Wideband Acoustic Immittance in Children, in partnership with Seminars in Hearing

Presenter: Navid Shahnaz, PhD

- [Kimberly] It is my pleasure to introduce today our guest speaker, Dr. Navid Shahnaz. Dr. Shahnaz is currently the Associate Professor of Audiology in the School of Audiology and Speech Sciences at the University of British Columbia in Canada. If you'd like to learn more about Dr. Shahnaz, you can read his bio on the course registration page. Today's course is the third and final series in the "Seminars in Hearing" series this year. If you haven't had a chance to catch the first two, please view them on on Audio Online on the course registration page. And at this time, I'll hand the mic over to you.

- [Navid] Thank you, Kimberly. Good morning to everyone, depending where you are. It's morning on my end in Vancouver. Here is our campus, with those of you who know Vancouver. So at Red Dot actually designate where the UVC is. Besides my co-authors and other co-authors in the special issue of "Seminars in Hearing", there are other people who helped to just make this presentation happen over the years. I've done this for many other workshops and seminar series, and updated this based on seminar series, for "Seminars in Hearing" that we published this special issue. The outline for today, we're gonna go over the background. And we're gonna talk about some principle. I won't go into any physics, so don't worry.

So it's not gonna be a abstract talk. Some practical issue for testing of children and outcome of wideband acoustic immittance, WAI in different middle ear pathology in children, then cover some cases, summary, and our future direction. I have no conflict of interest. Through the years, I was a beta tester for different companies. There are two companies, three companies, which I've not received any money for the type of research that I've been doing. So no disclosure here to disclose. Here are the learning outcomes. It's also on the Audiology Online website. So you can actually go over the learning outcomes. So background, where did it start? So here is the summary of one of the paper in "Seminars in Hearing".

So if we go from, hold on. Lemme actually grab my laser pointer, so it's gonna become easier. So here is the first actually commercialized machine in immittance testing, which was based on the work of Otto Metz, and developed in the same hospital by Terkildsen and Scott-Nielsen. And it was an impedance meter. It wasn't admittance meter. It's what's called impedance bridge. So those of you who are familiar with tympanometry, you know that your tympanometry has a single peak upwards. So impedance meter is downward, so kind of one over Y. And the reason that they changed impedance to admittance over the year, it was that shape of tympanogram greatly impacted by the ear canal volume. It changes based on gender and ethnicities.

So the first actual admittance meter, or the one that you're familiar with was developed by Grason-Stadler, and this is the one. And funny enough, this one was capable of running it at two different proton frequencies, and also was able to show you the components of the admittance, susceptance, and conductance. And I'll talk about why it didn't catch up, but it was the first admittance meter introduced in the market. And later on, the GSI actually introduced this machine. Had one version and second version was capable of doing multi-frequency tympanometry from 250 hertz to 2000 hertz, and was capable of running YVMGs, acceptance and conductance. And then, there was another company by Virtual. It's way back, and also had an excellent -based machine.

Never again caught up in clinical practice, but it was really good machine. The only drawback was a heavy pull. And later on, the first commercialized wideband acoustic immittance was introduced by the Acoustics. It was based on the work of the Jont Allen and Voss. Voss was doing her PhD with Jont Allen at the time. And Pat Jang is the wife of Jont Allen. And they introduced DP 2000 at the time. And then, later on based on the work of Jont Allen and Voss, they developed this system, which is the ambient pressure immittance. And it using ER10C and calibration cavity count with a laptop base and handheld device. But it's only capable of running wideband acoustic at ambient pressure.

We're gonna talk the ambient pressure and the . And later on based on the work of Doug Keefe, Interacoustic Commercial made the first available commercial machine on wideband acoustic immittance. And more recently, GSI introduced the same concepts into the same GSI Tympstar Pro, so it's available to that company. Now, you may ask why we do this thing was introduced in 1947, and first commercial machine introduced in early 60s? And still, we are doing it the same way. 226 has proton admittance. The only difference was babies. So we changed the protocol from 226 to one K proton. But when we do typical testing of the hearing, you test all the way to 8000 hertz. And when you do most of your middle year assessment just running at like 226, you may ask why that happened.

It has nothing to do with the diagnostic accuracy. At the time, back in late 50s and 60s, it was a technical issue for calibration, which was well overcome because they introduced the multi-frequency tympanometry, which was capable of running tympanometry up to 2k. So nothing to do with diagnostic accuracy. And as we are fully aware, Jerger, early 70s, developed classification system, which was a simple way of categorizing different pathology. And we're gonna come back to it, which is not sensitive or specific to many inner ear pathology. But because it was simple and easy to understand, it's still alive. And most of you are still using the same category. A much better category that was developed later based on multi-frequency tympanometry was Vanhuyse model, which is a much better model in terms of telling you if the system if it's stiffness dominated or mask dominated, and where the resident frequency is.

It was never caught up. And one of the reason was that people were arguing that it's taking too long. And we don't have the training. And we're gonna come back, what are those things? And what can be done to resolve those issues for switching from traditional testing to a more robust testing of wideband acoustic immittance? So the only change over those many years is the protocol for testing babies, which was changed from 226 to 1000 hertz. But wideband acoustic immittance, or wideband tympanometry, another term, and I come back to the terminology, can test basically within the same range as you would do your typical audiometry from 250 to 8,000 hertz. It could potentially go much higher. But the technology implemented the probe is actually make the restriction.

It can become very expensive to expand the range of the frequency. Also research needs to justify that. So we potentially can go up to 18 or 20 kilohertz for babies. So where did it come from? I did talk about the origin. The one that is currently commercialized by Interacoustics is the one based on the work of Doug Keefe and colleagues over the years, and was commercialized into the platform of the Titan. And later on, when the acquired GSI, they implemented the same technology recently in January, I think, or it was May of this year, into the Tympstar Pro. So one of the issues that that study, which was published in 2014 or '15, it's in our paper, can't remember the exact date, was it takes a long time to do multi-frequency tympanometry.

The wideband acoustic immittance pressurized will take as long as your regular tympanometries. That issue is no longer a valid complaint that it's gonna take long. It's the same time that you invest doing your regular tympanometry. What are the other advantage? Many advantage, basically, to make it simple. You're not gonna miss anything that you see with 226 tympanometry when you use wideband acoustic immittance. But you're gonna gain much higher accuracy and sensitivity with this procedure. Basically, your 226 tympanogram is not sensitive to ossicular chain abnormalities. And the typical AS or AD Jerger classification system is exception in differential diagnosis. And most likely, you'd get a normal tympanogram when you have fixation or discontinuity. Also, it's not sensitive to 226 to baby's ear, whether it's normal or abnormal.

It's not sensitive to development of the fluid in the middle ear, and also, the viscosity of the fluid in the middle ear. So if you have different level of fluid or different viscosity, you always get what is call type BT tympanogram, which are your classification system. But wideband acoustic immittance can tell you if the middle ear is filled with fluid or it's now the negative pressure is consistently . I'm gonna come back to it. It actually does a good job of middle ear assessment across a wide range of frequency or to 8,000 hertz in the commercialized machine. But as I mentioned, it can basically go much higher in research-based device. So why, beside what I've discussed, why the people did not adopt multi-frequency tympanography in their practice?

David Kemp, as you know, who was the first individual who commercialized the , provided a good timeline in our field between what we know in research and adoption in the clinic. It's about 10 years from first discovery for first article published to be accepted in the research community. And another 10 to 15 years to be accepted in the clinical practice. So we're having a gap of 20 to 25 years between what we know is gonna work better based on evidence-based practice to the time that the clinician are gonna adopt, which is very unfortunate because it's been working 20 years ago and takes 20 to 25 years to get adopted. Same thing happened to 'til late 70s that David Kemp actually produce the paper until early 90s, which the worldwide project implemented that in the first universal screening program in the hospital project.

So just summarize the advantages of the wideband acoustic immittance as fast, as fast as . Unlike tympanometry, you can pressure. There's no need for the change of the pressure, but there may be diagnostic value to it. It's a wide range of frequency. You don't have to run... Each frequency is done using short click or . So one signal can actually measure 250 to 8,000 hertz. And you can predict a conductive hearing loss, which you cannot do that with tympanometry. You may have a very well normal tympanogram with a significant conductive, so sclerosis, or else as an example. It can also detect the severity of the middle ear pathology, whether it's partial fluid, full fluid, dense fluid, or serous type fluid.

So here on the left is the time spectrum of a short click, and here's the four year transform to the right. So basically, you get a spread of the frequency across very wide range of frequency. And the limitation on the frequency is based on the type of receiver speaker that you use in the probe. So that's why I mentioned it can practically go to much higher frequency. But the commercialization will use something that more cost-effective. And also, there are some calibration issues, which needs to be attended if you go higher than that. But it's easy to address, but needs to be justified based on research. So what are the concepts? Let's go the to the initial concept that we have.

Most of the earlier paper published in what we call reflectance pressure . So lemme convey the concept first on this, and then move on. So basically, you will send a known energy in the blue one. And as you know, some of it is gonna actually get into the middle ear and some, it's gonna get reflected. And we get the ratio reflected energy over incident energy. So some will go in and some will be reflected. And we take the ratio of the red over the blue, and that become energy reflectance. It always vary from zero to one, or zero to 100% if you wanna actually described that in percent. And what that means that if you get one, everything is reflected.

And if you get a zero, everything is absorbed. So it's basically similar to impedance concept early on. But people don't like impedance concept. That's why they switched to admittance, just for ease of understanding. So this is the absorbance, the reflectance concept, which was the early papers published, so varies from zero to one. If you put energy in and everything's reflected, that's one. So nothing is absorbed. And then, that's Hell. You don't want that thing to happen. And it's not the case among cases. But it can happen. And the other extreme is when you put the energy in and everything is absorbed. That could be a paradise. So we would love already go into the middle ear and potentially gets to the inner ear.

So we switched the concept to absorbance because it's the other way around. And basically, one means that everything is absorbed. And zero is everything is reflected back. So this is a absorbance for the middle ear. And as you can see, at the very low frequency, you don't get much absorbance. And at kind of three to five kilohertz, you get a lot of absorbance. And then, you decline as you go to the higher frequency. And this is consistent with your hearing sensitivity because your hearing sensitivity is very sharp between three to five kilohertz, depending on some other factors. And if you have read your hearing science, when you do minimal audible pressure, that's where you get the the best sensitivity of around three to five kilohertz.

So there are different names through years for absorbance. I just put those names down. However, there was... It's not a reflectometry. So there were some machine that was being . That's not the same thing, it's very different. So was a symposium, or a group of experts, that got together in 2012. And they kind of coined a new term, wideband acoustic immittance. And within that term, they coined other terms, like wideband tympanometry, which is a pressurized type of wideband acoustic immittance, absorbance, and reflectance. So it covers all those terminology, and it's consistent with the NC standard of immittance tympanometry. Currently, the available commercial machines are from Mimosa Acoustics, has two version. One is laptop-based using the same probe for the handheld too.

And the handheld can do distortion emission and reflectance at the same time, but it's all done at ambient pressure. So there is no change in pressure. This is the Titan from Interacoustics. It's a laptop-based system. It's a Titan platform that gives you more capability when we connect to the laptop software. And it can run the wideband acoustic immittance at ambient pressure and for wideband tympanometry. It can run it at multiple pressure running different pump speed, similar to your tympanmetry. And this is a new version that we just introduced this year by the GSI, Tympstar Pro. It's capable of running the same concept as Titan. And they're sharing the same program technology. So this is a video that I've recorded and have presented.

So I'll let the video play that's kind of walk you through of the concept of why the test is being done, how fast it is.

- [Voiceover] Good morning and good evening to all the attendees for this live webinar. The intention of this demonstration is not to show you how to work with . So you have to consult the manual. I've already preset some protocol, as you can see on the left side of this panel. And the module that I have is capable of doing wideband tympanometry, as well as ABR, and the DPN TEOAEs. What I do in each of these 3D tympanometry and wideband absorbance tabs, I've made sure that the save to research file is activated. You can go to this gearbox and make sure that those boxes have been activated because the file is gonna be saved in a format that you can do later on analysis using your Excel macro sheet that you can actually get from Interacoustic, or your MATHLAB.

The machine is not connected to the laptop, so it's a simulation mode. I just want to walk you through to some of the tabs that are being used in clinical diagnosis. So I'll just do a start. It'll plot wideband absorbance across pressure, frequency, and you get a 3D demonstration. And a lot of information will be plotted in a very short period of time. So you don't have to run multiple tests. So it goes in order of the tab that you have set. I have preselected a criterion for reflex. You can change that based on the need of your clinic. So it should be done fast. I'll go to the 3D tympanometry tab. As you can see, you have pressure points in ear canal in decapascal, frequency from 250 hertz to 8,000 hertz.

And you have absorbance on the y-axis. So everything is reflected. And one, everything is absorbed. Again, it may be intimidating looking at this figure, but it's very useful because you can look at a two dimension, which is absorbance as a function of air pressure. As you can see it looks like tympanogram, like this one. Or you can look at the absorbance, which is the absorbance of the functional frequency. So if I click this box, tympanometric view, I'll go in a 2D dimension demonstration of the absorbence of the function of air pressure. And you can slide this to the right, and you will see that the protone changes from 2 26 to 8,000 hertz, and the impact of ab absorbent can be readily seen on the screen.

So you can look at a change, and this change can be different in different pathologies. Go back to 3D, now I can look at another 2D picture, which is the absorbance of the functional frequency. So I click on absorbance view. And right now, what you see is absorbance on the y-axis and the frequency on the x-axis. And this sliding bar will change the pressure. So you can see readily the impact of the pressure, negative or positive. Right now, it's ambient pressure, zero decapascal. If I go to the left, it's negative pressure. See the low frequency, you get more reflection. And you also see the maximum absorbance changes too. As I increase the negative pressure, first it gets higher, the high frequency.

And it gets shifted and lower at higher frequencies. And I'm going back to the ambient pressure. You will see that the pattern will become more normal, and then I go to positive. Essentially, a similar thing happens to the absorbence. So it's very useful to look at this figure in a 3D and 2D dimensions across different axis. It'll also give you information if you look at here, volume, resonant frequency, tympanometric peak pressure. So you can actually look at those numbers. Again, the system will drive other components from this 3D wideband tympanometry. And you can actually have your plot of 226, 1000 hertz. And here is a wideband average. You can change the frequency, so here's 226. By right clicking you can go six, seven, eight, 800 hertz.

Always I will look at uncompensated, take the phase angle off, so you can see Y, B, and G. Same thing here. And if it goes off a scale, you can adjust the scale to fit the tympanogram within the viewing window. And you can also look at the frequency at which the notch on the susceptance, or B, becomes equal to the tail, which is frequency. So you have a lot of information available, depending how you would like to look at it. And this figure right at the end is a wideband absorbance average at 375 hertz to 2000 hertz. And as you can see, you get a average absorbance at the ambient pressure because there was no negative middle ear pressure.

This can be shifted, you have a negative pressure, or positive pressure. And on the tail, you have a lower average. It could potentially be very useful in different middle ear pathology because the impact of loading on the negative, or positive, or at the peak can be different in different pathology. Developmentally could also be important as we, as the baby grows from birth to one month. And so, the impact at tails and peak can potentially be different. And in different middle ear pathology, it could also show some distinctive pattern. So it's a good way of looking at it. And the very last tab here is absorbance. And in this case, as you can see, there are red and gray superimposed and associated area of normative data, And the red one is the ambient, and the gray is the peak pressure.

So you can plot absorbance at the peak pressure if someone has a negative middle ear pressure, which is very important because negative pressure can actually mimic otosclerotic ear. So you want to know if compensating for the middle ear pressure will bring your absorbance to normal range or not. In this case, there's no difference because there was no negative middle ear pressure here. And the normative data here can be changed to a wider range, 90% range or 80% range, depending on how you want to look at your norm. Another very cool feature is that you can call up some examples here by clicking here. And then, superimpose those examples, so that compare your pattern to some typical patterns that may be associated with different middle ear pathology.

Okay, so we're gonna go back to the PowerPoint presentation. Okay, so I think that was a good introduction. Some practical issues, this is the reflectance. So if you recall zero on reflectance means that everything is absorbed. And let me actually get my laser pointer. So here everything is reflected and every thing is absorbed. So if you kind of switch this 180 degrees, it becomes absorbed. This is from work of Voss. And we wanted to know, what is the impact of the probe insertion depth? And as you can see, if it's a shallow insertion, the light baby blue, you see a lot of increase in absorbance, or less reflection at lower frequency. Not much changes above one K.

Most of the changes are below one K. And as you put the probe deeper and deeper inside, you will see that the reflectance becomes higher. And that's a very good indication to know how much you have to insert the probe. And the other advantage is that it improves test, retest reliability, and an objective way to know if you have put the probe properly inserted. And one of the drawback of otoacoustic emission is that people don't pay attention to the probe insertion depth, which may have a significant impact on the quality of otoacoustic emission. So running wideband in conjunction with OAE will give you a very good objective method to know if the probe insertion depth is appropriate.

So any changes in otoacoustic emission is as a result of a change in the system rather than the quality of . So take home message is this. So I intentionally put the probe shallow in the ear canal of one of my participant, and this is absorbance. Remember, absorbance one or 100% of everything you absorb. And zero, everything reflected. On the 3D, you see that the pattern jumped away from the baseline on pressure. And on absorbency, you see that the absorbance increased above the shaded area. So that's a good indication of the bad probe insertion. And still, I wasn't able to change the pressure. The seal is not a good indicator of insertion depth. And I replaced the probe on this picture on the same participant.

And you see that immediately, the 3D 10 moved toward the baseline on the pressure axis. And the absorbance, actually, the low end, low one k actually look within the normal range. So that's a clear indication of a good insertion depth, which you can use objectively to do your measurement. What would be the impact? Test, retest reliability. So this is a 10 test done with the proper probe insertion. And virtually, there is no difference. And if you do the same thing for long-term test, retest reliability, when there is no change in the middle ear, this is from Pat Feeney and colleagues paper, you'll see that between time one, time two, and time three, which was separate. So the previous one was same session.

By reinsertion of the probe, this is different timeline. There's virtually no difference, not even close to what we see in a pathology. So the take home message is deep probe insertion. It not only improves the quality of reportings, it improves test, retest reliability. But it's a good indicator for otoacoustic emission because the machine using the same probe will impact otoacoustic emission. Impact of the pressure, this is from one of my thesis student. So we did the maneuver to create positive or negative pressure in the middle ear. And this is done... And people asked why I have to run for pressure point. So this is a good way of showing Y. So if you look at the absorbance at ambient pressure prior to maneuver, you can see in all those participants that we tested are very close together.

And the variation of the confidence interval, 95% confidence interval. And when we did a pressure-induced maneuver using and these are different pressure points, you see the higher the pressure, the black one, the higher reflection you would get at low, around 2000 hertz. And as the pressure change gets smaller and smaller, you see it gets closer to ambient pressure. So it has a huge impact on your recording. And then, on the next slide, when I adjust it to the peak pressure, so it's the same test as this one, but this time I read it at the peak pressure, it becomes similar to prior test before the maneuver. So it will show you that you take this variability of the pressure out when you want the wideband acoustic immittance at the peak pressure.

So let's go into implication in the children. And as you know, the most common problem in children is middle ear infection. So just to give you an idea of what the normal looks like, this is what the normal looks, normal tympanograms, normal eardrums. 3D looks like this. Absorbent is within the range of a normal, as you can see. And you did your tympanogram 226, or you can change the frequency. And OAE is present very nicely in both ears. So kind of a baseline for you to move. Now, let's look at the perforation of the eardrum. This is, again, on reflectance. Again, reflectance zero, everything is absorbed. And one, everything reflected. If you wanna kind of get the picture of the absorbance, you just have to flip this 180 degree.

And at the very small perforation, so these are very small preparation. And it's done methodically by doing in category here by creating holes. You see a huge difference in absorbance at low frequencies below 1500 hertz. So absorbance increased significantly with very, very small tiny hole. So it showed the sensitivity of this test to rupture of the eardrum. And the funny part is, or the good thing about this is that it's also sensitive to a size of perforation. Because if you look at the big perforation, which is this light blue one, to very big perforation, which is a very small perforation, which is this one, you will see the pattern changes for a very, very small perforation, or tiny perforation, which may not be visualized by your otoscopy examination.

The majority of the changes are below 1500 hertz by increasing absorbance. And for a very big perforation, not much of the change on the low frequency. But most of the change happens at the high frequencies. So gives you a clear indication of the size of perforation. Here is another study that we did with my thesis students publishing here in "Hearing". So the black is normal, so absorbance. And these two are different level of a negative pressure. So this lighter pattern here is a kind of a mild negative pressure. The lighter dash pattern is the higher negative pressure. And you see fluid here. So it's confirming middle ear fluid. So you will see that progression from negative pressure to fluid, very different.

And here is the same principle across all participants that have middle ear effusion. It's reflectance, but again, sustanance and absorbance, but you have to flip it 180 degree. So one, everything reflected. And zero, everything is absorbed. And this white area is normal. And this light shaded area is abnormal, which means that's a lot of reflection. And all of the participant, 100% of the participants have a very high reflection across most frequencies that we can see plotted across the normative data. This was also replicated. So what one thing that you would like to know if the panel replicated across many research, published research paper. And it's been replicated on and on, that regardless whether you have a fluid, this is an absorbance.

You will get a lot of reflection across all frequencies. And this is normative data. This is from Ellison and colleagues that published this study. And this is a very good picture. I'm gonna come back to it from the PE tube when it's open. So if you have a PE tube and if it is open, you'll see a very high absorbance at the low frequency below one K. So if you wanna know if your PE tube is open or not, this is a very typical pattern that you would see. Here is of the published study of Merchant and colleagues. And they did from the . They looked at the viscosity and the level of the fluid. And it clearly showed that the wideband acoustic immittance is not only sensitive to the level of the fluid, but also the density of the fluid.

This is at the ambient... At the peak pressure and this is at ambient pressure. So you will see the normal is this one. And you will see a healed one with no fluid. And you see different level of partial fluid and full fluid, clearly showing you that as the fluid increases in the volume of the middle ear, you get more reflection, less absorbance across all frequencies. You see, very good indication of the level of the fluid. And it's the same figure at the ambient pressure here. Here is from... Lemme actually, I have to take my laser pointer out to be able to say the video, so bear with me. It's tricky. Okay, so this is a PE tube in the left ear.

And I'm sorry, PE tube in the right ear and fluid in the left ear. This is the video coloscopy that we did. And you can see the clear, abnormal retraction, the eardrums, fluid was confirmed by the pediatric otolaryngologist. Full fluid, actually, in the middle ear. And this one is the PE tube, which was considered open by the pediatric otolaryngologist. So they were blind of our tests. so they provided those information without the knowledge of our test outcome. Now, let's look at the wideband acoustic immittance results. So here is the result for the PE tube. So the 3D also gives you a very unique pattern that we can see increasing absorbance and it's fluttering. So a very unique pattern for perforation and open PE tube.

And I'll come back to it why this is important. And on the 3D pattern for the fluid on the left ear, you see a lot of reflection, not much of it. So let's look at the tympanogram on the right and left. So on the right, you will see a flattened tympanogram at 226 with a higher volume, which we often use to say if the PE tube is open. And on the left, we see a flat tympanogram with the lower ear canal volume. So all these things will be provided to you at the same run of the tests. You don't have to read on. So you get all your typical tympanogram . And this is the wideband absorbance average.

And as you can see, it's very different from open PE tube to fluid. So this is the absorbance from the same participant. As you can see, absorbance gives you a unique pattern at the very high absorbance below one K. This is a very unique pattern. And you see the fluid on the left side shows you have high reflection and less absorbance across all frequency. And the shaded areas are normal, 10 to 90th percentile for that age group. And the OAE on the fluid side was absent, and OAE on the PE tube side is present. And it's important because if the PE tubes open and the middle ear is clear from the fluid, then OAEs becomes present. Also, it's a good complimentary information for openness of a PE tube and no change in fluid filled middle ear, meaning that the fluid.

This is a acute otitis media with six-years-old on the left side. And so, we see a clear abnormality on video coloscopy. Here is the 3D. You see is just no absorption at all. Going to your , you get a flat , and with the normal ear canal volume. And absorbance you see a lot of reflection, no absorbance, much lower than the volume that the normal range for that age, OA absent. This is the negative middle ear pressure. And the negative pressure was different from the left to the right ear. And this is an important question, is the negative pressure accompanied by fluid? So let's look. The pediatric otolaryngologist, without the knowledge of our test battery, showed no fluid behind the eardrums, just a retraction, different level of retraction in right and left.

So this is the left. And this is the right ear. And here is the 3D. See the 3D on the left, which had a very high negative pressure, minus 280 decapascal? So it's a lot of reflection here. And then, maximum absorbance at the pressure peak, which is minus 180. On the right side, the pressure was minus 56 decapascal. And you see that the peak occurred at around that range. Now, let's look at the tympanogram. Tympanogram shows you the peak occurring at the minus 280 decapascal on the left side. Very nice discernible peak. And on the right side, the peak occurred around minus 56 decapascal. Now, look at the absorbance at ambient and peak. So this light graph here, let me actually could grab my pointer, so that I can point toward that.

So this light one is ambient pressure. And what's decompensated, this is the absorbance. You see at the low frequency, it's almost normal. So not likely associated with fluid. And this higher frequency indicate a retraction of the... So mechanics of the eardrum if it changes because of the pressure, may have an impact at the higher frequencies. And on the right side, you see that the low frequency of ambient pressure is clearly abnormal. And once we compensate it, it's just fully normal. That means that there's no fluid at all in the ear. It's just a negative pressure. And that can have an impact in the way that pediatric otolaryngologists may intervene, like wait see or do a more aggressive approach.

And this is also not related to a topic, but shows you if you want the otoacoustic emission at ambient versus peak, so the machine's capable of running otoacoustic emission at ambient or peak. If you look at the amplitude at ambient, it's very different than the amplitude at peak. So you can improve your OAE measurement for indication of the fluid. And there is no fluid because OAE is clearly present. So remember that I told you that this is a good, clear indication of conductive hearing loss. But there was no conductive component. Then you do odometry. And on the right side, you still see the improvement from ambient to peak, but not to the same level as the left because the negative pressure was minus 56 versus minus 280, left ear.

It's also sensitive to cholesteatoma, which is another chronic implication of a repeated otitis media perforation of the eardrum, the marginal area of the eardrum. I mean, you can see the normal, healthy ear is shown here. And you see cholesteatoma at ambient peak, clearly show a lot of reduction in the absorbance across frequencies, mostly at the mid-frequency. So by looking at this pattern, we can actually come up with a range of the frequency that we can average for different pathology to get a clear indication of separation. This is a typical pattern. Remember that when I talk about perforation, you get this fluttering effect on the 3D . So you get a lot of absorbance and this fluttering effect.

It's very typical of perforation. And it's very important because all these 3D tympanograms can actually be subject to a AI machine learning, which is a very hot topic. So basically, we can feed these data into the machine, and we can look at the pattern, and spit out the potential problem by pattern recognition. So it makes your job easier. Remember that when we had our conversation at the beginning, why audiologist did not adopt ? First was time, which is not an issue anymore. Actually, it's as or maybe more effective to know the time when you do this because it's subject automation. And the other one was problem with interpretation. And because of automation and machine learning, this one, it makes it much, much easier.

But also, would be subject to remote testing by sending the systems to remote area. And you observe the testing remotely for proper research and quality reporting. And knowing what kind of problem is in the middle ear to provide better indication of latency or referral to major urban area for further assessment. Here is a perforation from one participant. You see this clear fluttering effect on the 3D tympanogram. And you see this pattern. Because this is a big perforation, remember that the size of perforation will have an impact difference on the different frequencies. And it's a big perforation. You see most of the effect at the high frequency. If it was a small perforation, most of the effect would've been here.

And you see your flat tympanogram at 226 with the higher volume here. And it reflexes the graphs. To summarize, kind of with patterns that you could potentially observe this figure will make those patterns for you. So the thick black one is normal. And this green one is what you typically see in discontinuity. And also, perforation also shows the same pattern with some changes here in addition to this. The blue one, the baby blue one, is what you often see in fixation. So you get a lot of reflection at the lower frequency and some changes at the high frequencies. On the fluid, the red one, you'll see that you get a lot of reflection at the lower frequency, that mid-frequency.

And on the pressure, you have a discernible peak, but it shifts a bit to the higher frequency. and you get a lot of reflection. If you compensate for this, then it becomes very much normal, like if there is no fluid behind the ear. So what are the future directions? You can implement the same concept in newborn screening program. Right now, all the screening programs that are being implemented are binary outcomes that perhaps have failure. You know what the fail is. By combining wideband acoustic immittance, wideband acoustic reflex, and OAE, and if they all can be done with one machine, it cannot only do those tests of knowing whether it's a path or refer, you can also know what is the reason for refer.

Is it the middle ear, which is the most common part of failure? Or is it an arbitrary neuropathy, or it is sensory neural hearing? Or it can also tell the degree of sensory neural hearing, loss, whether it's mild, moderate, severe to profound. You can't do that with any AAVR protocol or OAE protocol. You can actually predict conductive hearing loss. Also, you can predict the level of the fluid and the density of the fluid. You can run at the much wider range of frequencies. Therefore, you can obtain reflex pressure at a much lower level. And therefore, in some people with oversensitivity to sound, it can be a very better option than the typical reflex pattern than we obtain.

We can also adjust OE pressure and adjust quality of the recording by using acoustic images. It's also subject to pattern recognition using AI, so makes things much easier, and gives you a probability of a disease with of good accuracy. Through the years, different people in my lab helped out to make these things happen. Again, passed away, rest in peace. Helped a lot in some of the project that we did. The people change after COVID. Well, depletion of the personnel, but it's just catching up again. And here is the that workshop that Eriksholm set up. And we did recommend the terminology and publishing in that special issue of "Ear and Hearing" before you, if you will actually look at that.

Another one is the book that we publish with Lisa, and it's also a good book. I have a conflict of interest. I get royalty every . So that's my conflict of interest. Another special issue published in the "Journal of American Academy of Radiology" I published a chapter in a two volume book, one by Hatzopoulos and colleagues. And most recently, "Seminar in Hearing" published a very good series with clinical focus on the implication of wideband acoustic immittance assessment of the middle ear in different populations, from babies to adults. So if any question is out there, I'm ready to answer.

- [Christy] Thank you, we have a couple questions here. The first question from our attendee. They say the walls of the ear canals of children are soft and not as hard as an adult's ear canal. How does the ear canal softness affect the measured absorbance, and thus, the diagnosis accuracy of middle ear pathology?

- Because it's capable of running at the ambient peak pressure. We can easily see the impact of ear canal changes of the function of pressure. And we have published good series of papers on that. In terms of diagnostic value, we did a test performance analysis of raw curve receiver operating characteristics for prediction of OAE middle ear problem. This significantly outperformed your in distinguishing normal and abnormal middle ear. It also predicts potential conductive component. And there's a good evidence published. So it'll actually show you the impact in differential diagnosis is much, much more accurate than conventional one K or 226 tympanogram in adult to a baby .

- [Christy] Thank you. Another question here from Donna. Is it bad to have a lot of absorbable?

- Well, and so, as you know, changes across participants. We did the studies in terms of defining what can contribute to potential sort of differences in normative data. And one of them are ethnicities. So what that means that if you have a smaller body size in , then potentially, your middle ear can be smaller. If you recall your ear canal and middle ear are different in female and male because of body size . Same thing can happen in

East Asia, like Chinese versus Caucasian. And if you kind of establish proper normative data, we can actually have a tighter normal, less overlap, and improve the diagnostic accuracy. So just to say if it's normal and you have a higher absorbance, it would very well be not fitting the typical normative data that people often mix different ethnicity and genders into it.

But you have the proper normative data, then it may be fit within that normative data for that population in general.

- [Christy] And the very last question that we have for today is, could you remind the participants what does WBA TPP stand for?

- A wideband absorbance of tympanometric peak pressure. WBTM means that wideband tympanometric ambient pressure. So ambient pressure means that we not change the pressure. Whatever the ambient pressure of the room is, you run it at that pressure. And peak pressure is the pressure to maximum absorbency.

- [Christy] And thank you so much to Dr. Navid Shahnaz. We really appreciate your time and your expertise, and also for being part of the "Seminars in Hearing" series. We'd ahead close the classroom. Thank you everyone for joining us today on Audiology Online.

- Thank you for lending me your ears.