Speaker 1:

Welcome to Optimal neuro|spine Podcast, a podcast about optimizing our brain and spine in health and disease. Each episode, leading neuroscientists, neurosurgeons, educators, patients, spine care, and quality improvement experts discuss their research, experience, emerging science, surgical advances, and insights about how to optimize neurological and spine care. Now here's your host, Dr. Max Boakye.

Dr. Max Boakye:

Welcome to the Optimal neuro|spine Podcast. Today I have a distinguished guest Dr. Susan Harkema. Dr. Harkema is Professor of Neurological Surgery at the University of Louisville. She's also the Associates Director of the Kentucky Spinal Cord Injury Research Center. She's Director of Researcher Frazier Rehabilitation Institute, and Director of the Christopher and Dana Reeve Foundation's Neurorecovery Network. Dr. Harkema currently holds the Owsley B. Frazier Chair in Neurological Rehabilitation at the University of Louisville. Dr. Harkema, welcome.

Dr. Susan Harkema:

Oh, thanks for having me.

Dr. Max Boakye:

It's really a true pleasure to speak with you today. Would you mind explaining to the audience, your training and background?

Dr. Susan Harkema:

Yeah, absolutely. So my PhD work was in physiology and I studied the control of oxidative phosphorylation in skeletal muscle using phosphorus nuclear magnetic resonance spectroscopy, which really had nothing to do with human beings or with a spinal cord injury. However, when I went to do my post doctoral work, it was a time where there was low faculty appointments. People were doing two postdocs. So I decided to do a kind of fun postdoc outside of where I was going to focus the rest of my career, which was going tobe in muscle energetics using nuclear magnetic resonance spectroscopy, which I had already secured a postdoc.

Dr. Susan Harkema:

And so there was no Google back then, but what I did is I went to the library. I picked what I thought that was the top four universities in the country. And then I researched different professors to see what might be interesting for me to do for a year or two before I started my career in that other area. And kind of long story short, I found and Dr. Reggie Edgerton and I picked each other. And so I went to UCLA and I was on a fellowship, which was an NIH fellowship that trained clinicians in basic science and gave basic scientists some experience in clinical research. So at the time I was doing animal research and human research, but what ended up happening is that the project that I was supposed to observe was just in its early development, which was to look at people who had complete spinal cord injuries and see if we could generate a locomotor pattern as they did in animals.

Dr. Susan Harkema:

And what ended up happening is that I ended up spending so much time developing that project, that it became overwhelming to do both animal and human. And so I went to Dr. Edgerton to quit the human work. And there was something in his office that pumps something into the air that makes you make

bad decisions, because he talked me into the human, but of course that ended up being a wonderful decision. So I stopped my animal work, and I really devoted myself to developing this human model. And so it was sort of a serendipitous thing. It wasn't something I thought about, wanted to do, or that I had a family member who had paralysis or friend, but I'll tell you the first experiment that I did, which I'm going to tell you was not that successful. Just looking at the spirit and the courage of this individual really hooked me for life to want to try to understand the mechanisms of the spinal cord and specifically apply them to chronic complete spinal cord injury. So that's really what my initial and still a big core of my focus is.

Dr. Max Boakye:

So you have devoted your life then to the treatment of paralysis and spinal cord injury. Can you explain the consequences of paralysis for patients and how do we currently deal with spinal cord injury?

Dr. Susan Harkema:

Yeah, so this was such a incredible learning experience for me about how difficult it is for a person, as well as the people who love them and caregivers, if they are fortunate to have them, how difficult their daily lives are. And I think about walking, "oh, you can't walk, you can't move," and it is devastating. But as devastating as that is, there are also consequences to cardiovascular function, respiratory function, bile bladder and sexual function, circulation, pressure sores, fatigue, metabolic problems. And these are things that they deal with every single day.

Dr. Susan Harkema:

So not only is it difficult to maneuver even in their home or in the community to do the things that they did and loved prior to injury, but they're really honestly sick a lot of the time. In and out of the physician offices, in and out of hospitals, anything that you can sort of imagine as an ailment, they're more likely to get, and then the consequences of it are more severe.

Dr. Susan Harkema:

And I think that the viewpoint has always been with these secondary consequences, and I'll just use blood pressure as an example. So a person with especially a cervical injury, but it's not exclusive to that, can range from a blood pressure of 70/40, which we would probably rush ourselves to the emergency room if that happened, to topping out in the same day at 180 systolic blood pressure, because they have autonomic dysreflexia. And when they have these really low blood pressures, they feel fatigued, they feel exhausted. They can't think, their cognitive function is low. And so they can't really do the things that they love or just daily activities during the day. But the viewpoint is, unless we repair or regenerate that section of the nervous system across the injury there really is no treatment for that, no treatment.

Dr. Susan Harkema:

So I hate this term, but it's used, "oh, it's the new normal." So these individuals live with this without any viable treatment. And so their daily lives are incredibly difficult. So I think that with this idea that unless we find a repair regenerative strategy, there isn't really anything we can do for these daily issues that they have, it's a very difficult life. And so I'm hopeful that the research that we've done and others are starting to show that, that's not the case. There's a significant level of plasticity and recovery of all these systems that can happen if we understand it and without regeneration of the spinal cord. It doesn't mean that's not important, it just means we shouldn't wait matter them until we have that answer.

Dr. Max Boakye:

So, clearly paralysis has tremendous impact for the individual. What about for society in general? Approximately how many patients live with paralysis from spinal cord injury? Do you have a number? And what is the socioeconomic impact roughly to society?

Dr. Susan Harkema:

So the numbers that are published do vary, and it depends on who obtains those numbers. So there's the spinal cord model systems centers that collect numbers, but those numbers are really focused on the people that come to those centers. So there's also many, many people who are in rural communities across the country that don't actually get counted. So the Christopher and Dana Reeve Foundation did a survey, and I think we could reasonably say there's probably 800,000 to a million people with spinal cord injury, not just traumatic but other types of causes of spinal cord injury that are now living with this condition. And it's a huge challenge because our healthcare system does not provide the sufficient resources for them really to recover or to get the assistive technology caregiving that they need. So of course these individuals are not likely to get back into the workforce for just some of the reasons that are maybe obvious to you, but that I just mentioned.

Dr. Susan Harkema:

And also because caregiving is limited, there's a big burden on the family. Then, because all these secondary issues, of course I already mentioned about their medical issues and hospitalizations. So the cost to individual families, loss of income that has to be focused on just getting these in individuals to have some quality of life each day, in addition to the healthcare that's needed because of these secondary consequences. I don't know if I can be accurate in the number and it may not even be completely calculable, but is in the hundreds of millions of dollars. If you add up all these aspects of lack of being able to contribute to society with a job, people in the family may be needing not to have to quit their job to care for them and then just the cost of the spinal cord injury itself, which for cervical individual is in the millions.

Dr. Max Boakye:

Mm-hmm (affirmative). As a neurosurgeon, I've been frustrated by the lack of pharmacological treatments for spinal cord injury. You have spent decades researching non-pharmacological approaches to treating paralysis. Can you describe some of the approaches that you've used over the years?

Dr. Susan Harkema:

So in the beginning, what really started this research was looking for what's called central pattern generators or sophisticated networks in the spinal cord that were shown to function in literally all other species, but still debatable in humans, designating a lot of control or the primary control of locomotion to the spinal circuitry. So we initial started looking for evidence that this circuitry existed in the human spinal cord. And we did that by really mimicking what had been done in the cat transected model. So we put people on treadmills who had motor complete injury, certainly at that time, that really felt like, or was considered to be a complete injury. We move their legs in a step like pattern because the theory of central pattern generation and locomotion is that efferent information specific to the motor tasks is integrated by these complex networks.

Dr. Susan Harkema:

And if you provided that efferent information after a complete transection, you could generate independent steps and they had done that in animals. So, that was where we started. But along that journey, what we started to observe was that the secondary consequences simply by weight bearing and activating these networks started reversing some of the other consequences where their bladder started functioning better, their bowel, their circulation, even their blood pressure. And interestingly enough, we started seeing changes in the arms and hands of individual who had cervical injuries improvements there, which was not anything that we were targeting. So as we kept having these observations, we started modifying what our theory was. And so I think if we kind of fast forward to now, the concept is that the human spinal circuitry is a primary controller of movement and locomotion. And I'll talk a little bit about that in a minute, but also an integrator of all the physiological systems.

Dr. Susan Harkema:

So when we are activating this circuitry that was known to be in the lumbosacral spinal cord for locomotion, it was starting to interact with other physiological systems. So we looked at locomotive training, standing and stepping paradigms, and just slowly and methodically started showing evidence that these networks existed and could be modulated in this population of people. But we got to a point where we started having people who were in complete injuries after years would walk over ground, but not the motor completes. And as I said earlier, that was really where my passion was, and still is, is in these chronic individuals with what are considered motor complete injuries. So also from the animal literature, really our experimental designs in humans are driven from what's already known, what's been shown in animals and what we observe in humans. But when we got to that point, we said, "Okay, we really need to be able to influence the state of excitability of these networks."

Dr. Susan Harkema:

In the animals early on if you dig in the literature, you find that they initial did it with epidural stimulation, but then went to drugs because it was better and more stable, at least experimentally. And so we decided that ourselves and others around the world had gathered enough evidence that it was worthwhile to implant an individual with a epidural stimulator in the specific locomotion where we thought these networks were and see if we could raise the excitability if we could get independent stepping. And so that's what led us into neuromodulation. And now we do a whole spectrum with epidural stimulation, transcutaneous stimulation and without stimulation, we're continuing to design these experiments. But I would say that the neuromodulation experiments with the implants have been the one that have really accelerated our understanding of how the human spinal circuitry works. Not only at the lumbosacral spinal cord, but also throughout.

Dr. Max Boakye:

So locomotive training is basically putting someone on a treadmill and doing some sort of stepping training?

Dr. Susan Harkema:

Mm-hmm (affirmative).

Dr. Max Boakye:

And you did have noted improvements with locomotive training, but you had almost like a ceiling effect for the motor complete individuals. And that led you to add the epidural stimulation, which achieved some breakthroughs. Is that a good summary?

Dr. Susan Harkema:

Yes, yes, absolutely.

Dr. Max Boakye:

So in 2011, you published a paper in Lancet, and one of the most sighted papers in spinal cord injury research on the results of epidural stimulation. That paper ushered in the neuromodulation as a very potential treatment for spinal cord injury. Can you describe this paper? What was the main findings? Why was it so groundbreaking? And then I would like to know when you began, how long you worked on this and when did you know you were up to something?

Dr. Susan Harkema:

Well, I guess if you know me, I always think I'm up to something, I don't know, good or bad. But yeah, and I think that the real advantage of designing hypothesis driven experiments in humans is that you get the absolute contribution of the humans. So there's a whole... From the humans. So you have a vast amount of information and knowledge that you just aren't able to get an animal experiments. And this discovery was a clear example of that. So, as I mentioned, we were really focused on stepping locomotion, independent stepping. And at that time, our working theory really was that it was this repetitive stepping was located in the spinal cord, but to individually move a toe or joint was much more cortically controlled. And there was no possibility that any of these individuals would ever move a joint independently.

Dr. Susan Harkema:

And so it wasn't even part of our design, we didn't focus on it. We had blocked off our minds to that possibility, which I think even at the time I would teach graduate students and postdoc, "Don't do that, follow your data." And even I had blocked my thought that that was going to be of possibility. So we had designed a stepping experiment, but two astonishing things happened separated in time. But the first thing was now we had trained this individual for over 170 sessions of standing and stepping locomotive training. And he had gained no independence in either. We found a neuromodulation configuration for standing and then to stand simply to get him to step. And we put him up on the treadmill and he stood completely independently. Now I have to say he had the harness on, so he was provided balance, but there was no manual assistance whatsoever.

Dr. Susan Harkema:

So this was quite stunning to us, quite shocking, because quite frankly, we didn't really think there was going to be a functional benefit. This was really a scientific study. We said, "Okay. It seems like there might be some beginnings of things that could be functional." So we changed the designing experiment to stand train this individual first. And so we did 80 sessions of standing overground. He was able to stand not all day long, not whenever he wanted for, but for significant periods of time overground without manual assistance, but he needed a bar for balance assist. And when we were doing what we call our post training mapping assessments, he kept trying to move his joint and he discovered that he could voluntarily move.

Dr. Susan Harkema:

And so for me, it was a huge paradigm shift because first of all, there was supposed to be no residual motor fibers available, and he was clearly intentionally moving. And also even if there was, how could if

sophisticated control of these movements was at the cortex level, could he be able to move simply by a continuous stimulation that excited the spinal cord? So I think those were the two things that I felt were to me quite significant and changed my thinking and, and maybe other people's thinking as well.

Dr. Max Boakye:

Hmm. That's fascinating. Since then you published several papers and many other labs confirmed your findings. One notable paper in the New England Journal of Medicine comes to mind. Can you describe that study, its findings and its significance?

Dr. Susan Harkema:

So I would kind of point to a few things and I really have to acknowledge Dr. Claudia Angeli because she's the Director of the Epidural Stimulation Program and she was the first author and the key leader in this paper. But I think the key findings were that we were able to get two individuals who were several years after injury, one at the thoracic level and one at the high cervical level, which I think is very important to be able to what I'm going to call walk overground. And I want to be clear about what our definition of walk overground means. Walking overground means that you can use an assisted device, but you cannot have any manual assistance from any people. And it doesn't mean if you get some assistance that it's not important, I'm just telling you what our definition of walking is.

Dr. Susan Harkema:

And so two of these individuals out of four that we were studying with this specific paradigm were able to walk over ground independently. And not only that, they were able to stand independently, again with balance assist. And then there was a lot of other motor movements that significantly improved. And I think that this was important on several levels. One, I think it really started to... There's something about walking I think that has a mindset change for everybody. And it demonstrated that this is possible. It also demonstrated that it wasn't within two years of injury. And I think it started to strengthen evidence for sophisticated networks in the human spinal cord for movement and certainly walking.

Dr. Susan Harkema:

Now, there were also two individuals who could not walk over ground, but on the treadmill, with different configurations for right and left and their intent to move those legs could do one leg independently or the other leg, just not put the two together. And this intentional piece again is so critically important because again, in our minds, these are clinically complete individuals. And so they comprised of ASIA A and B, as you know, those As are motor and sensory complete below the injury, Bs have some sensation, but are motor complete. And so this kept reinforcing this evidence for residual pathways that cross the lesion that can functionally reorganize in order to use the intent of the person to be able to in this case walk over ground. And it's also important to understand our neuromodulation paradigm is submodel threshold. So it is the efferent information associated with the task and or the intent of the person that starts either walking or stops walking or has them stand.

Dr. Susan Harkema:

So I think to link back to what I think the important findings are is that there are dormant residual fibers, most likely in almost everyone with a spinal cord injury. As you know Max, we haven't found one yet that after implant couldn't demonstrate that they could move or stand or to some extent with intent. So, that I think is really important. So if we can understand the spinal circuitry and how we can get it to a state of excitation for specific motor tasks that with practice and practicing the intent, you can start

driving really functional motor recovery. I think we need to think differently about what it means when we say someone is clinically complete or ASIA A or B, because in principle, they tend to just go straight to compensatory strategies.

Dr. Susan Harkema:

There isn't any real hope of them recovering early after injury, or certainly not years after injury as we're finding. So I think that that was one of a really important aspect. And overall, these individuals became much healthier. They had less medical issues, they felt better. So there's something about the entire system that changes once you activate the human spinal circuitry.

Dr. Max Boakye:

You also made another seminal discovery on the effects of epidural stimulation on cardiovascular system. Can you describe this discovery and how did you make it?

Dr. Susan Harkema:

Yeah, so what we call our original study was a cohort of eight in the New England Journal of Medicine was the second cohort of four, but we had a first cohort of four that we had started our local motor training with neuromodulation experiments on. And this person had a high cervical injury and he just could not complete the assessments. He couldn't complete training sessions because his blood pressure dropped so dramatically. He'd have to sit down and we'd have to stop sessions because of these fluctuations blood pressure. When we were mapping, I had noticed that there were some configurations that raised his blood pressure, but didn't activate his muscles. And so from a purely scientific view, I thought, "Wow, if we could in between use those configurations without activating his muscles, that would be pretty solid from an experimental standpoint, but would allow him to continue in the study."

Dr. Susan Harkema:

So we talked it over with him and we implemented it and then it worked. It worked really well. And then he said, again, human in the loop said to me, "Boy, if I could do this at home, it would change my life. I could go to dinner with my wife. I wouldn't have to tilt my chair back, it's embarrassing, I could dress faster." And so we then said, "Okay, let's design a study specifically for this," and The Nielsen Foundation funded this study of our first four cohort of just regulating blood pressure. And now we have from the Christopher and Dana Reeve Foundation, the first randomized, prospective clinical trial looking at the efficacy of this approach to improve blood pressure.

Dr. Max Boakye:

Mm-hmm (affirmative), that's really exciting. Other than the benefits you observed in locomotive systems paralysis and the cardiovascular regulation, other benefits of neuromodulation epidural stimulation have you noticed in the participants?

Dr. Susan Harkema:

Yeah. So as I mentioned before, all these physiological consequences of spinal cord injury appeared to change with any intervention that was activating the spinal circuitry below the level of injury. So as I mentioned before, we started seeing it with weight bearing and locomotive training, and then we saw it with epidural stimulation that was targeted to the motor system. So the approach we use to neuromodulation is there's different fields that we generate for different primary purposes, but even

with just targeting the motor system, we started seeing these changes in the cardiovascular system, circulation, bowel, and bladder, and even sexual function. Now, none of this back to pre-injury levels, I want to make that really clear. But things started changing and what was interpreted, and we could measure as being more towards normal. So we already mentioned that we can have specific targets only for the cardiovascular system, but we have also now started with Dr.

Dr. Susan Harkema:

Hubsher and Dr. April Herrity, specifically targeting the bladder. And we're funded for that with SPARC NIH. It's been a tremendous opportunity for us, and we've been able to specifically target bladder function, both to increase capacity and to be able to have some voluntary voiding. And along with this, as anyone in the spinal cord injury field knows is one of the places that there's this high level of blood pressure or autonomic dysreflexia is during a bowel program and or when the bladder gets full. And with the advancements in the technology that we've been able to make in, in partnership with Kessler Foundation and the Medtronic, we can provide what we call cohorts. So combination targeted stimulation configurations that help with capacity, but also at the same time control blood pressure.

Dr. Susan Harkema:

So we're really looking at this electrode at the lumbosacral spinal cord with the right available technology to be able to have multiple targets at the same time. So kind of in summary, we've seen a indirect effects on cardiovascular, respiratory, circulatory, bladder, bowel, and some sexual function. And with targeted stimulation, we're able to a higher or a more significant degree affect cardiovascular and bladder and control blood pressure while there's bladder. And we're just starting to target the bowel directly, but we don't have any evidence on that yet.

Dr. Max Boakye:

Mm-hmm (affirmative). So back when you were working on this, what kind of technology... I guess you used existing technology to do the epidural stimulation. Can you comment on the limitations of this technology and what are you taking to advance the technology and overcome the limitations?

Dr. Susan Harkema:

Yeah, so we started with just off the shelf pain stimulator. And so when you think about the technology, there's the basic hardware, there's the firmware that's inside the pulse generating device that controls that and then there's the software. I mean, of course there were... I mean, there were some, what we would consider quite remarkable results even with that technology, but as we started to advance and understand what we were doing and what we needed to do, we were very limited. So if you think back to the description of individuals only being able to step one leg or the other, that to us was a technology limitation because we didn't have the flexibility to provide a right and leg what we call cohort. We now have taken one step forward with Medtronic to develop very specialized software, that can allow that type of flexibility.

Dr. Susan Harkema:

So that actually as you know Max just happened in the last few weeks and we've seen some pretty big changes in people immediately because we have that flexibility to deliver the fields at the speed and at the complexity that we need to be able to do complex motor tasks, but also to control physiological systems while you're doing that. And we've also advanced the technology. If anyone's familiar with a pain stimulator, it's a tiny little device, which makes sense for people with pain and they literally almost

always just turn it on and leave it on. But now where we've moved to a tablet that has large button and people, even with extremely limited hand function are able to control that tablet themselves, which has allowed them to have more independence and reduced the burden on their caregiver. So in something that in a family that happened this week, I don't know if it was the person with the spinal cord injury was more excited or his wife who was going to be able to do other things while he was stimulating because she didn't have to control it anymore.

Dr. Susan Harkema:

So there's just some of the changes in the technology, but for this to really be successful in the home and community, there's really going to have to be tailored devices. I think the hardware that's already been out there tried and true with some firmware and some more or flexibility is at least from our scientific standpoint or what our knowledge is now is not the barrier. It's really the software that can deliver the fields in sequences and in the way that we need it, and to allow the individuals with spinal cord injury to be able to control the devices.

Dr. Max Boakye:

Mm-hmm (affirmative). You have been working with SCI populations for over two decades and we've talked here about the impact of SCI on multiple systems, so SCI is a systemic disease. Any observations about what is missing in SCI care? And if you had a magic wand, how would you design SCI care?

Dr. Susan Harkema:

So I think there are some places that do some of this, but if I could design the way care would be provided for people with spinal cord injury to be centric to them and to benefit them the most and keep them the healthiest that you would have really a team of physicians who would work together, who would see a high number of people with spinal cord injury, who would be trained in different disciplines. Because as we've already talked about, they have cardiovascular deficits, they have respiratory deficits, they have metabolic problems, spanning every physician specialty. And what I've learned from these individuals over the years, especially depending on who their physicians are, they kind of become their own medical navigator. They're explaining to all these different specialists, what works for them, what doesn't, what their spinal cord injury means for whatever they're going in for whether it's gynecology or a stomach ache or primary care. I would like to see a dedicated team.

Dr. Susan Harkema:

And I don't like this analogy, but it is like cancer, right? You have these individuals who have their own specialties, but have some focus surround spinal cord injury. This person it's hard enough for them to get around, can come to one place and they can see their specialist in urology, in cardiology, in pulmonary, in infectious disease. And that you would have this team who would work coordinated and collaboratively to support this medical paradigm.

Dr. Max Boakye:

That's great. In the last couple of minutes, can you talk about where we are in terms of getting this as a routine therapy for patients? Where are we with the FDA approval? And if you can also comment on ultimately, when should epidural stimulation be initiated in patients and who do you anticipate will be the best candidates for it?

Dr. Susan Harkema:

Mm-hmm (affirmative), okay. So that's a critical question and a really important one. From my perspective, it's a evolution, not a revolution. I would say from my personal view, I think there's enough evidence, both from cohort studies that we really need to really invest in these efficacy trials so that this can move forward because as we've already mentioned and what we observe with our 30 plus people we've implanted over the last decade, that their quality of life is better now. So neuromodulation is not regenerating the spinal cord and getting people back to where they were pre-injury at this point, but it can normalize their blood pressure so that their life is significantly better, their cognition is better. There's so many things that can incrementally, but significantly change their function and health where I see that translation should start occurring now. Now, having that said, we need to keep the scientific studies going to answer the other questions that you're asking, because right now there's other groups that are contributing significantly to this area as well and some of them stimulate very differently than we stimulate, which is better.

Dr. Susan Harkema:

Maybe a different type of stimulation is better for a different type of population. We need to still keep asking those questions. And then also it's, "Where is the technology?" Because in order for you to really have an efficacy outcome in the home and community, the technology has to be supportive in order for you not to get a negative because the technology not supporting what you're trying to do, even though with the electric fields in the lab, you can generate that. So if you look at all those aspects, I think that the first translation to the clinic that would have the most success and a broad impact on people's health and quality of life would be the cardiovascular function because the technology as it exists now, it's not ideal, but it's being used by our people in our studies at home very successfully and making a big impact.

Dr. Susan Harkema:

The technology is sufficient, at least now with our new release one with Medtronic where people can control it themselves. And so really because of technology and really cost because the evidence is showing that you may not need significant rehabilitation to get an effect that's clinically relevant, rehabilitation I think we're showing is it enhances that, but right now I think that could be the first step into the clinic. And then alongside that, you're going to follow these individuals over time to learn about long term effects. But also along with that, advance the technology and do trials in other areas. We have kind of a unique advantage because placing that electrode with the same IPG, but just continuing to provide sensing capabilities, control algorithms in these same people you can start studying and designing trials around the other effects. I would say that starting with cardiovascular to me makes the most sense. Now, where are we in FDA approval?

Dr. Susan Harkema:

It's complicated in the sense that, it really has to be a company that goes to get commercially viable approval. And then you have to get the healthcare providers of course, to support the reimbursement of that. So those are really out of our hands. I mean, really, I see our role working and advocating for those groups and continuing to provide the strength of evidence, both from an efficacy standpoint, but also in how it's going to reduce the burden of care and cost to hospitals and insurance companies. And then also the physicians have to understand and accept that this approach is a better one than what's conventional for people's spinal cord injury. So to say, when it's going to happen is dependent on a lot of stakeholders that we certainly are committed to invest in, to work with to move it forward, but isn't really out of our decision control.

Dr. Max Boakye:

Thanks, that's really awesome. My last question for you, Dr. Harkema is you have been an extremely successful scientist who has dedicated your career to improving the quality of life of spinal cord injury patients. What is your advice to upcoming young scientists as to how they can succeed at the same level?

Dr. Susan Harkema:

I would say you have to love science because there's a lot of challenges, so make sure you really love it. Number two, you have to be persevering. I think that's the most important quality. I mean, we're already making an assumption. These are course highly intelligent individuals with a scientific mind or clinical scientific mind, clinical scientists as well, but to be perseverent and then to believe in your data. Don't get yourself trapped into what's already well accepted. You may support that evidence, or you may not believe in your data. And I kind of told you a little bit of a story where I faltered in that way, and we almost missed it. If we didn't have a human there diligently trying to move, we would not have made that discovery. So I think perseverance, passion, and really trying to believe in your data, the data that you have.

Dr. Max Boakye:

Awesome. Well, this brings us to the end of our interview. It's been a fascinating conversation with Dr. Susan Harkema. The transcripts of this would be on the websites as in addition to the two papers in Lancet and New England Journal of Medicine that we discussed in the podcast. Thank you very much Dr. Harkema for taking the time to interview with us.

Dr. Susan Harkema:

Well, thank you very much for having me and I loved the series and I've loved all the ones you've done so far, it's been so informative. So thank you so much for investing in this podcast.

Dr. Max Boakye:

Thanks.

Speaker 1:

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