Aural immittance measures are more useful now than ever

By James W. Hall III

The late 1960s and early 1970s were an exciting time for diagnostic audiology. A new instrument developed in Europe—the Madsen electroacoustic "bridge," (Model ZO 70)—had found its way to the U.S., and tons of data were pouring in—most notably from Dr. James Jerger. Soon there was equipment from other manufacturers, and we had all kinds of new terminology to discuss. Were we testing impedance, admittance, or immittance? Did the "S" of A_S stand for stiffness or shallow? And what about the D of A_D—deep or disarticulation? Fun times.

Today, 40 years later, the immittance battery has become routine—so routine that the usefulness of the procedure may be ignored, or at least often overlooked. To take us "back to the future," we've brought in a guest author whose audiology career was emerging about the same time as the ZO 70—and he's still running!

When **James W. (Jay) Hall III** was completing his master's degree studies in speech pathology at Northwestern University, and specifically while taking a mandatory Introduction to Audiology course, he realized that audiology was his destiny. Despite that realization, he took a position as a speech pathologist at Methodist Hospital in Houston. However, soon he was spending only his mornings on speech pathology, and helping out in the audiology clinic in the afternoons. During one period, his whole job was conducting impedance measurements. In the evenings, Jay took coursework at Baylor College of Medicine, and before long he completed a PhD in audiology under the direction of none other than Dr. Jerger. And indeed, these times were the heyday of clinical research on impedance (immittance) measurements.

Dr. Hall currently is clinical professor in the Department of Communicative Disorders at the University of Florida, where he teaches doctoral courses, participates in funded research, and maintains a clinical practice. When he's not on campus, you can often find Jay in his study on the third floor of his 1907 vintage Victorian house in St. Augustine. As many of you know, Dr. Hall also is often on the road, giving lectures and workshops. His travels sometimes take him to the University of Pretoria in South Africa, where he holds the modest academic title of "Extraordinary Professor."

One of Jay's popular lectures these days is an evidence-based update on the clinical applications of aural immittance measurements. In this month's Page Ten, he'll explain why they are as important today as when they emerged 40 years ago.

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James W. Hall III

1 I'm not too sure I can come up with 20 questions on this topic. These measures have been around for so many years, there's not really much new to talk about, is there?

Not so fast, my friend. There's plenty of new information on immittance measures, from valuable new clinical applications of tympanometry to uses of the acoustic reflexes to new CPT codes!

2 Okay, you've piqued my curiosity a little. So, for starters, what's with the name "aural immittance"? We called it impedance back when I was in school.

Impedance, admittance, bridges, and meters. There have been a lot of terms tossed around since this test became clinically popular back in the early 1970s. The preferred term today is "aural immittance measures." Some people use *acoustic* immittance measures, but either term is fine.

Aural impedance or admittance (combined in the hybrid term "immittance") permits estimation of external ear canal volume, documentation of the integrity of the tympanic membrane, and description of mechanical properties of the normal or abnormal middle ear. Acoustic reflexes are, of course, measured when aural immittance is monitored during the presentation of high-intensity sounds to either ear. Therefore, if **you** say you're doing "immittance testing," that suggests you are also conducting acoustic reflex measures.

Immittance measurements are valuable clinically because they are quick, technically simple, have relatively high sensitivity and specificity, and can be recorded in persons of all ages without regard to developmental or cognitive status.

3 Got it. So let's start with the basics. What's new with tympanometry?

For starters, you're probably aware that aural immittance characteristics in infants are substantially different from those in older children and adults. Beginning in the 1970s, published reports described multi-peaked tympanograms in infants with apparently normal middle ear function and normal-appearing tympanograms with a low-frequency probe tone in neonates with middle ear pathology. Nowadays, a probe-tone frequency of 1000 Hz is recommended (e.g., Joint Committee on Infant Hearing, 2007[1]) for tympanometry in neonates and older infants (at least up to age 4 months). Ear canal volume measurements in infants, however, should be conducted **with** a low-frequency (e.g., 226 Hz) probe tone. By the way, with most immittance devices, probe-tone intensity is specified in dB SPL.

4 Do you mean it's possible to record a normal tympanogram on an infant who really has middle ear pathology?

Yes, that's the take-home message. With a low-frequency probe tone, there's a possibility of normal tympanometric findings in an infant with middle ear dysfunction. As you might guess, problems arising from such a false negative error in tympanometry may include failure to diagnose a disorder promptly or misdiagnosis of a sensory hearing loss. Either of these could lead to inappropriate or inadequate management of the child.

5 Regarding tympanometry, how come I always record a perfectly flat-line Type B tympanogram in most patients with ventilation tubes?

Sorry to burst your bubble, but it's not possible to record *any* type of tympanogram in a patient with patent (open) ventilation tubes. By definition, tympanometry begins by creating a relatively high level of positive (e.g., 200 daPa) or negative (e.g., -200 or -300 daPa) **pressure** in the external ear canal and then changing ear canal pressure. A hole in the eardrum (either a perforation or an open ventilation tube) makes it impossible to create or change pressure in the external ear canal. Therefore, the most basic requirement for tympanometry cannot be met.

Clinically, it's best simply to report the large measured volume and comment on the meaning of the finding without plotting the "flat-line-that-almost-looks-like-a-tympanogram." It would be very easy for an otolaryngologist, pediatrician, or even another audiologist to misinterpret that flat line on the chart.

6 Since we're talking about ventilation tubes, is there still a role for eustachian tube tests such as the Valsalva and Toynbee?

Absolutely. The Toynbee and Valsalva techniques are long-established but under-utilized measures of eustachian tube dysfunction. Both tests are conducted with the patient in a sitting position using a conventional immittance device and both are useful in assessing eustachian tube function.

The Valsalva technique was named after a famous Italian philosopher, practicing physician (surgeon), and anatomist. Dr. Valsalva actually invented the technique that now bears his name. Tympanometry is first recorded in the usual way. Then, with the patient's nose pinched closed by the thumb and forefinger, the patient is instructed to inflate the mouth with air and try to exhale. The Valsalva maneuver is most useful in determining if the eustachian tube can be forced open and negative middle ear pressure relieved by creating positive pressure within the mouth and nasopharynx. Sometimes the test is repeated several times in an attempt to restore normal middle ear pressure (approximating 0 daPa). This is the same technique we often use to "clear our ears" while flying on an airplane that is descending before landing.

With the Toynbee test, tympanometry is first performed in the usual fashion. Then, the patient is instructed to swallow (with mouth closed) while the patient's nose is compressed to prevent air from passing in or out. If the eustachian tube opens (a normal finding), middle ear pressure (and pressure in the nasopharynx) will decrease, as documented by a shift in the pressure peak of the tympanometry before rather than after the Toynbee maneuver. This maneuver can also be repeated several times in an attempt to restore normal middle ear pressure. The test is named for Joseph Toynbee (1815-1866), an English otologist who dedicated his life to researching the anatomy and pathology of the ear. You might be interested in knowing that Toynbee died when he inadvertently inhaled substances (a combination of prussic acid and chloroform) that he was investigating as possible treatments for tinnitus.

7 Hats off to Toynbee and Valsalva! You said earlier that there are other new developments in middle ear measurement. Can you tell us about them?

As a matter of fact, there's been a breakthrough recently in assessment of middle ear function: discovery of a technique referred to as "wide-band reflectance." Wide-band reflectance involves essentially simultaneous measurement of power reflectance, impedance, and admittance using either a broad-band (chirp) stimulus or multiple sinusoidal stimuli over a relatively wide frequency range from less than 100 Hz to over 10,000 Hz. As the stimulus is presented to the external ear canal, it is partially reflected from the tympanic membrane. Power reflectance is the energy reflected back into the ear canal and not absorbed by the middle ear system.

8 What's the advantage of wide-band reflectance over traditional tympanometry?

Wide-band reflectance very quickly (in less than a minute) provides information on middle ear function for many frequencies, rather than just 226 Hz or 1000 Hz. The results are valid for patients of all ages. And, wide-band reflectance is made at atmospheric pressure without need for an air-tight (hermetic) seal, which is a major advantage with pediatric patients.

9 I've begun to think differently about tympanometry! Is there anything new in the acoustic reflex area?

Well, acoustic reflexes themselves haven't changed, of course. However, in this era of early identification of hearing loss in infants, two clinical applications of acoustic reflexes are making a comeback. One is documenting the presence of a hearing loss with acoustic reflex thresholds. You might recall the SPAR (Sensitivity Prediction by Acoustic Reflex) technique introduced by James Jerger back in 1974.

10 I sort of remember that procedure, but I didn't think the threshold estimates were accurate enough for fitting hearing aids on young children.

Very true. Acoustic reflex threshold information is definitely not adequate for hearing aid fitting. Other objective techniques, such as the ABR, are much better suited for frequency-specific estimation of hearing thresholds in infants and young children.

However, the SPAR does provide a simple method for identifying hearing loss using acoustic reflexes in young children. All you need to record is an acoustic reflex for a broadband noise (BBN) signal. If you keep moving up through the signals available on a clinical immittance device, you'll eventually come to BBN. The acoustic reflex threshold for BBN increases rather systematically with hearing thresholds, beginning at a signal intensity level of about 70 dB SPL (or better) for normal hearers and increasing to over 100 dB for severe degrees of sensory hearing loss. Of course, it's important to first verify normal middle ear function.

About three-fourths of persons with hearing loss (as defined by a pure-tone average >35 dB HL) have BBN acoustic reflex thresholds exceeding 90 dB SPL. And, persons without serious hearing loss (pure-tone average <35 dB HL) almost always yield acoustic reflex thresholds for BBN better than 85 dB SPL.

11 But don't we need more specific measures of threshold?

In many cases we do, but objective information on the likelihood of normal hearing versus hearing loss contributes importantly to clinical decision-making. The acoustic reflex threshold for a single signal (BBN) can help identify a child with a hearing loss that needs to be further evaluated, perhaps with a sedated auditory brainstem response (ABR) assessment. On the other hand, if the BBN acoustic reflex threshold is quite good (e.g., ≤70 SPL) and information available from otoacoustic emissions or sound-field behavioral audiometry is consistent with reasonably good hearing sensitivity, then closely following the child is a good management strategy. The costs and potential risks of sedated ABR can be avoided.

12 That certainly makes sense. You mentioned that there is a second application of acoustic reflexes that is making a comeback.

Yes, there is. Acoustic reflexes play an important role in neuro-diagnosis of auditory dysfunction. A good example is the application of acoustic reflex findings in the diagnosis of auditory neuropathy.

Let's say you have a child in your office. The parents and pediatrician are convinced that the child's behavior is consistent with what seems to be a significant hearing impairment. Word-recognition scores are remarkably poor (<40%). An audiogram, however, shows only a moderate, low-frequency, apparently sensorineural hearing loss. Otoacoustic emissions are well within normal limits. You're confused by the conflicting pattern of findings. If acoustic reflexes are absent bilaterally in this type of patient, auditory neuropathy must be considered. The patient should undergo a full diagnostic workup for auditory neuropathy. As this points out, almost any audiologist with equipment for aural immittance measurement can identify possible auditory neuropathy in the office.

13 Good point. But you know, some clinics don't even do reflex testing! So, do you have other favorite neuro-diagnostic applications of the acoustic reflex measure?

Oh, I have at least four more! One dates back over 30 years, but it has renewed clinical value in this era of malpractice litigation and healthcare cost containment. Acoustic reflex threshold and decay measures are very useful in verifying risk of retrocochlear auditory dysfunction in patients with certain symptoms (e.g., unilateral tinnitus) or other audiometric findings (e.g., asymmetry in pure-tone hearing thresholds). Abnormal acoustic reflex findings in such patients warrant immediate referral for medical neuro-diagnostic workup.

14 If acoustic reflexes can help prevent a malpractice lawsuit, I'm all for them. What else...

I'll gladly tell you—and you can relay the message to your friends who have forgotten about their usefulness. Another neuro-diagnostic application of acoustic reflexes is valuable in patients of all ages, from pre-school and school-age children at risk for academic failure to veterans with traumatic brain injury. In these patient populations, language and/or cognitive factors may reduce the reliability and validity of behavioral hearing tests.

Acoustic reflex measurement is, however, entirely objective. First, it's important to record acoustic reflexes in four measurement conditions: ipsilateral (uncrossed) and contralateral (crossed) with right- and left-ear stimulation. Abnormalities in crossed acoustic reflexes, in the presence of normal uncrossed reflexes, indicate possible central auditory nervous system dysfunction. Patients with this acoustic reflex pattern need to undergo formal assessment of auditory processing and should also be referred out for further medical neuro-diagnostic workup.

15 And you have more?

Oh, yes. Whenever a patient has a large air-bone gap in pure-tone hearing thresholds yet normal tympanograms and normal acoustic reflexes, the diagnosis of superior canal dehiscence syndrome must be considered. As you know, acoustic reflexes would not be expected for most patients with a big air-bone gap. Patients with this unusual pattern of findings must be referred for neuro-otological consultation and a complete vestibular assessment, including vestibular evoked myogenic potentials (VEMPs).

And, here's yet another reason, one that you might recall from graduate school. The presence or absence of the acoustic reflex also contributes to the identification of facial nerve abnormalities. Acoustic reflex measurement is dependent on the integrity of the facial nerve, specifically the little motor branch that innervates the stapedius muscle. Again, it's important to record acoustic reflexes in the four measurement conditions we just talked about. Absence of acoustic reflexes when the probe is in one ear, in combination with a normal tympanogram (and normal pure-tone thresholds, if they're available), is a strong sign of facial nerve dysfunction.

16 You've convinced me. I really should be performing acoustic reflex measurements more often. My co-workers and I have had some disagreements over which procedures are "best practice." Can you help?

Well, I don't know exactly what procedures you are referring to, but here are the answers to the questions I most commonly get from AuD students.

- ***Crossed and uncrossed:*** As I mentioned earlier, I think you will always or nearly always want to conduct both crossed (contralateral) and uncrossed (ipsilateral) reflexes. Doing this adds only a minimal amount of time and can be very useful in differential diagnosis. Granted, if both contralaterals were coming in at 80 dB or so, there probably wouldn't be much reason to do ipsilateral. But by the time you know that, you've already moved the probe to the other ear, so you can also record ipsilateral reflexes in just a few seconds.
- ***Frequencies tested:*** In a busy clinical practice or with young children who may not cooperate for long, I recommend at least ipsilateral and contralateral reflexes recorded with a 1000-Hz pure-tone stimulus from each ear. If one of the goals of acoustic reflex testing is objective estimation of hearing status (as we discussed earlier), then I begin with a BBN stimulus, rather than a pure-tone signal.
- ***Upper input level:*** When acoustic reflex testing was introduced, we used devices that could go up to 115 to 120 dB (HL). Today, I recommend limiting the stimulus intensity level to 100 to 105 dB. Except for very young children, always be sure that patients understand that they can stop the test at any time if the sounds are too uncomfortable.
- ***Reflex decay:*** Reflex decay was a popular test back in the 1980s, and in terms of the time required it's still one of the most efficient techniques available for assessing retrocochlear auditory dysfunction. Evidence of acoustic reflex decay always warrants an immediate medical referral for neuro-diagnosis of possible retrocochlear auditory dysfunction.

17 Thank you. That was very helpful. I contract audiology services in a variety of sites around town. Is there anything portable that will do the tests you've talked about?

I have good news for you. There is a new generation of small, lightweight, battery-powered, hand-held devices. Some of these have remarkable diagnostic features. With most of the portable equipment, you can save the data for a number of patients. Then, when you return to your office at the end of the day, you simply download the data onto your office computer for record keeping and report writing.

18 What about billing for all this? Can I assume the billing codes for aural immittance measures haven't changed over the years?

You know what happens when you assume. Several additional CPT codes went into effect in January 2010. The CPT code for tympanometry remains 92567, and the code for acoustic reflexes is still 92568. However, new CPT codes are now available for combinations of measures. Code 92550 is used for the combination of tympanometry and acoustic reflex threshold measurements.

19 What a minute, I'm confused. You mean we don't use a separate CPT code for each of the aural immittance procedures?

No, the new CPT codes are used when multiple procedures are performed on a single patient. The two traditional aural immittance codes (92567 and 92568) are not used with the new CPT code 92550. The descriptor for another new code for acoustic immittance testing (92570) includes three procedures (tympanometry, acoustic reflex thresholds, and acoustic reflex decay).

20 I never realized how much clinically useful information was available from aural immittance measurements. Any idea where I can get a concise and clinically oriented update on the topic?

I thought you'd never ask! A new book entitled *Objective Assessment of Hearing* is hot off the press.[2] I co-authored it with my South African colleague De Wet Swanepoel for audiologists just like you. The book provides practical information on all the objective test procedures available in audiology today, including electro-acoustic measures (immittance and OAEs) and the auditory evoked responses (ECochG, ABR, and ASSR). I think you'd like it.

REFERENCES

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