Introducing MED-EL Cochlear Implants for Persons with Single-Sided Deafness (SSD) and Asymmetric Hearing Loss (AHL)

Recorded Nov 21, 2019

Presenters: Meg Dillon, AuD; Allison Racey, AuD

AudiologyOnline.com Course #34117

Partner: MED-EL

- [Allison] I am Allison Racey. I am the manager of Regulated Research at MED-EL, and I'm excited to be here today with Dr. Margaret Dillon from the University of North Carolina to speak with you about the Single-Sided Deafness & Asymmetric Hearing Loss Indication for MED-EL cochlear implants. Meg Dillon will be here to also talk to you about some of the data that they have found at the University of North Carolina in this population. Okay, so after today's discussion, you should know a little bit more about who might qualify for a cochlear implant for single-sided deafness or asymmetric hearing loss with the MED-EL cochlear implant system, and also have a better understanding of some of the data that UNC has collected in particular with quality of life. And you'll be able to understand a little bit more about spatial hearing and fine structure, some concepts that also relate to cochlear implants in this population.

So MED-EL is very excited. In July of this year, we became the first and only cochlear implant manufacturer to have approval from the FDA for single-sided deafness and asymmetric hearing loss. This is a population that traditionally has not had a lot of options in terms of treatment for single-sided deafness or asymmetric hearing loss. So this was a really big breakthrough for us and for the field of cochlear implants in general. I think before we get into talking about the data or the specifics of the FDA approval, it's important to consider the impact of unilateral hearing loss on these patients. And so what we know is that this is something that can impact a large number of people. And of course, these patients do fine hearing and quiet. If they're talking in a one-on-one conversation with somebody, they do have a normal hearing ear or a better hearing ear and so that can of course help them compensate for missing what they're not getting from the ear with profound hearing loss. But when you're talking about hearing a noise or even locating where sounds in the environment or speech originate, that can be much more problematic. It can have a large impact on quality of life as well. So this is something that, although people are able to compensate in many situations, it can certainly increase fatigue and stress throughout life. Patients really report that it does have a significant impact. This is something that we can't ignore or just say, "Well, you're fine. "You're getting by okay." Previous

treatment options have included traditional hearing aids as well as CROS or Bi-CROS hearing aids or bone conduction devices. And while these options can route the signal from the poorer hearing side to the better hearing side, they don't restore binaural hearing. So they can't help with those situations like improving localization or improving hearing in all noise configurations and things of that nature. So they can provide some benefit in various certain situations, but they, again, don't restore that true sense of binaural hearing or that sense of hearing in stereo or picking up sounds from all sides. So there is a limited benefit to these options. I think the best thing we can do is to hear straight from someone who has been affected by unilateral hearing loss, how much of an impact that did have on their life. So I will let one of the patients, that UNC actually implanted that Dr. Dillon sees, tell you about his experience with unilateral hearing loss.

- A lot of the things I did in my life changed. Loved going to movies, was impossible, it was impossible. I did try to return to work. My wife was kind enough to accompany me on a trip. I had a business meeting in Atlanta. We arrived the night before and stayed in Buckhead. We were gonna dinner at a restaurant with outside seating. I was unable to conduct myself and handle the meal, because of the noise of the roads. And the meeting itself, I was, you know, I kinda stumbled through it. I knew it, I just couldn't be effective in the state that I was. So I basically made the decision to retire, and really didn't know what my next step would be.

- [Allison] He just speaks so well, I think, to again, how much of an impact this can have outside of just, "Oh, I miss an occasional word "or parts of a conversation." But impact enough to the point where he felt his best option was to retire early. So research in the unilateral hearing loss population has actually been going on for quite some time. MED-EL has supported research in this population for over a decade. At first cochlear implants were used for patients who had unilateral hearing loss, as well as incapacitating tinnitus. And this was first done in Belgium with Prof. Van de Heyning in 2008. They published showing that there was some benefit for patients who had

tinnitus and were implanted with a cochlear implant for unilateral hearing loss. But what they didn't expect to find is that these subjects also reported that they experienced benefit in their ability to perceive speech, as well as how this affected their life, so their subjective benefit from the device as well. So this was a surprising finding for the group in Belgium, and they soon published the results on binaural hearing looking at that speech perception and subjective benefit as well. So research has continued and there is now a significant body of evidence that comes from around the world as well as from North America and that also that there was really a need for this population to have cochlear implants approved by the FDA as a treatment option. And so what we were able to do was to take this large body of evidence and submit that to the FDA. So primarily the University of North Carolina at Chapel Hill with again, Dr. Dillon as the principal investigator, has been running a clinical trial for single-sided deafness and asymmetric hearing loss for a number of years now. We were so grateful to Dr. Dillon for sharing that data with us and all the investigators from UNC to allow us to submit that to the FDA.

So again, we combined that data along with some other confirmatory evidence from House Clinic, again, Antwerp University in Belgium, and the University of Western Australia and completed an extensive literature review to submit all that combined data to the FDA to gain this approval. This was something, again, that was really brand new for FDA to consider something like this. But the data was so strong that in the end, we were able to gain that approval. So this really was a very exciting time for MED-EL. In terms of what exactly got approved. So when we talk about single-sided deafness and asymmetric hearing loss, those two indications do share a number of similarities. So first of all, we were approved for both SSD and AHL in five years of age or older. So this is a pediatric and adult approval, again, going down to five years of age or older. We're looking for hearing loss in the ear to be implanted that is profound and sensorineural in nature. We define that profound hearing loss as a pure tone average of greater than or equal to 90 dB at 500, 1,000, 2,000 and 4,000 hertz. And so you'll notice this four frequency PTA, of course, is a bit different from what we often think

about with a pure tone average. But hopefully, the inclusion of 4,000 hertz will be a little more accurate in terms of really defining that profound sensorineural hearing loss. For both indications, we're looking at a word score in quiet worse than 5% in the ear to be implanted. For adults that is specified as CNC words, and for children that could be any list that you deem developmentally appropriate. So again, looking for that really profound hearing loss with a poor word score preoperatively. Where these two indications differ is in terms of the contralateral ear. And truly for your purposes, you don't really have to think about them as two separate indications. FDA does view them as such, but as far as you're concerned if someone fits either the SSD or AHL indication, they can be an implant candidate and together we might call that unilateral hearing loss. And again, for the SSD indication, we're looking for someone who has normal hearing to mild sensorineural hearing loss in the contralateral ear, again, using a four frequency PTA and defining that as being less than or equal to 30 dB. And then the asymmetric hearing loss or AHL indication would go from mild to moderately severe sensorineural hearing loss.

So again, 31 to 55 dB with that same four frequency PTA. Again, as far as you're concerned, the numbers here don't really matter as long as someone is between zero dB and 55 dB in the contralateral ear and then have that profound hearing loss in the ear to be implanted, they would qualify under either of these indications. An additional point to the indication is that candidates should have prior experience with a CROS or Bi-CROS hearing aid or other relevant device. And this is an interesting piece of the indication, because I think here where it specifies other relevant device that does give you some opportunity as a clinician to make your best judgment as to what that relevant device may be for any particular candidate or someone who is interested in a cochlear implant. So that's great if someone comes in and they're interested in a cochlear implant, but they've been wearing a CROS or Bi-CROS device for a while and finding that that isn't helping. But they may also have experience with bone conduction devices. It could be a bone conduction hearing aid or a soft band or even a bone conduction implant. Or if they have some aidable hearing in that ear to be implanted,

they may just be wearing a hearing aid. So I think any of those options where someone can say, "I've trying something that's nonsurgical," or even a bone conduction implant, "and I'm not happy with that, "and I'm interested in pursuing a cochlear implant," can certainly meet this criteria. In terms of contraindications for both SSD and AHL, the first bullet point here is profound hearing loss for more than 10 years. And this is not talking about any kind of progressive hearing loss. So if someone has had hearing loss for more than 10 years, but it has just slowly walked down the audiogram and eventually in that ear to be implanted has become profound, then you would not have to worry about this contraindication. But if it's someone who truly has had profound hearing loss for more than 10 years in that ear to be implanted, then again, they would be contraindicated to receive a cochlear implant for SSD or AHL. Additionally, if they have an acoustic neuroma present, then again, that would be a contraindication. If that's something that they just have a history of, but it has been treated and is no longer present, then that would be fine. But if it is actively there, then again, that would be contraindicated. And the other contraindications for SSD and AHL really follow along with what we typically expect for cochlear implant candidates.

So if the auditory nerve isn't functional or if they're not able to wear the processor due to skin allergies or other things of that nature, then of course they would also be contraindicated for SSD and AHL. So with the amazing data that we were able to use from UNC as well as from the other sites that were performing their own studies in this population, we learned a lot about the impact of the cochlear implant on patients with unilateral hearing loss. And what we've learned is that we do see that the cochlear implant improves speech perception and noise for these patients. And in addition to improving speech and noise, we also do see that these patients report an increased sense of spatial awareness or that sense of hearing in stereo. So this goes back to that sense of true binaural hearing. So whereas other devices, again, can route the signal from one ear to the other, they're not restoring binaural hearing or being able to utilize both ears. And so we do see with a cochlear implant that it does restore that sense of binaural hearing, and again, hearing with both ears. Because of that, we do also see

better localization of speech as well as other environmental sounds, which of course can be a safety issue in patients being able to tell if a car's coming toward them, where that's coming from, as well as just being able to locate where in a room someone may be talking to you. And then with those improvements, our participants in the studies do also report that they have reduced fatigue. They don't have to try as hard to listen always. They don't have to concentrate as much on following conversations. And to that end, they are able to better participate in social and work activities as well. So across the board we do see that this has a really great impact on patients and their quality of life. And so from there, I will turn this over to Dr. Dillon who's going to tell you some more details about what she and the other investigators at UNC have found with their clinical trials and walk you through some of that data.

- [Meg] Okay, so I am Meg Dillon from the University of North Carolina at Chapel Hill, and I'm the director of our Cochlear Implant Clinical Research program. We conducted this clinical trial starting back in 2014. Today's lecture is gonna be specific to the adult cohort, so the single-sided deafness and asymmetric cohorts. We are also running a clinical trial in children, and Dr. Lisa Park who's the lead audiologist on that clinical trial presented an Audiology Online lecture on the initial data that we have seen from that. So if you are interested in pediatrics, I would encourage you to see that lecture as well. As my disclosures, we received a research grant from MED-EL Corporation in order to conduct this clinical trial. For the outline of this portion of the talk, I'm first gonna go over the clinical trial and the specific cohorts that we investigated and our protocol. The study results that I'm going to be sharing today are specific to the spatial hearing task, and then mostly our data on the quality of life piece. So two points to make here is when we started this clinical trial, we initially started with patients who we defined as single-sided deafness. And if you look at the literature, there's variability in what some people are defining as single-sided deafness versus an asymmetric hearing loss. And so for the purposes here, when we say single-sided deafness, we are thinking about someone who has normal hearing sensitivity across the frequency range in that better hearing ear. So we define that as less than 35 dBHL thresholds from 125 to 8,000

hertz. In the ear to be implanted for both our single-sided deafness and asymmetric hearing loss cohorts, we defined the hearing loss had to be moderate to profound, which is what we would consider an adult cochlear implant candidate to be. So you'll see for both groups they had moderate to profound hearing loss in that poor hearing ear. For asymmetric cohort after we saw the success of cochlear implant use in the single-sided deafness group, we went back to the FDA and asked to do a second group with some hearing loss in the contralateral ear, but still not enough to qualify them for conventional cochlear implantation candidacy criteria, and we defined that as a mild to moderate hearing loss.

So as Dr. Racey covered, we know that patients who have poor hearing in one ear and either normal hearing or some hearing loss in the contralateral ear, that when we compare them to normal hearers, they have poorer speech perception in noise. They have variable ability on localization tasks, and thus they're also reporting increased hearing handicap, and that ultimately a reduced quality of life. What I'm gonna define as initial treatment options, because at the time we conducted the study, cochlear implantation was not an improved indication and that has since changed this summer, so I will say initial treatment options for patients with AHL and SSD, we know that they can either be fit with a conventional hearing aid on that poor hearing ear depending on the severity of the hearing loss. They might be candidates for bone conduction devices or CROS, Bi-CROS hearing aids with the aim of those two latter technologies being to send that signal from the poor hearing ear over to the better hearing ear and everything is going up one auditory pathway. So even with those technologies, so even if we did the optimal fitting for these patients based off of those initial treatment technologies, we saw that their binaural hearing was not improving because we were sending everything up one auditory pathway. So if we tested their speech perception, particularly in noise, we saw that there were primarily weren't improvements unless you really restricted the listening condition where the noise was being delivered in a certain condition and then you would see that improvement, and also found their localization abilities were at chance. And again, it's because we were not restoring binaural hearing

but just providing that cue from the poorer hearing ear over to the better auditory pathway. And so that's where the idea behind using a cochlear implant in that better hearing ear came to be. Because if we could restore the hearing in the poor hearing ear and we're sending that signal up the poor hearing ear's auditory pathway, then potentially the brain could use the signals from the better hearing ear and from the cochlear implant and put those together to have improved spatial hearing. And then ultimately, we would hope that that would influence the patient's quality of life where they found that they were no longer staying at home or needing to retire early, but could participate in the activities that they could before they had this hearing configuration. So we proposed our study to the FDA and our biggest questions were, if you provide a patient with a cochlear implant, could they integrate acoustic and electric stimulation for improved spatial hearing when one ear has normal hearing?

So we've seen that patients who have poor hearing in the contralateral ear have bilateral cochlear implants that they can do better on spatial hearing tasks when they're listening in either bimodal stimulation, so a cochlear implant plus the contralateral hearing aid or if they're listening with bilateral cochlear implants. But at this point in time, we didn't know if patients could use that signal from the cochlear implant and combine it with normal hearing. And then the bigger question was would that distract the better hearing ear? So if we've listened to simulations of cochlear implants, we know that it's not a clean signal. We didn't know if somebody had a normal hearing representation of the signal in the better hearing ear, would they even want to wear the cochlear implant all day, every day where we would expect for them to demonstrate an improvement with the implant. So we submitted this application to the FDA and received an investigational device exemption to run the clinical trial again, first in patients with single-sided deafness. And then we went back and asked for the second cohort for asymmetric hearing loss. Our primary aim was to determine whether subjects who have these configurations of hearing loss would they experience an improvement in speech perception, localization and quality of life when listening with a cochlear implant as compared to an unaided listening condition? So again, we have

our two cohorts, one with a mild to moderate hearing loss in that better hearing ear, and then one with normal hearing. Both groups had to have moderate to profound sensorineural hearing loss in the ear to be implanted. Aided speech recognition had to be less than 60% correct on CNC words, which when we're thinking about adult cochlear implant candidates, that's the criteria that we are basing that on is to say, do they have that moderate to profound hearing loss and is speech recognition less than 60% correct? For our SSD group we had 20 subjects, again, all with moderate to profound sensorineural hearing loss. The mean duration of the hearing loss was three years. So when we think about what affects cochlear implant patient's performance, we know that patients with longer durations of hearing loss tend to do poorer than those with shorter durations. For the inclusion criteria for this study, we did cap it at 10 years.

So this is something to keep in mind is that this cohort had a short duration of hearing loss in that affected ear. However, their speech recognition performance with CNC words was poor, so we see this mean aided CNC word score of 22% correct. Again, we defined normal to near normal hearing in the contralateral ear as equal to or less than 35 dBHL from 125 to 8,000 hertz. The mean age at implantation for this group is 50 years of age. When we look at our conventional cochlear implant patient population at UNC and we look at their average age at implantation, I believe as of last year it was 71 years of age. So this is also a younger adult population than we are used to working with clinically. For our AHL group, we see that there are some similarities between the AHL group with the SSD cohorts. So again, we had 20 subjects. Mean duration, again, was three years, so they all had a short duration of hearing loss in the ear to be implanted, poor aided CNC word recognition. So we see the mean aided CNC word score of 8% correct. And now we can see this difference in the hearing in the contralateral ear. So our unaided pure tone average of five, one, and two kilohertz had to be between 35 and 55 dBHL. We also said that they had to have a aided CNC word score in that contralateral ear of 80% or better. So here we see a mean of 87%, so we know that they had good word recognition in that contralateral ear. And the other thing

that I'd like to point out is the mean age at implantation in this group was 70 years of age. So this is more reflective of our clinical population as far as age at implantation. But it is significantly different from our single-sided deafness population and that's something we're gonna talk about a little bit later when we compare the performance over time between these two groups is that this is an older group. That was not intentional. The candidacy criteria was 18 years of age or up. However, if we think about hearing loss in the contralateral ear, we know that there is that effective age on hearing thresholds over time in some patients, and so it makes sense that we would see this trend for older adults fitting the asymmetric hearing loss cohort as compared to younger adults who may fit that single-sided deafness indication based off the hearing in the contralateral ear. But again, the two significant differences between these two groups is the hearing in the contralateral ear and age at implantation. Our protocol, we tested these patients preoperatively. They then underwent cochlear implantation. Our initial activation is typically two to four weeks postoperatively. And then we followed them at one, three, six, nine, and 12 months post-implantation where they conducted these different test procedures that took about two to three hours each. And so that speaks to the dedication to these patients.

And as you saw in the earlier video, these were patients that were looking for us. They were frustrated with the current treatment technology and were really looking for a different source. And they also were very dedicated to participating in the study protocol so that hopefully this would be a technology that would be available to other people. We really have to thank them for their efforts on this project because I think that's what's helped one, provide us with the data that we needed to show the benefit of this, but also have the change that's happened in our country recently. So again, they completed a full test battery that took about two to three hours. But the testing that I'm going to talk about specifically today is their performance on these spatial hearing measures. We did a masked speech recognition task where we would present the sentence in front of the patient, an then move the noise around their head. That was covered in an earlier lecture that we have on Audiology Online, and so would

encourage you to see that. Today, I'll talk about the localization differences between our single-sided deafness and our asymmetric cohorts that we have both of those measures today. And then the quality of life metrics, they would complete at each interval. All subjects received the standard electrode array from MED-EL Corporation. This was based off of previous data from our center where we randomized patients to receive either the standard electrode array, which is a 31.5 millimeter in length electrode array versus a shorter electrode array. And what we found at that time is that patients that were implanted with the longer electrode array that their speech recognition improved faster than those that received the shorter electrode array. So we thought that it was important to provide this patient group with that longer electrode array, one, because we had seen those significant differences in speech recognition growth and wanted to provide them with the best possible outcome. But two, we thought that it would provide a closer approximation with the natural cochlear place frequency and that might also match with what they were receiving in the contralateral ear to provide them with what we would refer to as this inner aural place match where we are presenting that similar frequency to the same place as they would in that normal hearing ear. All subjects listened with an ear level device, so either the OPUS 2 or the SONNET processor.

We chose this just to have some consistency with that microphone placement to control some of the variability in performance that could happen with different processor styles. All subjects also received the FS4 coding strategy. We developed a pretty strict mapping procedure where we measured threshold and comfort levels behaviorally at each interval. And this was to ultimately to ensure that we were providing each recipient with the best possible map at each interval. So we did a lot of measures with loudness balancing. So first, the audiologist would plug the contralateral ear to control for any environmental noise influencing especially the perception of those threshold levels. And they would behaviorally measure thresholds and then comfort levels, and then conduct loudness balancing across all active channels to make sure that there was this equal loudness representation across the electrode

array. We would then take the insert out of that better hearing ear and then balance the loudness between the cochlear implant and the contralateral ear so that they would have this equally balanced representation of the signals between the two ears. Some patients at initial activation will tell you that they don't like the sound quality of the cochlear implant. I think the first inclination is to turn it down to turn down those comfort levels or turn down the overall volume. But for those of us who work with cochlear implants, we know that patients don't do well if they don't have appropriate loudness. And so we told the patients that were participating in this study that they needed to listen to it at an appropriate loudness from minute one with the cochlear implant. And I think that's also contributed to some of these early improvements in speech recognition and spatial hearing performance that we have seen is that we are encouraging them at that initial activation visit to listen to it at an appropriate loudness.

Okay, so first on our spatial hearing measures, again, we're gonna talk about the localization performance. At UNC we have this 11 speaker arc that spans 180 degrees. We would randomly present a 200 millisecond speech tape noise burst from one of those speakers at different intensity levels so that they weren't tracking the loudness, but were really just focused on the orientation of where the speaker or where the sound source was coming from. And so we would present one of these noise bursts randomly and that the subject would indicate which speaker number they perceive the sound source to originate. And from that, you can calculate a root mean squared error to see the discrepancy between where we were presenting the sound and where they were perceiving the sound. So at the preoperative interval, they were tested either in an unaided condition or with a bone conduction device. For our SSD cohort, that normal hearing ear was open for both of those conditions. And for our asymmetric hearing loss cohort, they had a hearing aid that was fit to NAL-LN1 targets on that better hearing ear. At the postoperative intervals, we again measured them without anything on the cochlear implant ear, and then with the cochlear implant on, so device on/device off. But again for the SSD group, the normal hearing ear was open, and the AHL group was listening with that contralateral hearing aid. So here we have the results from our SSD

cohort. And if I get the pointer, there we go. Nope. There we go. So what we have here is results are reported as root mean squared error. So a smaller value indicates better performance, so there's less of a difference between where we are presenting that signal and where they are perceiving it. And then we have each of the intervals over the study period. So again, at the pre-op, and then one, three, six, nine, and 12 months. We also collected data from a normal hearing cohort to see what the range of performance would be for patients with bilateral normal hearing. And so we'll talk about that in a moment. So first at the preoperative interval, this is showing their performance in the unaided condition. Each of these circles represents the individual subject.

So we can see a wide range of localization performance that's pretty poor as far as what they are able to discriminate. And then if we look at the one-month interval, we see that the majority of subjects are already demonstrating a significant improvement in localization abilities after only one month of listening experience. That is maintained over about a 12-month interval. There are two subjects that we like to point out at the one-month interval that continue to have performance that was similar to what they were doing preoperatively. Both of these participants were listening with the OPUS 2 processor, so we didn't have the ability to look at data logging. But when we asked them about duration of daily device use, they were under six hours. So one of them was listening to the device for only three hours a day. And then the other one, I think, this person was listening to it for six hours a day. And we talked to them about needing to increase their duration of daily device use in order to benefit from the cochlear implant, because we have seen that documented in conventional cochlear implant listeners. Both of them increased their daily device use, and so we can see this was, this subject here improved here. And this was now listening to it for, I think, eight hours a day and then they got a little competitive and decided to listen to it for 12 hours a day. And so they became one of the subjects closer to the mean performance. But that brings up the point that when you're working with these patients, it's important to encourage them to wake up in the morning, put their device on and listen to it for the

duration of their day in order to benefit with the cochlear implant just like you would do with any of your conventional cochlear implant listeners. What's particularly interesting is if we look at our normal hearing cohort, we see that a 12 months our cochlear implant recipients are doing pretty well, I mean, still significantly different from our normal hearing group. But there is one subject that is performing the same as one of our normal hearing subjects, and that is not something I would have expected to have seen, but shows us that we still have a lot to learn about the benefit of cochlear implantation in this population and what might make someone a performer who is performing similarly to a normal hearer as compared to someone who is showing less of a benefit with their cochlear implant. Here we have the scores from the asymmetric hearing loss cohort which we have just submitted for publication. At the preoperative interval we're also showing you their unaided condition, but also their performance with a bone conduction device. We repeated testing in that unaided condition and with the bone conduction device at the 12-month interval. That was really to show that even if a patient underwent cochlear implantation, you're not changing any of their abilities in that unaided condition.

So we don't see a difference in spatial hearing abilities between either the unaided condition and the bone conduction device or performance in that unaided condition and bone conduction device between the preoperative and 12-month interval. So we have not caused harm to these patients by providing them with a cochlear implant. We do see, again, that benefit, the significant benefit demonstrated at that one-month interval. However in our asymmetric hearing loss group, we see that they are continuing to improve through that 12-month interval. So with our single-sided deafness cohort they were reaching asymptotic performance by I believe it was the six-month interval. Whereas with our asymmetric hearing loss cohort they are continuing to take a little bit longer. And this could be because you're having to combine the signal from an impaired ear, so it's not a normal hearing representation. It could also be because they are listening with a hearing aid, they're now having to fuse the signal from a hearing aid and a cochlear implant, instead of the cochlear implant and normal

hearing, and/or it could also be that this is our older adult group and so it could take patients a little bit longer to demonstrate, or not demonstrate benefits, but reach asymptotic performance on these spatial hearing tasks because of just natural aging processes. If we move on to our quality of life measures, subjects completed the Abbreviated Profile of Hearing Aid Benefit and the Speech, Spatial, and Qualities of Hearing Scale at all intervals. They also completed the Tinnitus Handicap Inventories that we could look at their perception of tinnitus severity in the ear to be implanted. And we saw on the Tinnitus Handicap Inventory that subjects were experiencing or reporting an initial drop in the severity of their tinnitus. It was improved to that mild or slight range at that first interval, so the one-month follow-up interval in these subjects, which was wonderful to see.

For the abbreviated profile of Hearing Aid Benefit, this is scored on ease of communication, effectiveness and background noise, reverberation, and aversiveness to sound. And then you can also derive the global score from the ease of communication, background noise, and reverberations of scales. This is scored as a difficulty percentage, and so again, a lower score indicates better performance. For the SSD cohort we are showing here their performance at the preoperative interval in white. In the light gray is their reported performance at the one-month interval and then the darker gray is at the 12-month interval. And if you look across the subscales, you can see that we have a significant improvement between preoperative reported abilities and that one-month reported abilities with the cochlear implant early on on each of these measures. And that on some of the measures we are continuing to see another drop by the 12-month interval. So exactly what we would wanna see on spatial hearing measures, and also in regards to the pleasantness of the sound. For our asymmetric cohort we have each of the intervals defined here. So we have that pre-op again in white. But each of the gray are demonstrating this postoperative intervals, so one-month, three-month, six-month, nine-month, and 12-month. And this is just to show that change in perception over time. So again, our asymmetric cohort, similarly to what we observed in our SSD cohort, reported an improvement as early as that one-month

interval on each of these subscales except for the aversiveness of sound. So they are still telling us that the sound quality of a fire truck going by is uncomfortable. Or a fire alarm happening in the building that that's still an aversive sound, as opposed to what was observed with the SSD cohort. And then if we look over time, we can see that there is some change over time on some of these subscales which could be the patients acclimating to the sound quality of the cochlear implant are starting to fuse the signals between the cochlear implant and the contralateral hearing aid. For the Speech, Spatial, and Qualities of Hearing Scale we are now looking at perceived abilities. So a higher score indicates better performance. Again, we've got our total score for SSD group, we have in white, pre-op, light gray, one-month, darker gray, 12-month. And then the speech, spatial, and qualities we know can be divided into the three subscales of speech, spatial, and qualities of hearing. And again, if we look here, we can see that our SSD cohort was reporting as early as that one-month interval a significant improvement on each of those subscales, and then another jump at that 12-month interval. We see the same trend in our asymmetric cohort of that initial significant benefit. But then some improvements, again, over that study period.

So we see that jump in spatial hearing, for instance, that continues to grow over the study period through the 12-month interval. One of the interesting things about the SSQ questionnaire is that you can break down each of those subscales, so speech, hearing, spatial hearing, qualities of hearing into pragmatic subscales. That was proposed by Gatehouse and Akeroyd in 2006. And here we have labeled each of those. So we have, for instance, our speech hearing subscale, and we can see each of the pragmatics subscales, so speech in quiet, speech in noise, speech in speech contexts, and then speech in a multi-speech stream processing and switching scenario. For spatial hearing you can divide that into localization and then distance and movement. And for qualities of hearing we have sound quality and naturalness of the sound, identification of sound and objects, segregation of sounds and then listening effort. We all know that listening effort is becoming a more popular metric in our field. So if we look at our SSD cohort and we break down each of the pragmatics subscales

for the speech hearing metric, again, we have in white, pre-op performance, light gray, one-month. dark gray, 12-month and now we can start to see where they're really reporting big jumps in benefits. So in quiet preoperatively, they were doing pretty well, which makes sense because they had one normal hearing ear. And we see a significant improvement, but we're already near ceiling effects for that particular pragmatic subscale. It's really in these noise measures and these more challenging noise measures that we see this big jump in perception of how they're doing which is wonderful to see that they are experiencing and reporting these early initial improvements on these spatial hearing tasks. For the spatial hearing subscale, again, we have localization in distance and movement. And for our SSD cohort, again, we see this significant improvement between pre-op and one month and continued improvement out to that 12-month interval for both of those subscales. And on the qualities of hearing, we start to see some pretty interesting trends.

So first, the naturalness of sound. When we observed that there was not a difference between the naturalness of sound, between the pre-op and one month, we weren't too concerned about that because you wouldn't expect a cochlear implant to sound the same sort of naturalness, or an improved naturalness, as compared to just the normal hearing ear. But what was compelling was that over time we saw that they were starting to say that it sounded what they remembered it to be like when they had bilateral, normal hearing. And what they would say to us is they would put their cochlear implant on in the morning and for a few seconds it would sound robotic, but then it would start to fuse with the sound quality of the normal hearing ear where it sounded like normal hearing bilaterally. And that's something that we are continuing to investigate of what could be contributing to those perceptions of sound quality, whether it was because we were using the long array and so we were matching closer to cochlear place. Or was it because we had that inner aural pitch match between the two ears and so the normal hearing ear was almost cleaning up the signal that you're getting from the cochlear implant? So those are some things that we are currently investigating. We also see listening effort that they are reporting a large jump in

listening effort between that one month and preoperative abilities, and that could also contribute to why they were wanting to wear their device more consistently is because they were observing that it was easier to use and easier to be in some of these challenging auditory environments than what they were experiencing preoperatively. So if we look at our asymmetric cohort, again, this is plotted a little differently and now we can see each of those intervals across the study period. But we're seeing the same sort of trends where if quiet, they were not doing or not reporting as good performance preoperatively, but still closer to ceiling than they were on some of these other measures. But if we look at the speech and the multi-speech pragmatic subscales we're seeing that big jump between the pre-op and the one-month interval. And then continued improvement through that three and six-month interval where they could just be acclimating to that signal over the study period. For the spatial hearing subscales, this is reflective of what we were seeing in the sound field on our localization task where at pre-op we're seeing poor performance on localization and they're reporting this improvement in localization abilities that's continuing to improve over the study period.

Again, just like what we saw for the asymmetric cohort on that localization task. And similar trends on the distance and movement where they're improving over the study period. And then if we move to our qualities of hearing, we can see that they are also reporting an improvement in the naturalness of sound. If you ask this cohort if it sounded like normal hearing with the cochlear implant, that was not happening as early as what we observed with our single-sided deafness cohort. And again, older adult group, hearing loss in the contralateral ear, they're having to fuse a signal from a hearing aid and a cochlear implant. So that is more in line with what you would expect to see from this group. But what was interesting, again, is we're seeing this big jump in listening effort abilities that is maintained over the study period. And so that could speak to some of the benefits that they are experiencing in the real world that we are not capturing on some of our sound-field measures and one of the important reasons why we should include measures like the SSQ with our clinical population, so that we

are capturing some of these things that we are not able to test with our current test batteries. So in summary for the clinical trial, we saw that subjects with SSD and AHL demonstrated significant benefits in spatial hearing and quality of life with CI use as compared to their preoperative abilities. The differences in spatial hearing abilities and reported benefits were observed between the SSD and AHL cohorts. And as I mentioned, we are currently looking to see what variables might be contributing to those differences between those two groups whether it be age at implantation or the severity of hearing loss in the contralateral ear or some other patient or device variables so that we can continue to provide patients with the best possible outcomes for both indications. And with that, I'll turn it back over to Dr. Racey.

- [Allison] Thank you, Dr. Dillon, that's great. The data that you're showing here really demonstrates these patients are receiving significant benefits from the cochlear implant even earlier than what I certainly might expected and to a greater extent as well. You touched on this a little bit, but are there other factors, specifically in regards to the device or in regards to your study protocol that you think really contributed to seeing these results so quickly and to such a great extent?

- [Meg] We've been doing a lot of research recently thinking about length of the electrode array and how we are presenting the signals based off of this data to see what could contribute to early performance. So I do think that being close and delivering that electric frequency information close to the natural cochlear place is important in this group, especially for the patients with normal hearing in the contralateral ear so that you are providing that inner aural place match. There's been a lot of work in simulation studies and in bilateral cochlear implant patients showing that if you're delivering frequency information to the same place in each cochlea that patients tend to do better on some of these spatial hearing metrics. I also think that it's important to provide these patients with the best possible map at initial activation instead of slowly increasing the stimulation levels over time until they get acclimated to the signal, but performing these loudness balancing procedures so that they are

walking out the door with the best map that they could have at each interval. Something else that we did with this cohort that I didn't mention earlier is they all completed aural rehabilitation at initial activation and at the one-month follow-up interval. What our speech language pathologists would do is they would isolate the implanted ear with direct connect simulation, and I think that also helped our patients learn how to acclimate to the loudness in the implanted ear. Because if you're listening to a book on tape and it's direct connect, then you're having to adjust the loudness and you're not incorporating it with the contralateral ear, but you're learning what loudness is in your implanted ear. And I think doing that at initial activation helped those patients earlier on.

- [Allison] That's great advice, I think, for someone who maybe is starting to see candidates for cochlear implantation who have single-sided deafness or asymmetric hearing loss as well, so that's helpful for sure. Is there anything else that you think might be important for someone to remember maybe who has not seen a lot of cochlear implant candidates, necessarily, but does have a patient population with single-sided deafness or asymmetric hearing loss that is interested in talking about cochlear implants? Are there things that they should consider in who makes a good candidate for a cochlear implant?

- [Meg] So I think we have to first think about our test protocols. That's one thing that our group has been paying particular attention to is how do you take two to three hour test protocol and condense it into a reasonable clinical protocol? And if you're testing these patients speech/front, noise/front, they're gonna do well, because they have a normal hearing ear. You really start to see more of what's happening in the real world when you move the noise to either distract that normal hearing ear or over to the contralateral ear if you're trying to test the benefit of a bone conduction device or Bi-CROS hearing aid. So we've changed that where we're now doing testing speech/front, noise/front, but we also deliver the noise 90 degrees to the contralateral ear to see how much difficulty they have. But then also, postoperatively when they get

the cochlear implant, how much benefit are they experiencing by having that cochlear implant on, and then you concert to see some spatial hearing performance as well. I think it's important to counsel these patients that it's not an instant fix and it does take work. Again, our cohort were younger adults and they were looking for us. They were not talked into getting a cochlear implant by any means. They were very frustrated with other technology, had tried other technology, and needed a different option so that they continue to be successful at work and were motivated to really make the cochlear implant work. So I think having those conversations is important. You're not gonna get the cochlear implant, put it on two hours a day and see these big bumps in speech recognition and report these improvements in quality of life unless you're willing to put the work in. So very similar to what we would counsel conventional cochlear implant patients on. But I think the role of aural rehab and doing some of these things at home are also beneficial, particularly for this group, to make sure that the cochlear implant ear is getting trained up. And then being in some dynamic listening environments so that you are fusing the two signals from the normal hearing ear and the cochlear implant to see some of these early benefits.

- [Allison] Great, thank you. That's very helpful advice. Where could someone go if they're interested in learning more about the findings that you're seeing from the pediatric clinical trial?

- [Meg] So Dr. Kevin Brown is the principal investigator on that study. We are currently writing up the results, the initial preliminary results, that we have seen from that group. To backup, so for our pediatric study, we are looking out to two years for spatial hearing benefits and quality of life. With the adult cohort we monitor performance for the clinical trial out to a year. But for children we know that there other developmental considerations that are needed. The majority of our patients has completed that six-month interval. So Dr. Park in her Audiology Online lecture I believe talked about the speech perception and spatially separated noise, the improvement when you're testing the cochlear implant alone, and then as well as what the parents are reporting for

improvements in quality of life in these children. Dr. Park in her lecture talks about how you should test these children, particularly if you're wanting to isolate the cochlear implant ear, which is something else to think about with postoperative management is how much time do you wanna spend testing speech recognition in the cochlear implant ear alone, as opposed to speech recognition in the combined condition? I think we're all used to testing cochlear implant alone and that's how we show performance. For our clinical trial, we collected aided sound-field thresholds. You would mask the better hearing ear to get those aided-sound thresholds for the cochlear implant, so you would understand more about your map. And then we would only test CNC words to see if speech recognition was improving. But our primary aim was really what are they doing with the cochlear implant plus the contralateral hearing aid. Dr. Park mentions that too with children that you're really more concerned now with what is the combined condition doing for these recipients, not so much what's happening in implant ear by itself. We've seen some variability in what the children are doing in that combined or in the unilateral conditions, or what they're doing with cochlear implant alone. But when you combine that with the contralateral ear, then they're doing remarkably well, and it's really exciting to see. Dr. Brown will also be sharing some of that content at the International Conference on Cochlear Implantation CI2020 coming up in March. And hopefully we'll have a couple of that data published soon.

- [Allison] That's very interesting. Thank you for sharing. I certainly look forward to learning more about that as well. And just in terms of another few other resources for anyone who may be interested in learning more about some of the things you touched on, such as the long electrodes from MED-EL, we also talked about that in terms of complete cochlear coverage, and we do have an ask-the-expert online available through Audiology Online from Melissa Waller in terms of complete cochlear coverage. And then for our fine structure coding strategy we also, again, have an ask-the-expert available from Peter Nopp who talks about some of the impacts that fine structure can have on speech perception and sound quality, and specifically on music as well. So I think we can wrap this up by hearing from our patient again who was implanted at

UNC. I think there's nothing more powerful than listening to someone tell you directly about the impacts that the cochlear implant has had on their life. So we can hear from him and then we'll open it up to any questions.

- It gives me a benefit in that I can compare pretty clearly to my hearing when I don't have the implant on. It took about six months, I guess, for full integration. But I don't notice at all any difference now. I mean, there is no difference. I don't have any resonance. It really has completely blended in. And that's maybe the advantage for single-sided deaf people is that because you have good hearing in one ear, it quickly melds into it and gives you that balance. What's amazing, I still do this from time to time. I was watching a movie at home the other night, and it was an action movie and I have a surround system, I wanted just to see how it reacts when you pull the sound away. It literally just empties the room. I still hear the movie, but it becomes kind of flat. It's a monaural sound. This gives depth and range that doesn't exist in any other way. So it has been a remarkable journey, remarkable journey.

- [Allison] All right, and any additional questions? All right, I don't see anything coming through, but thank you very much for your attention. We certainly appreciate it and hope that you found today's discussion informative.