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Pediatric Evoked Potentials: Principles and Clinical Practice

Presenter: Stavros Hatzopoulos, PhD

Greetings everyone.

And it is a pleasure to welcome you all to this new session of the Inventis Academia Webinar series. We are delighted to welcome back Professor Stavros Azopoulos from the Audiology and ENT Clinic at the University of Ferra, Italy. Professor Hadzopoulos is widely recognized for his work in auditory electrophysiology and has contributed extensively, I would say, to the field through his research, teaching and many scientific publications. Today's webinar is titled Pediatric Evoke Principles and Clinical Practice. During this session, Professor Stavros will guide us through the current clinical protocols in pediatric auditory electrophysiology, discussing some of the diagnostic challenges encountered when assessing hearing in infants and young children.

I would say please feel free to submit your questions using the chat during the webinar. As usual, we will address them together with the speaker at the end of the session. And as usual, you will also receive a short survey after the event and your feedback is always very valuable to us. And now, without taking any more of your time, it is my pleasure to hand over to Professor Stavros at Zopoulos. Enjoy the session and see you later.

Good afternoon everybody and thank you for coming in this webinar. The title is Pediatric Evoke Potentials Principles and Clinical Practice. And we will try to make this computer active a little bit faster so you can see my screen a little bit better. So the basic question to start with is why acoustic evo potentials or auditory evo potentials matter in pediatrics. And these are a summary of the facts that I'd like to present to you.

First of all, EEPs are objective non invasive neurophysiological tests.

They are critical for the hearing ascension in non cooperative children. And here I may say ABR is a great procedure. Also, they are considered the gold standard in neonatal hearing screening. And also

here we are referring a lot to ABR and automated ABR AAPs are essential in the diagnosis of retrocochlear pathologies. Okay, they are extremely valuable.

Interoperative monitoring, especially about cochlear implants and EAPs are very, very helpful into assessing the development and the auditory maturation of the auditory pathways. As you can see over here is a little bit graph that shows all these strains oscillations that we call auditory or acoustic evoke potentials. Now, in order to make some important decisions in pediatric neurophysiology, we have to have some important facts at hand. And for example, when we're discussing what sort of intervention strategies we need to design, these are the facts that we have at our disposal that is 1 to 3 per 1000 newborns born, have they present permitted hearing loss? The AAPS, primarily the ABR can detect up to 95% of hearing impairments early.

I'm saying early because you will see later on we need to intervene as soon as possible with some sort of strategy that is a hearing aid or a cochlear implant in order to maintain speech and language development. And that time is. We know that we have to do that in a time interval about six months. And we also know that universal neonatal hearing screening programs they rely heavily on AAP based screening and primarily on automatic AVR. Also remember that AAPs can help us assess the functional integrity of the auditory pathways.

And when in our case, when we have the what sort of issue at hand when we have a pediatric patient, what is non verbal that is young or is sedated or the previous idiometric tests are not conclusive. So in this area the ABR and all the other protocols that we'll discuss today are very very helpful. Now some of the reference that you should have if you're into the clinical neurophysiology of in the area of childhood and pediatrics, the Holmes book is a must have the same thing. Over here the pediatric Clinical Neurophysiology this is a compendium of various is out one book. It's a contribution for many well known authors.

Olufsen is a very, very well known neurophysiologist. Now if we move into aaps, of course we have the Handbook of Clinical Audiology. Probably by the time you're going to look at it it will be at the 8th or 9th edition by Professor Katz. And of course you can have yours truly the two volume book Advances in Audiology and Hearing Science where we're treating a lot of aaps. Now if you're interested only in abr, this is the bible by Jay hall, the ebook of auditory evoke responses and also a very very well written book by a very good clinician and Annie Krishnan from Boston Auditory Berenice Evoke responsibles.

This is a kind of book that you would use also in let's say in a student professor type of relationship. Very, very educational. And these were J. Hall is the book to have and in terms of practice and so forth. So this is an infographic I generated for you and we will see a little bit how this huge area is being divided the auditorium of potentials.

Okay. And the first division is we have the transient potentials and the steady state potentials. Okay. And later on in 2027, we'll deal with one of my favorite topics, which is the auditory steady state responses. Okay?

Now if we go back to the transient APs, we have another classification which is very practical for us, that is classification by latency. And we can have short latency responses, we can have the middle latency responses, we don't use them as much, and we can have the late latency responses. And this is also something that a lot of research being done lately. And we will have another webinar on the cortical responses later on in 2026. Today, primarily, I'm going, I have to focus in one area, undoubtedly, and that will be the short latency responses, because this is the area that primarily we use in clinical pediatrics.

And you can see, for example, newborn hearing screening, threshold estimation, neurodiagnosis, eight nerve brainstem problems, and so forth. Okay?

Now this is a great auditory pathway, and this is primarily for transient auditory vocal potentials. Over here I have a graph with the potential. I hope you can see the colors. These colors correspond to this. Okay?

And the reason for that is you can see where are the primary generations of each potential. This is the short ones, which is of course, the echo G and the abr. And then we can have the AMR and the LLR over here. And you can see that primarily, most of the cortical responses that we're familiar with, they start from 10 milliseconds. And we're talking about this part of the pathways where we're talking about the abr.

We start from the cochlear nerve, okay. And we go up to the inferior colliculus. And you have to understand that these are multiple contributions. There is not only a single contribution. There are multiple contributions to these responses.

And when we're talking about the cortical potential, the responses are really from a large part of our cortical brain. So let's see a little bit. Let me play you this so you can, to get your attention. So let's assume that the dot is a sound stimulus that enter into the ear, crosses the meatus. Okay?

Okay. Puts into motion the tympanic membrane, the ossicle. The tympanic membrane, the ossicles, is being mapped at the staples inside the cochlea, where is being decomposed into the its fundamental frequencies. Then we have the firing of the neurons of the auditory nerve, which are mapped onto our brainstem. And from there we have multiple circuits that eventually map all this information into the auditory cortex.

So you can see that In a little bit, in a higher speed.

Okay. These processes are extremely complicated, and of course, the reason for it we are presenting like this for educational purposes. Now, let's go the other side, and let me show you a little bit what happens with the cochlea. One of my favorite, also my favorite topics, when you can see the cochlea over here, that we have to uncoil the cochlea. And over here, we can see the basilar membrane inside the cochlea inside the inner ear.

And what you see right now is the displacement of the basilar membrane according to the energy of the stimulus. The basilar membrane is extremely tonotopical. So what you see over here is that you see that this displacement moves across the membrane, reaches a peak, and then the wave dissipates. And this is why, from the time of von Beckeze, we call this the traveling wave. Okay, you can see them like this.

All right. Reaches a peak, where is the resonant point, and then dissipates and ends. What? You have to realize that as I'm talking to you, you have hundreds of traveling waves inside your cochlea as they're interacting one another, not only a singular one. Okay, we stop this.

We stop this, and we move to the next slide. So the evoked potentials are electrical signals that are generated by a group of neurons in response to a stimulation of a sense organ, and in our case, it's the ear. They're very, very small signals, we say. Usually we require by surface electrodes. In the clinic, we use disposable electrodes.

In classical electrophysiology, we use single disk electrodes. And the signals that we are acquired from these electrodes, they're being amplified and averaged in order to estimate and construct a coherent response. Now let's see what sort of classes of potentials we have. And of course, we will go from the low latency to high latency. Okay.

With the only exception is this. So we start with electrocochleography, which is the technique used to measure potentials generated in the inner ear in the cochlea and the auditory nerve. And usually we have the patient under sedation, and we used to use a transtympanic electrode onto the promontory in order to collect the necessary information. As you might realize, this is not an easy procedure and requires a lot of attention. Good old times.

We needed an anesthesiologist. Right now we have electrodes that they call the sponsor electrodes that they. We need to just attach them gently of the tympanic membrane. And we can record not as good a signal as with the transympanic electrode, but still a good one. But electrocochleography has lost its verve because we used to imply this technique before, a long time ago, before even the auditory stage, the responses for cochlear implants and so forth.

Now the next step in latency is the auditory response. It's the most widely used in pediatrics. It measures the neural activity from the auditory nerve through the up to the brainstem. And the automated version is the one that is being used globally in neonatal hearing screening. One of my favorite all time protocols is the auditory state state response.

It's an objective test that uses continuous amplitude and frequency tones in order to evoke a response. Many times we'd use it in conjunction with the abr, especially for patients that they show very, very high levels of hearing losses. So here we get into the cortical responses. The beat latency response is something we don't use it very often in the clinic. Primarily we're talking about cortical responses, we're talking about late latency responses.

Okay. And these are the ones who capture the processes, the neural processes from the auditory cortex. And this is really important. Unlike the ABR and unlike the echo G, the cortical auditory potentials, they highly dependent on the state of arousal. In other words, the patient has to be awake and in many times has to be busy with some sort of task.

Now let's group together a little bit. What we have said so far, where we primarily you use it in the pediatric domain. And what is the status of the patient prior to the test? Okay, let me have a break.

Now we start with the echog. What we can do, we can measure cochlear function. Okay. Cochlear function in the sense of threshold. And also it's an excellent tool for auditory neuropathy, a spectrum disorder diagnosis.

And most of the time, as I told you before, the patient has to be sedated because it's not an easy procedure. Then we move to the ABR and we have ABR for to understand what is the status of the auditory pathways. Also we can use it to diagnose auditory neuropathy. And using the right stimuli, we'll see that later on we can have the ABR2 estimate threshold. Again, the patient could be quiet, could be in natural sleep on sedated.

If we're talking about newborns, what's happened is, is that most of them, they are naturally sleeping. Now if we go to the steady state responses this is an excellent protocol. It's very fast. Many times the infants, they are in natural sleep, they can be sedated. Here we might have some issues with the sedation because it may alter a little bit the levels of the signals and therefore the detection of the signals.

And we'll see more later on, maybe next year.

And over here we have our cortical responses. And for central auditory processing, the patients have to be awake and quiet. And in the case of, when we try to measure cortical maturation, the patient has also to be alert. All right, now how these potentials are being generated and recorded. Okay, first of all, they are being considered far field recordings.

That means that the disposable electrodes record signals not at the locus of the genesis of these signals, but a little bit further away. This is why they call far field. Now we're using electrodes that are, or the disposable or the fixed ones. These electrodes should have low impedance and the inter electrode impedance also should be small. We're using differential amplification in order to reject noise and a common mode and a common ground.

Okay. Also we need to average a lot of them. Okay. In order to get rid of the background EEG noise. And it is very, very important to get a significant signal noise ratio, this potential by doing a lot of averages in order to arrive at the conclusions we need to arrive.

Now let's see a little bit the latencies and the generators of these potentials. So the echo G is within 2 milliseconds. Generator is the auditory nerve prime. Primary use right now is detection of auditory neuropathy. Okay.

Auditory nerve, auditory neuropathy. Okay. Spectrum disorder. Okay, now you can see the term the ABR. The latencies are between 1 to 10 milliseconds.

Primary generator, we're saying the brainstem, of course, is much more than that. Primary clinical use, detection of any neurological complications, the status of the, the pathways to the brainstem and, and sometimes threshold. I'm saying threshold because we're using the steady state responses more right now to do that. The two type of cortical responses from 10 to 50, 50 to 300, primary generators, the cortex. And we use for cortical processing and for identification of cortical thresholds.

And one of my favorite all time protocols, which is a P300 that we use this sort of test in order to identify cognitive function in cases which present some sort of anomalies. Okay, Central anomalies. Now the nomenclature, if you come from the audiology realm, you will be talking about auditory brain response. Instead, if you're coming from the neurosciences as myself, you will refer to brainstem auditory vocal

responses or brainstem auditory potentials. Okay, it's an issue of.

So the terminology immediately tells you if you are into the neurophysiology realm with animal experiments, or if you're in the clinical realm doing assessment of patients. Now, this is an important note I like to make, and please pay attention to this. That is the ABR that we evoke with transient stimuli, that is clicks, is used for a rapid broadband assessment of neurological integrity. Broadband, because the click has a rather broad spectrum and in such a way evokes reactions and decompositions of, let's say, stimulates a large part of our cochlea. Now, this protocol, that is with a click, it cannot be used to define hearing sensitivity for audiometric frequencies or specific frequency regions.

In other words, we cannot use this protocol in order to identify threshold, what we call the electrophysiological threshold. No, we have to use tomb bursts and chirps in adult or pediatric applications. And I do remind you that the threshold, the electrophysiological threshold is around 50dB higher than the actual normal threshold. Okay, this is the overall responses we'll be dealing with this part over here. There you can see auditory nerve.

Okay, brainstem, okay, this part over here, up to 10 milliseconds. And later on in the second part of the webinar and the end of the year, we will be talking about the rest of the latencies. Now, this is a very nice graph that somehow tells you how complex the ABR generators is, because, okay, even that I try to be to provide only one connection. For example, wave one is being generated by the distal cochlear nerve. The wave 2 is for the proximal cochlear nerve.

The wave 3 is for. From the cochlear nucleus and so forth. These are only approximations. In reality, there is a lot of going on with the ABR and the signals. This is why in the neurophysiology, when we do a lot of experiments, it's more difficult to predict things than in clinical practice.

So let's see something which I found a little bit interesting to discuss about abr. That is what happens if we use a tone burst for a stimulus. And these are the responses. For example, you can use a 500 stimulus, a 1000 Hz stimulus, 2000 Hz stimulus, 400 Hz stimulus. What happens is the morphology of the ABR changes slightly.

But what is more interesting is that the location of wave five. Okay, Changes and the high frequency TOM burst, they have latencies that are shorter than the low frequency TOM burst. And I believe, for example, we are 653 at 4 kilohertz to 853 at 500 hertz. And I hope you can understand the reason for that is because the higher frequencies are being mapped at the base of the cochlea where we have the mapping of higher frequencies, the middle frequencies, blah blah, blah, lower frequencies at the apex. So in other words, in order for the stimulus to arrive at the apex obviously requires more time.

And this is why over here, the latency of wave 5 in the lower frequency tone burst is larger than the wave 5 from the higher frequency tone burst.

Another issue that is really nice to discuss is the developmental clock. And what I mean by this is that the cochlear functionality is mature more or less by 26 or 28 weeks of gestation.

Now the myelination of the auditory pathways continues up to two years of age, that is 18 to 24 months.

The synaptic refinement, although is going through childhood, that is six to seven years. So the ABR latencies, they are progressively getting shorter with the maturation of the wave five, which reaches an adult values by around 24 months, that is two years of age, where wave one, which is more or less the output of the cochlea, reaches adult values around in six months. So let's see this in a nice table. Okay, let's assume we have a stimulus of about 90 decibels NHL, okay? And we compare the five components of these ABR.

The ABR maturation and we start with these two age groups we call preterm term usually is 38 to 40 weeks. Okay. And you can see the 28 weeks gestational age, the wave one latency is around two seconds, two milliseconds. I'm sorry. And when we move down to two years, it's almost 1.5.

Okay? And in adult life we have also 1.5. So we may say that in about two years the pediatric value reaches the adult one. So if we move over here, so wave five, you see, we start with eight milliseconds and by the end of two years we almost there, we're very, very close to the adult one. Okay, so the I, which is what we interested in the Inter Peak Latency 1 to 5, which is one of the most important and used metrics in abr, you can see because it's being influenced by the maturation of wave 5.

It follows the same pattern that is of wave 5, that is, we are starting with a high value and about approximately two years we have reached whatever the value of adulthood. So let's focus on abr. These, we have talked about it in the previous webinar. We talked a lot about transducer electrodes and so forth. This is an insert we use for to for the stimulation.

This is a disc electrode. This is more or less what we use a classical neurophysiology, not the disposable electrodes that we use in the clinic. And this is a bone conduction oscillator. And you can see over here, very nice diagram with the ground with a positive electrode, negative electrode, and the generation of our abr. So what are the common stimuli that I need to talk a little about Disease are more or less common across the whole range of potentials.

We use clicks primarily because it's fast, because they have a very broad spectral profile, because we stimulate as much as we can. Okay? And if we want to be more specific and we need to use numbers and you see the profile, the spectral profile is much narrow. Now, if we want to have the best of both worlds, we go to chirp stimuli. And you can see when you take a chirp and modulate a little bit, a little bit, what happens is that we get a spectrum that is more narrow and we can also use this sort of stimulus to predict threshold.

Now, this is something I've generated with artificial intelligence. And this is why I've never seen. It's very difficult to find responses that are so clean. So when you do a lecture, you need to have as examples which are clean, as clean as possible. This is what AI is doing.

For example, this is the response from a click stimulus. This is the profile by a thousand Hertz tomb burst. And this is the profile by using 500 Hertz. Now, what happens here is, you see the morphology is more or less the same. We still seeing five waves.

Look what is happening over here. Wave five obviously is moving in terms of the latest is being shifted to the right over here. The AI that generated this made a small mistake because the click stimulus is primarily focused on 2 kilohertz. So I would expect that this B would be a little bit to the left, slightly less to the left of this graph over here. Okay?

Now the comparison between the two, why we use the chirp instead of the click is because of the wave 5. So with chirp stimuli, we can register a much larger response of wave five. Okay. Sometimes could be two times in amplitude. And registering larger amplitude of wave five gives Us a lot of clinical advantages.

That is, we have a more confident identification of wave five, especially close to the levels of threshold. The detection of the ABR or lower intensity levels gives us also a more accurate estimation of the electrophysiological threshold in the pediatric realm implies that we can get an ABR in less than time. And this is very, very important because many times infants, they move and they generate biogenic artifacts and so forth. Now, there's also another type of stimulation that I would say, not a new type of simulation, a new protocol. And it's a mixed bag between the classical ABR and a frequency following response, because as you can see, the stimulus is the syllable da and their response occupies something around 60 milliseconds, which is very different than their classical ABR.

And we use this sort of protocol in order to understand better speech processing difficulties.

Now, I have talked about technical issues in my previous webinar, but when we're talking about pediatric applications, there are a few areas they require additional attention. One is, this is the electric montage, also the basal artifact. Okay. And the medications. Okay, medications.

Because primarily I'm referring to infants who are coming from the NICU or children that they are there some medication for whatever sort of problems they have. Now, this is a slide, of course, is typical, I know, but I always like to use that. That is, as the stimulus intensity increases, the latency decreases and the amplitude of the wave 5 increases. So if we're using a high stimulus, okay, the latency will be short and there obviously the amplitude of our wave five will be higher. So we know that this is why we go.

Usually when we try to search for threshold, we go from 90 to 60 in steps of 5 or 10 NHL.

Now, why I'm referring to the stimulation grade, because many times it is necessary to accelerate the test, in other words, to do the test in a shorter time. And a way to do that is to increase the stimulation rate. For example, from 7.7, this is classical, a little bit old. Usually we're at this level over here, around 20 to 30 samples per second. So we go from 7.5 to 7.7, which is a tenfold increase.

And I look what happened over here. You lose the coherence of the response. And basically instead of seeing all the waves, you see as a prominent wave three. Okay. Of course, this depends, although.

So the electrode combination, but this is the, with a classical application of electrodes that we will see later on, look what happens. So we lose inflammation. So the stimulus rate has a more pronounced influence primarily on the ABR latency of premature two term neonates on young children under the

age of 18 to older children or older children up to 13 to adults. So if you compare these two groups, applying a higher stimulus rate, that rate will affect more the premature, the younger children and the children before the age of 13 more than the other corresponding groups. Now the electron montage, okay?

For one channel system, primarily, this is the positive electrode, okay? This is the ground. Okay. Now depends where we want to stimulate. For example, if we have the stimulation at the right ear, we usually use as the negative electrode at the other side, okay?

The mastoid or the contralateral side. Okay, so positive ground negative. Now what I'll today I'd like to tell you to relax a little bit, tell you a few stories. I wanted to present to you with some sort of an image how these electrodes were being done. So I use, obviously the use AI and this is the text I tried to say.

Okay, give me the image of an infant. And these are the positions. The electrode that the red electrodes are the center of the forehead below the hairline. Now the black electrode are the lobe of the right ear and another green electrode at the center of the lower forehead above the nose. So in order to generate the Image Took me 15 minutes and still gave me this is which is wrong.

Okay? So it's not always easy to use these tools and you have to use them with great, great, great attention. Of course, then somebody told me use another, another AI and I did that with the nano banana imaging. And I have to admit, so I provide the same description, gave me this very lovely picture which is what we what we use today. Of course, this took me one only minute.

But I hope you can figure what is wrong with this picture. And what is wrong with this picture is that over here it should be the side when we stimulate with an insert, okay, which is not shown. So let's go back and see. Let's talk about the electrodes always positive electrodes around the hairline, okay? Ground electrode above the nose and a one and a two electrodes to the left and the right mastoids for a two

channel system.

So when we can use to stimulate and we can both the right and the left ear, okay, so again, positive ground negative. Negative. Okay, depends of course. Negative here if you stimulate from this part and negative here if you stimulate from that part. Okay?

Let's say a few things about abnormal responses. First of all, the electrode issues. And first of all, if you have your clinical experience in the nicu, recording anything in the NICU when you have a lot of electrical artifacts, you'll see something like that. And of course, what is the solution to keep on averaging with the hope that you will be able to reject all these artifacts and get a clean, a rather clean response like this. Of course, if you see the time over here is six minutes.

And six minutes for a single ear response is really, is a lot, which implies that you have to have an infant that is sedated because it's almost impossible to have an infant relax for about six minutes. Over here is a collection of what can go wrong when one of the three electrodes is being moved. And this is a normal response. And this I really like that one of the three electrodes is being removed. And you can see you have a lot of noise over here that the inverting electrode on the mastoid is being somehow detached.

So you see, you have a lot of noise over here is the positive electrode is partially detached, which is really tells you that you have to have a clue about what the response should be in order to understand what's going on during the registration. Of course, right now, a lot of the clinical systems, they have some sort of intelligent, let's say, software that tells you that you need to stop and try again or something is wrong with the electrodes and so forth. Now, an interesting topic also is maturation, because maturation, especially in the pediatric field, is very, very important, because what happens, the latencies, they tend to squeeze as we grow older. We need to know if we have to check about the latencies and the peaks of these waves. We need to know the age and the possible maturation

process, which is ongoing.

Okay. For example, you see newborn over here. In two months, we have a good maturation six months. Okay. Remember, the wave five is mature about two years.

So we have an ongoing process going on for all these recordings.

Now, I want to talk a little bit about anesthesia, sedatives, because it is an important part of the abr. And especially in the good old times, we were using electrocochleography. We had to sedate the patient or the infant or who was going to get the test done. Okay. Now, the effect of drugs on ABR latency or amplitude can interact with the.

Okay. To the effects of other factors. So if we have people that are having some sort of hearing deficits or having some syndromes or, and they are under some sort of pharmacoceutical regime, we need to know that because we can have an interaction of factors. Now, what we know is that anesthetic agents and sedatives, they influence the abr, but much less than the cortical responses. Okay?

Now, and please pay attention to that is we have data, they confirm that anesthetic agents and sedatives, they have a statistically significant effect on the ABR latency. Okay. Or amplitude, but clinically they're not significant. So implies that we might see something, a significant change of latency, but for our clinical setup, it is not significant. Okay?

So one thing is the clinical significance, and one thing is the statistical significance. Now, why do we need to sedate? And especially primarily for ECOG and abr, okay? Because children who are older six months old are increasingly unable to remain calm. They are very active.

And you have to remember that any movement generates artifacts which degrade obviously the signal, the potential being recorded. Now, what happens is that children who are older than six months, they don't sleep naturally, okay? They tend to be active. So it is a good thing to think about sedation. Now, also, sometimes if we have a problem with a particular child and we need to apply lengthy diagnostic protocols, we might need to provide sedation.

Okay? And this is very often when we need, especially when the child is around two or three years old and we need to do a lot of tests or long tests like ABR and OES and tympanometry and steady state tympanometry, not so much because, well, you know, they can be distracted for a moment, but for the other tests, probably is a good idea, is a good idea to be having the child sedated. Now, what I'm bringing you over here is a table where we see the method and what agent we're using, what is the route, how it's the age, suitability, how long it starts in duration. So natural sleep, we know we can use it up to four months. Duration, obviously, is sometimes variable because many times the mothers come in the clinic with their children and they are asleep.

And then the moment we're ready to do the test, somehow they start moving or crying or whatever. So then sometimes 5, 10 minutes pass into a quiet room and then they go back to sleep. So this is variable. Another thing is, for example, the sleep deprivation. So you keep the child active until you do the test you need to do.

And this is theoretically up to 18 months. It's okay if that deprivation means that the time you come in the clinic, the child is ready to sleep in a quiet room. And they usually. So we can do the ABR easily is also variable. And this is not a good thing for cortical potentials.

Okay. Because for cortical potentials, we need the child to be active. Now, primarily, this is the golden, let's say, sedation agent. Okay. And you can use it orally or you can use it per rectum.

I have not seen that ever. This is from the literature. And you can use it from six months to three years. And it takes about half an hour to take effect and lasts about an hour, more or less. Midazolam is also very good.

You can take it intranasal many times or orally. And you can use it up to six months. Takes also half an hour and also lasts. Well, it says 45, 90 minutes. We have seen that much less and depends.

Also usually we use the sprays which are easier, so the absorption is not as effective. So the time you have is less than 45 minutes. The Dexman, they use it in the states primarily. Okay. Intravenous, intranasal, all state, blah, blah, blah.

Now, propofolk, ketamine in general anesthesia. I'm a little bit against that. And the reason is that they generate some normal pressure in the middle ear. And I know for sure that that alters all the latencies and the amplitudes of all possible tests you're trying to do. So I would try to avoid it if possible.

Primarily the ketamine. Now let's go to the part that you were all were waiting for is the differentiation of hearing loss by using the abr. Okay, so these are the four possible scenario that is branormal hearing, conductive transmission, hearing loss, censoring your hearing loss, and retrocochlear hearing loss. And I designed this with an AI program, the one I mentioned before. So you can see these results are really excellent.

This is what I have taken from Jay Hall. Of course, this is from adults. They're not from pediatric population. I always like this slide. He designed this slide by hand, I think something about 20 years ago.

The beauty of it is that you can see what I'm going to tell you is all written over here also. So we can compare easily pediatric and adult responses of abr. So we start with normal children. So what we

should expect, we should expect something like that. I've never seen, of course, anything like that so clean in a child or on an infant.

The wave 5 should be clearly identifiable at less than 35 decibels. NHL. Okay. Now the waves should be into absolute and inter peak latencies. So we should see them where we expect to see them.

And they should be age appropriate for the maturation issues we're talking about this Is lovely. The wave 5 to the wave 1amplitude show should be greater than 0.5. And as you can see over here, the amplitude of 5 or the amplitude of 1 is exactly 0.5. And then as maturation goes on, this, okay, wave 1 is getting smaller and then wave 5 is getting larger. And we get to something like over here, okay, where the ratio is the number 5 over here is, has a double amplitude of wave 1.

Reproducibility should be nice and the waveform should be superimposed. And what is very important is that we should have a consistent morphology. That is, if you do a test today and you do a test tomorrow and you do a test in a month, somehow the morphology of the ABR should be consistent and compatible. Now, if we have a case when we have transmissive or conductive hearing loss, what happens is we have elevated thresholds by air conduction, we have normal bone conduction thresholds. And what happens with the ABR is that all waves are delayed by an equal amount.

That's we call the parallel shift. And I like this, what Jay has shown, that is 1 and 2 and 3 and you can see 1 and 3, they're almost over here. So somehow there is a shift, an equal shift of the latencies, the ipl, the inter peak latencies are normal because they remain in the same, for example, wave one, wave five, they remain within normal limits. And what causes this sort of hearing impairment primarily is otitis media. Otitis media, some sort of ocicular anomalies, and of course, atresia.

I don't know if you know what atresia is, is we have a partial or a total block of the external meatus. Now, what happens now when we have sensorine or hearing loss primarily, we see absence or

extremely reduced amplitudes of the first waves. Okay. We also know that the air conduction, the bone conduction thresholds are elevated. The inter peak latencies, they are typically normal.

If we have more peripheral lesion now, in terms of the morphology of the wave, 5 may be poorly defined. And of course, we need to use chompers in order to get some sort of threshold estimation. Now, if we're going into retrocochlear patterns, for example, cases of multiple sclerosis, because in the pediatric realm, we don't see a lot of the classical retrocochlean patterns that we see in the adult population, basically all entropic latencies that are being elongated. The 1 to 3, the 3 to 5, the 1 to 5 really primarily in the case, for example, when we have Demyelinization. And as I told you, in multiple sclerosis and the wave 5 to the wave 1amplitude goes less than 0.5.

What causes this sort of cases? Except okay, of course tumors or ischemic hypoxia situation, of course, hydroencephalus and so forth. But these are rare, more rare in comparison to the transmissive and hearing loss. So here I made another graph to show you the extension that everything is being delayed and all three important inter peaks they're being enhanced and they're being prolonged. Okay, and you can see it over here, for example, when we have the IV becomes 5 milliseconds and so forth.

Now I all use this slide in order to summarize what's going on so you can see it immediately. What you need to do is first of all, this is more or less of course depends what is your stimulation, the reference of stimulation. Usually we use 80 or 90dB in HL, so we know the latency of wave 1, wave 2, wave 3, wave 4, 5 and so forth. So we know where are the latencies, we know where to mark them, for example with the normal. So we have to detect the wave and mark the exact latency.

And also we need to calculate the interwave latencies. Once upon a time this was done by the audiologist or the technicians. Right now the system is doing it for you. So you can immediately see in which category are you. As the test is being conducted primarily in all the normal conductive and sensory cases, you see that the very important inter latency value of 1 to 5 is more or less the same.

So if you see something different, you immediately know that you are facing most probably a retro cochlear situation. By the way, these values over here are primarily for mature children, children that we don't have any maturation process going on. Now, yes, we have some time to talk a little bit of another important topic that I really really like.

And this is hearing newborn hearing screening. And primarily we have two categories. One is the well babies and the other is the preterm infants. The protocols we apply on this are different because we have the time to test the well babies more than the preterm infants. Primarily for the well babies we have a three stage going on when we test them with the acoustic emissions.

And the second test is again without acoustic emissions. If you have a refer then you use automated br and if you have a refer again then you go to stage three when you do a clinical ABR. The preterm infants, we test them at the discharge, that is when they're around 36 weeks. Because obviously due to maturation processes, the ABR is very difficult to be identified properly. So we test them first with acoustic emissions and then if we fail that, another test and then the third test is with a automatic abr.

And if also this fails, you go back to the clinical ABR in some places. If the second, in this category, the second test with acoustic emissions fails, you go directly to automated abr. Okay. You don't have to get three phases. So the first.

If the. Sorry, what I want to say is the first acoustic emission test fails, then you go directly to the automated abr. Usually we do this within a time period of about three months because we need to intervene in the time period of six months. We know that the automated ABR is an excellent protocol and it has a sensitivity 100% implying that we can identify normal hearing subjects and a specificity of 96 to 98% that is subjects with hearing deficits. Now one of the trick is the auditory the automated ABR algorithm they usually see the presence of a concrete signal and either specific latency range.

This is why many times we need to specify if the test is for a newborn, for an infant or for an adult. And these protocols, they are widely used for usually to do the whole screening assessment of the infant population. And these two protocols are. Are the. Let's say the key factors in identifying cases of auditory neuropathy and connection mutations.

I do remind you that connects mutations is a non syndromic sensorineura hearing loss with mild to profound effects. They are primarily in the cochlea and we sometimes we need to apply both tests because many times the automated ABR will not provide an answer and the acoustic emissions will be partial. So in this case we know that we are facing or auditory neuropathy or a connexin mutation. So this topic is also something I really like because it used to be the nightmare of our clinic for. I'm talking about in the early 90s when neonatal hearing screening started.

What was going on? We were trained the ometrist and to do the test with acoustic emissions. But then many times from residents of the nicu, the neonatal intensive care unit, we will see that later on they would develop some sort of hearing loss that could not identify only without acoustic emissions. And many cases of Connexin 26 as well. This is a period when we learn that we need to do more things in terms of screening.

This is how the auditory neuropathy was developed by Arnold Starr back in the 90s and the definition is that you have present acoustic emissions, a cochlear potentials. Okay, Cochlear microphonic. Okay. And you might not have, you can have an abr, but the alter term that is auditory, the synchrony was the expression of what was going on. You would see an ABR that was completely the synchronous.

You couldn't see any waves. Okay, so what happens if you do that? If you do the measurements, the ABR might be absent, maybe severely abnormal, not wave 1, waves 2, 3 and so forth. The wave 1 is usually present because it's the output of the cochlear is very also, how you say, relative to the value of

the cochlear, microphonic. Now one trick in this case is that once you have a cochlear microphonic, then the issue is to change the polarity of the stimulus.

And of course if you see that the cochlear macrophonic changes its polarity, you have a very strong clue that you're facing an auditory neuropathy case. Okay. Of course you do that once you're having emissions present and automated abr, which is dubious. So one of the data, what data we have is the prevalence in the NICU graduates neonatal intensive care unit. Ten of those will failing hearing screening.

What sort of factors are being related to. Okay, primarily prematurity, various hearing syndromes, hyperbilirubinemia and anoxia. We don't have a gender prevalence and most of the time auditory neuropathy is bilateral. We have genetic causes and primarily the autoferrillene from the auto gene mutations. And also some other mutations are being discovered lately.

In terms of syndromes that might contribute to that, the most well known is the Usher syndrome, the Marie Tooth disease and the Friedrich's ataxia, which is not so much because primarily ulcer syndrome generates the vast majority of auditory neuropathy cases. Now what is the clinical presentation of the auditory neuropathy in terms of newborns? Okay, the newborn fails the screening if it is ABR based but passes the OS test. The it has a normal response to loud sounds but does not understand speech. And this is a problem with parents that many times do not understand what's going on.

Okay. Because sometimes, you know, you do this and the child is responding, you say okay, there's something going on. But then you talk to the child and you don't see any, any response to single words and that's a problem. This is why it is crucial that we identify this case before six months so the child can. How can I Say recover the handicap of processing language and development of speech.

So as I told you before, the parents report inconsistent responses to sounds. Okay. Depends on if we're talking about preschool.

These are older, how can I say, data of children than somehow we didn't detect with screening. So eventually if they go to preschool, they have delayed speech and language development. They appear to hear selectively a few things, but they're not consistent. Obviously they don't understand speech in noise and of course they perform much better in quiet environments. And the school age children, they have many academic difficulties.

They are. It's very difficult for them to understand, for example, long lectures like this one. Okay. And cannot follow a multi step verbal instructions. Don't worry guys, we're almost getting there.

So from the key findings are we have absence of neural waves. We don't have very good 3 and 5. These are the key findings. We have the cochlear microphonic which inverse with polarity. The good old.

I like that because we may have some people who have a technical orientation. In the good old times, in order to distinguish the cochlear microphone from an active, you have to take the transducer and record without a transistor to see if what you were recording is an artifact or actually the microphonic. Okay. Now these days I think nobody is doing this. We are just using these parameters over here.

In other findings, we have present acoustic emissions absent reflexes. Not always, at least not in the beginning.

The behavioral thresholds may be from normal to profound. Okay? Speech perception is very poor relative to the audiogram. So the audiogram, if you can have an audiogram of a child, it will not give you an idea about its speech perception. And believe me, what we still do not understand is the rate by

which this disease proceeds.

Okay? Because maybe for one or two, three months you see nothing of all these things except the presence of microphonic and the acoustic emissions. And suddenly you see the whole expansion of all these symptoms. Okay, so what can we do? We can use hearing aids and we can use cochlear implantation here.

Imaging is crucial. We have to do imaging in order to understand we don't have a cochlear nerve damage because if we have a cochlear then damaged, then we have to move into auditory brainstem implants directly. And the good thing is that for example, the autofurlin, which is the primary cause of auditory neuropathy, we have excellent results by using cochlear implants. This is the more or less the profile that we have over here. The polarity to the response.

Positive, negative. The latency does not shift if you increase the stimulus intensity and the latency does not shift when you increase the rate. So these are very good indicators that something is wrong. And over here you can see that you have acoustic emissions which are distortion products. Okay, Let me go directly to the last slide.

Okay, so and which is my last slide to give you. What is the absolute pediatric scenarios where we need a clinical abr. First of all, if we fail the newborn hearing screening, we have a family condition from a family history of hearing loss in a. In an infant that is in the nicu. Okay.

The same thing if we have a history of hearing loss. Okay. In the family of the child if we have craniofacial anomalies. And usually these will be expressed as retrocochlear anomalies in the ABR syndromes that are associated with hearing loss. Okay.

And as I told you, the Vandenberg and Down syndrome are the most known ones. Okay. Bacterial meningitis. Okay. Of course, auditory neuropathy.

As we said before, if we have any speech language delays, then we should do clinical ABR immediately. If we have neurological concerns, that is maybe some sort of demelination disease. Okay. We do that also before doing a cochlear implant. And also this is something we do to monitor what is the status of hearing loss for autotoxicity treatments and of course, post surgery or whatever surgery we do in the area of the year.

And I believe this is it. And thank you for listening and for staying with me one hour and ten minutes. Okay.

Anna, do I respond directly to the questions? Yes, professor, can you hear me? Okay. Yeah, yeah, yeah, yeah. Okay, first of all, thank you very much for this insightful presentation and for sharing your experience and expertise with us today.

So, professor, now may you be so kind to open the dedicated box. Yeah, yeah, yeah, yeah, yeah, yeah, I have it. I have it on my screen. Okay, got it. I can see.

Yes. Four questions till now. Yes. Yes. Okay, so.

All right. So how do maturation relate. Changes in a nervous system affect latency and amplitude in pediatric. Okay. The maturation, of course, is the one that affects the detection of the waves.

Okay. So if we're using an automated system, we have to tell the system that we're testing a child. If we are doing it ourselves, we have to consider. Okay, what were. Where are we?

Are we before 24 months? We're above. Let's say we're 36 months. Where? Six months.

In order to understand where, we should try to find the latency of wave 5. Okay.

Indications contraindications of sedation. The only thing where I can tell you. Alteration slide alteration of the latency values. Okay. As I told you before, ketamine is something that generates also more complications.

That is you can have. It generates what ketamine does. It can generate a transmissive hearing loss because generates a negative pressure in the middle ear. Do you cross check with cortical tension or GI to define hearing aid users? No, we don't do that yet.

Okay. Do you cross check with cortical potentials in ASND to define hearing aid use? No, not yet, sir. Am I okay? Okay.

Alejandra, as I hope I responded to your question. Do you think it's hard to get for children till. No, usually. Primarily. Okay, the question is, do you think it is necessary to get wave seven for children or till wave five is enough?

I think wave six and wave seven, they are used primarily for academic purposes in terms of, let's say, their classical applications. I haven't seen any so far. And I think the gold standard here is wave one, wave three. Okay. If we're talking about high rate stimulation and of course wave five.

And because of these waves, we also have the inter peak latencies that we estimate 1, 2, 3, 3 to 5, 1, 2, 4 to 5. So 1, 3, 5 are the best ones. Okay.

Oh, I have somebody from Greece. I'm very happy for that. In a child with speech delay, can we rely on normal ab? Oh, this is a really difficult answer. Okay.

Okay. Speech delay with acoustic emissions absent implied that you are in a realm of a very strange central problem. Okay. So I would go directly with cortical potentials on that. Okay.

Normal. By the way, automated nbr, they are not very accurate. I would definitely. We use that in terms of screening. But I will definitely do, let's say, of course, some sort of chirp evaluation of the patient and cortical potentials.

If we're talking speech delay. All right, but this is. It's a very strange scenario that. Because usually with acoustic emissions you have to be. I don't know what sort of hearing loss we're talking about here because emissions missing implies that you have losses around maybe 50dB in the mid frequencies.

Okay. About waifa on. Well, Dr. Kumar says please explain about wave 5 to 1amplitude ratio. It is an index that it tell us something. It gives us a little bit of information regarding if it is somebody's normal or if we have some indication about a retrocochlear hearing loss.

So if the wave 5 to wave 1 is, is small, less than 0.5. We have good reasons to believe that there is something retro cochlear that is delaying the response. Okay, this is it. If the ratio is high, as I told you in the that slide, then we are in a normal regime for that index.

Does putting the ground electrode elsewhere. Oh, yes, very good question from the anonymous attendee. Yes, you can get. No, no, no. You can get the granular lecture also in the back of the neck or in the shoulder.

What that does, it alters wave three or wave five. Okay. So the best position will be in the front. Because the. The wave 5 definition is better when you move them in the back.

The wave five gets is a little bit smaller for the shoulder. I know somebody is doing it for children. We're talking about children now. I don't remember which wave it does affect. Okay, thank you.

Thank you. Okay, for threshold detection we do chambers. And what frequency should we start with? Well, frequency. Okay.

Threshold detection electrophysiologically is not like we do in. When we do a classical audiology that we start from one and then we change bands. You can do 501, 2 and 4 kilohertz. Tombers or chirps. Okay.

What are your comments regarding the use of ABR and CAP for cochlear implants? Well, it is. It's a standard technique by Dr. Ahmed. It's a standard technique to use some sort of electrical ABR or cortical potentials during the cochlear implantation. But you have to realize we don't do that the whole time.

We do that in the beginning and towards the end of the operation. Okay, thank you. Thank you. Okay. From my great friend.

Hello. As we say in Greek.

Okay. Dr. Matocharo. I'm sorry for the name. I need to put my glasses on to see it correctly. Okay, let's see.

Okay. What if the ABO Results show wave 5 at 20dB by the ASSR does not show a response at 20dB, which results should be used? Okay, that question depends on the hearing loss profile of the patient. Okay, I would definitely go with ABR if we were talking about the lower levels. Okay.

The low threshold levels, 20dB is something really rare, to be honest with you. Speaking about threshold ABR and steady state between the two procedures, remember that when we have profound hearing loss, we are more prone to use the steady state responses. But for the rest of their threshold estimation, ABR is the protocol to use. Okay. For patient with auditory neuropathy, is it necessary to perform or is to perform steady state Responses or is sufficient to confirm the BEN result behavior test.

Well, I believe using the steady states is always very good. Especially as I told you before, if you have a patient that has profound hearing loss due to the auditory neuropathy. Okay. If the hearing loss is more or less moderate, it's in the beginning. Then it's not necessary to use steady state responses.

And you can use only ABR for the auditory neuroplastic patients. We use hearing aids. How should the hearing aids be properly fitted? Well, this is a huge question over here.

Actually what we were doing for this question is we were talking about cortical potentials that we were using in conjunction with hearing aids. Okay. This is not an easy answer. And to be honest with you, I would. How can I say fit it?

I would use the standard techniques of fitting and then use cortical potentials to verify that the fitting is efficient. Okay, but this is huge. I mean, we should do just a lecture just for that. In case of absence of wave of always except wave one. What is the possible causes?

I would definitely say this is from Dr. Gamal. I would say that we are. Well, you have to realize, Dr. Gamal, that when you have a sensorineuro hearing loss, the first waves are usually very, very small. So

if we have wave one, that means that most probably we have the. Let's say the periphery working.

Okay. And then something is desynchronized. So I would suggest that it's probably a retrocochlear hearing loss case. Okay. Now, Dr. Susan, how early can unaided corticals be used in children and R3?

This is something we will talk a lot about in the latest part of this year. But I guess from what I know, what I've read is a few months old. Okay, for to be used if a baby with emissions present absent ABR and MFCC presence with sound filter, what would you do? Hearing aids. Difficult hearing aids, probably.

I don't know. For example, Alejandra, it tells us about this question. I believe that hearing aids in this particular profile won't be very useful. Okay.

If I understand correctly now, in the case of auditory neuropathy, if the other cells are present. Well, other cells were. Oies, you mean. Dr. Sukant, do you think it's necessary to prescribe hearing aids or weight? Well, Dr. Sukant, is only a matter of time.

So if you have this profile, because usually emissions, they. They are present for a few months and they might vanish. So I would definitely prescribe hearing aids as soon as possible. By the way, if this is a unilateral or bilateral, I'm assuming since you're talking about auditory neuropathy, this is a bilateral case, so yes. Hearing aids and anonymous attendee.

Is there any method to know about the fifth peak? If done at lower intensity, the morphology is not smart clear. If there's any method to know about the wave 5 peak.

Usually we get these values directly from the devices that we use, if this is what you mean. I'm not quite sure I understand the question. Okay. If you want, you can express it in a better way as I'm going

through the questions. Thank you so much.

Thank you. Ben Gizzou. Okay, an anonymous attendee. Are there any dangers with using melatonin or diazepam as sedatives on the test? Do this bring any effects?

Well, as I told you, melatonin, to be honest with you, I don't have any experience with it nor with. Well, I have experience with Dazepan side effects. Always. There are problems with the. The tests become a little bit more dilating in terms of latencies because all sedatives, they create micro mini transmissive hearing losses.

Okay. And if you remember the slide that I told you before, something that might be significant in terms of research is not significant in terms of clinical experience. So I don't know about melatonin, but the diazepam. No, I wouldn't say there are any important clinical side effects. Okay, thank you, Alejandra.

I hope to see you the next seminar. Okay. Dr. Ibrahim, is there any new machine or acoustic emissions not needing sleep during exam? Well, most of the new testers, they're very fast and most of the time they can record emissions in seconds. About automated abr, I think the same.

Okay. I don't know if I'm allowed to. To give names. Okay. But yes, they are.

Okay. Okay. Can SD be unilateral? Yes, I've seen. Dr. Gerald, I have seen this in the literature, not in my clinical experience.

Dr. Melinda Wells, how do you professionals advise NICU parents regarding hearing aids when you identify hearing loss and lactate in awe, for example? Yeah, this. Dear Dr. Wells, this is really a very difficult situation. Our line of thinking is we always try to improve the quality of life of a patient, even if it's terminally ill. So that's.

I. And this can be interpreted in various clinical contexts differently. For example, in Italy, we try to use that as much as possible. Even I haven't, to be honest with you, I didn't have experience with many times in these 40 years. I'm doing these things.

But I can tell you the few times we were very positive into getting hearing aids. The infant that of course we have lost in the NICU. Okay, Dr. Mutho. Haro. Okay, well, the last name as difficult as mine, I guess.

A pediatric patient with profound hearing loss is using hearing aids. What is the maximum duration of hearing used before designing? Well, I mean it's not. For example, I don't know the age of the patient, so I cannot tell you. But I would say at least 12 months.

I don't know the age. So I can tell you about the possible cortical neuroplasticity that we have to deal with and what happens with the hearing aids because you reprogram your brain to hear. So I would say at least a year. At least a year. But again, if it's possible.

For example, right now we have a lot of research indicating that we should use a cochlear implant at the age of 10 or 12 months. So if it's possible, and it's an economic issue, and I don't know in which country you are, but the cochlear implant solution is an optimized solution. But again, at least one year with the hearing aid. Can you highlight. Dr. Sukan, can you highlight why high frequency hearing loss shows prolonged in latencies?

Ah, this is also a nice question. Let me guess how many questions we have. Okay. Why high frequency hearing loss shows prolonged in. Because what is what we're seeing there is a presentation of lower frequencies that they have already prolonged latencies.

Okay. And the fact that you don't have the same amount of myelin in the neural fibers, so the signals take more time in order to move from point A to point B to point C from the auditory nerve to the brainstem. Okay. And I hope this helps you. Okay.

I think this was it. These were all the answers. Anna. Okay. Yes, Professor, I'm here.

Oh, good. 29. Okay. No, thank you. I thought another, another question was coming.

Professor, thank you and again for these fantastic presentation. We have really appreciated a lot. Thank you so much. Thank you for having me. Okay, before we conclude, I. I would just like to briefly mention that Celesta Inventive System for Auditory and Vestibular Evoke Potential has now been supporting clinicians worldwide for over a year, more or less.

And looking ahead, we are excited to announce that in the coming months, more or less June, July, we will introduce a new module called hear lab A.C.A. aided cortical assessment. Dedicated to the objective cortical assessment of amplified speech signals. Further expanding the clinical capabilities of the system. Anyway, our next webinar will take place on April 30, featuring Dr. Jay Jindal, an experienced audiologist from the UK with nearly two decades of clinical practice.

The title of the webinar will be Starting with vamp, the fastest way to level up your vestibular Clinic. We hope to see many of you there, of course. Thank you once again for attending today's session. And please remember to follow Inventis on our social channels to stay updated on all upcoming academia events. Thank you once again.

Thank you, Professor Stavros, and thank you. Have a nice day. Bye bye bye to all.