Revolutionizing Auditory Hearing Screening: Methods and Best Practices

Presenter: Stavros Hatzopoulos, PhD

Greetings everyone. It is a pleasure to welcome you all to this special session of the Inventis Academia Webinar series. Today we are thrilled to have with us once again Professor Stavros Arthopoulos. A distinguished expert in the field of audiology. Professor Artopoulos 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, tele audiology and long distance learning. He has authored over 245 peer review publications and has actively participated in European projects on otoacoustic emissions and nanotechnologies. Professor, thank you once again for accepting Academia's invitation and I would say that we are honored to have you back with us. Thank you so much. Thank you.

Thank you for the beautiful words and the wonderful introduction. Okay, the title of my presentation today is going to be Auditory Hearing Screening Methods and Best Practices. And as always, things are okay. And the first thing we need to know is why do we need to implement hearing screening practices? And the proper question depends on on the aids of the subjects in question.

The data collected from the World Health Organization are suggesting that hearing loss is as present as ever in the early and the late ages. So hearing loss in the early ages affects significantly the linguistical developments of the child, whereas hearing loss in the late ages affects issues related to well being, social integration and balance, etc.

So as you can hear, can you see the cursor thing? Yes. Now, well, okay, so this group over here is more or less of a folkloristical expression because we consider as adults or late adults, people above 65 years old. This is quite discussable, but in any case, for this lecture we will accept it as it is. So the early detection of hearing losses is needing an optimization of possible resources and possible intervention strategies.

So one unfortunate event is that hearing screening in the older group ages has not received the necessary attention so far. And the emphasis of my lecture will be placed only in the hearing loss detection of the early years. And a possible second lecture in 2025, 2026 will affront the screening in children and adults. This is the nomenclature I have built regarding the lecture and you can look at it later on. And one thing to mention immediately is nhs, which is Neonatal Hearing Screening Unit hs, which is Universal Hearing Screening.

These are the programs which include screening of, well, babies and babies in the neonatal intensive care unit nicu. Another name will be ad, which means Early Hearing Detection intervention. These are the programs they detect and also they offer solutions like hearing aids and cochlear implants. Okay. Auditory neuropathy, the nightmare of the old audiologists and hearing scientists in the late 90s.

The disease which involved inner hair cells and neurofibers, this disease is extremely connecting with this, the Connexin 26 and some mutation of the genes which are encoding this particular protein. Okay. And we'll see that later on in the lecture. Something about the measurement units db spl, which is in reference to 0 db spl, which is the quietest sound that the average human can hear around the pressure of micro 20mpa. And I do remind you that most calibrations are conducted in DB split dbnhl.

Sometimes we call it nano, but in the actual word is normal and refers to the decibels relative to the subjective click threshold. For the ABR hearing screening, we usually use stimuli around 30 to 40 db NHL. So we're done with most of the nomenclature. This is more or less for you that you want to go back and see if something wasn't clear. Right now what I would like to do start with the concept of statistics.

And the word screening by itself means the meaningful separation of two population of subjects. And in our case that would be normal hearing versus the population of subjects which are presenting some sort of hearing impairment. So this is the situation. We have population one. Let's assume these are the

normal hearing subjects population two subjects presenting some sort of hearing loss.

So we record from both some sort of test in our case could be our favorite abr. And the idea would be we need to extract from this recording some sort of features that we be able to use them to identify a recording from this population towards a recording of this population. And usually these features, these characteristics, they are called discrimination or screening criteria. So theoretically, if the criteria are good and we apply them on the recordings from these two populations and we get this sort of separation, okay, this is ideal and this is the correct discrimination. Sometimes, although what happens is that we get a recording and when we applying our scoring criteria, it might be that is mapped is classified to the wrong population.

So we might have some sort of a small overlap of characteristics, characteristics of the ABR response. I mean, so if the overlap is from 2 to 5% still is almost ideal, is still acceptable. And we can go, we continue our work. But this is all hypothetical because in real life you would get an overlap of around on more than 10%. That is, you would get recordings with characteristics they could be or from Population one or from population two.

And in these cases, we cannot say with certainty if that particular response is from population one or from population two. Okay, so this is the real life. Okay, let's go back now to the. To see what we get in terms of screening. And we have to define what we call condition.

Condition. Condition in our case will be the presence of hearing loss. And what we're interested in, especially when we're looking at newborns, not at adult or children, only for the newborn situation, this is really critical. So can you imagine that we are getting some sort of a case that it says you have no condition present or. Okay.

And that condition is present. Okay. Or a condition like somebody who is normal and shows the test is showing that he's not. So these two cases are really, really, as we say, the crucifixion of every administration or screening, because these are the ones who are generating most of the problems. What I like to say is this is the most important thing.

Why? Because this is the case of a subject with a hearing loss that according to the screening procedure is okay. Is normal, so escapes the subsequent tests. Okay. And this is what we don't want.

Something else. Regarding screening, the specificity is the percentage of correctly identified normal hearing subjects. And usually with the procedures we have, we can vary from 90 to 97. You will understand later on why I'm saying this. Sensitivity is also the percentage of subjects correctly identified with a hearing loss.

Okay. And usually we're between 90 to 95. Now, we cannot have 100% specificity and 100% sensitivity as of today, maybe tomorrow, employing some sort of algorithms of artificial intelligence. But right now, with the algorithms we have, we have to, let's say, privilege a little bit more sensitivity or privilege a little bit more specificity, depending what is the aim of screening? Screening could be we want to identify with the highest precision possible all the normal hearing subjects.

Or on the other hand, we want to identify everybody who might have some sort of hearing loss. And obviously this is the choice of the majority of screening programs. So according to some studies, false positives could be. For example, the normal subjects were underestimated, are about more or less 1%. And most of the time you have to realize that it's somebody who is presenting a problem and is the end result of a screening is okay.

So most of the time this is something technical. And most of the time we can take care of that. Now, the other case, which is very, very interesting for the false negatives, that is for the subjects with a hearing

loss who are Passing the screening. Luckily for us, with the three phases that we employing right now, two phases without acoustic emissions and a final phase with an abr, we are able to detect these cases very well. Some, okay, the data that we have is say that these cases might be less or about 5%.

In my personal experience, this is much less. But all depends where you are conducting the screening. Okay. If you are in an environment that you have a lot of noise, sometimes you accept some, let's say, conditions which are not optimal, so you might get a little bit more of, or false negative or false positives. So what is the status of the NHS today?

These are the data, the average data that I got from who from 2022. Okay, and what we got is that the incident of hearing loss in the well baby population, okay, the normal infants, they're about 0.7 to 1.5 per thousand. Usually all these averages are per thousand the incidence of hearing loss in the intensive care unit population. These are the infants with a lot of risk factors. They're always associated with very high possibility of hearing loss.

They're about 3.5 per thousand. Incidence of auditory neuropathy, primarily in this group, is 1 to 1.6 per 10,000. And as I told you, these are averages which I got from the website, which In 2032, of course, we will say, okay, now we are in 2025. What can be wrong? But let me tell you that life is not so nice.

We published a paper in 2024 on the European neonatal hearing screen. Data from all the publications that we were able to found in PubMed from various countries. And over here, I have used the gray background to give you the estimate of hearing loss per thousand. So you can see Germany, 7 per thousand. In Italy, we have 7.8, even 41.

That was a small study. In Poland, we get 1.44. Here, we don't know if it's from the well baby ward or if it's from the nic. For example, the uk, which is also a very big. They have a very big sample base.

We have less one for the well babies, between five to seven for the nicu. So you understand that the averages that we were seeing in the WHO database, even in Europe, they are much worse. Okay? And we do that because when we take all this data and we pull them together, obviously the averages from the industrialized countries are very, very small and they bias all the estimates. Now, I like to talk to you about a very wonderful job that Kathryn Newman has done with her collaborators.

She did a wonderful publication, a Survey of the Global Status of Newborn and Infant Hearing Screening and published in 2020 in the Journal of 80. Okay. And what they did, they set questionnaires to more or less all over the world to most clinics and colleagues that are able to build this map. Okay. So you can see, for example, U.S.

canada, Alaska, Russia and so forth, Australia. They're in the range of about 85 to 100% screening. All right? And then we move, for example, to another green, and we are about 50 to 84. Blah, blah, blah, blah, blah, blah, blah.

We go to gray, which is no data. Okay. And. And red, which is between 0 and 1%. Okay.

Now this is really, really interesting because 2025, we did another review paper on the African data with my, with members of my lab. Okay. Here is what you can see from Catherine's work. And this is our work. This is based on questionnaires, and this is based on published data.

And we can see that we have much, much less data. Okay. That we can verify that what Catherine and collaborates were able to get. So I would say the situation has really worsened than improved. So something else which is really good right now.

It's to give you a perspective of how these screening programs were involved and what are the actual technologies we used in order to put them forward. Okay. And most of the impetus of these programs

comes from late 90s and the beginning of 2000. Okay. 1993, the first suggestion for screening comes from NIH.

1994, from the Joint Committee on Infant Hearing, 1999, from the European Consensus on Screening. This is very interesting because this is the first time a European group was suggesting to do screening with the possibility to correctly identify cases with sensory neural hearing loss higher than 40 dB HL at 1, 2 and 4 kilohertz. Finally, 2000, the Joint Committee on Infantering made a very good and polish and structure statement and says that all infants have to have a hearing screening. Now, if the infants are not born in, in a hospital, they have to be tested within a month. Everybody else have to be tested again within a month.

And we also have to test the, well, baby infants and the infants from the NICU who are in the face of discharging. Okay? So the whole thing together is what constitutes the universal newborn hearing screening. There were a lot of resistance in that because of the cost involved, because most people say, well, most of the cases that we need to intervene, they're coming from nicu. There's no reason why we should try to do everybody.

Also, it's a very big issue. Once you Identify hearing loss if it is unilateral or bilateral. So the scene is not extremely clear yet, but a lot of guidelines have been applied and I may say the screening goes on. So the show goes on. The screening goes on.

Wonderful. Anyway, let me talk a little bit about the neonatal hearing screening technologies. And I like to mention that I will not talk about pure tone measurements. And the reason is that we cannot use pure tone measurements in infants, only in children and adults. We can use in infants, but not in a screening point of view.

There are technologies they use. They, we can use that right now, but they're within our clinical tool of assessment, not for screening. Anyway. For this reason, I will not refer to those other acoustic emissions. So acoustic emissions are acoustic energy produced by nonlinear cochlear processes, okay.

In the inner ear and recorded in the external auditory canal. Remember, we're referring to acoustical energy that arrives in the meatus from the inner ear. Okay? So acoustical energy. Very important point.

Why we have to use emissions as the first screening assessment and the reason or why we don't use tympanometry, why you don't use abr. Why? Why we use emissions. And the answer is because we have very, very fast recording times. Fast, I'm saying 5 to 10 seconds in order to get a response.

The whole procedure is inexpensive in comparison to the abr. The technology is easy and its application is easy to master. You don't have to have an extensive training in order to to do a test of autoacoustic emissions. But there is a crucial point that is the proposition. The position of the probe inside the acoustic emmatus have to be very good.

You have to have a good seal so you'll be able to capture whatever comes from the inner ear. Let me show you a small video. Teoas are elicited by a short traction transient soft click that sounds like this. Teoas are elicited by. Well, why did that.

Because you can hear. You can see where the probe is and what a click toi look sounds like. This is not. We'll see that we have another type, but we'll see that later on. So let me show you something else.

Now, with this sort of technology, we're able to understand problems through the transmission chain of the stimulus that is Outer ear, middle ear, inner ear. Okay? So if there is some issue at the outer ear or

the middle ear, okay. We cannot record, well, otoacoustic emissions. So this is a good point over here.

I'm just showing you that this is where the backward traveling Waves from the inner ear are going back to the external meatus. Okay. And again, if there is a problem in the middle ear, obviously we won't be able to capture these responses. So middle ear is crucial. It's crucial because not only from the stimulus that has to go in, but also from the reflection of the stimulus that have to come out.

Now, one thing we cannot do, we cannot get information about the status of the inner hair cells. So far we go up to the level of the outer cells, you get the reflection of the acoustic energy. And this we record as a backwards traveling wave. So we have no clue what happens with inner hair cells or neurofibers. There is a way that we can understand what's going on, but we need to use the efferent pathways and we need to use different stimulus paradigms.

So this can be done but on a clinical setup and not with a screener. What clinical types of emissions we use in neonatal hearing screening, we can use transients, which are evoked by stimulating the cochlea with a transient signal. And a transient signal could be a click, a tone, pip, a chirp, or we can have what we call distortion product of acoustic emissions. And these are evoked by stimulating the cochlea with two pure tones at different frequencies. There is another category called spontaneous, but this category is not being used in urinary screening.

So let me tell you a few things about the Klikovo Commissions. In the past, the click evocations were also called ceoies, and they were discovered by David Kemp in 1978. And in the beginning, David was doing something else, but also sent a series of pulses into the inner ear. And to his amazement, he was able to record something coming out. In the beginning, everybody thought that he was due to some reflection of the middle earth, but eventually it came out and it was evident that has to do with a cochlea.

One of the problems that we have with this sort of stimul stimulus paradigm, I.e. 1, 2, 3, 4 positive clicks, 1, 2, 3, four positive clips and so forth, is that one part of the stimulus energy is being reflected back from the tympanic membrane to the probe and actually is being recorded before the backward traveling waves coming from the cochlea. And so David used another paradigm is called nonlinear, which was used also in the recording of ABR. When we have a sequence of 1, 2, 3 positive pulses and a negative one with the amplitude three times their amplitude. So when you average them together, you get rid of all the linear contributions and mostly of the reflection from the Tympanic membrane.

Later on, David did another alteration. He took the 20 millisecond window of the emission and he shrank it to 10. But we will see that later on in order to make the whole process even more faster. Okay, this is a beautiful picture from the good old times when you would do a recording and you would see it in front of you. This is a beautiful response from a well baby with a post gestational age of 39 weeks from a stimulus of 84 db spl.

And this is the response. You can see this beautiful oscillation. This is in light blue. It's the spectrum, the frequency, this composition of the signal. The red is the noise.

All these beautiful numbers are things that we could use to understand what the heck is going on with this response. Okay, but these were the good old times. Now regarding the good old times, we have also a recording with a different software from a premature infant of 32 weeks with a stimulus of 80 db spl. You can see very, very nice and present oscillation. And all this is, is mostly related to a peak at 4 kilohertz.

Now let me show you a very interesting case. This is from a premature infant of 28 weeks with a stimulus of 77 db spl. And what we have over here is, you can see, well, you know, there is no response. Well, these are the good old times. You can see the recording is 25 years ago and autodynamics that were manufacturing the devices by that time and the probes, they didn't have a

probe that would be small enough.

The tip of the probe and the probe itself to be able to be inserted in the very, very small external and flexible matters of a premature infant. So in this case I recall we were able to just put the, the probe very, very close to the opening of the miatas, trying holding it very, very slightly with the hand because holding it by the hand, okay, you introducing noise to the recording but eventually weren't able to record any emissions. Obviously this is not a refer, it's a technical problem because we don't have a good seal with the Emmatus and the or a probe. The testing protocols, as I told you, are three. Usually they are linear, non linear.

What we call quick screen automatically these days are set to the third one which is as I told you, a 10 millisecond window with a nonlinear stimulus. The responses are evaluated as pass or ifer according to a very easy rule. So signal to noise ratio at 2, 3 and 4 kilohertz. Please note this over here. That other dynamics being a British company, they have to do things differently.

So they selected 2.4, if you can see over here, 2.4, 3.2 and 4 kilohertz. So anyway, the minimum signal noise value for a pass at a specific frequency was 6 dB. And we wanted a correlation of this analog recording more than 70, 70%. And the correlation indicates how much noise you have in that recording. Complicated issue.

If somebody wants you can write me an email, I can explain to you. Okay. The specificity we have is about 95%. By the way, all these things, I'm telling you, they refer to the past in order to build you some background. Because now with the automated screeners, you don't see these things.

You just see something says recordings being conducted, recording done, recording fail. This is it, you don't see anything of that. Now we can do something with the adults. This as you can see, a response from an adult subject. Very nice response, Very, very different than the response we have from a

neonate.

And this is a time frequency graph that shows you on the axis. You don't have time, you just have latency and amplitude. Beautiful. And you can see exactly where the concentration of energy is very, very different than in the neonates. Again, the same criteria apply, linear, non linear.

Well, we don't have quick screens, but sometimes you do, especially for children. The again the response is evaluated with signal noise ratios. The frequencies are the same and the minimum is about 3dB instead of 6. We had with children. The take home message for the neonatal testing is do the test as early as possible, but after 24 hours in order to avoid the presence of the amniotic liquid in the middle ear.

And also it is important to clean the external ear from any sort of debris. And one way to do that, you insert the probe once and then you insert it again. And by inserting and reinserting it, most of the wax is coming away with the 60B values or the signal noise values are considered a valid expression of a good signal. And usually in order to say pass, we need to have at Least for the TOAs, 2 out of 3 tested frequencies higher than 60B. In some cases it is 3 out of 4.

Okay, higher than 60B. Now take home message is the screeners offer an optimized evaluation. You don't see any of this, you just see the exam being taken. But be aware that we also have borderline cases and borderline cases we may find not only in the NICU but also in the neonatal clinic when there is a little bit of a noise. So in these cases, they we need the attention of a human operator.

Now, what happens in this case is you might have one or two frequencies with a pass criterion. Not all three out of four, not all two out of three. Okay? And if you do that, it's a very good indication that there is some signal coming out of the cochlea. And since we know that the emissions do exist or they don't exist, it's highly improbable that you will have a good response in one band and not in the others.

This is probably an indication that you need to do the test again, because we have noise because the probe is not properly sealed and so forth. So this is the case when you need to do the test once more and you need to have a human operator doing it again. So let's talk a bit about the distortion products. Okay? Now, the distortion products, they are generated by two discrete pure tone frequencies called F1 and F2.

This is the spectrum of the response. And as you may recall, the spectrum of a pure tone is represented by a line. So here we have where F1 and F2, okay? Each stone has a specific amplitude, okay? We call L1 and L2.

And actually the frequencies of these stones, they cannot be very far apart and they cannot be very, very close. So they must be within a particular ratio that will stimulate intermodulation processes in the organ of Corti, which will generate what we call our distortion products. So in order to have the distortion products, the two primary frequencies, they have to have a particular, what we call frequency ratio between them. So, for example, if this is 1000, this can be, for example, 1200 with a frequency ratio 1.2, which is the mostly used. So when you do that and you send this sort of this pair of tones inside the cochlea, the intermodulation processes generate an infinite series of new elements of U sounds of new acoustical components.

We call them families. One family is called two F1 minus F2. And we can identify this very well. And let me tell you which is really important to notice. This is the family that we use clinically.

There are other families that could be three F1 minus F2, four F1 minus F2 or combinations this and the one. This is the one we use clinically. And let me tell you something important. If the value f1 is 1000 and the value of f2 is 1200, this component over here will be 2 times 1000 is 2000 minus 1200 is 800. So the value of this component is at the location 800.

So it's an apical component. In other words, with DPOies, we're testing elements of the cochlea more apical to the stimuli. And I hope this is clear. And something else. The amplitudes can be the same.

And if, for example, L160, L260, like in the graph, this is a symmetrical protocol. But working in with many types of patients, we have discovered a very interesting concept that when L1 is bigger than L2, like L1 is 65 and L2 is 55. And this is an asymmetrical. Asymmetrical protocol. With this sort of protocol, we can get responses which can discriminate better cases with presenting sensoridorial hearing loss.

Okay. Than the cases from normal hearing subjects. So what I want to tell you here is that we set the F2 frequency is always the same. For example, we set the frequency to 1500. We know the F ratio is 1.2.

We know immediately the F1, we calculate the product, okay? And let me show you something that for the product we're talking about, the two F1 minus F2 in this case will be 1250 times two is 2500, minus 1500 is a thousand. Let's go, go here and look at here you can see that we plot a point, but at the F2 frequency of 1500. Why? Because it is easier to plot the distortion products in terms of the F2 frequency and not in terms of.

Of the frequency of the distortion product. I hope this is clear. So we plot all these points and we get what we call the DP gram. But the actual frequencies we're plotting them, they refer to the F2 frequency. Okay.

Also you can see what happens with the protocol that has a lower intensity towards a protocol that has a higher intensity. You get higher responses, not necessarily with higher signal noise ratios, because we also have more noise in this area. Okay. Also with the distortion products, we have a phenomenon which is very, very similar to a frequency notch around 3 kilohertz. Something like this, okay.

Is like the knots that we see when we have hearing loss due to an impulse noise. The acoustical, the famous acoustic trauma. So in the good old times where we would see something like this, we would push gently the little probe inside the external meatus. So the space between the tympanic membrane and the tip of the probe will be smaller. And the frequency, the resonant frequency of the standing waves, which are the acoustical condition causing this phenomenon, would move to a higher frequency, something around 6 kilohertz.

And we were able to move from something like this to something like this. Okay. Now the newer software does this automatically when it detects this drop. This significant drop in the amplitude of the distortion product moves the testing a little bit further to let's say 3.2 or 3.4 kilohertz. So it does not capture all the destructive interaction of the standing wave and they're able to capture more what's going on from the cochlea.

Okay. The ideal thing would be obviously to move things to a much higher frequency. But what we get so far is pretty good automatically. So what is the take home message? Dpoes, they show higher signal noise ratios than the toies.

Higher level DPOE protocols can compensate for noisy environments in the NICU primarily or in the well baby clinic. The pass criteria again consideration signal to noise ratios above 6 decibels at least in 3 out of 5 frequencies. And they also consider the level of the noise floor. And over here if you look, we have the amplitude, okay? The amplitude of noise, you know, the single noise ratio.

Okay? And you can see at 5 over here we have a very good. We have 13dB of signal noise ratio. But the actual level of the emission is really really low. So this is not something we can depend on.

So this software is not considered a second take home message. The DPO responses are more specific in frequency than the toes. As we know with the ABR when we use tonburst. No, both frequencies are equally frequency specific because it's the cochlea that decomposes all stimuli. Okay.

Is not like the ABR when we are talking about the toxicity of the fibers of a click stimulation versus a tombstone is very, very different. If this thing is not so clear, you can send me a message. This scoring criteria can be good for all the public. Scoring criteria can be good for all devices. And the answer is no.

Because we don't have established criteria of how to build. We don't have standards of how to build the acoustic emission probes. So eventually each device records its own otoacoustic emission reality. So of course most of the time all these responses are underestimated. So we don't have a lot of complications.

These are two papers we have done from my lab. They show this, this problem. If you want to continue reading in that manner, the answer is can we do better? Okay. And yes, we can do better with the distortion products by employing an additional technique that is multi frequency tympanometry.

And there is also a book reference at the very end of my presentation. And look at this graph over Here when I'm talking about power reflectance and power reflectance is the ratio of the reflected energy from the tympanic membrane over the energy we sending in. Now, reflectance is the opposite of absorbance. So we like many times to talk about absorbance of the middle ear. For example, here we have power absorbance and you can see the absorbance.

Okay, the, for example, the maximum is around 2 kilohertz. This is from a NICU resident. And this thing over here, the red is from adults. Let's go over here. And you can see the different classes of subjects.

They have completely different profiles of the wide band acoustic emittance. And we call emittance, which is the resistance, the complex resistance. But if you don't understand what I'm saying, forget about it. You can see something like wide band tympanometry and you will be okay. For example, over here is the absorbance of normal hearing children.

And over here in purple you can see significant, significant differences with children with ear infusion. I mean you can see you have very, very small absorption. Now the next slide is very, very important, comes from a wonderful work by Lisa Hunter and collaborators. And what they trying to do now we go back to reflectance. The opposite and what they try to do, they try to say, is there any connection between reflectance and refers of dpies?

And the reason for that is reflectance indicates that something is not working very well in the middle ear. And it's true. They did the assessment with 324 infants and they reported that the power absorption between 1.5 and 3. Okay, absorption again here we have reflectance is the opposite. But I'll show you in the next slide is strongly correlated with the screening outcome.

So once you see a very high reflectance or a very low absorption, this is an indication that you have to do a retest with DPO is because probably you have some sort of a middle ear problem. And let me show you this graph. This is the original graph and reflectance. I took it and flip it over so you can see in absorbance and you can see that we are over here. All right, all right.

And you see that once you get something like that, you have to be alarm that something is not going so well with a milieu. Maybe you have some sort of amniotic fluid. The problem is that this is a very good way to combine two procedures together with excellent results. The problem is that Mimosa Acoustics, which builds these sort of testers, they don't do portable testers that we need now let's go to the automated brainstem responses to the our lovely abr. And the question is, wait, wait, wait a minute.

If screening with acoustic emissions is so efficient, why do we need to do? Why do we need to use something else? And the answer to that is that the screening with acoustic emissions, we arrive up to one part of the cochlea, and that is we get information, a partial information, till the level of inner cells. Let me tell you about the presence of auditory neuropathy, which was the nightmare of all audiologists and screening administrators in the late 90s. Why?

Because we have cases where infants were passing the screening test, and later on they were developing some sort of a synchrony with their VR and they were developing hearing loss. Okay, now, after some time, we start from the US Some people start correlating this problem with something that Arnold Starr and a dream team of American audiologists, they've published back in 1996, where they have described a condition called auditory neuropathy, which was resulting in a lack of synchronization of abr. Later on, we were able to understand that this lack of synchronization was caused by some problem in the protein of. Of connexin 26 protein and how this protein was built in these fibers. And we were able to understand that mutations on the connexin 26, they were causing the synchrony in the neural fibers.

That is, we were not getting any information to the brainstem. And with time, also they were causing problems at the level of the inner cells. So the signal wasn't even going to the neurofibers. So eventually, with the auditory neuropathy, what was going on? You were losing the ABR and then you were losing your emissions, or in some cases, you were losing both together at the same time.

Losing means not having synchronized the VR and not having any coherent emissions. So one way to capture this is to use the automatic abr. So once you have a pass with emissions and a fail with automatic abr, you are immediately alarmed that that is the case of auditory neuropathy. Now, the cons of abr, we said evoke responses are very small. You need to use electrodes, you need to average, and then you need to amplify them.

Okay, Something else to remind you that the ABR that we evoke with highly transient stimuli cannot be used to define hearing sensitivity, hearing levels, or cochlear status, because that sort of ABR gets contributions from a lot of cochlear partitions. In order to do that with the ABR, to get the hearing Level the hearing sensitivity. We need to use tone burst and filter chirps. Okay. This is not related to screening, but always is good to remind.

Let me show you some old clinical data. We have for example, an identification of a 32 week post gestational age infant at 811 milliseconds. And somebody say 8.1 milliseconds. Yes. Because this is a preterm infant and preterm infants they have a dilation of the ABR latencies.

And this is also a pass with the oes. Now let's go back to another interesting case where this is a 30 week. We couldn't find anything.

I think one of the. The right ear. Yes. And also the acoustic emissions were not coherent at all. I do remind you the morphology of the ABR at least of the 5 out of 7 waves of the ABR that we assume they're being contributed from the medial geniguloid body.

But that's not true because the ABR gets contributions from all over the brainstem and also from the inferior colliculus. Now let's talk a little bit about stimuli. And for example, with the clicks. The clicks, usually they stimulate at maximum frequencies, auditory frequencies. The we call the octaves around 2 kilohertz.

This is the electrical click. This is the electrical click. When you get through, let's say a transducer and it's called, differentiates the click and it's called acoustical click. This is the very nice spectral waveform that is you can actually stimulate a lot of partitions. Look how lovely this tone burst is and how concentrate, okay.

Concentrate the spectral energies. So we can really stimulate a particular area in the cochlea. When we talk about Chinese chirps, also we have a very large area very similar to click. We need to use filter chirps in order to get some sort of a hearing level. Okay, now chirps and clicks.

The chirp has the advantage that shows better the wave 5, which is much better when we do screening because we can identify better the wave 5. We can detect wave 5 better at lower frequencies and we also can do that in a less time possible. So this is what most of the time we use or a click or a chirp chirp give us the advantage of better time, better amplitude. Okay. Very, very close to the click.

Okay. And I like to explain to you right now how the algorithms work, how the ABR algorithms work. In order to do that, we do a lot of recordings from infants at a particular stimulus and we can detect a range of latencies that These infants present, we take 20 infants, we record them, let's say at 80 db spl stimuli and we get a range of latencies where wave five is present. So when another recording comes in, okay, or we are recording something else, we go directly in that latency range and we're looking for a coherent signal. Once we found it, and we can verify that it's coherent with some statistical metrics, then the recording stops.

Now what I want to tell you is what we get with automated APR is way different than the morphology of the typical 5 way response. Wear custom and many manufacturers don't even give us this form. Not necessary. For example, over here, you just see the exam being conducted, you don't see any form. So the good thing about the ABR is that you can have a response very short times, many times less in 1 minute.

The technological developments make the cost of the ABR very, very similar. Personally, I would use, for every screening application, I would use automated ABR and then emissions. If I need to do some control on the repairs. Okay. But this option is kind of prohibited because the disposable electrodes have a specific cost.

Now let's talk a little bit about the montage.

As I told you in the last lecture, you've been followed. The first of all, we have the positive electrode on the front. Below that we have the ground. And somewhere in the earth close to the ear we're interested in, we have the negative electrode. Why I'm showing you this, because traditionally we said the positive electrode is red, the negative electrode is black, the ground is green.

But that's not always the case, as you can see in this montage over here. So color does not mean what is the type of color connection, positive or negative. Now, since it is necessary to test a lot of infants, we cannot use very easily our clinical devices. So portable devices are highly recommended. And we have the fourth generation devices by Everest 25 years ago.

And at the same time the the same thing with accuscreen and both of those, they were providing automated ABR and automated acoustic emission protocols. Now we're sixth generation. You can see all these devices, beautiful devices, very fast, extremely informative. And what we have is that they have a small size, the hardware is very fast, they offer all types of protocols. Some people also, some companies are also considering to add in multi frequency tympanometry capabilities.

The cost of the electrodes goes down, the probes are becoming better and better. Also we have better detection algorithms. And because we are in the moment of artificial intelligence, some manufacturers are referring that we might see some artificial intelligence implementation if the device can be connected to the Internet. Because we know that in many, many cases where we do screening, there is no Internet connection. Let me tell you something about the steady state responses.

This was one of my favorite topics about 15 years and I can show you why. A connection between the ABR and the steady state responses. First of all, with the ABR we can test, let's say octave

frequencies, let's say 500,000, 2,000, 4,000. With the steady state we can go to lower frequencies, which is very good. Also the intensity of the stimulus with the ABR maximum can go up to 90 decibels, where with a steady state we can go up to 120.

And as a result we can assess better severe hearing loss. This is a paper from 2010 and it provides a very interesting set of data regarding how well the steady state responses coincide with the results of distortion products in high risk neonates. At the Same time, around 2006, some people from the cubit school of aesthetic responses with Dr. Perez Abajo, they were also offering not only devices but also protocols and automated protocols and also to use that in screening. And we're talking about 2006.

Later on, when I was building this presentation, I realized by doing a very simple PubMed search that there were only five papers, two from the the same Perez Abajo. And somehow this sort of technical information was never passed on to the industry. So we don't do a lot of screening with steady state responses, although it's a pity because it's a very, very valid technique. Let me tell you how and when we can apply these screening protocols, which is very important. When we talk about the, well, babies we have to start after 24 hours of life, but within 48 hours we thought acoustic emissions.

If these things fail, we can go to a secondary test with emissions. If these things fail, we go with automated ABR and then with ABR and we have to do that within 30 days mostly. So we'd be able to plan accordingly. The intervention with hearing aids and possible with cochlear implants. Just to tell you, if we have unilateral cases, we do no intervention, we just monitor.

We do the intervention once we have the bilateral. Of course, this is kind of, this kind of a problem. There are some colleagues who insist that, you know, we can improve also the unilateral situation with a hearing aid. But that's a very big discussion. For another presentation also over here, I'd like to tell you that for these past cases, the concept of auditory neuropathy is considered like 1 in every 100,000 infants.

So more or less negligible. Let's see over here, what happens in the pre terms that we do the testing at discharge that is 35 weeks first with probably DPOES. I would say some people use toes. If you fail, you use immediately auditory, the automatic abr. And if you fail, you go back to the ABR again.

Okay, now the artificial intelligence in signal processing. I'm not a very good supporter of artificial intelligence. And the reason is most of the work that we have done with the papers that we have submitted is the artificial intelligence bots right now they hallucinate. It means that you ask for something and they can made up some of the responses. So the human operator always has to control what the AI is telling him or her.

Okay, so this is something I'm not very fond of. Probably if we go to right now we're at the level of 4.0 in some of the bots. Probably if we get a 6 or 7, this hallucination will be very, very small negligible. So we'll be able to use it. So one of the thing I found which is really interesting was a group from San Diego, they did a toolbox of auditory brain semi spinal analysis code named Abra.

And you can consider Abracatabra. This is some data from their paper. Look over the ABR over here. You realize the morphology is very different becomes from the mouse. And in the mouse we have wave one, wave three as the most important contributions of abr.

And what they do, they collect the data, they extract a lot of morphological features with a machine analysis. And this tool, once you go in and throw in one of your data, they can extract some features and tell you what's going on. And this will be very good for pharmacological testing. When we have alteration of the ABR caused by pharmacological treatment abcd and with this tool we'll be able. This is not screening exactly, this is screening of pharmacoceutical agents.

But this can be very useful in the future. This is a review paper from a Turkish group which I find very interesting. And it's telling us that there is a dynamic focus progressing from hearing related technologies, including hearing aids. Two diagnostic innovations, which is very interesting for us in screening lack audiometry, psychoacoustics and so forth. So is there more to hearing screening?

Okay, and the answer is yes, we have suggestions in the literature that we can do something else in parallel. Now in the paper that I showed you before which was from it was the review paper on all the publications on universal Neonatal healing screen from Europe. There was a group from Russia and they analyzed 1292 pediatric patients. And they analyzed of course, genetic, audiological and screening data. And to make the long story short is that they understood that the cases with confirmed genetic etiology, I.e.

securely they would go towards a development of a hearing loss. In 21% of those cases they passed the screening criteria, which is terrible. So when they suggested is we should do at least some sort of genetic testing with the most frequent connection mutations in order to capture the majority of these cases. And I know, for example, in Italy we have telephone projects when you throw on a chip, let's say some sort of blood taken from a subject and immediately you can identify what sort of mutations you might have, at least for connection. And I know that the chip is in development status.

So I'm assuming in three, four years will be out in the market. But again, how this can be go into a small device that can be easily coordinated with the very small devices we have for hearing screening that will be very. I'm not so positive about that. And of course, if you consider what's going on in Africa in remote areas, that is something we need to resolve. But in any case, the technology for genetic testing must be applied in order to capture also the percentage of cases that we right now they're leaking from our system.

This is the reference section. A lot of the things I've told you there in the first volume of my book Advances Audiology and Hearing Science. And Navid Senad, who did a lot of the tympanometry section, has a wonderful section over here regarding pediatric applications. Here is a beautiful book by Jay Holtz dedicated on emissions. Here we have a book with Lisa Hunter and Navid, who is the person to a very nice book and of course a very nice book by Carly drisch called Bradley McPherson in the concepts of the Screening Systems.

Thank you so much for your attention. If you have questions that I'm not seeing right now, this is the actual email you can use to ask me questions regarding this specific section. I'd like to show you that there is some more to the presentation about the efferent pathway and how we can detect changes in the efferent pathways without acoustic emissions by testing this part of the pathway. And also here is the link if you want to go to the abracatabra website and ask them information or, you know, show them your data, if you have any animal data and so forth. So Here I am again at your disposal.

Thank you, Professor. Thank you so much for this insightful presentation and for sharing your vast expertise with us. And I can see three questions at the moment. May you be so kind to press the question and answer button. Can you see it, Professor?

No, I cannot. Where that would be in the zoom main bar in the lower part of the. Of the zoom main interface. Let me. Can I.

The thing is, where is the zoom bar? Because I'm here. Let me, Let me do this.

Otherwise I can read everything for you as you prefer. Maybe shoot more record. No, no, no, no, no. There are questions in the chat. Maybe in the chat.

Not in the chat, close to the sharing screen button. Okay. Folder is called question and answer. Ah, I love that. I cannot see that.

No. Well, that's a beautiful thing about Macintosh there. Okay, Share is here. You're okay, stop sharing. Maybe something more.

No, no, Professor, I. I can read the question. Okay, okay, okay, okay. No worries at all. So, Burku.

Sorry for my pronunciation, ask you, by correlation, do you mean waiver reproducibility, which needs to be over 70%? Yes, yes, that's it. Okay, Fantastic.

Always this attending some testing equipment evaluates pass at an SNR of 4 at the three frequencies. What do you think about this? 4 is better, by the way, if, if people need more email.

Okay, so I kindly invite our attendee to send an email to professor in order to get further details about this question. Yes, I would gladly. I would gladly respond to everybody and they could be more than one question is now it's not a problem. I'm terribly sorry that I cannot find the questions that I record. Last time they were there, now they're not.

Okay, okay, but we can continue. Yeah, yeah, yeah. Please, please do so. Rim Asari. Sorry for my presentation, for my pronunciation.

Professor Stavros, at what amplitude during DPOA would you consider it absent or present response? I understand that SNR should be more than 6dB, but how about amplitude? Well, that's, that's one of the, the problems. If we're talking about toes, we have a some sort of estimate of the noise. If we're talking about dpoe, things are more okay.

Anything that is negative in terms of response, in terms of amplitude is not good. Okay? If you're getting up to three, three means you're getting very close to noise. If you're getting at zero means your amplitude, okay? Not signal noise ratio amplitude.

So things should be positive. 0, 1, 2, 3 and so forth, okay? Even if you have a noise that is Much lower and the signal noise ratio is beyond 6, 7, 8. The response has to be positive, more than zero.

Okay, got it. Thank you. Professor, what do you think about artificial intelligence on neonatal hearing screening nowadays? Reason? I don't think I'm against it.

And. Okay, the reason is because of the hallucination. I would love to have a protocol that can extract features correctly so I don't have to film 10 times for, you know, cases that they are not on the ordinary. So far the level has not been there. So instead of risking saying something which shouldn't be there, I would say I will wait for further developments of the artificial intelligence engines to be more precise and then we'll talk.

But have in mind that screening is done or in peripheral areas of the hospital, in periphery of who knows where. You are not always in connection with Internet and to have devices that they can locally process information regarding artificial intelligence. I think we need a lot of time. You need processing power to do that. So if you cannot connect, then your artificial intelligence facility is reduced.

Okay, we can wait for more, but you know, I'm just, you know, so we can respond to everybody. Okay then. Professor, you mentioned that you can't use tone in auto emission testing on infants. Can you please clarify or discuss further? Yeah, well, I mean we use the tones with children and adults.

We cannot take a child and say, do you hear this? You know, show up your hand. Okay, we don't have from the, from the person. There are of course some other procedures that automatically will detect

reflections coming from the tympanic membrane. And they with some complex models say, well, yeah, probably something is happening there, but we cannot use that for screening.

Okay, so the pure tone approach that we used to requires the collaboration of the subject. Okay, so we don't have collaboration, we don't use them. Okay, basically. Okay. Okay then, Yasha.

Okay, ask you. I have heard of integrating impedance and otoacoustic mission. Okay, Is it available for you? Well, as far as I know, Interacoustics is trying to do that. And the problem is the probe.

The problem is the probe that will seal the. The external meatus. Well, you will have to be small in order to use it with children and everything else is easy. As far as I know they were working on it. Not sure it's still in the market.

Okay, we can continue.

Sarah. No, sorry. Sar Mohsen asks you, can we diagnose a hearing loss that hyper bilubinemia caused to auditory system early by abr? Yes. I don't know.

Okay, yes, we can because alters the latencies and it's easily. Well, what we have is a response that could be related to three or four different risk factors, not only one. With the ABR I'm talking about. Okay, the answer is yes, but you have an alter response that could be hypobidaluminemia, agar and hypoxia. There are three or four if I remember correctly.

So you're not exactly sure which one of the four, but yes, you can capture these subjects? Yes, with abr, not automated abr if this is clear. Okay, automatic abr. It doesn't have this find resolution for these cases.

Burku our the attendees who asked the first. The first question to you professor, ask again. In my previous question I meant this. I have an equipment which evaluate tea OE pass when SNAR is at level 4 DB at 3 frequencies but you are recommending 6db SNR. Maybe my equipment needs an upgrade or not.

No, no, this is okay. You're absolutely right. Wondering about this. This is one of the thing I told you that we have a bit of a mess with the published data and the data from any manufacturer. So if the manufacturer of your teal of the click evoke emission that you have suggests four, it's okay.

Most of the time you will get more than four when you do your test, when you see your pass, although the Criterion is at 4, you will see 10, 12, 15. So that's not a problem. But that's okay. It's one of the problems we have because there is no standard with the OA probes. If you have more problems, email.

Okay, thank you professor. And the last question for the moment is it, is it in fact another one is coming. Okay. Is it okay to use the otoacoustic emissions plus click with IDR only in babies in one babies. Sorry, you understand the question?

Sorry, yeah. Is it okay to use the autoacoustic submission plus click abr? So I think which is the time kind of stimulus in ABR in a. Well, in. Well, babies in general.

Well, the. The thing is most of the time you don't do that. Most of the time if you have a pa. Okay, you do that when you have a refer. When you have a refer you go or to automated abr.

If you are in. In the. I don't know, in the NICU world or if you are not in the clinic or if you can call the people to come back then you can use Qlik ABR to see what's going on. This is basically what we all Do. Okay.

If you are somewhere with your mobile equipment, obviously you can use automatic abr, but you do that only when you have a refer in your otoacoustic emissions results. Okay. If you have a pass, you don't do that. I mean, you may do that if you have the time. We don't do it as a protocol.

Okay, thank you, Professor. Sara, ask again, in diagnosing hyper beery lubinia, which stimulus is better term burst or click. Now the best thing there, Distortion products. Distortion products. Protocol 6555 is fine.

If you don't have it any, you can use a toe with about 80, 85dB stimulus. Okay. Okay. These are the cases that we record in the O neonatal intensive care unit which is very, very noisy. So this is why we're trying to use distortion products if possible.

If you don't have it, high level. Click. High level transit level commissions. Okay, okay. Okay, Professor, I think we have covered all the doubts which has come from come from the audience.

So I just want to say thank you once again for your insightful presentation and for sharing your knowledge and your expertise. But see you at the end of the year more or less for another fantastic class. Yes, thank you so much. Thank you everybody. And again, if everybody has any problem with more questions and so forth, please send me an email.

I would gladly find the time to respond to you. Okay, Fantastic. As a side note, let me mention that Inventis has recently introduced Celeste, our new tool design for the acquisition of auditory and vestibular evoke potential. So we are continuing, I would say, our commitment to offering a scalable and advanced solution for clinical needs. Before we conclude, I'm so pleased to remind you that Academia's journey continues.

Our next and final webinar before the summer break will take place on May 20th featuring Dr. Vishal Tavar from Dubai. And it will be the third and final lesson on his VHIT series titled Fundamentals of Video Head inputs. Test lesson number three, advanced techniques and case studies. So please don't miss it.

Thank you once again for attending. Thank you Professor Stavros. And we look forward to welcoming you to our future Academia event. Thank you so much. Bye bye everybody.

Bye bye.