A Comprehensive Overview of Auditory Brainstem Responses (ABR)

Presenter: Stavros Hatzopoulos, PhD

Welcome to today's course, a comprehensive overview of auditory brainstem responses. These are the risks and limitations associated with today's class and these are the learner outcomes that are associated with today's class.

At this time, I'm going to turn this class over to the presenter. Greetings everyone. It is a pleasure to welcome you all to this special session of the Inventis Academia Webinar series today. Let me say that today marks an important milestone as this is our first Academia webinar focused on auditory evoked potentials, specifically auditory brainstem responses abr. And we are honored to have with us Professor Stavros Hatzopoulos, a distinguished expert in the field.

Professor Hatzopoulos has been a faculty member at the Audiology and ENT Clinic at the University of Ferrara here in Italy since 1994. With a background in biomedical engineering and hearing science, he has contributed extensively to clinical auditory electrophysiology, teleaudiology and long distance learning. He has authored over 245 peer review publications and actively participated in a European project on otoacoustic emission and the nanotechnologies. Professor, thank you for accepting Academia's invitation. We are very honored to have you with us and warmly welcome you to our pleasure.

So thank you, Anna. Thank you, thank you, thank you. And I honestly thank everybody who is dedicating their late afternoon to this presentation. Sure. Let me.

Let me tell you what the presentation will be. Just a moment, Professor. Give me one. Ten second. Ten second.

Thank you. This webinar marks the exciting countdown to the official launch of Celesta, our clinical two channel system for auditory and vestibular evoke potential. Scheduled for March 2025, Celesta is designed as a scalable solution offering configuration versatility to meet different clinical needs through

various modular setups. Fully integrated with Maestro, the only inventive software managing all our devices. The first Release will support ABR, ECOG, MLR, LLR, OVamp and CVEMP exams.

But this is just the beginning. In fact, in 2025 we are taking Celeste even further by integrating aided cortical assessment in collaboration with Hair Lab Australia, bringing even more advanced functionalities to Celeste. But I won't take any more of your time. Let's dive into today's discussion. It's an honor to hand over to our speaker, Professor Stavros Abdopoulos, who will lead us to a comprehensive overview of abr.

So enjoy the webinar and see you later. Okay, everybody. Okay, as Anna was talking, I present you a little bit the first slide which will Give you an idea what we're talking about. Basically what I like to discuss today is the historical perspective of the abr, anatomy and waveform terminology, stimulus parameters, acquisition parameters, so forth. More on the technical part.

Okay, analysis of the response, conventional, non conventional responses, a little bit of discussion about the effect of drugs on the ABR morphology. And at the very end I will present a very small exposure of various clinical ABR applications. We're going to have another one later on in 2025 on the hearing screening. So mostly the applications will be dealing with hearing screening disorders with hearing impertinent and a bit of some details or intraoperative monitoring. Okay, now let's see what are the references for this webinar.

And basically the course I'm teaching, the grads course I'm teaching in Ferrara, the volume one of Advances in Audiology and Hearing Science, which is the book I have co authored with two well known other authors, Mark Cram, who is very well known in audiology and Andrea Zorba, who is an expert in vestibular science. And of course then we pass to the book of my friend and mentor, Jay Hall. This is a must have for everybody who wants to have a reference book on abr. Now we move to the Handbook of Clinical Audiology. This is the bible of course by Jack Katz.

And the chapters which are of interest to us, they're authored by the very well known Linda Hood. Then we move to an excellent book. Actually I have debated whether to put this one or the one by Picton. Nani Krishnan is an excellent neuroscientist and this is a really, really good reference for all of you. And then we go back to something oldie but goody.

This is something from the late 70s, a book by Linda Hood on the applications of the abr. This is an excellent thing to have, but I would say it's difficult to find. So I would suggest at this point to search it in your library. Excellent, Excell, excellent book. Now let's move a little bit to the historical perspective of the abr.

A little bit of the anatomy, morphology and of course we'll be talking about the famous seven peaks or the famous waves.

Let me stimulate a bit your attention here. You can see what I want to emphasize is the sound transduction pathway. So this should be a representation of an acoustical stimulus, in other words an acoustical field that is being captured by the pinna and then is actually propagates the acoustical energy towards the middle and the inner ear where it's converted and then is mapped onto the brain stem and so forth. So bear with me. What's going on?

I have slowed down the file to remind you a little bit, but we're talking about. Okay, here we have obviously, the translation of acoustical energy to a pressure wave. And then this pressure wave stimulates the in her cells, which then they are synaptically connected with a ganglia. And then we have the mapping of all this information on the brainstem. And then, of course, through an extremely and complicated circuitry, neural circuitry, the information is being mapped on the cortex.

Now, if we go to the other side, I wanted to say something also on that, because once we have the acoustical energy that enters through the round window inside the cochlea, what happens is there is a translation of this energy into a pressure wave. And so if we uncoil our beloved cochlea, you'll be able to see a disturbance on the basilar membrane. So this is the basilar membrane, or the organ of Corti. This disturbance is the famous traveling wave that Becket had Described for us 140 years ago. Now, something else.

This is a very nice representation, but let me remind you that this representation of only one particular frequency in real life, we have a multiple of frequencies because the external auditory environment is complex. So we would assume that here we would have a superimposition of many, many traveling waves and also their interactions. Okay, now let's go to our definition, the definition of evoke potentials. These are electrical signals generated by a group of neurons in response to a stimulation of a sense organ. And let me remind you that we also have ocular evoked potentials when we are trying to map various processes into the around and inside our eyes.

Now, what is important to mention here is that we refer to potentials because we are having different signals. In other words, signal A and signal B and signal C. And also, it's very important to remind you that these are very, very small signals, usually acquired by surface electrodes. Then we have to average them, we have to acquire a lot of them and amplify them in order to arrive to what we will call evoke response or auditory potentials. Now, something interesting for all of you.

I am not sure where each of you is coming from. The nomenclature obviously refers to the area of expertise. So if you're coming from neurosciences primarily, you will be referring to Baer are brainstem auditory evoke responses. Lately, we also have BAEP, I.e. brainstem auditory evoke potentials.

And there is a reason for that. I'll explain to you later. On most of us who are coming from the medical and the audiology regimes. By the way, in Italy, audiology is a medical specialization, okay. It's not part

of the communication science that we have in the agloci action countries.

Well, in the audiology and medicine we are talking about AER, I.e. auditory brainstem response. Okay, let's see the historical perspective. Actually, every time I'm presenting this slide, really I have the goosebumps because I was lucky enough to meet during my US years summer and find measure. And these are the people who wrote this incredible paper back in 1967 called Cochlear Action potentials recording from the external ear in man.

Okay, now this is a great paper. Describe something else. We're not talking about ABR yet because we have to wait three more years in order to get to the abr. But the beautiful thing about it is that while they were discussing some non invasive techniques in order to record the electrocochleography, the echo g. Actually what they were supporting in their paper was some ensemble that is very close to what we use today.

That is what we use in the abr. That is a non inverting electrode, the positive one which is connected to the earlobe and the inverted electrode which usually is on the bony bridge of the nose, which is not the way we do it. For example, here is how we basically do it. And this is the most applicable montage that we have for hearing screening. That is the red is the non inverting.

The, the black which is above the ground is the inverting. And this is why in their case, okay, in the summer paper we got the ABR inverted. Okay, now this is something I took from the Handbook of Jay hall, the Handbook of Auditory Book Responses. And I like to show you it's a list, it's a table of what happened from 1970 to 1980. And I like to underline that.

First of all we talk about the great work that by John Jewett. He first described the in the animal model and the same year with Romano and Wilson, they describe it in the humans. Now if you go a little bit with me in this list you will see the people who actually form the modern audiology as we know it. We're

talking about pillars of our science. So Galambos in 1975, we're talking about the ABR in the premature infants.

Star was talking about the central nervous system pathologies. We go down for example Stockhart with the same variation of ABR in central nervous system pathologies. Arlington Stoker, Don and Egermont, Jerger. And of course we end up. This is something really very interesting for a lot of us.

We're doing a screening, the work by Jerger and Hall when they study the effects of age and gender on the ABR responses. Now let's see what happens. Let's go back and understand a bit what happens once you stimulate the cochlea by a broad sound of a transient stimulus, like a click, which, due to its particular spectral properties, activates the hair cells into a wide region of the basilar membrane. Okay, so if you remember before, when I show you the traveling wave that was the result of one particular stimulus, now we're talking about something that excites many, many, many, many locations of the cochlear of the basilar membrane inside the cochlea. So what happens is once you do that, then you get a response.

This response is very, very small. So what you need to do, you need to average over time. And in the beginning, we're using about 500 and 1,000 repetitions in order to get some sort of signal, which eventually, in our days, clinically, we may end up doing up to 2,000 sweeps, that is, repetitions. If we are in an environment that, for whatever reason, is not very friendly to the registration of these responses, once we have these averages, then we need to amplify them. Usually this sort of procedure we do in a, let's say in a closed booth, a silent cabin or whatever you call it, so, which is electromagnetically shielded and also protected from external noise.

Now, the frequency content of the ABR response depends also on a variety of other factors, that is, for example, the stimulus intensity, the properties of the transducer, and all of you who have worked not only with the headphones, but also with the inserts, which are the new technologies in order to facilitate

a lot of other tests. You realize that, for example, the properties of the transducer of the headphones and the insert are completely different. So we have to take that into consideration also. What is the situation, the conditions of the external and the middle ear, which affect a lot, the sound transmission towards the interior, towards the cochlea, and of course, the functional status of the cochlear amplifier. So depending on how well cochlear translates, okay, the acoustical energy into a pressure wave, this results and changes and modulates the frequency content of our response.

Now, something which is really important to mention at this point is that the ABR responses that are evoked with transient stimuli, such as clicks, cannot be used to define the hearing sensitivity or the Cochlear status at our audiometric frequencies, at our audiometric octaves, or in any specific frequency regions. And the reason is the click, as I explained to you before, has the tendency to stimulate the whole cochlear partition. So if we need specific information from specific areas of the cochlea, we need to use other types of stimuli that either called tone bursts or chirps. And these are mostly what we use in the pediatric applications and the adult applications of abr. Now this is a slide I took from Terence Pickton.

And the reason I'm using it over here is because I like to show you that the evoke potentials are of many kinds. So we will be dealing with what we call early potentials. And we are register them, recording them up to 10 in a window of 10 to 12 milliseconds. From 10 milliseconds to almost 50, we have the middle evoke potentials. The middle latency evoke potentials with the AMLRS.

And for 50 to almost 500 we have the late potentials. And of course the cortical potentials like the P300. In our case, we'll be dealing only with the first part of this figure. So let's ask again, what happens upon stimulation? And now we're using the signals that are giving us information from a particular location that is 500 hertz, 1000 hertz, 2000 hertz and 4 kilohertz.

And what you can see here is the abr response. The wave 5 is the dominant wave in all these recordings here you have the intensity of the stimulus. And I want to just to mention something really interesting, it does make sense, But I always like to underline this. If you notice the latency of the wave 5 at 500 Hz to the latency of 4000 Hz, what do you see? The latency is getting smaller and smaller and smaller.

So if you want to go down and look a little bit at the numbers. So we are 8, 5, 53 milliseconds for the 500 Hz tone burst to 6.53 milliseconds for the 40004000 Hz tom burst again. So what exactly is going on? I do remind you that here the latency is less. So I do remind you what's going on.

This is a more basal side of the cochlea because it's a higher frequency. So it's being mapped at the base of the cochlea. So the delay from stimulation to response is less. We need more time to go to the apical part of the Cochlea when we have the mapping of the 500 Hz tombers. Okay, now let's talk a bit about the peaks that we have.

In abr. Primarily, we have seven. In clinical practice, we use the first, the third, and the fifth. The others don't have a particular, let's say, practical application. Okay?

But anyway, I'll go over and explain a little bit. V wave and more or less where is the location, morphologically speaking, which generates this response? And. But you have to have in mind one thing that we're talking for a very complex system. And from the moment we are passing this area over here, which is the second peak, the second wave, we are getting contributions from a lot of areas, okay, from the eighth nerve to the brain stem.

So the. We don't have one particular area which responds or corresponds or generates one of these peaks. Okay, More or less, we can say that from wave one. But for the rest of the waves, we have a lot of, or let's say, ecosystem combined contribution from many generators till the brainstem. Okay?

So let's start again and see what's going on. The wave one arises from the eighth nerve in men. Also in animals, we can say that the second wave, we can say, arises from the activity of the first neuron of the eighth nerve versus, okay, the auditory brainstem. Now, wave three. Traditionally, we were thinking that the generators reside in the area of the superior Olivary complex.

Okay, soc. And a lot of books in the past that you see, they are saying, okay, wave three is soc. Basically, this is not the case. It could be that we have a contribution, but data that we have from intracranial recordings and dipole moments with animals, of course, they suggest that the wave 3 is generated beyond the eighth nerve, closer to the cochlear nucleus. Okay?

And this part over here is generated from the trapezoidal body. Why? I'm saying this because in the many years that I'm teaching this course, there are some people, there are some students or colleagues in various meetings and say, well, you know, do we know exactly where a wave is coming from? And the answer is no, we do not know exactly. The only way we can do that is we can have an animal model and we can implant electrodes in particular locations of the brain.

And even in that case, we won't be able to be 100% sure we can understand the contributions where they're coming from. So we're going back again to wave four. Okay? We can say this is the leading part. The leading part usually is the leading part.

Of wave five. Okay. Intracranial research suggests that we are dealing with generators in the superior olive oil complex. Now we go. Sorry, that was the mouse.

We going back to wave five. It's an ABR with wave three. Wave one are the cornerstones of our understanding this sort of response. It has been hypothesized that we are dealing with neurons in the inferior colliculus. Okay.

Again, with more recent experiments using dipole moments, that we are dealing with much more broader area that spreads from the head of lateral lemniscus and the areas of inferior colliculus. Okay. Now wave six and wave seven. We are not very sure where we're coming from. Theoretically, they are within thalamus and the medial geniculate body.

Okay. Some other work. They were saying there are contributions from neurons from inferior colliculus. But again, and I want to underline, this is a very complex system, and sometimes it doesn't make sense to say where this wave is coming from. We would like to see the performance of the whole response.

This is something that I borrowed from Jay. Jay Hall. Okay. And this slide is telling us, more or less, with the latest research that we have, where the most prominent generators of the waves are coming from. Okay, now let's pass to section two, and let's talk a little bit about the technical aspects of our response.

First of all, we need to talk about transducers and transducers. Primarily, we have the acoustical transducer, like the headphones or the inserts. We have also the electrodes that we attach in order to collect the various electrical differences from our patient. And of course, we can have, for example, over here that I have, a bone conduction oscillator. Okay.

So most of the time, we're using the three disc electrodes. And then I'll show you the various montage schemes that we have. Okay. Before going to the montage, I like to tell a few words about the stimuli. And what is the effect of the stimuli on the morphology of the abr?

Okay. First of all, if you remember, before, I was talking about the click. And the click is a very short stimulus, has the capacity to stimulate a lot of places in the organ of Corti. Why? And the why is because its spectral characteristics are very broad.

So this part over here, okay. Translates into a spectrum that is the ensemble of frequencies which are contained in this response, which is very broad. Okay. Now, if we take the same waveform and we. Applying some manipulation is called windowing.

And we can take this spectrum and somehow shape it. Okay. And make it Less broad, more narrow. And we can continue with this application of this windowing technique. For example, here we have what they call the Blackman window.

And the Blackman window, what gives you, gives you a spectral response that is very narrow, okay. And looks like this. So the idea why I'm telling you that because when we're dealing with the abr, we wanted to get responses most of the time which are correlated with the auditory frequencies. Many times we're using the click in order to have an overall idea what's going on. But if we want to talk about hearing level, we using specific stimuli which have specific characteristics, like narrow band spectra, like this one.

Something else that is very common is the tone burst. And the tone burst is actually a signal when we are manipulating the rise time, its plateau and its decay time. Okay? And these are the frequencies that mostly were used, which are related to our audiometric frequencies. And these are, let's say this is the recipe of how to make a tone burst for 500, 1000, 2000 and 4000.

For example, the rise time here is 4 milliseconds, okay? And the fall time is 4 milliseconds. So you get like a triangular form. There's no plateau. And you get a plateau once you get it into the 4kHz stimulus.

Okay? Now something else which is also interesting. You should know when we're talking about these signals, that is, for example, we get a click. This is the theoretical representation of the click. Eventually, if we measure what comes out of our headphones or inserts, it's what we call the differentiate a

changed form of this clique that looks like that.

And if we try to understand what are the frequencies contained in this representation, we see a very broad spectrum. Okay? Now when we go, this is a click. And you see very short, broad spectrum. Now we go into a tones burst, for example, let's say 2 kilohertz.

And if we go to see the spectral representation of this stimulus, we see something like this, which is very nice. That is all the energy that we're sending in is concentrated around a specific point. Okay? This is what we want. We want to particularly stimulate a part, a specific partition on the cochlea and the organ of corti.

And then we go to something that we use lately. It's called the chirp chirp. And the chirp is a wonderful signal that it can provide either a broad spectrum or in certain cases, a very narrow spectrum. And this is what we use to mostly when we do, we're having to do with kids, infants and Many times, even adults. Now what I was telling you before is back when you use different stimuli, what happens?

The morphology of the wave that you record changes. So if you remember this beautiful response that comes from a click where you can see wave one, wave three, wave five, if you're trying to do that with a tone burst, you will get something different. Okay, Something like that. I think this is, this is also from Jay. And of course you have to realize the scale is a little bit different, all these responses, but the message is that using different stimuli you get different morphologies.

So you have to take that into consideration. And I always like that with the 500 Hz that sometimes you cannot even see wave 1 and wave 3. The only thing that you see is a peak that you go by nose, as we say in audiology. That is, we have to understand where this latency is being mapped. And from that you understand, oh, this must be wave five.

Okay, now this is something from our own system, the Celesta. And one of the things I wanted to say here is that when we're using the chirp, we have another advantage. That is, we can record a response that can be twice as large. And having a response that is twice as large has a lot of advantages. So first of all, we can be more confident to identify the wave 5 where not in the very high level simulation when we go down and we'd like to figure out where is the threshold.

So when we can detect the threshold at lower intensity levels, these levels represent valid responses. Okay, because we have a better single noise ratio. Now in some cases we can have a decreased acquisition time because we, as I'm going to tell you before, when we average, okay, we don't average forever, we average. Still we reach a particular criterion. And if you have a strong longer response, you arrive to that criterion earlier.

And this is a great advantage, especially if we're doing automatic ABR and we try, you know, to record from neonates and infants and we don't have a lot of time in our disposal. Now before we were talking about the stimuli that we use for the traditional abr. Now I have something else for you that I won't going to spend a lot of time because it's a different chapter in the abr. Signal analysis is what we call speech evoked abr. So most of the time we're sending in a transient or a tone burst, okay, Or a chirp, okay, still a transient.

And we are getting a response. This time we're sending in a stimulus that is this syllable da and According to this, we have a different type of response in a longer window, of course, not in 12 or 15 seconds, milliseconds. I'm sorry, but we're talking about almost 40. And this response is called frequency following response has six particular points of interest. This what I call here, the V, the C, D, the E, F and so forth.

Also A, which could be the seventh. Most of the time it is all the V or the A. They are our points of reference. Okay, now let's talk a little bit about the factors and the parameters that are affecting our

recording. And here I have a list of these factors and I want to show you and share with you.

In the beginning, when it was being in the 70s and the 80s, when the ABR basic research was conducted, you can understand that it was really difficult to take in consideration of all these factors. For example, if we're doing about the stimulus we're having intensity rate, polarity, duration, frequency, modality of presentation of the stimulus. If you're talking about the recording, what sort of montage you're using, filters, time window, number of channels, number of repetitions. And we go to the bigger problem here, the patient, that is the age, okay, Young, very young, old, very old. The gender, women, the female tend to have wonderful responses, much better than the male one.

If the patient is under medication, you will see the drug. How the drugs can affect the actually the latency and the amplitude of our response. Attention, the body temperature, muscle artifacts. This, for example, is a big issue when you're trying to do screening and you have to record this from infants and neonates. It takes something, you know, a little bit of a spasm and the whole recording is corrupted.

So let's. I will accelerate a little bit. I don't want you to, you know, to put attention on something that we have resolved in the last few years. But there are things that you should know. For example, as the stimulus increases, what happens the amplitude increases and the latency decreases.

Is this famous latency amplitude graph that it's a classical thing that, you know, you start with an intensity and a latency and as you go down, okay, you see different things. So this is really, really important. So what also to remember, basically, there are most of the latency changes. They're happening between the 60 and the 90. We have some sort of slow latency change.

When you go below 60, things accelerate a little bit. So the changes that they happen in the latency are a little bit different. Okay, and you can see that over here. This is of course, wave 5, which is the most prominent, the most observable, from 80 to 0. Actually, in my clinical practice, I've never seen a 0dB

response.

Maybe in the, in the older time, usually we might be able to go up to 20. Because in this level it is really, really difficult to identify any, any wave independently. What sort of scale you use is really, really difficult. So something also very interesting that once you go below the 30 decibels nano HL, okay, it's difficult to recognize if the response has any other components. So the only thing you see, you see a little bump, and that little bump is wave five.

Now this is something that it used to be true mostly for male subjects. It is not quite true for females because females have better responses. That is close to the threshold. The response, the wave 1 is around 4 milliseconds. Okay, remember that we start from 1.7, okay?

And the wave 5 drops to 7, 8, 9. Usually female subjects can be around 6.5 to 7.5. Okay, now let me see. This is also the same. This is from Nani Krishnan, a very nice, nice graph that we know.

Okay, what happens with stimulus intensity as the stimulus intensity drops? Okay, what happens? The latency increases. And this is very beautiful. Also here you can see that the 4, the 500 curve obviously is much above the 4000.

That is we have lower latencies. And this is how he explains the same explanation I gave you you before. Okay, this is a table I wanted to you to have because it's very useful, very useful in every lab, in every clinic, for example, to know to have some values per nano HL and peak equivalent, or we can say SPL at these levels that are the same for wave 1, 2, 3, 4 and 5. Okay, these are, and also the in wave latency, these are very useful to have, have of course, every lab they have to, to do their own, let's say normative values and so forth. Let's talk a little bit about the rate, the simulation rate.

This is something we used in the past in order to get responses, especially for neonatal subjects. We have a limited amount of time, so we wanted to use high stimulation rates in order to get a response as soon as possible. And you can see here, we can start at 7, we end about 77. And what do you expect? I mean, what do you expect is the latency is increasing.

And why, why the latency is increasing? Because the neural fibers don't have time to relax and they start, you know, moving slower and slower and slower and slower as the stimulation rate increases.

Okay, there are some Interesting things that the high stimulation rates affects differently different populations. So if we're talking about premature infants, the latencies are more influenced of the premature than the well babies. The term well babies, that is, we have different effects, more significant effects here than here. And the same thing for younger children in comparison to older children and with older children up to 30 years of age than adults. So we have populations, they respond differently.

Let's talk a little bit about montages. And this is what we use, of course, I explained to you before that use for infants. And primarily we want to use, okay, one of the two lobes in order to get the. Our positive. The ground usually is in the forehead.

Okay. And then the idea is, where do you place. Okay, you're inverting your negative electrode. And this is the famous CZ that. That they want to use in the vertex.

Well, this is the classical montage. We provide very, very good results. For example, we can have with this case, more prominent waves one and three. Okay. If we use the earlobes, for example, we have less muscle artifacts.

And in some cases we want to really separate. Well, the wave five we might use, okay. The negative electrode up to the C7 vertebra. Okay. Most of the time I've tried this with infants.

It does work. But at the same time, it does work very well because we automated abrs, they don't need. You don't need to see the results. I mean, the device tells you immediately what's going on. You have the same result even if you put your electrode on the forehead.

So in the clinic, we might need. Sometimes we have some particular cases and we don't see very well. For example, auditory neuropathy is one of these cases where we need to really extend the potentials in order to understand what's going on. We have also DSD similar data over here. What I like to speak very briefly is the filter, okay.

And filtering. Okay. Although we do these tests in the booth and which is also shielded. Okay. A lot of times we.

Especially if we're doing screening, which is a different ball game and not many times we can do it in a shielded room. We need to use filter in order to eliminate as much as the internal noise of the subject. Okay. And the external noise, the 50, 60 hertz that come from all these devices that eventually we sealed. This is again from our Celeste recording.

And you can see that we're using a high pass filter of 100 and a low pass filter at 1500 hertz and we get this very, very nice response. Well, basically, one of the Ideas that I want to pass is that you want to have, have some low frequency components. Because these are the components, they provide an increase of amplitude, okay. Although somehow they also increase the latencies. Okay?

Now what happens is that if you cut your signal, let's say you go from 3000 to 1500, what happens is somehow you rounded, you make it more, more visible. Okay? And let me show you this, for example. Look, this response that we filter from 30 to 3000 and from 30 to 1500. The difference is that here, this lovely, let's say particular peak is somehow smoothed out.

Okay? Now also look something between this part and this part we have permitted more, okay, low frequency content. And as a result here we get a response that is higher in amplitude. And this is very good. As I told you, when we need to identify threshold, we do screening and so forth.

Now we're going to dedicate the last, I would say five to 10 minutes to the analysis of the ABR response. Okay? And we can see, okay, the idea is to record the data into two different locations, okay? And stop when the correlation between these two locations, locations, I mean of course in a computer buffer they are very, very highly correlated. And there is a way to do that.

There is a criterion that is a statistical criterion most of the time is called fsp. So as you collecting data, okay, you reach a moment where your FSP is telling you, okay, stop with the autom. You don't even have to control this. The device do it by its own in clinical. When we do clinical recordings many times we will see and Sometimes if the FSP is not high enough, that is above 3, we might do the recording again.

So why it is important to have good quality responses. We know that and this is why it is very common to use the chirp stimuli in order to get the maximum single noise ratio out of these responses. So let's see what we are talking about. Okay? And the, the lovely thing about this from Jay hall is that he indicates the position of each wave, okay?

And the distance between the waves. That something we like. For example, what is the absolute latency of wave one of wave three or wave five? And then we go and we say, okay, what are the differences between 1 and 3, 3 and 5 and 1 and 5. And these are indices that are very useful when we try to use the ABR to differentiate.

Is this a transmissive case? It is a cochlear case, is a retro cochlear case. Even without using of course our PTA information just from the abr, we're Able to identify what is the general region. Okay? It's the middle ear.

It's the cochlea is the retrocochlear region. Were that we having some sort of the genesis of that impairment. Okay. Or in many cases, we can have the mixed cases of the transmissive and the sensory neural losses, which we call the mixed hearing losses. Okay?

Now let's go here, over here. And let me tell you. So, for example, I have a table over here, of course, this table, most of the time we have it memorized after years and years of practice. And let me show you some interesting situation over here, okay? For example, this is normal and this is a transmissive case.

Okay? So what do we expect is that the latencies increase symmetrically. Okay? Okay. And what happens is that, for example, wave one now is at a latency of 2 milliseconds.

Now, what happens if we have a case where most of the deficits are located inside the cochlea, inside the inner ear? What happens is that we're going to see a much smaller wave one. Okay? But again, if we try to look, for example, where is our wave 5? Wave 5 is showing a little bit of a delay.

Okay? And the idea is, with the conductive cases, once you give enough stimulation, then the generation of the ABR proceeds as if we're dealing with a normal person. The only thing you need to do, you need to raise theoretically, okay, the amount of stimulation once you do that, that the structure is the same where when we go to the cochlear case, due to the fact that some areas, okay, do not function well. Okay. Obviously the output of the cochlea is not as big.

So what do we expect wave one to be? Less. Okay. And then I will talk about a little bit about the retrograde retro cochlear example. The retro cochlear example implies that I have some complications out the level of the ethnare and above.

So what should I see? That wave one is perfect. Okay. Wave five is much more delayed. Okay.

And of course, what else? The. The distance between 1 to 5 is also more increased. Okay? So we can put all these things, combinations together, okay?

And we can give some very good comments. That is, with wave one, small amplitude, immediately you say you're saying I am at the output of the inner cells inside the cochlear nerve. Nerve, probably a cochlear lesion. With a wave 5, we'll have a small amplitude and we probably have some sort of upper brainstem lesion. Okay, now how we can identify the upper and the Lower.

So if we also have a interpic latency which is increased, that is we have a prolonged value, okay, from one to three in this case. And of course a small wave five that might be, because we can never be sure, a lower brainstem lesion.

Again, we can also control the difference between wave three and wave five. And if there is a prolongation, then we again we verify side, it's the upper part of the brainstem. And sorry about that. If the interpic 1, 5 is prolonged, implies that we might have both parts of the brainstem involved.

Okay, let's see what happens. Now we have electron issues and this is something it takes some time really to master. And a lot of times that we may have an electrode issue. Electric issue implies or the electrode is not attached or the wire to the electrode is connected, okay, so you can see any of these things. And one of the things I really liked is this part over here when you can see a response.

Okay, this is, these are noisy responses here you see the response, but there's no ground. Okay. And eventually what happens, this is like a virtual ABR that is being formed, okay, by. Since we don't have a specific ground, but some sort of the electrical field of the patient, okay, if the, the non inverting electrode is gone, then you don't see any response. And then these are what happens when you move, move the electrodes in one position or the other here also look at this.

This is really nice. You will never see this in a booth or in, let's say in a far decade. In what sense? Because most of the time we shield our data from this sort of artifact. But if for whatever reason you record in open space and open field, as we say, you might see this sort of artifact.

This is the 50/60. Now let's talk about maturation. And this is what we will can find in a newborn. And this is what we will find in the same response when the child is at 2 months, 6 months, 1 year and adult. So what do we see?

We see that the wave 5 is becoming more pronounced and the latency is getting less, less and less and less. And sometimes one of the problems we have when we do screening and we have to do with premature infants is to be able to identify the wave 5 at a specific latency. Because if we have maturation issues, wave 5 might be in a latency which is way over from the window where the device, our device is looking. For example, most of the time time these devices, they check from 6 to 8 milliseconds if we have maturation issues, we might be at 9. Okay?

So that could be a problem. And in that case we won't be able to identify a wave 5 and a decent coherent ABR. Now let's see a little bit the effect of drugs, and we say anesthetic agents, sedatives and potential toxic drugs must be considered when we do ABR recordings. Okay? Now the effect of the drugs is primarily amplitude is not a big deal, okay?

The big deal is the latency. Because with the latency, all the measurements that we have and we be able to identify, to differentiate what is what, but they're being completely shift, okay? Now the anesthetic agents and the sedatives influence the ABR less than the P300. So we need to do a cortical recording. With the acetative it will be very difficult because the whole thing will be shifted, okay?

The peaks, the, the N and the P peaks will be shifted. Shifted. Okay. Now, okay, sometimes what we know is, especially with children, that we need to sedate the children in order to get a good response. There is an effect, but fortunately this is not a statistically significant effect.

Okay? Now this is something I really like, and I'm always saying this to my students. One must be very careful on the distinction between the statistical significance in ABR differences for a group of research subjects. Okay. Between the significance between the members of this group and the clinical significance that we have for a single patient.

So the statistical significance is one thing, the clinical significance is another. Okay?

Now we have a little bit of time, so I'll go over the differences between the ABR and the steady state responses. I mean, this is the new kid in the block. And they're both evoked responses. For example, the stimulus, we can have a click or a tone burst. Here we have pure tones, more or less.

We have a lot of interesting things to say. Remember that here we can go from 500 to 4,000 hertz. With the steady state we can go up to 8. Now the maximum intensity is 90, probably very close to 80. And this is a limitation of the.

Our, let's say inserts and transducers were. With the steady state responses we can go up to 120. Okay. The filter so far, good. In terms of threshold again, we might.

Might. If we're lucky enough, we can reach up to 80dB HL. And with the steady state responses you can go more than 120 dB. Okay. And of course, shorter latencies for females.

Okay. Than males, of course. Now let's see the clinical applications in the last five minutes that we have, the identification of the hearing loss and the classification of deafness. Primarily, the. The way we handle this is that the ABR is an addition to the battery of tests that we use.

I mean, if we can use a lot of things, we use a lot of things. If we don't have the time, we might use a click ABR to understand what's going on. Where are we most of the time? In the clinic. We have a battery of tests that you do the pure tone and then you can do your abr.

If there's something else you don't understand, you do a P300 still, if you don't understand what's going on and you have a problem with the periphery, you might use an acoustic emission. So none of these tests can be a standalone. We need to integrate the whole thing with the battery test. So when we say we're trying to identify, we have some idea and we try to verify that or we try to explore more details with these techniques. Okay, so for example, there's something also a slide I really like.

Jay did this slide by hand. These are not original. He draw the whole thing and it was very nice. So for the last 25 years we're using it because the result is very good. So this, for example, is the ABR of an normal subject.

This is the ABR of a subject that has transmissive conductive hearing loss. And you can see the wave one is being shifted. Here we have the sensory that is cochlear here, neural, which means retrocochlear. And this is something we really, really like, the auditory neuropathy spectral deficit, which is the auditory neuropathy, where we do not have a coherent ABR and you cannot find any peaks. And I have to say that why I'm telling you that because depending on this end, of course, on the values of the I of the first and the five and the first and the third wave latencies, we're able to build, let's say, a

table that we can understand what's going on.

So also obviously the retrocochlear pathology is something that we have to be very, very careful, especially when we're talking about the vestibular swannoma. Okay, but we need to remember that we can probe our, let's say hearing apparatus up to 80dB HL. Now, now ADDB HL for an acoustic neuroma could be okay. In some cases it's not. So we will need to use another technique and we move to or cortical or to the assr.

Now we can discuss newborn screening. And this is something we are doing for the last 25 years. It's a combination primarily between automated ABR and otacoustic emissions. The automated ABR can reach a sensitivity. In other words, you can identify with 100% the normal subjects.

And with about 96 to 98 the specificity the subjects that they have some sort of hearing deficit. Okay. And primarily what these algorithms do, they seek at a particular latency interval the presence of a coherent wave five. Okay. Usually as I told you, we have the combination between the two.

There is a different protocol that we use for the well babies and a different protocol we use for the NICU residents. The neon dental intensive care unit. Okay. What is the problem there? The maturation.

So we need to make sure that we test when.

When we are at the level of discharge, that is that the child has reached the 36th week of life. Okay. We use this combination in order to be able to affront the auditor neuropathy and the. Oh, I have no water. And I'm sorry about that.

That this is the alternative. You don't have synchrony. You don't get. You get the microphonic. Okay.

You don't get any other waves, but in many cases for a little bit of time you get acoustic emissions. Intraoperative monitoring is really good, especially when we're dealing with the tumors of the eight cochlear nerve. Okay. And we want to make sure that this nerve is preserved anatomically. And sometimes unfortunately it does happen and there is some small accident and then we get in some other complications.

And here we go. We you asked for one hour and you got one hour. And thank you very much. And let's see. See what we have over here in the chat.

Okay, we have five. Can you share it? Of course. Okay. Take place during testing while connected.

Well, let me tell you. Most of the time we are using, for example, Hisham is telling me what about the artifact taking place during the testing? Most of the time we will be using, using, if it's possible, battery operated devices. If not, the signals are being acquired inside. If not, we have to use what they called a notch filter of 50 or 60 hertz.

Can you share the PowerPoint? Ali Lund is saying if I can share. Of course you watch is. Thank you.

It's the AFSP. Yes, the AFSP. Right now actually. It was a development in the 80s. It is statistical algorithm that sees the significant components, primarily spectral components of wave five.

Primarily. So when you reach this statistical significance, you can stop now. The A lot of manufacturers, they present different values for their devices. Okay. And they suggest what is the accepted value?

Usually a value about 1.65 to 1.1 to 2.5. There are the acceptable values. I have seen beautiful responses below one. So the doesn't tell us anything but give us a degree of sensitivity to say that what you see right now is good and the latency calculation is correct. Okay.

Okay. Well. Okay. An anonymous attendee asking about the anesthesia and the sedative. Well, the effect is very little.

The effect of the sedation is very little. Changes a little bit the latencies, but not so much. Okay. The control. Oh yes.

This is very. Some very nice. Some very nice questions about the contralateral abnormalities. What happened is, is if understood correctly, you're asking me when we do the stimulation, you can have a stimulation that comes from the contralateral ear like the ipsilateral ear. And in this case what happens is that we have an enhancement of the response.

Again, in this case, if you don't have an experienced operator, you might get confused. The latencies of wave 3 BC testing, the bone conduction testing is a very good question. Most of the time gives US latencies about 3 and 5. They are recalculated because the. The stimuli are different.

Any protocol and montage reference I've given you, the one that we use for the infants is the right now that is positive, positive, negative, ground. Okay. These are what we accept right now, more or less. And of course I can tell you unless you invert the the negative and the ground most montages will give you the wave five you want. Okay.

Now some. In some cases when we have the auditory neuropathy, we might need to distant a little bit the electrodes. Just make sure that we're getting the wave five that we need to identify.

From whom do we go? Speech evoked avr. Beautiful. Beautiful topic. Usually these are the types of infants or patients that they have difficulties in processing speech.

Could be patients that they have been implanted lately. That is not within the window that we have within the 12 months window. And they have difficulties in acquiring and processing the speech problems inferior colliculus. So we use this pixel ABR to understand their performance metrics.

I. You're asking me. You're asking me about the C Chirp. To be honest with you, I'm. I think.

Are you referring to ce. That is the Klaus and Berlin chirp. This is the right now is what we use the most and not because it's the best, because it's the more commercially available, available. Repeat one speech. Okay, Well, I mean, you cannot.

Okay, this is a very nice question. I love these questions. You say, okay, what are the effects they happen when children are watching their mobile and they're not sleeping while doing a. Well, I mean, you might. We are asking a little bit of trouble.

Okay. If we're talking about mobiles, what we have is some sort of video games or tablets which are. Do not emanate any electromagnetical radiation. So in our clinic and most of the clinics I know in, in Europe, since I'm gone from the US for a very long time, and that time we didn't have mobile phones. But right now we do not accept a mobile phone.

We have a tablet that we give to the child and let the child play in order to relax the child and be able to record an abr. It is not a very good practice to use mobile phones. Of course, older mobile phones, they didn't have all the problems that we have now with the emission, the emissions. Right now electromagnetic emissions are much higher than they used to be in the past. So I would say mobile phone is not a good thing.

A tablet, okay, which is not connected obviously to a mobile network. Okay. Why Newbor. Okay. The question about abdesis, nor is why in the newer ABR is we have the 30 DB8 cell.

Because we are considering a threshold. This is the threshold we considered. It's about depending on the manufacturer. I think it's about 50, 50 by DB split. And this is the threshold that we have considered, you know, acceptable for hearing.

Okay?

Yes. Iftikar, can we give sedation? Yes, you can. Okay. Well, Emmanuel Contouri says my ABR machine can go as high as 95.

You have distortion there? Yes. It's less reliable. Of course, this is the theory. I don't.

I'm not. I don't know. This particular device if goes up to 95, from 80 to 90. There is still we have the. That intensity doesn't generate distortions.

Okay. And the problem is not only distortion will be calibration. The calibration with 95dB is difficult. Okay. Does it have EABR?

EABR? Mostly we use it in cochlear implants. Yes, but I haven't referred to that because it's something a little bit outside. Maybe for another lecture. Okay.

Okay. Concerning the hearing level. Okay, Best. Okay.

Amani is asking. The last one is if the intensity is. If the maximum intensity is 80 dB. Okay. How do you pronounce Profound.

You don't pronounce with abr. Okay. You do pronounce it with state. State responses. Okay.

And I think this is it. It.

Thank you for all your questions.

I have to say. I'm here, Professor. I'm here again. Okay. So thank you so much, Professor Stavros, for this insightful presentation and for sharing your vast expertise with us.

Before we wrap up, I'm pleased to announce that Professor Stavros Hatzopoulos will return as a speaker for an Academia webinar in 2025. So next year, an event not to be missed. Definitely.

Thank you. Bye Bye. Fantastic. And coming back to Celeste, let me remind you that our innovative system for evoke potential analysis will be available on the market starting from March 2025. For any inquiries, please reach out to our local Inventis distributors.

Thank you for joining us today. And don't forget our next webinar on December 4, focus on video TOSCO with Clayton Fisher. We look forward to seeing you at our future academia events. Bye for now.