Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

Recorded November 22, 2019

Presenter: James Hall, PhD

AudiologyOnline.com Course #33939
Partner: Otometrics

-- [Mary] Thank you, Anna. Hello everyone, my name is Mary Normson. I'm the Medical Education and Training Manager for Hearing and Balance at Natus Medical, and we thank all of you for joining this presentation entitled, "Simple and Evidence-Based ABR Protocol "for Infant Hearing Assessment." I am so pleased to have the opportunity to introduce our speaker, who I'm quite sure many, if not all of you, are quite familiar with already, Dr. J. Hall. James W. Hall III PhD is an internationally recognized audiologist with 40 plus years of clinical teaching, research and administrative experience. He received his bachelor's degree in biology from American International University, his master's degree in speech pathology from Northwestern University, and his PhD in audiology from Baylor College of Medicine under the direction of James Jerger. During his career, Dr. Hall has held clinical and academic audiology positions at major medical centers and leadership roles in the American Academy of Audiology. He's the recipient of numerous professional awards and honors and has authored over 190 peer reviewed publications, invited articles, book chapters and also 10 textbooks. Clinical and research interests include early diagnosis of infant hearing loss, auditory processing disorders, tinnitus, best practices and audiology applications of telehealth. Dr. Hall now holds academic appointments as professor part time at Salus University and the University of Hawaii, a position as extraordinary professor at the University of Pretoria South Africa, along with other adjunct and visiting professor positions in the United States and abroad. Dr. Hall currently serves as Chair of the Board of Directors of the Accreditation Commission for audiology education. I'll now turn the presentation over to Dr. Hall.

- [James] Thank you very much, Mary. I'm pleased to have this opportunity here to give you a very practical clinically oriented lecture on how to record ABRs for the purpose of really defining hearing thresholds and diagnosing hearing loss in infants. I can be reached at any time via email, using the email address that you see on the screen, and I also have a website, which you're welcome to visit, which has a lot of my presentations and articles and other information that many audiologists would be

interested in. Now, I'm going to follow an agenda in this one hour lecture that's quite a tight schedule. I often give workshops on this topic which go a half a day or a day or even a day and a half, so I'm going to try to discipline myself to stay within our timeframe for this particular talk, but again, there's plenty of information on my website that can fill in many of the details. I'll also give you some other resources for more detailed information. These are the learning outcomes for today. After this course, you definitely will be able to identify some key test parameters for optimizing ABR outcome. Now all of you, I'm sure, could list the test parameters used in an ABR assessment, but we're going to be talking about those in particular that will allow you to get the very best results in the quickest time on the infants that you're evaluating or any patient really, any child. We're also going to cover the unique role of ASSR in infant hearing auditory assessment, so at the end of the course I'm sure you will be able to describe that. I want to highlight four specific strategies for minimizing test time without losing out on any of the diagnostic accuracy of the assessment, and these are easy to implement strategies, and they really will work. I've been using them for years, and they will get your test time for a full diagnostic ABR and threshold ABR in an infant down to a half an hour or less.

And of course, there's major advantages in doing that, which we'll highlight throughout the course. And finally, at the end of it all, I think you'll be able to sit down and, or sit in front of your ABR system and put together a clinically applicable test protocol that will allow you to more efficiently and more accurately assess infant hearing. Now, this is the time ordered agenda, and I'm going to spend the first 10 minutes on the rationale for ABR assessment, maybe a little less because I don't want to get us behind right away and I think many of you are familiar with the rationale. I'm assuming we started around 12:02 or so with the introduction, so that's when I'm kind of starting my time clock here for the time ordered agenda. And then we're going to work through these topics, and at the end, I'm going to do all I can to finish my lecturing a little before the hour, perhaps 55 minutes into the lecture, five minutes before the end of the hour so

we can have time for questions and answers, and I welcome you, your questions and please don't hesitate, as you think of them to send them, type them and get them to Mary and she will collate them and then we'll take care of them at the end of the presentation. Well, I think that in the United States, at least, but really throughout the world, we can track the rationale for infant hearing assessment back to the 1960s. Before that, there were very few efforts, there was really no way to evaluate, diagnose an infant accurately even if you did have some suspicion of a hearing loss, but this wonderful woman, whose name you've all heard, Marion Downs, got it all started almost single handedly. I always enjoyed my times with her. They're precious times, really. I view her kind of as my audiology mother. Well that always got a chuckle, particularly when I was commenting on that to her when James Jerger was in the audience, because he's my audiology father.

But in any event, um, she basically conducted research that's even to this day is quite amazing, using some type of physiological response like eye blink response or sometimes other physiological responses to children and of course behavioral responses. Now this was totally inadequate for newborn hearing screening, that we do now, universal screening, but nonetheless, she was able to collect data on 17,000 neonates, I mean, it's just amazing. This was well before computers were available, and her conclusions based on her analysis was we have to be identifying children as close to birth as possible, and we need to start the intervention as soon as possible. And that led to her formation of the very first Joint Committee on Infant Hearing in 1969. So that was 50 years ago, she started the first Joint Committee on Infant Hearing. Now at the time, screening infants was pretty much out of, out of possibility for most audiologists. They just weren't capable of doing it. Behavioral techniques are totally inadequate. There are too many false positive errors where you think a child has a hearing loss, but they don't. And, worse than that, there were quite a few false negative errors with behavioral screening where the child seemed to respond. So, to sound. So, you thought they passed the screening, but in fact they didn't, and there

are many reasons for that. And it was really not until Robert Galambos and his colleagues Don Jewett and others, first described the ABR. It wasn't until then that people could have any way of evaluating infants, but with the ABR this revolutionized early identification of hearing loss. And you will see the most recent Joint Committee on Infant Hearing, the 2019 statement still regards the ABR as the quote "gold standard "for diagnosing hearing loss in infants and young children." So the screening efforts that we now use can be traced back to the mid 1970s when these classic articles were published.

Now, I was very fortunate, after leaving Northwestern University, as Mary had mentioned in my bio, in 1973 in speech pathology, I wanted to go someplace where there was audiology. I already knew that that I wanted to become an audiologist and I was told by the folks at Northwestern, go to Methodist Hospital in Baylor College of Medicine in Houston, Texas. Try to work with Jim Jerger, he's the audiology guru, the biggest name in audiology. Well, I was seeking a place where there was warmer weather anyway. I grew up in Connecticut where it snows and I was in Chicago where it snowed, at Northwestern, so off we went, my wife and I, to Houston, and it was a perfect time to be there. I won't go into all the details, but it turns out that Dr. Jerger was good friends with Robert Galambos and almost as soon as ABR became used to evaluate hearing in infants, Dr. Jerger started doing it, long before almost anyone in the world was doing it, right there in our clinic. So my history with ABR and diagnosing hearing loss with ABR literally goes back a good, solid 45 years. And that's me over on the far right. My hair was a little bit longer, a little less, definitely a lot less grayer. Anyway, it was a wonderful experience because I got to appreciate from my actual clinical experience mostly just putting electrodes on and doing the menial tasks of the assessment, how important ABR was, and of course that was also the time of the cross check principle article. So, I'm 100% convinced that ABR is the way to go to diagnose hearing loss in infants, and of course to estimate hearing thresholds. And it's not just my opinion. There are thousands of articles in support of that statement. So

over the years, I was involved in ABR on one of the very first efforts to screen, at least some babies, occurred in early 80s . Fortunately by then I had my PhD and we used equipment like this, the old Nicolai CU1000. These are the risk factors. So if you had to say well, when did ABR screening, at least in the United States, really start to be used in a clinical setting? This was the time frame, early 80s. We now knew which children were most at risk for hearing loss. We knew that if we used these risk factors, we'd identify roughly half of all babies with hearing loss just by screening in the intensive care nursery. And so that wasn't all babies, but it was still a big step in the right direction, and of course, we could define hearing loss when these babies were still in the nursery, so we could start the intervention quite early. So the Joint Committee began to develop these risk indicators or risk factors for hearing loss in the early 1980s, and they're all evidence based. Problem is, people were realizing that, as this slide shows, that if you do that, use an at risk registry, it's not a bad way to start, but the problem is you're only identifying about half of all the babies with hearing loss. And of course, the half that you're not identifying are in among those almost 4,000,000 babies in United States, of course, and under other countries like India, you might be talking about 20, 25,000,000 babies born every year.

So, at risk screening was good, but it wasn't really adequate to identify all children with hearing loss. The other problem is that even with at risk screening sometimes, there were babies without risk factors who were being identified quite late and even some of the babies who had the risk factors still were being identified too late, particularly if they had mild to moderate hearing loss. And most of these babies, of course, would be born in the well baby nursery. We wouldn't even know about them. And the myth or the misconception that, well, a mother or a pediatrician, they'll know when their child has a hearing loss, was proven over and over. People just couldn't figure it out. I mean, there's no way to know from watching the child's behavior. There's too much variability in the normal development of speech and language and auditory responses. And so intervention was far too late without some type of universal newborn hearing screening

approach. Of course, there's no way to do that until the mid 1980s. Now, at ABR had been around for at least a decade and been used with infants for a decade, and I had another good fortune to be involved, along with colleagues Paul Kileny and the late Roger Ruth, on in a study at the very first automated ABR system. It was a clinical trial. And to make a long story short, in the mid 1980s we found that you could use an automated technique, which has now evolved into the ALGO Three, but it was then the just plain ALGO. It was a basic primitive little device, but it actually could be used to screen hearing automatically, and we validated against a diagnostic ABR and found that it was just as good as a diagnostic ABR operated by an expert, and we never had any false negatives. We never passed a baby who should have failed and a very low percentage of false positives. And so this technique really caught on, not just this one device but people realize hey, ABR now in mid 1980s could be automated so that anybody could operate the equipment. It wouldn't have to be an audiologist.

Pardon me. Very rapidly, within a few years there was a consensus conference where, in the United States, the National Institutes of Health organized an incredible meeting. I could talk for an hour just about it. I was there, I presented the ABR data, and it was very nerve wracking presentation because there were over 500 people in the audience and it was a really big deal. Anyway, at the end of it all, in 1993, a panel of experts involved in this consensus conference came up with a document, and essentially, they endorsed universal newborn hearing screening. Well, that was a huge step forward, because at this point, no one really had been recommending it on a widespread basis. And that study, or I mean that conference in 1993 did raise some research questions, and one of them was how early is early intervention? And, Christie Yoshinaga-Itano, shown here, I'm standing next to her and I'm really not that tall, but next to her I look like a giant. Anyway, she published this paper based on a study that she conducted, a funded study that started in 1993. The paper came out in 1998, and basically it showed several very important points. Number one, the intervention's gotta start by six months. Any child receiving intervention for hearing loss later than that is not going to do as

well. She also found that, you know, a child who does get early intervention can develop normal speech and language. With the right intervention they're going to develop along with every hearing child. I mean, there will be no difference in their speech and language development. And the third thing she found was that any degree of language, I mean, any degree of hearing loss can impact negatively on language. So this was a huge, huge study, and it led to some very important developments. One of them is it led to the endorsement of universal hearing screening by the American Academy of Pediatrics. So now fast forward 20 to 30 years, or 40 if you want to look back at the early ABR studies, and now we have the most recent Joint Committee on Infant Hearing position statement. If you haven't seen this, it just came out in October of this year, 2019. If you haven't seen this, I strongly recommend you Google for it and download it. If you can't find it, contact me by email. I'll send you a copy.

I've read it all a couple times. I've lectured on it already. It's a wonderful document and it is the blueprint, or the final word, the definitive document on early identification, diagnosis and intervention for infant hearing loss, and although it was developed here in the United States, it will certainly have a worldwide impact, because it describes principles that are important for early intervention. One of the key points in this document, and I've got some quotations here, is that ABR is the gold standard for hearing threshold and diagnosis of hearing loss, including the determination of the type of hearing loss, the degree and the configuration. Of course, it also talks about the entire test battery. It endorses the cross check principle. So we also need measures of middle ear function, including acoustic reflexes. We need OAEs, and of course we always need to utilize and attempt to evaluate the child using behavior audiometry. Okay, we're moving right on schedule here, and so now I'm going to spend some time, roughly 20 minutes, on reviewing an evidence based ABR protocol. Now I can't do this adequately in 20 minutes. This could easily take a day. But what we'll do is highlight some of the important points, and the emphasis is going to be on evidence, that is everything I tell you is going to be supported by research evidence, and it's also going

to, along the way, emphasize how we can save time. A little later on in the course, I'll actually talk about specific strategies for minimizing test time. You know, there's a lot of evidence on ABR. Back in the early years, many of us kind of were flying by the seat of our pants, so to speak, we're just doing ABRs with kids and infants the way we had done them with adults, and we didn't have any good research to support much of what we did, but now that's all changed. If you just do a PubMed search with the abbreviation ABR, just ABR, pardon me, you'll come up with more than 6,000 articles, and thousands and thousands of articles have been published on every aspect of clinical ABR measurement. So we've got all lot of research to support each and every parameter in our test battery. I've recently summarized all of this in a yet one more handbook of auditory evoked responses. This is an ebook. If you haven't seen it, you can easily acquire it by downloading it from the internet onto at least one or two electronic devices.

If you print it, it'd be over 1,000 pages, but of course it's very easy to get around the book and, of course, carry it around if it's on a tablet or a computer or even a smartphone. So I encourage you to check it out. It's got all the information I'm talking about here and much more. So let's take a look at the stimulus parameters, that is, how we evoke the ABR. Well, insert earphones are the way to go. They weren't available early on, and it took a little while before people started to utilize them regularly, but insert earphones are, have so many clinical advantages. There's absolutely no reason not to use insert earphones. Everyone in recording ABR in infants should use them. A bone oscillator is a must. You must have a bone oscillator, because roughly 10% of all infants undergoing diagnostic ABR are going to need a bone conduction ABR. There's gonna be some concern or risk factors or maybe even clinical evidence of middle ear pathology. And nowadays, there's a new bone oscillator that if you're buying a bone oscillator, you should get the new one, the B-81. Stimulus types, well there's two main types. Clicks, .1 millisecond clicks, which you're all familiar with, and very, very brief bursts of tones. Tone bursts are usually around, oh, three to

four milliseconds in duration. Now, the actual duration of tone burst is almost always defined in cycles. So you have the same number of cycles, whether it's a high frequency or low frequency tone, two cycles of rise time, two cycles of fall time, and actually no plateau at all, zero cycles. Now, we're going to talk a little bit later about variations of these two types of stimuli, variations of the broadband stimulus, which is a click, and that's a chirp broadband stimulus, and then we'll talk about the variation of the narrowband stimulus, which is a tone burst. Remember, this is a single frequency. If you have 1,000 hertz tone burst, it's not just 1,000 hertz, that stimulus actually is about an octave band or a little below 1,000 or a little above. And we have a chirp counterpart for narrowband stimuli also. Now, polarity is an important parameter. You can really make your ABR look much better, much more robust, larger amplitude, by using a rarefaction stimulus polarity. That activates the cochlea most effectively. You can get in an ABR with a condensation, but it won't be as big and it won't be usually quite as good looking.

So start with the rarefaction, but if you're first beginning an ABR on an infant who's never been evaluated then actually you should use both rarefaction and then condensation, or with some devices, you're actually able to use an alternating polarity stimulus to start with and then you can separate the ABRs for the rarefaction and separate the ABRs for the condensation clicks. Why do we do that? If the ABR looks almost identical for rarefaction and condensation, that's really an ABR. If the response you're recording actually changes in polarity, the peaks become valleys and the valleys become peaks when you switch the stimulus polarity, that's not an ABR. It's probably cochlear microphonic, and it's a good indicator that the child might very well have auditory neuropathy spectrum disorder, or at least you need to look into it. Now the rate of stimulation, you might say well, that's not very important, but it is, it's huge, because the faster the rate, the quicker the test goes. So the goal is to go as fast as you can with your stimulus presentation rate before you start to produce some negative effects on the ABR. The analogy I use is if you're traveling a long distance,

most of us are going to go the speed limit, or maybe a little bit above the speed limit. My policy is 10% above the speed limit is not a problem. So if the speed limit is 50, 55's okay. If the speed limit 75 miles an hour, 77's okay, and that's what I do with ABR too. I push the speed right to the limit, but I don't want to go and get into trouble. I don't want to get into trouble with the ABR becoming smaller or delayed in latency or maybe even disappearing in a very, very young child. So the faster the stimulus that you can present with no negative consequences, the quicker the test will go, and we'll get back to that more later. Obviously, intensity's important. We're always varying intensity, we're trying to find threshold, at some point, and so we need to get down to the point where the wave five disappears, if we're estimating hearing thresholds. You need to know what your intensity is. You need to make sure your equipment's calibrated, but also, you need to know where the average normal hearing adult or young adult, will just barely detect all the stimuli you use for ABRs. That level is zero dB nHL. That's your reference for ABR intensity, and most pieces of equipment that you will get nowadays will come to you with the signals calibrated in dB nHL, and it'll be pretty close to where a perfectly normal hearing person will just barely be able to detect your stimuli. How many stimuli do you need to present?

Well, that's another way we can really manipulate the speed of the test. If you use a fixed number for all intensities and all conditions, such as 2,000 hertz, you're wasting time. What you really need to do is present as many stimuli as you need to record an ABR that's three times bigger than the background noise or an ABR with a signal to noise ratio three to one. The ABR's the signal and all the electrical noise, all of the muscle artifact, that's all background noise. If you present more stimuli than you need to get that, you're wasting time. If you present too few stimuli, you're not quite at that point of a three to one signal to noise ratio, then you may very well make mistakes. You may be looking at what you think is an ABR, but it may not be an ABR. Now, the insert earphones. The advantages are just so, there's such a long list. I won't go into all of them. Obviously, infection control is a big one. Patient comfort, minimizing the effect of

background noise on thresholds, increased intra oral attenuation, so you have less worry about masking. But, one of the things I'm going to point out is that you can take this little tube, plastic tube and pull out the normal foam plugs that the machine comes with. Buy one of these little rubber, plastic adapters, actually, probably buy a half dozen in case some get lost. And you want to stick one in each tube. One in the red tube, one in the blue tube. You can buy them from companies such as Oak Tree Products. By the way, I don't work for any company. I don't consult for any company. I'm just giving you this information all this information for your benefit. I focus on the technology, not the actual equipment. But these devices are very handy. I've used it for years because then you can use any of these emittance probes with your ABR insert earphones. You can either throw them away after every use or you can disinfect them, but you've got a size that ranges from a size for a neonate to a size for an adult. Very quickly I mentioned the B-81 bone oscillator. It is, by far, a superior bone oscillator to all of the old versions, the B-70s and B-71s.

More output, wider frequency response and the design, which it should be shown here. I don't know why it's disappeared from the screen. It should be in that big open white space, but the design is unique in that the actual pad that comes into contact with the patient, you know, that presents the bone oscillations, is not connected firmly to the rest of it, so you can actually hold the bone oscillator still against the patient's head and still get a really good signal. The other point I want to make is you can put the bone oscillator anywhere on the temporal bone. It doesn't have to be on the mastoid. In fact, the mastoid's really not the best place to put a bone oscillator for ABR, because the electrode, the inverting electrode, which you must be using in recording, is too close to the source of this potential stimulus artifact. Okay, keeping an eye on the clock here as we move on to stimulus rate, and I've already mentioned, the faster you can go the better. I would recommend a click stimuli where you're actually trying to get a really clear response, a clear wave one, a three and a five, 21.1 works very well, or some, some odd number in the early, low 20s. If you want to speed things up,

which you always want to with an infant or a young child, then for tone bursts, you can get up into the high 30s, or even the low 40 stimuli per second. So my lucky number's 37.7, but doesn't have to be that. That'll really speed up the testing without any negative effect on the ABR. And as you can see from these waveforms over on the left, as you increase the rate of stimulation, you can easily get up to 40 per second and it has no significant effect on the ABR. So anywhere in that range is a safe rate. Okay now, excuse me, we're gonna move on to acquisition parameters. Now, many systems come with more than one channel, but if you have a system or if you need to purchase an ABR system, and it only has one channel, don't be discouraged. One channel is adequate for almost all ABR applications. I don't mean to imply that you can't use more than one channel. Sometimes it does help you.

But in reality, almost all ABRs you conduct on infants can be done with a single channel with three electrodes, the non-inverting up on the high forehead, but the f in FZ does not stand for forehead, the f refers to frontal lobe. All the electrodes are are named based on the anatomy that's underneath them. So f is for frontal lobe, p is for parietal lobe, o is for occipital lobe and a for the inverting electrode, that stands for auris, ear. It's on the ear and that stands for ear lobe. If you did put an electrode on a mastoid, your inverting electrode, that would be called m, that would be the label you'd use, but I would caution you not to do that. Many audiologists do use a mastoid placement for an inverting electrode, but there at least three major problems with that, which I'll highlight momentarily. Filter settings. Well, you need to get the low frequencies. Not really low frequencies, but the frequencies from 30 hertz and above into your ABR, because the infant brain, which is immature, their infant, the infant nervous system, is dominated by low frequencies. And if you start filtering those low frequencies out, if you change your high pass filter setting to 150 hertz or 200, or worse than that, 300 hertz, you're filtering out a large part of the amplitude of the ABR, so try to keep those low frequencies in your recording. Filter the frequencies below 30 hertz out of it, out of your recording, because that's just EEG, that's brain activity that

does not contain ABR energy, but keep the other low frequencies. The only other parameter I'm going to comment on here is the analysis time. 15 milliseconds is perfect. 10 milliseconds is not long enough. Some of the ABR, under certain conditions, say low intensity or a young infant or a tone burst, will be beyond the 10 milliseconds. That would be very bad. You wouldn't see the ABR even if it's there. But, going the other extreme is not good either. For example, if you use a 30 millisecond analysis time, which is much longer than it needs to be, the whole ABR will be crammed into the very beginning of that analysis time, so you're gonna have a hard time distinguishing waves, but equally important, post auricular muscle artifact, which usually occurs around 15 to 20 milliseconds, post auricular muscle artifact from that big, big muscle behind the ear, can contaminate your ABR. Sometimes it's not even possible to see the ABR. By using a 15 millisecond time window, we're going to include all of the ABR components and yet we'll eliminate post auricular muscle artifact. Okay, just real quick comment on some of these recommendations that I've just made, all of which are evidence based.

Some people say well, I always use a vertex. I use the top of the head, put it on inverting. That gives me the best ABRs. In fact, there's no research to support that when you look at ABRs from infants. The infant ABR is recorded just as well with a electrode on the high forehead, midline high forehead, versus the top of the head, the CZ location. And there are some very practical advantages for using a high forehead placement versus a top of the head placement. We won't go into all the details, but having recorded thousands of ABRs in hospital settings, including neonatal units, neuro intensive care units and head injured adults, and of course many, many babies, I can assure you that the high forehead placement has many practical advantages and no disadvantages. Now what about the inverting electrode? Well, again, many people use the mastoid. I strongly recommend you try to use the ear lobe. And here are the advantages. I don't do anything, when it comes to ABR recording, I don't do anything without a good reason, or in many cases, two or three good reasons, and the reason I

am such a strong proponent of the ear lobe inverting electrode is listed here. You get a bigger wave one, which is always a good thing, because then you can look into wave latencies, and most importantly, you can be verifying by the presence of the wave one in the inverting electrode recording, you can be sure that that's the area you're stimulating, because that wave one comes from the ipsilateral eighth nerve. Also, you minimize post auricular artifact, because you're getting the electrode off the post auricular muscle, away from it. And when you start using bone oscillators, the ear lobe electrode will give you at least a little distance from the bone oscillator, so why not use it? And you can, even with infants, you can usually take a disposable electrode and curl it around the ear lobe, or for older infants, older children and adults, I use a ear clip electrode, a reusable electrode. The ground electrode can be anywhere. Some people recommend the forehead. Some people put it on the cheek. I've always used the low forehead, because I'm already up there scrubbing for the non-inverting electrode. So, I found that if you do this, you know, take these little steps, these little tips or techniques, you can save a tremendous amount of time as you're performing an ABR. So whenever you can do things the same way consistently without any mistakes, that's always a good thing.

Okay, I've already talked about the 15 millisecond analysis time, and this is just a good example. If you take a bunch of ABR wave fives, they're almost always right in the middle of that 15 millisecond timeframe, so that's a nice balance tracing. And if you look at all the different factors that can delay wave five latency, if you add them all up, you almost never get beyond 15 milliseconds. So, 15 milliseconds is long enough, but it's not too long. How many stimuli should we present? Well, again that's a very, very important factor in speeding up your test time. Our research has shown for years, if you perform signal averaging, keep presenting more and more signals, and you keep averaging response, the biggest benefit in the signal averaging occurs in the first couple hundred stimuli. And as time goes on, you get smaller and smaller benefit, diminishing returns. This is looking at the background noise as you average, and the

biggest drop in the background noise is in the first one or 200 or maybe 500 stimuli you present. After that, continuing to present stimuli doesn't give you much advantage in the signal to noise ratio. So, what is the proper number of stimuli? Whatever it takes to get a wave five that's three times bigger than all the background noise. That is an evidence based, acceptable way of determining how many stimuli you present. I would recommend don't present less than 500, although you can see in some cases even with 100 or 500, you're getting the perfect ABR, but don't present less than 500, but after that, don't present any more than you need to to get the signal to noise ratio three to one. Okay, we're gonna move on now to a brief review of how we actually conduct the ABR measurement, assuming we've got our optimal protocol, and then, how we analyze ABRs. Now as this figure shows, a sleeping baby's a beautiful thing. We all love sleeping babies, particularly if you're doing ABRs. In fact, one of my mottos I've developed over the years is never wake sleeping baby. If they're sleeping and you're finished with what you hoped to accomplish with the ABR, just keep getting more information, go to more frequencies, refine my threshold, maybe even perform OAEs or some other test.

So let's talk about the different steps in measurement that can assure that you're going to get the very best possible ABR on that particular child. First of all, make sure you know why the child is being evaluated. Did they fail a hearing screening in the nursery? Did they fail a hearing test somewhere else? Do they have risk factors for hearing loss? What other tests have they had? And that way you can develop your initial strategy for measurement before the baby you can get to the clinic, so you're not wasting time and you're getting the information you need to get as quickly as possible. So your equipment's ready to go, you've got your initial game plan, you know what you need to do, all the supplies and equipment, all your transducers, electrodes, tape. Whatever you need, it's all ready to go. You're not going to waste time. If your child is in outpatient, make sure that they've been sleep deprived. And we could talk for an hour about sleep deprivation. There's some good strategies for doing it, and in my

experience with the proper sleep deprivation protocol, where everybody knows what they're doing, including the parents, the receptionist at the front desk who gives them their reminder and of course you, everybody knows what to do, you can almost always get a child to sleep for at least a half an hour. Always schedule the patient early in the morning when they haven't slept, they were woken up early and they haven't taken a nap, they got to bed late. Put them in a quiet area, scrub them right away, because that's going to wake them up if you let them fall asleep, and then you're ready to go. Now, there are certain patients, maybe 10, 20% of the time depending on your population, who will not sleep long enough naturally for you to get all the information you need, and if you have to, you always have to get ear specific information, frequency specific information, and it's got to be accurate at low intensity levels. So, that means sometimes you're going to need to have sedation or anesthesia in place to get that child to sleep. You may or may not do that yourself, but somebody is going to have to be available to do it in a small percentage of the children, but we try to minimize that as much as possible to minimize risk and cut down costs.

So these are all just simple things that you're all familiar with that we want to have in place before we actually start the ABR. Now, I'm always going to test whichever ear is most at risk, so if a child failed a hearing screening unilaterally in the nursery, I'll start with a bad ear even though I always want to test both ears. That's one of the most important recommendations from the Joint Committee on Infant Hearing. When a child comes back for a follow up screening or diagnostic ABR, always evaluate both ears, even though they might have failed one. Start with a click, the click ABR. Don't spend much time on it, just two to three minutes. Click ABR is a really good choice to start with. Number one, we can rule out auditory neuropathy by comparing the rarefaction stimulant polarity ABR and the condensation polarity. The other important thing is we know what a click ABR looks like. There's good normative data. You know, we've got 50 years almost of experience recording click ABRs. So we can quickly distinguish between a normal ABR, a conductive pattern where all the waves are delayed, but the

waves are very well formed, a sensory pattern where the wave one may not even be present, and there's a very small amplitude for other waves, or a neuro pattern where the interwave latencies are delayed beyond wave one. We can get all that information in a matter of seconds with a click ABR. Then from that we go to the tone burst of course. If you don't get the response you think you should be, there's no wave one, maybe no response at all, it just doesn't look like what you thought you'd get, start troubleshooting immediately. There are many things we could do, and in my book I have tables of suggestions on how to troubleshoot. Then once you get past the click, you'll know how you need to approach the tone burst ABR, usually based on the click outcome. So if there's no click ABR at all, couldn't get one at all, then the first thing I would do is go down to 500 hertz. If there's no response at 500 hertz, I'll probably assume there's a profound loss and probably go straight to ASSR, whereas if there's some click ABR activity, maybe at 70 or 80 dB, but not at lower levels, then I'll assume there is some hearing, and I'll try to estimate hearing at lower frequencies, maybe 1,000 hertz, then 500, and I'll try to get 4,000.

So there's different ways of approaching an ABR, but it all depends on how that click ABR comes out at the very beginning. Okay, and then we're going to wrap up the management here by mentioning that once you get the ABR, now you've got to analyze it. Once you've recorded, you have to analyze it. We're usually looking for latency of the waves, but we also want to at least calculate wave five amplitude. And then we want to take into account any factors that might influence ABR results in infants, those would be young age, up to 18 months, we know the ABRs are immature at birth, body temperature, the lower the body temperature, the longer the latencies, and if they're in the operating setting, anesthetic agents. They all usually have a very slight effect on ABR. Now many pieces of equipment will have normative data, of course, built in. So once you enter the child's birthdate and once you enter the date of testing, or maybe that's already automatically recorded, then you'll get normative data for the age of your patient. Okay, we're going to wrap up the lecture now by focusing

on these last topics, strategies for minimizing test time, the role of ASSR in infant assessment, and then I'll talk a little bit about the cross check principle, and using an appropriate objective test battery for diagnosis of infants, not just relying on ABR. Well, I've already emphasized this, but I'm going to keep coming back to it because I really want you to change the way you perform ABRs to make sure that you're performing them as efficiently as possible, with the goal of getting down to the point where you're not taking more than a half an hour to perform an ABR on a naturally sleeping child. If you can do that, you're going to get all the information you need to manage that child for most patients. It'll not only help you manage the patient more accurately, but it will also be a big benefit for the parents who don't have to come back again for a second or third assessment. And also, it will actually improve patient safety, because you'll be recommending sedation and anesthesia less often if you can get all you need from that child to manage them in half an hour.

So the way you do that is you try to get the biggest ABR you can, you try to minimize noise as much as you can and you only present enough stimuli to give you this signal to noise ratio or ABR to noise ratio of three. So let me just give you some quick data that I've put together, just hypothetical, but it actually is the way it really works. If you have four stimuli per ear, just going to take that as an assumption, one click and three tone bursts, maybe 500 hertz tone burst, 1,000 and 4,000 plus click, and let's say you use four intensity levels. Most of the time, 80, 60, 40 and 20, although the actual levels may be different. We may do less, but let's say we use four, and let's say you actually replicate at each level, which you don't have to do very often as you're dropping down in intensity, essentially you're replicating, so I usually replicate at the highest intensity, then I don't replicate until I get to the threshold intensity, but let's say you do. And of course the baby has two ears, so essentially you're recording 64 separate ABR waveforms with any child. Well, if we're only using 1,000 stimuli, and we go to a rate of 37.7 for most of these averages, tone bursts, you can see we can easily get our test time down to less than half an hour. Now, if you needed bone conduction, of course

that would add a few more minutes, but not many. Here's another way of looking at it. Let's say we're not going to average 1,000 or 1,500 for every ABR, we're going to stop at 500 sweeps for the higher intensities because we already have that signal to noise ratio of three to one. And then, as we drop down, we're going to add more and more sweeps, so I calculated all of that. Well, if you do that and you're still using the fast rate of 37.7, you can actually get your data collection time for both ears, all the information you need, down to less than 15 minutes. You might say, well, I don't believe that, but I've done it many times, literally dozens and dozens of times. The key ingredients are a quiet baby, perhaps, a child that's been sedated or anesthetized or naturally sleeping, and a very efficient test battery. Now, one way you can speed up test time and one way you can actually get far more accurate confirmation of the ABR is by using chirp stimuli. Now, chirps stimuli on average, research shows this, will produce ABRs that are twice as big as conventional stimuli. And so not only are you able to see the response more confidently, even when there's some background noise, but you can actually sometimes get to more accurate threshold levels, and it always will take less time, because the signal that your recording's automatically bigger, so you're going to reach that signal to noise ratio of three to one much quicker.

What does the new Joint Committee say about chirps? Well, I was curious to see, I mean, I was just flipping through this new set of clinical practice guidelines with great interest and when I got to the ABRs, when I read what they said, it kind of made sense. The recommendation of the Joint Committee is you can use them. There is quite a bit of evidence that chirps produce bigger ABRs, but the Joint Committee has a couple concerns. One is they don't want to require the use of any new technology unless it's absolutely necessary, because then every hospital and every audiologist would have to buy a new, they need to buy a new system. So the way they approached chirps was they're great, there's plenty of evidence that they help. If you want to use them, go ahead. In many cases they will enhance your ABR, but they're not mandatory. And that's pretty much my recommendation. Okay, now we're down to the role of ASSR in

infant assessment. The ASSR traditionally dates back to the early 1980s and Robert Galambos, who we already mentioned, actually was among the first to describe steady state responses. At that time, he was calling it the 40 hertz response because it was being recorded with stimuli presented at 40 per second. Over the years, people have used one general approach to record ASSR and that is using a pure tone stimulus that's rapidly modulated in amplitude, and sometimes slightly modulated in frequency, and that produces a narrow band of energy around a single frequency. Now, more modern devices for recording ASSR have also, some systems also use very, very rapidly presented tone verse, or transient stimuli. So, whatever ABR system you have, find out if it has ASSR. If it doesn't, some pieces of equipment can be upgraded to include ASSR. If you're buying a new ABR system at this point, I would strongly recommend that you have ASSR as one of the options. When you have ASSR you have the option of of utilizing many different frequencies, not just 500 to 4,000. You can usually get down to 250 hertz and up to 8,000, which is a big advantage if you've got a child with a corner audiogram for example and you want to know is their hearing sensitivity at 250 hertz or if you're monitoring for ototoxicity in a very young child or an infant, you can get up to the highest frequencies.

The rate at which you present the stimuli, sometimes it's variable and it's set automatically by the equipment, so it may give you a different stimulation rate or if you're using pure tones, the modulation rate may be automatically set, but that's something that all systems will have. It'll have different modulation rates or different stimulus rates if the stimulus is a tone burst. The big advantage, really big advantage of ASSR in my experience is it will allow you, because of the, particularly if you're using a pure tone stimulus that's modulated in amplitude, you're now using a stimulus that's got lots of energy. It's a pure tone. It's a steady state stimulus, and you can easily get up to 110 or 120 dB with your stimulus. Now, with a typical ABR, with a click or tone burst, the maximum intensity for that very, very brief stimulus, usually it's about 90 dB, whereas, that means you can't really detect an ABR clearly if the hearing thresholds

are worse than 80 to 85 dB. You know, you've got to get at least five to 10 dB above behavior thresholds before the ABR is apparent. So you do have this region with ABR where you really can't estimate thresholds even though the child may actually have some usable hearing. ASSR, of course, allows you to estimate thresholds throughout that region. The other advantages of ASSR are real quickly, and I've found is if you've got an infant, and you're performing an ABR and there's no ABR, nothing for tone verse, nothing for clicks at the maximum stimulus level, you switch over to ASSR. If there's no ASSR in an infant, two or three months old coming in for a diagnostic assessment, you already know that if the parents are interested, and if there's no medical contraindication, that child's going to be a cochlear implant candidate. There's no hearing to amplify, and you can put the child on a fast track to start evaluating candidacy for a cochlear implant, and that's very reassuring to parents to know that you're exactly sure of what the hearing status is, and you have very, very confident information, good information on how they should go ahead with what the management options are, rather than saying, well, we don't really sure, we'll bring your child back and maybe we'll figure out whether they can get a cochlear implant sometime in the next year.

Okay, what does the new Joint Committee say about ASSR? Again, it's a good supplement. You don't have to use it, but there are advantages to using it. You're welcome to use it. It can sometimes provide you with information you don't get from an ABR. So there's no reason not to use ASSR. It's certainly in compliance with clinical practice guidelines. Okay, I'm going to just take a minute or two, so we stay on time, to talk about where ABR fits into the overall diagnostic approach for infant hearing. Whoops, sorry. You're all familiar with the cross check principle. I hope that some of you actually have read it. If you need it, you can't find it, let me know. I keep a copy on my computer. I'd be happy to send it to you. It was described first in 1976, and as I said earlier, I was actually in the clinic there at Baylor College of Medicine when this was developed and we'd see children, some of whom had been diagnosed with normal

hearing, who weren't developing speech and language. The diagnosis was done with behavioral audiometry at some other clinic. They come into our clinic, where because of Dr. Jerger, we had ABR, we had oral emittance measurements, we had tympanometry, we had acoustic reflexes even back then in the mid 1970s, and we'd find that that child, who had been diagnosed or told, the parents have been told your child has normal hearing, actually they had a severe loss. They've been misdiagnosed. And then we'd just see the opposite as well. Somebody would be diagnosed with a profound loss and that child would be wearing a big, big, powerful body aid and they'd come in and we find, actually, they had normal hearing sensitivity. And that led to this article, the cross check principle, which is five different case reports. And here's the bottom line: don't accept the results of any test, whatever it is, behavioral or objective, until you've confirmed those results with an independent test. So every audiologist should be using the cross check principle, and particularly if they want to be in compliance with Joint Committee recommendations, because all the recommendations are based on this cross check principle.

Now, I've written an article in 2016 on the 40th anniversary of the cross check principle paper entitled, "A Cross Check Principle in Pediatric Audiology Today: "a 40 Year Perspective." If you want a copy of that article, just contact me. It basically explains where we've come from 1976 and why the cross check principle is just as valid today as it was then. We now of course have many, many more tests in our test battery. We have behavioral audiometry, which we always want to include. We have all of the objective measures, including ECochG and cortical evoked responses, which we're not talking about today. So, I strongly encourage you to read the cross check article again if you need a refresher and always apply this principal. Okay, well, I didn't know if we could do it, but it's 12:55 according to my computer, and so, that's Eastern time. But 55 after the hour, so I'm going to stop there by simply summarizing that ABR has been around for 50 years, but we're still learning more and more about how to perform ABRs, and the emphasis in recent years has been on not just accuracy, but efficiency.

And if we can evaluate a child thoroughly using ABR and we can get ear specific, frequency specific estimations of threshold, if we can rule out auditory neuropathy and we can define the type of hearing loss, conductive, sensory or neural or maybe mixed, then we can properly and appropriately manage that child well within the six month deadline for early intervention. And I hope that you actually apply the techniques that I've talked about today in your clinical ABR measurement, and I think you'll find that you the results you get will be quite impressive. You'll be performing ABRs more quickly and you'll be getting more information that you need to have to manage your patients. And with that, I'll stop and take any questions that you might have.

- [Mary] Thank you very much, Dr. Hall. That was great. You actually stuck to your agenda, your time ordered the agenda, with so much information, so I'm quite impressed. I do have a few questions and I'm waiting for our attendees to type some questions into the chat box as well into the Q&A box. Firstly, you mentioned the new B-81 bone oscillator. Can you summarize the advantages of utilizing this new bone oscillator over the most recent version before it?

- [James] I'd be happy to, Mary. First of all, bone oscillators aren't, you just can't buy 'em for five or 10 cents, so if you have a bone oscillator and it's working, I'm not saying, run out and buy a new B-81. But, if you're getting a new ABR system or if you wish and you've got the money in your budget to upgrade to a new bone oscillator, or you want a back up, that's not a bad idea. I've seen many a bone oscillator fall off an ABR cart onto a floor and now suddenly you've got a child with oral atresia but you don't have any bone oscillator. Go to your manufacturer of your ABR equipment, whatever the manufacturer is and and ask them if they can supply, or your distributor of equipment, a B-81. The big advantages are the, it is a modern design, the output is greater and that's always been one of the main limitations with bone conduction. Your maximum intensity very often has only been 45 or 50 dB nHL, so you really can't evaluate more than a mild to moderate loss. The new B-81 gives you a greater output,

wider frequency response, so you're getting more high frequency energy, and the other big advantage, although it looks a little bulkier, you can actually hold the rectangular plastic bone oscillator without dampening the part that's actually oscillating on the child's skull, and the advantage of that is that you don't need to use a band if the child's head won't tolerate the band. You can literally hold the bone oscillator, and I've done that many times or, or you can have a colleague hold it just while you're presenting the stimuli. So I would encourage you to consider upgrading to a B-81. As time goes on, you can read the literature and verify that you really are, are wanting to do that and that there's enough benefit.

- [Mary] Excellent, thank you. And also, another bone conduction question. So thinking about the cross check principle, how you so eloquently described that, if, for example you ran a click ABR, air conducted click ABR at a high enough intensity level where you saw a wave one, three and five clearly with normal latency of wave one, and then your click threshold was maybe 50, so maybe you had a normal wave one at 80, and no response to clicks below 50, so of course you'd have to do some frequency specific tests, but would you necessarily need to do bone conduction or could you make the assumption that based on the normal wave one latency at 80, that there's not a significant conductive component?

- [James] Very good question. First of all, when you're using bone conduction click, you're really estimating hearing thresholds up in the two to 4,000 hertz region, and that's well established. The closest correlation between behavioral threshold in an audiogram and the click ABR threshold is for that two to 4,000 hertz region. It's a very high correlation. But, that means you're not getting information on low frequency hearing sensitivity with the click. So it's certainly conceivable that the child could have some conductive component in the low frequencies, and yet you could still have an ABR that looks, with all the latencies normal at high levels. Usually, if there's an airbone gap, it will delay the wave one slightly. But in your example, I would the answer it by

saying this: to play it safe, I would do a bone conduction assessment. You shouldn't get anything by a bone conduction if you've got a 50 dB pure sensory neural hearing loss. So one way to approach it would be I'm going to do one quick bone at 40 or 50 and if it's not there I'm going to assume this is sensory, not conductive. The other thing of course would be to apply the cross check principle. If you had normal tympanograms in that same child or some other evidence of normal middle ear function, normal wideband reflectance, for example, then that would be another reason why you wouldn't need to do bone conduction. Remember my motto, don't wake a sleeping child. This is a perfect example of how you can apply that. You don't think there's a conductive component, you don't really have any suspicion, but you know, this child's sleeping. Who knows when they'll ever be sleeping again for an ABR, so why not at least rule out a conductive loss, and the reason we do that is if, even with a normal tympanogram, I've had children who have a very shallow but normal tympanogram, and they had a congenital fixation of the ossicular chain, so you're not going to see it in the tympanogram, that child could be medically managed, or if they need a hearing aid, you may be much better off using a bone anchored hearing aid rather than a traditional hearing aid, or perhaps surgery or medical management will solve the problem. So whenever possible, if you have any hearing loss at all, make sure it's not conductive loss by doing some bone conduction. Now real quickly, if you've got a normal ABR down at 20 or 15 db, and the latencies are all normal, then you don't need to do bone conduction, just like you wouldn't need to do bone conduction, pure tone audiometry in a child with perfectly normal hearing sensitivity.

- [Mary] Thank you. Another question, this comes up frequently in my travels in the field. What are your thoughts on clinics establishing their own clinic specific normative data versus using published normative data?

- [James] Boy Mary, you're, even if no one else asks any questions, you're asking some really good ones, and it's obviously you've been talking to audiologists out in the

field. Yeah, I've got a very specific answer for that, and I've actually used this strategy for years. When you get a new ABR system or maybe right now with your existing ABR system, take a look at the normative data, first of all, make sure you're using a protocol with the same general parameters, the same filter settings, polarity, et cetera, that was used when these normative data were collected. So you can usually find out what was the protocol that was used to produce the normative data on your equipment? Then, let's say we're looking at normative data for anyone 18 months or older, basically an adult normative data. Record a couple ABRs and see if your ABR data for your actual people, like your wave five at 80, 60, 40, 20 is exactly in the middle of the normative range on your equipment. And with some equipment they actually have a nice, like a yellow or orange vertical bar that kind of fits over your ABR wave five. Well, see if your wave five from a real patient's right in the middle of that, that little normal region, and then do that for one or two infants. They could be, you know, a baby that a friend has just had, not a child in the clinic, but just an infant where you know they've got normal hearing. If your patients or your subjects are producing normative data right in the middle of the range of the normative data you have on your equipment, then you can just use their normative data. If you find, though, you're getting. Maybe you have a very atypical population, maybe you're in a Veterans Administration medical center and you see a lot of older adults who have hearing loss, sensory hearing loss. It's totally appropriate to get normative data for a bunch of adults with with cochlear hearing loss if your goal is to use that normative data to rule out retro cochlear. So, if your normative data fit your actual data that you're collecting on normals, you don't need to worry about collecting your own. Most people don't have the luxury of being able to collect their own.

- [Mary] Perfect answer, thank you. And one final question. This is probably an easy one. You were talking about saving time and faster is better when possible, you know, faster stimulus rates and so on will save time. Would you agree that any stimulus rate for clicks under 40 per second is a good place to start? Like you were saying 37.3 or

37.9, and if you see what you expect to see, that's fine and if you don't, then you'd have to maybe lower the stimulus rate and see if that made a difference. But under 40.

- [James] That's actually a very good strategy, Mary. No that's, that's exactly right. You could, for example you could use 37.7 all the time and if you're starting at a high level with 37.7, with say a click and you see a clear wave one, three and five, no sense in going down. But, and this is true for not just ABR, it's also true for the cortical evoked responses. If you don't see what you're looking for, particularly in an infant or somebody with pathology, slowing the rate is always a good idea. Not much, but enough to enhance the ABR, but that's right. If you don't have a problem, you don't need to solve the problem. You may have a perfect ABR at the rate of the high 30s or even low 40s, and if so, you can stay with it. Absolutely.

- [Mary] And finally, that made me think of another question that I've heard, oftentimes in the field, and it's about the filter settings, and that high pass filter, setting it down to 30 hertz. Sometimes, if you don't have a perfectly quiet sleeping baby, sometimes that can introduce a little more noise into your recording. What are your thoughts on increasing that high pass filter initially to 100 or 150? If you have a nice response, go with it, and the same idea as with the stimulus rate. If you don't have a good response, then start to lower that filter.

- [James] So yeah, that is exactly the way I would approach it. I'D start at 30, but if you got, after a while you'll kind of recognize when a child is adequately quiet for an ABR. If you got a child is even restless and you just scrubbed them, you put the electrodes on, the earphones, but they're not quite settled down, you can go to a higher rate, because at high intensities you can still see the ABR. Not a higher rate, but a higher high pass setting. I would not jump too far up. So usually with a lot of modern devices you can go from 30 to 75 to 100 because that's usually muscle artifact and very often that'll settle down. You'll see the number of stimulant rejects that for your averages start to drop

down and then you can gradually ease the filter setting down to a lower level. In fact, I would always have different protocols on my equipment for 30 hertz, 75 hertz, 100, so if I wanted to very quickly change the high pass setting if conditions change, I can just quickly call up another protocol and and use it. But, you bring up a good point. Whatever works, whatever it gives you an ABR that is usable, whenever you get the information you are looking for, then you're doing the right thing, and there are a lot of different ways to get to that point.

- [Mary] Thank you, and I'm not seeing any questions in the Q&A box, so either our participants learned everything they needed to know or they're too shy to ask questions, or the other, but I'll remind everyone that's in the meeting today that they just simply need to email us at Audiology Online with questions, and also Dr. Hall was kind enough to share his email address as well. And I would like to thank him very much for his time and expertise. I know that in retirement, he is very busy with all of his activities and publications and so on, and we really appreciate your time today, Dr. Hall.

- [James] Well, you're welcome. You can ask my wife if I'm retired. I think she'll sure point out that I'm just doing different things than I used to. But at any rate, thank you very much. I enjoyed this and I was happy to have the opportunity to give this webinar.

- [Mary] Thank you very much. This will end our meeting today. Thanks everyone for attending.

.