to ask.

Q: Okay. So, over your time in the field, and for housekeeping purposes, I don't think we ever said – do you remember what year exactly it was that you joined Hologic?

[01:29:15]
A: It was 1999 that I joined.

Q: Okay. So, since 1999, what would you say is the largest change you've seen in your field?

[01:29:40]
A: Well, I think the transition from analogue mammography to digital mammography was the [01:29:49]. Images looked different. They were acquired differently. They were stored differently. They were displayed differently. There was a lot of reeducation, let's say, that radiologists had to make to be able to feel comfortable looking at those images. All the other changes that we've made, well, while they were more revolutionary in terms of healthcare [01:30:15] were easier for the radiologists. So, breast tomosynthesis – so digital mammography, by and large, performed just as well as film mammography [01:30:26].

[01:30:30]
But its reasons for introduction were not the improved clinical performance. They were the other things I talked about [01:30:37]. But we introduced tomosynthesis. It was a lot better than digital mammography, okay? But the images looked like mammograms. So, people were pretty comfortable with it. Maybe the hospital administrators that had to buy more storage for their computers. But from the point of view of the people doing the diagnosis, there wasn't that same transition, that need for reeducation, let's say, that there was from [01:31:08]. And the other

things we've developed – biopsy and contrast mammography – these are kind of natural small improvements or known technology advancements that we expected were coming and [01:31:24].

Q: Okay. So, this is kind of the opposite side of the coin. Has there been anything that you really anticipated would change, but hasn't really?

[01:31:45]
A: Well yeah, I'm sure there are probably examples of that. One example that comes to mind is the adoption of breast tomosynthesis outside the US, specifically Europe. So, there are just a large number of clinical studies demonstrating that breast tomosynthesis is just a better mammogram. It just finds more cancers and reduces false exams. And the initial studies were done in Europe, research studies. And the results were very positive. The results – and then we got results in the US which, by and large, mirrored those same results from Europe. And the US adopted breast tomosynthesis pretty rapidly. I don't know the exact adoption rate, but my guess is it's more than 50%. All the exams are 3D mammography. Might be more.

[01:32:43]
But in Europe, there are almost no centers that are currently performing our breast tomosynthesis. And this is a little bit of a surprise to me. And it's a surprise because 3D mammography performed better than 2D mammography. There are places in the world that don't do mammography screening. Okay, and I get why they're not doing breast tomosynthesis. Because they're not doing digital or film mammography. But if you're doing annual screening or doing a regular screening mammography like they're doing in all the countries in Europe – UK, France, Germany, Italy, Germany, Spain – I've been actually a little surprised by the almost zero uptake. And those screening situations are organized differently than in the US. They're run by the governments. And the governments are people that look at a new technology and say, oh my god.

[01:33:47]

We have to spend another hundred million euros to upgrade all of France to this new technology. We can't afford that. Or we really need to be sure that it's going to work. So, they have been extremely conservative. And it's been a surprise to me because there were a number of papers, studies in Italy, Norway, and other countries in Europe demonstrating that this technology really, really works well. And these trials were done by basically single or small numbers of sites on their own. And then you have the governments of those countries saying, well, we need to move very slowly and we need to redo the studies and we're in country A, and even though we're right next to country B that has a study, we have to redo that study in our country.

[01:34:45]
So, it's just been very, very frustrating. And interestingly that you should mention that because just the other day, there was what I might call a potential breakthrough on that in that the European Union governmental organization finally has formally endorsed breast tomosynthesis for imaging women with dense breasts. And so, now I'm hopeful that with this official government endorsement that the government agencies that were kind of putting the brakes on adopting this new technology will move more quickly. And it's been actually frustrating, I think, for a number of our customers who know that breast tomosynthesis is better than regular digital mammography that are unable to [01:35:34].

Q: So, looking back over your whole career, is there any single moment that you would put atop the rest and say "There, that was the most important or the single thing I'm most proud of?"

[01:35:55]
A: Oh, there's so many. I think getting FDA approval for all the products that I've been involved in. Neural imaging to the breast imaging. Those are great days actually.

Q: Would you say those are the best days?

[01:36:16]
A: You want me to say which is the best?

Q: Sure.

[01:36:21]
A: I'm not going to. I'm not sure that I differentiate them in my brain.

Q: Well if those were all great days at work, what was the opposite like? What made a bad day at work?

[01:36:41]
A: Well, a bad day at work was about 95 days ago when I had to not go into work anymore because of this COVID-19 crisis. It hasn't affected my ability to work so much because most of what I do is on the phone anyway all day long. But to see that the things that we work on, clinics and hospitals all have to shut down – they can even go into hospitals. That was bad days.

Q: But that's still – I mean, if a bad day at work means not being to go into work, that means you must really, really like your job. That's great.

[01:37:29]
A: Well now that you mention it, I don't like my commute, which was an hour each way. And I do like that extra two hours that I'm home to be driving on the highway. So, maybe it's not the worst day of my life. I've had some frustrating days with the FDA. But I'm not going to go on record as saying those were the worst days of my life. Who knows?

Q: Yes, you never know. Has there ever been any development or work-related concern – like, what kept you up at night the most often?

[01:38:28]
A: Well, so you're assuming that I'm up at night. As it turns out, I am up every night. But I've been doing that since I was very, very young. I fall asleep instantly, and then I always wake up for two or three hours. Just thinking about the – I don't think I anguish over anything at night. [01:38:59] be making up something to say that I was really concerned about something

[01:39:07] worth solving problems. It's not always linear and it's not always positive. Sometimes there's setbacks. But it's never been – I've never been in a situation where I felt like we [01:39:18] problems.

Q: That's good. Okay.

[01:39:38]
A: I'll tell you what's not kept me up at night but what's made me excited at night is again, when we first introduced tomosynthesis, getting those phone calls – and I would literally get them at two in the morning from doctors congratulating our [01:39:53]. Those were immensely gratifying moments.

Q: How did the doctors know that you were the guy to call for that to pass on those congratulations?

[01:40:11]
A: Well, I don't know. Maybe they were doing it for everybody [01:40:15]. But I was one of the very early – from the company's point of view, promoters from a scientific point of view. I would go around giving a lot of scientific lectures, wrote a lot of papers, write papers and other things. So, my name was – I was not by any means the sole inventor or [01:40:36] anything. Everything was a joint effort. But I think my name was better recognized perhaps. I'm sure the CEO of Hologic was getting similar emails. Maybe a little bit different. Maybe they weren't getting the actual mammogram images showing the breast cancer, but they were – you know, the chief executives were probably getting the same type of ra ra messages from our customers. I was getting the technical ones. I think it was just because I was out there traveling the world, really.

Q: Yeah. So, we've done a lot of comparing and contrasting the United States and Europe. Did you ever work elsewhere other than the United States and Europe?

[01:41:25]

A: Well, yeah. Well, I worked a lot in Asia – Japan, Korea, China, Taiwan. I'm sure I'm forgetting a lot of countries. A little bit in South America. I've been in most continents giving scientific talks at scientific conferences on the technologies. Always gotten a lot of good feedback. It was a good way of promoting the products, promoting the technology, promoting the company. We're a small company. Our name is not well known. Go to a country and give a talk in Thailand or something, they've heard of GE [01:42:20] tell people that our company is working on some pretty cutting edge – so yeah, I've worked in many countries over the world. I've learned that almost anywhere you go in the world or anywhere in the US, that radiologists by and large are all uniformly excellent. That was a great learning thing for me. I predicted that, but that turns out to be the case. I mean, they don't always have the same resources and the same knowledge to buy equipment [01:42:56].

Q: Okay. Cool. I am just about at the end of my list of questions here. So, I guess now is the time for the most important one, which is – looking back on the last not quite hour and 45 minutes, is there anything that I haven't asked you that I really should have asked you? What did I miss?

[01:43:29]
A: Well, I did most of the talking, so I covered everything I wanted to. So, I think you need to – or maybe you have gotten – learn more about the history of Hologic as itself. And I'm not the right person to do that because it's really – it's a great success story, honestly. And you know, it started as a startup and got involved – and really invented the field of x-ray bone densitometry. It's been enormously successful and has been able to fund the acquisition and the growth of these other companies to produce these great digital mammography company, great company in gynecological health and diagnostics imaging, general diagnostics imaging which is turning out quite important in these days of COVID. So, I think learning more about the arc of Hologic as a company would be quite interesting to your business. But I'm not the person for that. I'm okay. [01:44:41]

Q: I think we got it then. Okay. Well, thank you so much for sitting down and speaking with me today. And then, I'll go ahead and stop recording for now. And we'll wrap things up.

[01:45:03]

A: Okay. Thank you, man.

END OF INTERVIEW