Cochlear Implantation in Single-Sided Deafness – A Focus on Mapping and Rehabilitation

Hello everyone. My name is Dayse Tavora, I come from Perth, Western Australia, from the School of Surgery, University of Western Australia and Fiona Stanley Hospital.

What I'm going to be talking today is about cochlear implantation in single side deafness with a special focus on mapping and rehabilitation for this population. So, what we're going to be covering in this lecture is, reviewing the protocol, the current research results, and as I said the rehabilitation and mapping optimization.

So, let's go back in history, how everything started with cochlear implant in single side deafness. If we go back, we are celebrating in 2018, 15 years of the use of cochlear implant in single side deafness. But everything started as actually a tinnitus treatment, not a hearing treatment. And the first publication by the Belgian group was very positive, showing the results of cochlear implant in the tinnitus treatment in single side deafness.

Of course what they found was that the results were not only positive for tinnitus management but for hearing outcomes as well. And we have the first paper published by the same group in 2009.

And as expected, as a new field, several papers were published along the years and, here you just have very quick short of what was published, few of the papers published.

What happened for the last 10 years now of publications, is the fact that every single group looking at the results, the benefits of cochlear implant in single side deafness, but everyone was doing things slightly differently, using different protocols, different testing, framework. So, the experts from the HEARRING group working with single side deafness gathered together in two meetings, 2015 and 2016, working to develop a unified testing framework for single side deafness. So, this paper was published back in 2016 and the purpose of this work was to increase the evidence, to be able to gather the data together from different centers to increase the evidence of the cochlear implant in single side deafness.

So, based on this consensus paper, the current protocol that we are using, we implemented since the publication of the consensus manuscript, what was agreed by the group is that, to show an improvement in terms of speech understanding. What was proposed is the spatial configurations that we can see on these slides, trying to measure the binaural benefits including, head shadow, squelch and summation. If we add implants in patients with single side deafness, what we are trying to achieve is binaural hearing. So, it's just fair that we try to measure binaural hearing.

One of the main issues that patients with single side deafness report is the lack of ability to localize where the sound is coming from, so it was also agreed by the group that sound localization should be part of the assessment and evaluation protocol.

In addition, quality of life questionnaires, tinnitus reduction for those who have tinnitus. And it was also agreed by the group that the rehabilitation process should be part of the discussion with the patients, and should be a very strong point to defend.

So, in this slide, what I'm showing is the long-term results in terms of speech understanding and noise, in three different spatial configurations. In this left here, what you are seeing the results of CI off, CI on, in this signal and noise, coming from front. So, the results are represented in dB Signal to Noise Ratio, which means that, lower the number, the better the result.

This is the configuration where the sound is coming from front, and noise is coming from the hearing ear. And again, you will see a very clear benefit from the implant situation.

In this third column here on the right, what you are seeing is probably the most challenging situation for patients with sing side deafness, is when the speech is coming from the deaf side, and the noise is coming from the hearing ear. Just remember that is the long-term data results, which confirm the results that we have achieved and published through the last few years.

In terms of quality of life improvement, these are the long-term results as well. Looking at the Speech Spatial Quality of hearing, the simplified version, using only 12 questions. And what we have is the pre-op results and the long-term results. There is a significant improvement, subjectively speaking.

In terms of localization, again we see a significant improvement from the CI off condition to the CI on condition. We can see that the mean was around 52, RMS error degrees, with the CI off, down to approximately 18 degrees.

But I'd I like to focus on the rehabilitation program that we follow, and from the conversations with different groups, different experts through the world, it looks like that we have agreed that rehabilitation starts at the CI assessment. These patients, they have a strong counseling interview, discussing the intensive rehabilitation program that they are going to need to follow post implantation.

Another topic that we take very seriously in our center, is that expectations and the understanding that the sound coming from the implant side will be different to the normal hearing to certain extent and for a certain period. We cannot guarantee how long it's going to take for the sound to integrate to the normal ear, and how long it's going to take to perceive the implant as more natural as it could be.

In our center, to avoid mistakes, misunderstandings, we do ask the patient to sign a consent at least, that telling us that they are aware that we would like them to be committed to the rehab program, that we would like them to be wearing the sound processor all walking hours to avoid a delay in the process of rehabilitation. We also ask

them to commit 20-30 minutes of practice using Direct Audio Input. The reason for that is that patients with single side deafness, what we learned for the last 10-12 years is that they need an active training, they cannot, they will not benefit from the CI if we use passive learning, that's how I would call. As we have been using through the years with the conventional implant.

If we don't stimulate the patient, don't ask them to actually stimulate the implanted ear, the preference for the good hearing ear will be present. So, we do ask them to use the Direct Audio Input, through the cable, if possible using wireless system, but it has to Direct Audio Input to stimulate the ear, using the implant.

So, how do we do that? At switch-on, which occurs approximately 2-3 weeks maximum post-surgery, we perform the MCLs measurement as with the conventional cochlear implant uses. And what we try very hard to do is to balance the loudness between the implanted ear and the normal ear. To avoid to create an asymmetry where the implanted ear is still softer that the normal hearing ear, or the other way around, the implanted ear is too loud compared with the normal hearing ear.

We do include fine structure processing, if possible, and we use the widest frequency range. The reason for that is there is an increase in acceptance of the sound. Remember that the single deafness patient, they are comparing an electrical input to normal acoustic hearing. So, if we can make the sound as more natural as possible, we have better chance that these patients will persevere using the implant and will achieve the benefits that they are looking for.

In the second mapping session, which occurs a week later, we adjust the MCLs to ensure audibility, and again making sure that we have binaural balance. And that this session we also create a dedicated map for auditory training through the Direct Audio Input. Why am I calling this dedicated map is because through the last decade, what we have learned is that an average patient needs an increase in MCLs to be able to hear clear speech through the Direct Audio Input.

Usually the map for the Direct Audio Input is on average at least 6-12 percent louder than the average map that they use throughout the day. The reason is very simple, if they are hearing through the implant alone, they need a little bit of more power, that's how I would put it. And of course there is an impedance going through this cable, if it is a cable. So, we do increase the MCLs for this map. When they are not using the wireless system or the cable, what they need is relatively lower MCLs, because in this situation they are using binaural hearing, and they need less stimulation. So, we use the Direct Audio Input, the cable we also use the Bluetooth streaming.

Another way that we use to keep the patient engaged is actually asking them to keep a log, a diary actually recording the hearing activities that they are doing and actually trying to identify the sounds that they cannot hear well, or they cannot hear at all, or they find that the sound is confusing of unclear.

The reason why we do this is because we use this information to fine tune the map. Cause if we know which sounds they are not hearing, they are struggling to understand, during the training sessions we are able to fine tune the map in that specific area of stimulation, and optimize it as soon as possible.

Another aspect that we believe that are very important to keep the patients engaged is to tailor to each individual needs. So, how do we do that? We use different materials, we try with the patient to identify materials that mean something for the patient. We don't really specify you have to go through this material in particular, but we try to work with them, which is interesting for them. So, if they like books, we do use audio books, if they like video, small videos, documentaries, that's what we are going to be using. If there is a subject that is the special interest, particularly for the younger kids and teenagers, that's what we try to find with them, things that will keep them motivated and engaged in the rehab program.

So, at the very early stage, we try to make sure that they are able to identify full names, we go through very basic environmental sounds, speech identification, just to make sure that these tasks are very clear for them, and then we move forward to a more complex listening. We include, as I said previously, we include videos, where it's just one person talking, we do ask them not to use movies where variety of sound source. Usually we ask them to use simple videos, where there's one person talking, clear and direct. Another benefit is that you can look for videos that is in the person's first language, take into account accent and other aspects.

So, in the third mapping session, we go through fine-tune the map, if it's required. We make sure that the patient has understand the use of the Direct Audio Input, that the patient is able to access all the online exercise, the rehab software, if everything is going well for them.

In the fourth week post activation, which is around 6 weeks post activation, we perform an optimization of the map. We have learned through the ears that with the single side deafness, if we are able to provide good outcome at very early on, we are in better position to keep these patients engaged in using the sound processor. Because they are not totally deaf, they have different expectations. If they take too long to obtain the results that they are looking for, we believe that they tend to give up the sound processor sooner, let's put it this way. So, [inaudible] what we decided is to make sure that these patients actually can see the benefit of the implant at very early on, and get used to the sound processor very early on. So, what we have been using for the last 3-4 years, using the cortical auditory responses to measure what the patient is detecting with the sound processor, and we use it as a tool to fine tune the sound processor.

So, that's the setup that we use. We use a system that's a [inaudible 00:17:29], very simple, that's available to the clinics and we us the four speech tokens to give us an idea which area of the speech spectrum the patient is hearing or is not hearing. So, we present the four speech tokens, the m, t, g and s. So, if there's any of these sounds that the patient cannot hear, or the cortical auditory response is not clear to us, we fine tune the map in that specific region. So, it's just an extra tool to make sure that actually we are able to optimize this implant, ensure that the patient is hearing the whole speech spectrum at very early stage. So, we perform these measures, as I said before, at 4 weeks post switch-on.

So, we have published the results of this study recently, and we also looked at two specific population within this study. The question that several people around the world have made is deafness duration, an issue for sing side deafness, as it can be for conventional, bilateral deafness.

So, what we found within our group is that we could measure the cortical auditory responses in patients with up to 40 years of deafness duration. So, these patients, they are full time wearers, they have long term experience with CI. So, we cannot say how long it would take for them to get these nice cortical responses, but we can say at this stage after chronic stimulation, we have a nice cortical response for them. They are full time wearers, which means that they are very well adjusted to the implant and all the objective measures in terms of speech, understanding and localization are also confirming the results.

So, also using the cortical responses, we looked at the early onset of deafness, that is a cohort that we agreed that we still don't have enough data to say that this population should receive a cochlear implant. But it's increasing the number of patients who come looking for a treatment and they have lost hearing at very early age. So, we confirmed that the duration of deafness was not a parameter that we could use to say that these patients are not candidate for a cochlear implantation. But what about those who actually are adults looking for a treatment but they lost the hearing at very early age.

So, we have recently published this in the new report, and these are some of the results that we use the cortical again to confirm if these patients could detect the sound well. So, that's an example of a patient that lost the hearing at the age of six and this is the cortical response. Again, localization and speech understanding was performed and we confirmed that is a good outcome. That's another young adult who lost the hearing at again at an age of approximately six, and this is the cortical response for this person.

Going back to the rehabilitation, that is the setup that we use. So, we use in the clinic, if the patient doesn't have the availability of material, or hardware, or software at home, we invite them to come to our clinic, and this is the setup that we use. So, I can say that we use a laptop or iPad to access online materials, and we have the ability, if we are working with children, we have the ability to split the signal and listen to the same sound that the patient is hearing. I find this quite useful when the patient is telling me that the sounds that they cannot hear, I can see by myself, which are the mistakes that they are doing, which phonemes they are mixing up with each other. This give me information which electrode or electrode band that I would need to be fine tuning, for better outcome.

SO, as I said before, we use several online materials. But we also use recorded voice of a family member. How do we do that? Very simple, we ask a family member to read a page of book for house for example, and we record it using telephone or iPad, or whatever is available. We particularly use this type of training if the person has a long deafness duration, because as anybody would expect, these patients, they really struggle to understand speech through the Direct Audio Input unless you are using something that is familiar to them. So, we start with very simple material, such as can you record numbers, in different orders, can you just record colors, or fruits, or open questions, can you just read a page of a book for us. With this type of approach we eliminate the difficulty with accent, for example. And because this is a family member, usually the patient finds much easier to understand.

So, if they are not able to, for example, they are really struggling, if they report that they cannot hear the noise, they cannot make up what they are hearing with the conventional online material, we usually use recorded material with the family.

Or even with the on patient, first time is we have used for example, we ask the patient himself of herself to record themselves reading, and then listen to it again. We find it very effective, particularly with those who are struggling at the beginning.

Another strategy that we use is very early, we ask them to use visual cues. So, to watch a documentary for example, with vision, reading, with subtitles. So, they are learning at the same time. What we explain to the patient that, to sit there and listen to something that you are not understanding at all is not going to help you to progress forward, because you are actually not learning to recognize the sound. So, we use visual cues for the first few sessions, and then once they are ready, they feel comfortable, they are understanding more and more of the sound, we remove the visual cues.

We find that online materials used to teach, free materials of course, used to teach English as a second language are very helpful, particularly because the pronunciation is very clear, and we use them particularly to emphasize the different between sounds that are very similar to each other. As, I said before, we use short documentary, particularly of topics that the patient enjoys, and we use it with and without subtitles.

Audiobooks, when the patient is already understanding speech through the Direct Audio Input training, we use audiobooks. We try, if possible, use audiobooks that are recorded using slower reading rate, and increase this reading rate gradually. Until the patient is able actually, to follow any audiobooks as anybody else.

One free online material that we use in the clinic is the AngelSounds, that is specifically developed for deaf people for rehabilitation. And the patient enjoys it because they can score themselves, and they know how they are doing.

So, that is an example of a log of an 11 years old patient, that created and sent to me, she sent it to these over two weeks telling me what are the results that she is getting. So, we can see that she can track it down, how she's progressing. She tells me which are the listening conditions that she is using, so she's using quite, she's adding noise to the speech signal. And I have information how she's doing, I have the information which type of fine tuning I'm going to need to work with her.

So, to conclude, what we have learned in the last 12 years, which are the critical factors for success, that's what I think. Realistic expectations, so these patients need to know what they are signed up for, they need to have a very clear message from all the cochlear implant team, from the ENT surgeons, from the audiologists, from the speech pathologists. We need to deliver a consistent message with evidence-based approach, not what we believe, not what we think, that what we have been found the last few years.

Early success, it's very important to keep these patients engaged. So, we use the approach of rehabilitation target at the level where the patient can attain success. So, they keep engaged. As I said before, we use the Direct Audio Input, passive learning for these patients do not work. So, we use the direct input to ensure that the ear implant is being stimulated on its own. Consistent rehab, I'm not going to try to repeat this, regular and consistent rehab is very important.

So, the patient from very early on, they are set to fail or set to succeed. So, in our center we always tell them that we celebrate the success and learn with the failures. Because what is not working for them, we need to use that to work together towards developing a rehab that actually is more useful for them. And that's my message for today. Thank you.