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Evidence-Based Clinical Applications of OAEs in Children and Adults

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Evidence-Based Clinical Applications of OAEs in Children and Adults

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Evidence-Based Clinical Applications of OAEs in Children and Adults

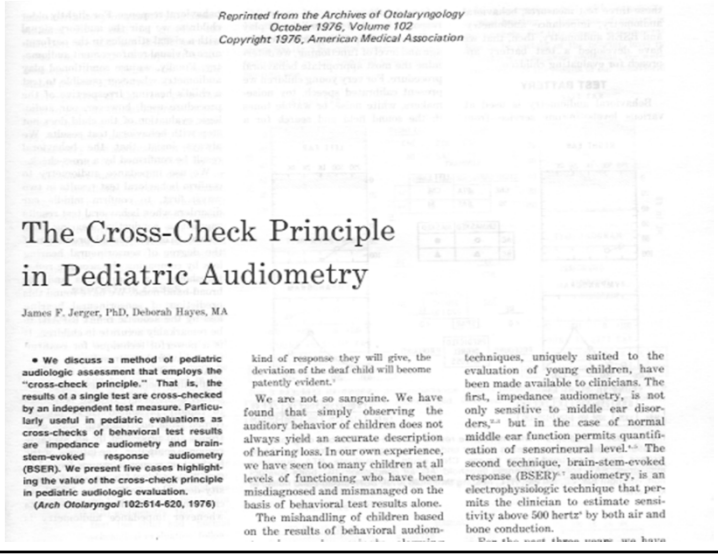
- **Learner Outcomes:** ***As a result of this Continuing Education Activity, participants will be able to …***
  - **Identify 4 evidence-based applications of OAEs in children**
  - **Identify 4 evidence-based applications of OAEs in adults**
  - **List 3 clinical advantages of OAEs in the auditory assessment of children**

Evidence-Based Clinical Applications of OAEs in Children and Adults

- ❑ Introduction
- ❑ Clinical advantages of OAEs
- ❑ Evidenced-based applications of OAEs in children
- ❑ Evidenced-based applicationsof OAEs in adults

The Cross-Check Principle in for Diagnosis of Hearing Loss in Children

(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)



The Cross-Check Principle in Pediatric Audiometry

James F. Jerger, PhD, Deborah Hayes, MA

• We discuss a method of pediatric audiologic assessment that employs the "cross-check principle." That is, the results of a single test are cross-checked by an independent test measure. Particularly useful in pediatric evaluations as cross-checks of behavioral test results are impedance audiometry and brain-stem-evoked response audiometry (BSER). We present five cases highlighting the value of the cross-check principle in pediatric audiologic evaluation.

(*Arch Otolaryngol* 102:614-620, 1976)

kind of response they will give, the deviation of the deaf child will become patently evident.[1]

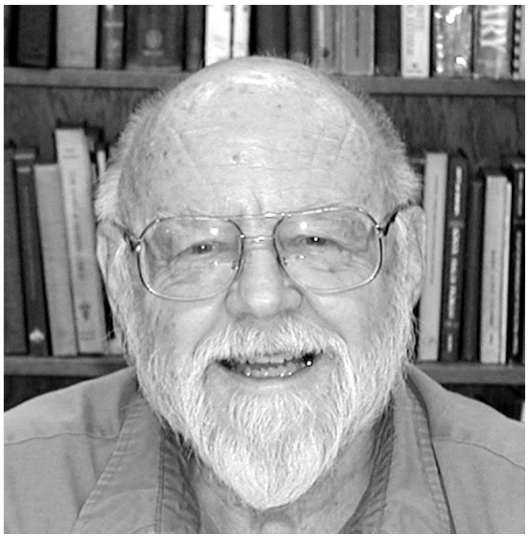
We are not so sanguine. We have found that simply observing the auditory behavior of children does not always yield an accurate description of hearing loss. In our own experience, we have seen too many children at all levels of functioning who have been misdiagnosed and mismanaged on the basis of behavioral test results alone.

The mishandling of children based on the results of behavioral audiom-

techniques, uniquely suited to the evaluation of young children, have been made available to clinicians. The first, impedance audiometry, is not only sensitive to middle ear disorders,[2-5] but in the case of normal middle ear function permits quantification of sensorineural level.[4-6] The second technique, brain-stem-evoked response (BSER)[7] audiometry, is an electrophysiologic technique that permits the clinician to estimate sensitivity above 500 hertz[8] by both air and bone conduction.

The Cross-Check Principle in for Diagnosis of Hearing Loss in Children

(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)



The Cross-Check Principle Pediatric Audiology

(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)
What's missing from the test battery?

"We have found than simply observing the auditory behavior of children does not always yield an accurate description of hearing loss"…

"The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure."

Test Battery:

- **Behavioral audiometry**
- **Immittance (impedance) measurements**
  - ✓ **Tympanometry**
  - ✓ **Acoustic reflexes (contralateral only with SPAR)**
- **Auditory brainstem response (brainstem-evoked response audiometry or BSER)**
  - ✓ **Click stimulus air conduction**
  - ✓ **Click stimulus bone conduction**

The Cross-Check Principle in Audiology Today
40-Years of Clinical Experience

- Behavioral Audiometry
- Otoacoustic Emissions (OAEs)
- Aural Immittance Measurements
  - Tympanometry
  - Acoustic Reflexes
- Auditory Brainstem Response (ABR)
  - Air- and Bone Conduction Stimulation
  - Click, Tone Burst and Chirp Stimulation
  - Auditory Steady State Response (ASSR)
- Electrocochleography (ECochG)
- Cortical Auditory Evoked Responses

Evidence-Based ("Best") Practice in Audiology:
Clinical Guidelines for Pediatric Assessment That Include Otoacoustic Emissions

- 2007: Joint Committee on Infant Hearing Position Statement
- 2010: American Academy of Audiology Clinical Practice Guidelines: Childhood Hearing Screening
- 2010: Guidelines for Identification, Diagnosis, and Management of Auditory Neuropathy Spectrum Disorder
- 2012 American Academy of Audiology: Audiologic Guidelines for the Assessment of Hearing in Infants and Young Children
- 2013 American Academy of Audiology Clinical Practice Guidelines: Pediatric Amplification
- American Academy of Audiology Clinical Practice Guidelines: Otoacoustic Emissions *(in progress)*

2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation for Hearing Loss In Infants from Birth to 6 Months

- ❑ Child and family history
- ❑ Evaluation of risk factors for congenital hearing loss
- ❑ Parental report of infant's responses to sound
- ❑ Clinical observation of infant's auditory behavior
- ❑ Audiological assessment
  - ● Auditory brainstem response (ABR)
  - ● Otoacoustic emissions (distortion product or transient OAEs)
  - ● Tympanometry with 1000 Hz probe tone
  - ● Supplemental procedures, e.g.,
    - ✓ Electrocochleography (ECochG)
    - ✓ Auditory steady state response (ASSR)
    - ✓ Acoustic reflex measurement (for 1000 Hz probe tone)

OAE MEASUREMENT AND ANALYSIS: *Current OAE Taxonomy … "Mechanism Based" Shera & Guinan (1999). JASA, 105, 782-798*

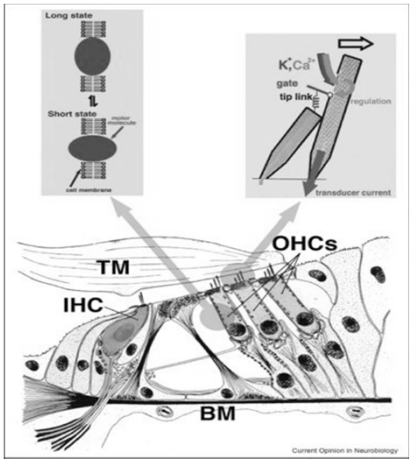
Evoked otoacoustic emissions arise by two fundamentally different mechanisms: A taxonomy for mammalian OAEs

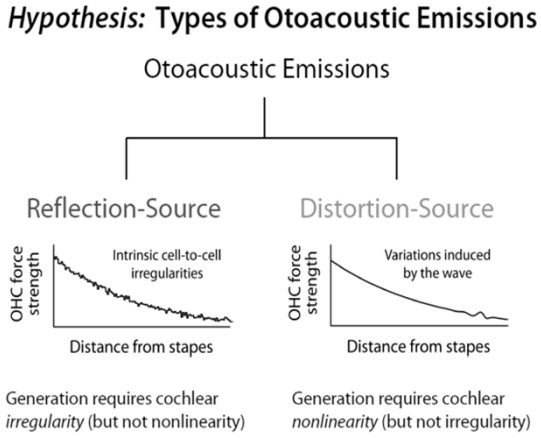
Christopher A. Shera[a] and John J. Guinan, Jr.
Eaton-Peabody Laboratory of Auditory Physiology, Massachusetts Eye and Ear Infirmary, 243 Charles Street, Boston, Massachusetts 02114 and Department of Otology and Laryngology, Harvard Medical School, Boston, Massachusetts 02115

(Received 2 June 1998; accepted for publication 27 October 1998)

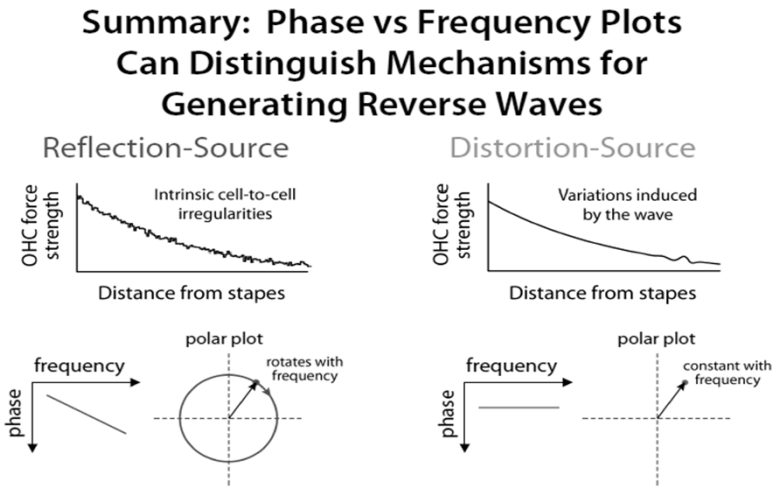
Otoacoustic emissions (OAEs) of all types are widely assumed to arise by a common mechanism: nonlinear electromechanical distortion within the cochlea. In this view, both stimulus-frequency (SFOAEs) and distortion-product emissions (DPOAEs) arise because nonlinearities in the mechanics act as ''sources'' of backward-traveling waves. This unified picture is tested by analyzing measurements of emission phase using a simple phenomenological description of the nonlinear re-emission process. The analysis framework is independent of the detailed form of the emission sources and the nonlinearities that produce them. The analysis demonstrates that the common assumption that SFOAEs originate by nonlinear distortion requires that SFOAE phase be essentially independent of frequency, in striking contradiction with experiment. This contradiction implies that evoked otoacoustic emissions arise by two fundamentally different mechanisms within the cochlea. These two mechanisms (linear reflection versus nonlinear distortion) are described and two broad classes of emissions—reflection-source and distortion-source emissions—are distinguished based on the mechanisms of their generation. The implications of this OAE taxonomy for the measurement, interpretation, and clinical use of otoacoustic emissions as noninvasive probes of cochlear function are discussed.
[S0001-4966(99)02202-X]

OAE MEASUREMENT AND ANALYSIS:
Current OAE Taxonomy





Phase is a Factor in the Generation of TEOAEs versus DPOAEs

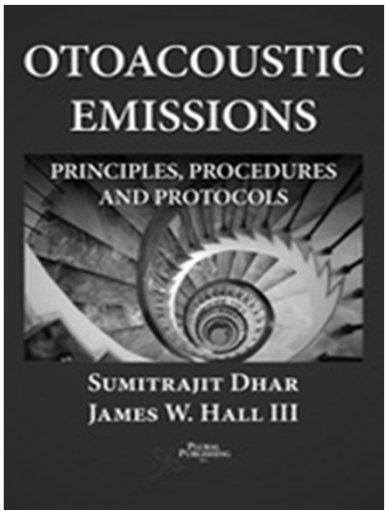


Shera, 2009

Auditory Anatomy Involved in the Generation of OAEs

- Outer hair cell motility
  - Prestin motor protein
- Stereocilia
  - Motion
  - Stiffness
- Tectorial membrane
- Basilar membrane mechanics
  - Dynamic interaction with outer hair cells
- Stria vascularis
- Middle ear (inward and outward propogation)
- External ear canal
  - Stimulus presentation
  - OAE detection

Evidence-Based Clinical Applications of OAEs in Children and Adults: *More Information on Clinical Rationale and Mechanisms*



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Evidence-Based Clinical Applications of OAEs in Children and Adults

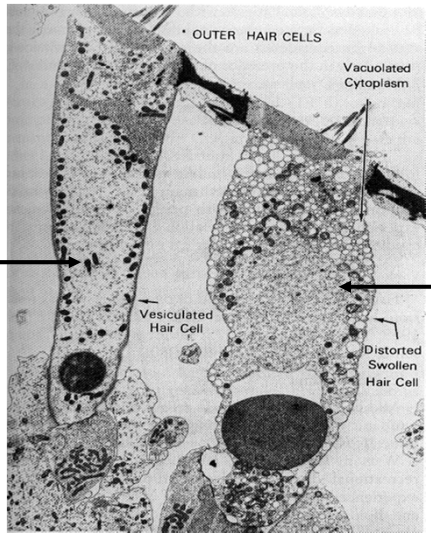
- Introduction
- Clinical advantages of OAEs
- Evidenced-based applications of OAEs in children
- Evidenced-based applicationsof OAEs in adults

Evidence-Based Clinical Applications of OAEs in Children and Adults

- General Advantages
  - Highly sensitive to cochlear (outer hair cell function)
  - Site specific (to outer hair cells)
  - Do not require behavioral cooperation or response
  - Ear specific
  - Highly frequency specific
  - Do not require sound-treated environment
  - Can be quick (< 30 seconds)
  - Portable (handheld devices)
  - Additional value when combined with other technology
  - Relatively inexpensive

OAEs in Early Detection of Outer Hair Cell Dysfunction: *Rationale Underlying Many Clinical Applications*

Normal OHC (OAEs) →



← **Abnormal OHC (OAEs)**

OAEs are "Pre-Neural": *Very Important for Identification of ANSD*

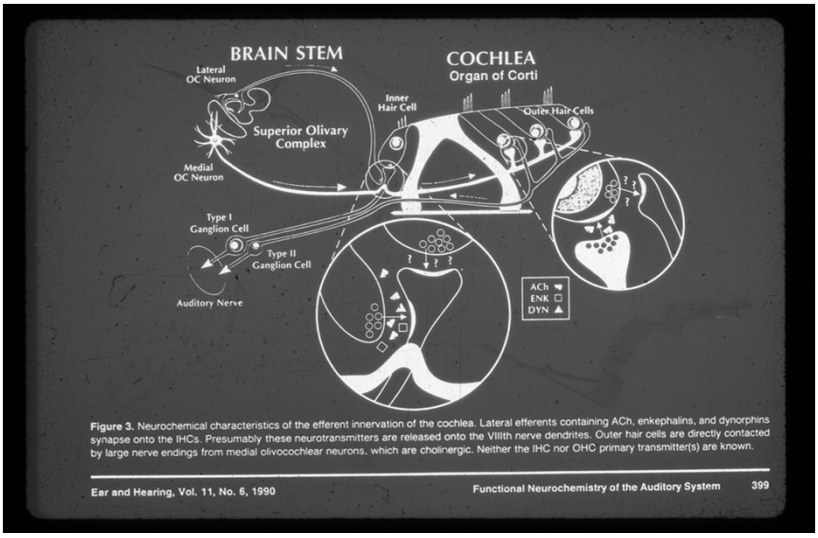


Figure 3. Neurochemical characteristics of the efferent innervation of the cochlea. Lateral efferents containing ACh, enkephalins, and dynorphins synapse onto the IHCs. Presumably these neurotransmitters are released onto the VIIIth nerve dendrites. Outer hair cells are directly contacted by large nerve endings from medial olivocochlear neurons, which are cholinergic. Neither the IHC nor OHC primary transmitter(s) are known.

Ear and Hearing, Vol. 11, No. 6, 1990 — Functional Neurochemistry of the Auditory System — 399

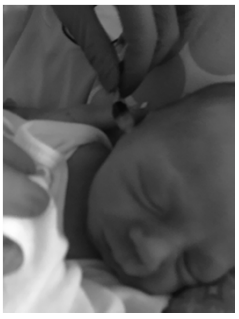
Evidence-Based Clinical Applications of OAEs in Children and Adults

- Clinical disadvantages or limitations
  - Susceptible to effects of noise
  - Affected greatly by middle ear status
  - Provides information only about outer hair cells
  - May be abnormal or not detected with normal audiogram
  - Not detectable with hearing loss > 40 dB HL
  - Cannot be used to estimate degree of hearing loss
  - Not a measure of neural or CNS auditory function
  - Not a test of hearing

Evidence-Based Clinical Applications of OAEs in Children and Adults
(www.nlm.nih.gov = > 4,500 references for OAEs)

- Pediatric Applications
  - Infant hearing screening
  - Diagnosis of auditory dysfunction in infants and young children
    - ✓Confirm or rule out outer hair cell dysfunction
    - ✓Identification of ANSD
  - Monitoring ototoxicity
  - Pre-school/school screenings
  - Identification of false or exaggerated hearing loss

Grandson Charlie Hall
October 2012
(age 2 weeks)



Grandson William James Finn McNeal
April 2015
(age 24 hours)

Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

Joint Committee on Infant Hearing (JCIH). *Pediatrics 120*: 898-921

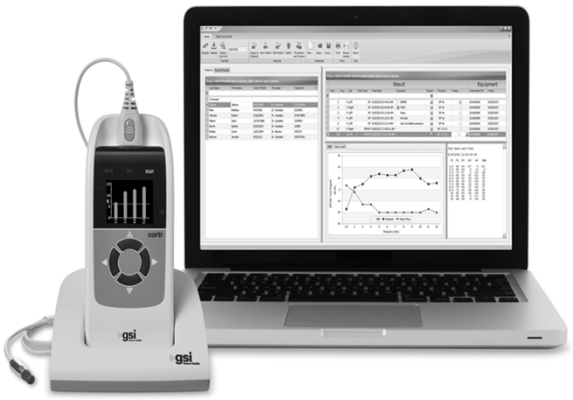
- **"Physiologic measures must be used to screen newborns and infants for hearing loss. Such measures include OAE and automated ABR testing." (p. 903)**
- **"Both OAE and automated ABR techniques provide noninvasive recordings of physiologic activity underlying normal auditory function." (p. 903)**
- **"Neural conduction disorders or auditory neuropathy/dysschrony without concommitant sensory dysfunction will not be detected by OAE testing."**
- **"The JCIH recommends ABR technology as the only appropriate screening technique for use in the NICU." (p/ 904)**
- **"Some programs use a combination of screening techniques (OAE and ABR) to decrease the fail rate at discharge." (p. 904)**

Diagnosis of Hearing Loss in Infants and Toddlers (0 to 6 months): *Year 2007 Joint Committee on Infant Hearing (JCIH) Position Statement*

- **Child and family history**
- **Otoacoustic emissions**
- **ABR during initial evaluation to confirm type, degree & configuration of hearing loss**
- **Acoustic immittance measures (including acoustic reflexes) *using high frequency (1000 Hz) probe tone***
- **Supplemental procedures (insufficient evidence to use of procedures as "sole measure of auditory status in newborn and infant populations")**
  - **Auditory steady state response (ASSR)**
  - **Acoustic middle ear reflexes for infants < 4 months**
  - **Broad band reflectance**
- **Behavioral response audiometry *(if feasible)***
  - ✓ **Visual reinforcement audiometry *or***
  - ✓ **Conditioned play audiometry**
  - ✓ **Speech detection and recognition**
- **Parental report of auditory & visual behaviors**
- **Screening of infant's communication milestones**

Selected Clinical Applications of OAEs in Pediatric Populations

- Pediatric Applications
  - Infant hearing screening
  - Diagnosis of auditory dysfunction in infants and young children
  - Monitoring ototoxicity
  - Pre-school/school screenings
  - Identification of false or exaggerated hearing loss



Identification and Diagnosis of Auditory Neuropathy Spectrum Disorder (ANSD): Minimal Test Battery (2010 ANSD Guidelines)

- Tests of cochlear hair cell function
  - Otoacoustic emissions (OAEs)
  - Cochlear microphonic (ECochG and ABR)
    - ✓CM may be present when OAEs are absent (e.g., with middle ear dysfunction)
- Tests of auditory nerve function
  - ABR for high intensity click stimulation (e.g., 80 to 90 dB nHL) with separate averages for:
    - ✓Rarefaction stimulus polarity
    - ✓Condensation stimulus polarity
- Additional tests
  - Acoustic reflex measurement (generally acoustic reflexes are absent in ANSD)
  - Suppression of otoacoustic emissions (abnormal, e.g, no suppression in ANSD)

Selected Clinical Applications of OAEs in Pediatric Populations

(See Chapter 9 in Dhar & Hall, 2012)

- **Pediatric Applications**
  - **Infant hearing screening**
  - **Diagnosis of auditory dysfunction in infants and young childre**
    - **Confirm or rule out outer hair cell dysfunction**
    - **Identification of ANSD**
  - **Monitoring ototoxicity**
  - **Pre-school/school screenings**
  - **Identification of pseudohypacusis**

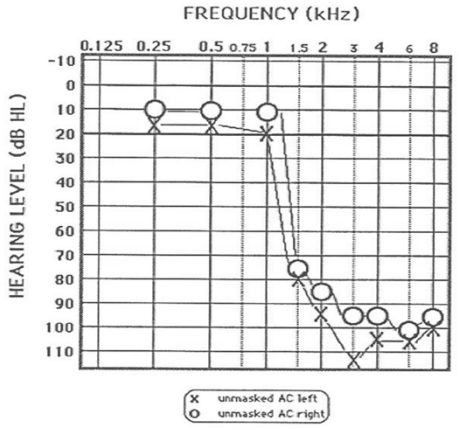
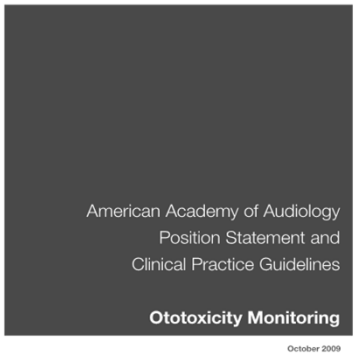


FIG. 1. This 24-year-old woman with cystic fibrosis received frequent tobramycin therapy since her diagnosis at the age of 3 months. Her audiogram shows a hearing loss at high frequencies.

Clinical Guidelies for Ototoxicity Assessment and Monitoring



- **Task Force Members**
  - **John Durrant (Chair)**
  - **Kathleen Campbell**
  - **Stephen Fausti**
  - **O'Neil Guthrie**
  - **Gary Jacobson**
  - **Brenda Lonsbury-Martin**
  - **Gayla Poling**

Current Trends in Ototoxicity Assessment and Monitoring
(American Academy of Audiology Position Statement and Clinical Practice Guidelines for Ototoxicity Monitoring, 2009)

- **Assessment and Monitoring Techniques**
  - **Pure tone audiometry**
    - ✓**Conventional test frequencies**
    - ✓**High frequency audiometry (HFA)**
  - **Distortion product otoacoustic emissions (DPOAEs)**
    - ✓**Determine reliability during baseline measurement**
    - ✓**High frequency protocol with many frequencies/octave**
  - **Frequency-specific electrophysiological measures as indicated**
    - ✓**ABR (tone burst and chirp stimuli)**
    - ✓**ASSR**

OTOTOXICITY:
Rationale for Monitoring with DPOAEs (*not* TEOAEs)

- **Highly sensitive to cochlear (outer hair cell) dysfunction**
- **Most ototoxic drugs first damage outer hair cells**
  - **Aminoglycosides (e.g., gentamicin)**
  - **Loop diuretics (lasix or furosemide)**
  - **Cisplatin**
- **Objective (can be performed on sick patients)**
- **Brief test time (one or two minutes)**
- **High degree of frequency detail (selectivity)**
- **High frequency limit up to 10,000 Hz (DPOAEs only … TEOAE limit is about 5000 Hz)**
- **Earlier detection of cochlear auditory dysfunction compared to audiogram**

OAEs in Monitoring For Ototoxicity: Recording and Analysis

- Utilize distortion product otoacoustic emissions versus TEOAEs to reach higher frequency region
  - Record to highest available test frequencies (> 8K Hz)
  - Sensitive stimulus intensity levels (L1 = 65 dB; L2 = 55 dB)
  - Use multiple frequencies/octave (> 5)
  - Replicate DPgrams to determine normal variability
- Analysis
  - Verify the presence of DPOAEs for each frequency
  - Compare average amplitude for replications for baseline versus post-drug recordings
  - Report any decrease in amplitude exceeding variablity

Selected Clinical Applications of OAEs in Pediatric Populations

- Pediatric Applications
  - Infant hearing screening
    - ✓Confirm or rule out outer hair cell dysfunction
    - ✓Diagnosis of ANSD
  - Monitoring ototoxicity
  - Pre-school/school screenings
  - Identification of false or exaggerated hearing loss

Otoacoustic Emissions in Audiology Today: Pre-school and school age hearing screening

- Few published papers on pre-school or kindergarten age hearing screening with OAEs (despite widespread use of OAEs in Head Start hearing screening programs)
- Screening auditory function in first grade children (≥ 6 years old)
  - Lyons A, Kei J & Driscoll C. DPOAEs in children at school entry: A comparison with pure-tone screening and tympanometry results. *JAAA 15: 2004* (Univ. of Queensland, Brisbane, Australia)
    - ✓ N = 1003 children
    - ✓ "When the results of a test protocol which incorporates both DPOAEs and tympanometry were used in comparison with the gold standard of pure tone screening plus tympanometry, test performance was enhanced. The use of a protocol that includes both DPOAEs and tympanometry holds promise as a useful tool in hearing screening of schoolchildren, including difficult-to-test children" (p. 702).

Hearing Screening in the Pre-School Population

Effective and Efficient Pre-School Hearing Screening: *OAE Research Findings*

- **Kreisman BM, Bevilacqua E, Day K, Kreisman NV & Hall JW III (2013). Preschool hearing screenings: Comparison of distortion product otoacoustic emission and pure-tone protocols. *Journal of Educational Audiology, 19*, 48-57**
- **Methods**
  - **198 preschool children age 3 to 6 years (mean 4.5 years)**
  - **Testing unsuccessful for another 2 children (PTs only)**
  - **Screening procedures**
    - **✓DPOAEs**
    - **✓PT screening with conditioned play (block in bucket)**
  - **Data collected by audiology and SLP grad students in 8 different preschool facilities**
  - **Protocol consistent with ASHA 1997 guidelines**

Hearing Screening Time for DPOAEs versus Pure Tone Technique in Pre-School Children *(Kreisman et al, 2013)*

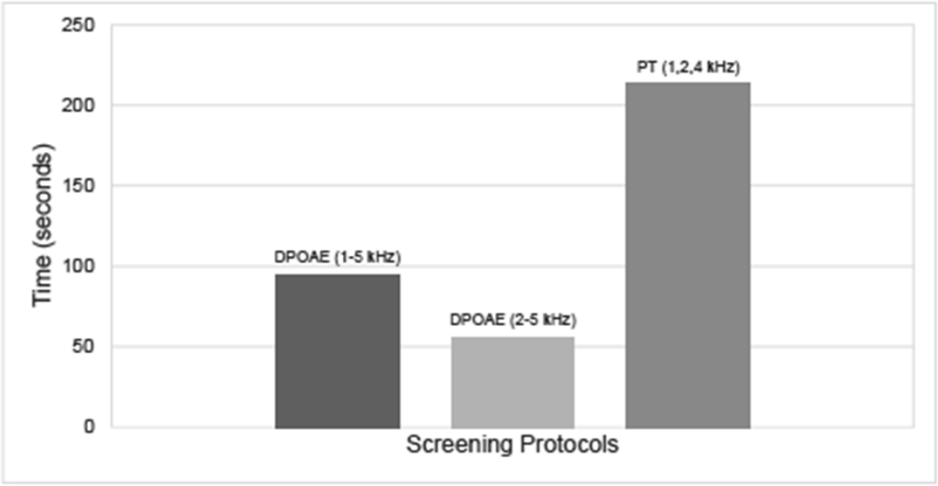


Figure 1. Mean time to complete each screening protocol.

Hearing Screening Pass/Fail Data for DPOAEs versus Pure Tone Technique in Pre-School Children

(Kreisman et al, 2013)

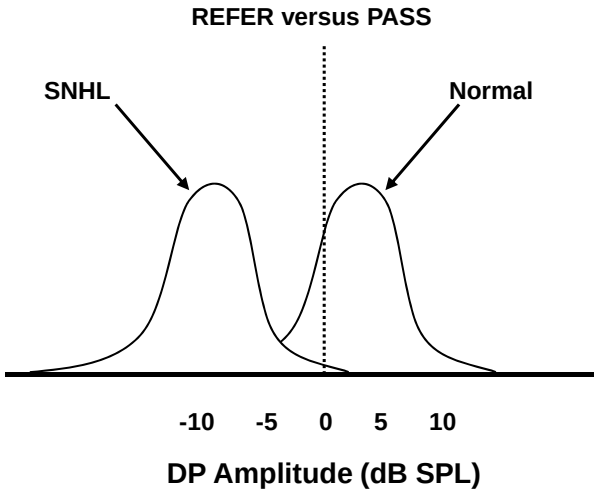
Table 2. Pass/Fail Rates for DPOAE (1-5 kHz), DPOAE (2-5 kHz) and Pure-Tone (1,2,4 kHz) Protocols

Protocol	Pass	Fail	Total
DPOAE (1-5 kHz)	134	64	198
DPOAE (2-5 kHz)	141	57	198
Pure-Tone (1,2,4 kHz)	175	21	196

Note. DPOAE=Distortion Product Otoacoustic Emissions. Two children would not cooperate to be screened using pure tones.

OAE Screening in Pre-School and School Age Children: Criterion for PASS versus REFER

(Data from Gorga, Stover & Neely, 1996)



Selected Clinical Applications of OAEs in Pediatric Populations

- Pediatric Applications
  - Infant hearing screening
  - Diagnosis of auditory dysfunction in infants and young children
    - ✓Confirm or rule out outer hair cell dysfunction
    - ✓Identification of ANSD
  - Monitoring ototoxicity
  - Pre-school/school screenings
  - Identification of false or exaggerated hearing loss

Selected Literature: Detection and Diagnosis of Pediatric Pseudohypacusis with OAEs

- Balatsouras et al (2003)
  - At risk children include those with emotional trauma
  - Tendency to more common in adolescent girls
  - OAE findings contribute to increased cooperation and valid behavioral thresholds
- Saravanappa et al (2005)
  - OAEs contribute to quicker, easier, and more confident diagnosis
  - Patient and parent awareness of OAE findings results in "improvement" in hearing and disappearance of condition
- Holenweg & Kompis (2010)
  - Without evaluation with OAEs, one-out-of-five children with pseudohypacusis were fit with hearing aids

Selected Literature: Detection and Diagnosis of Pediatric Pseudohypacusis with OAEs

- **Morita et al (2010)**
  - **Late or misdiagnosis can lead to**
    - ✓ **Increase cost of health care**
    - ✓ **Litigation**
    - ✓ **Inappropriate medical (e.g., steroid) treatment**
- **Ioannis et al (2009**
  - "Otoacoustic emissions were used in all children who participated in this study and in some cases their role as 'lie detector' produced a striking and immediate result."

Evidence-Based Clinical Applications of OAEs in Children and Adults

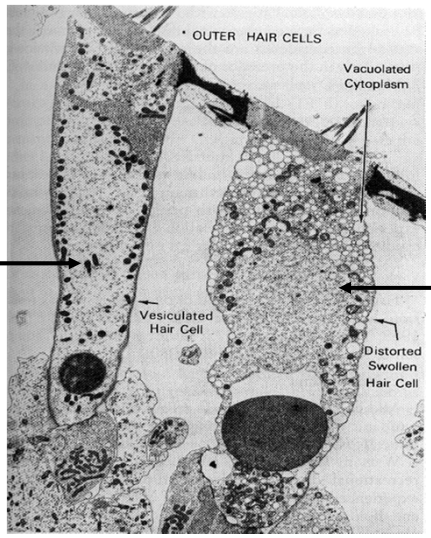
- **Introduction**
- **Clinical advantages of OAEs**
- **Evidenced-based applications of OAEs in children**
- **Evidenced-based applications of OAEs in adults**

Evidence-Based Clinical Applications of OAEs in Children and Adults

- **Adult Applications**
  - **Diagnosis of cochlear versus retrocochlear auditory dysfunction**
  - **Identification of false and exaggerated hearing loss, including malingering**
  - **Monitoring ototoxicity**
  - **Hearing screening**
    - ✓**Industrial settings**
    - ✓**Military personnel**
  - **Early detection of cochlear dysfunction in noise/music exposure**
  - **Diagnosis and management of tinnitus & hyperacusis**

OAEs in Early Detection of Outer Hair Cell Dysfunction in Exposure to Excessive Sound (Noise or Music)

Normal OHC (OAEs)



Abnormal OHC (OAEs)

OAEs in Early Detection of Recreational Noise-Induced Auditory Dysfunction

- Sporting events
  - Football games
  - Soccer games
  - Automobile racing
- Exposure to gunfire
  - Hunting
  - Target shooting
- Power equipment
  - Power tools
  - Chainsaws

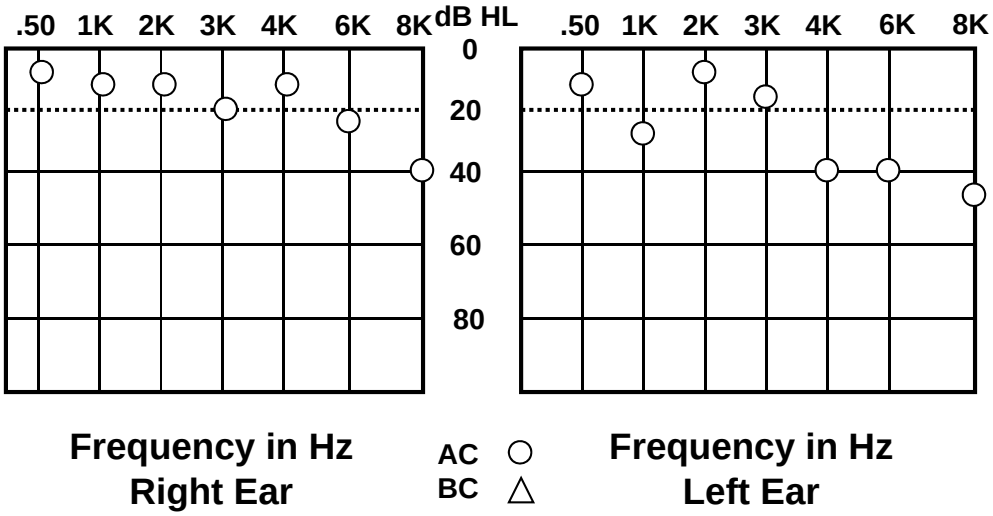
OAEs in Early Detection of Recreational Noise-Induced Auditory Dysfunction

- Motor vehicles
  - Motorcycles
  - Off-road vehicles
- Computer games
- Music sound exposure
  - Symphony musicians
  - Popular band members
  - School bands
  - Workers at music venues
  - Audio engineers
  - Patrons at concerts
- Personal audio players

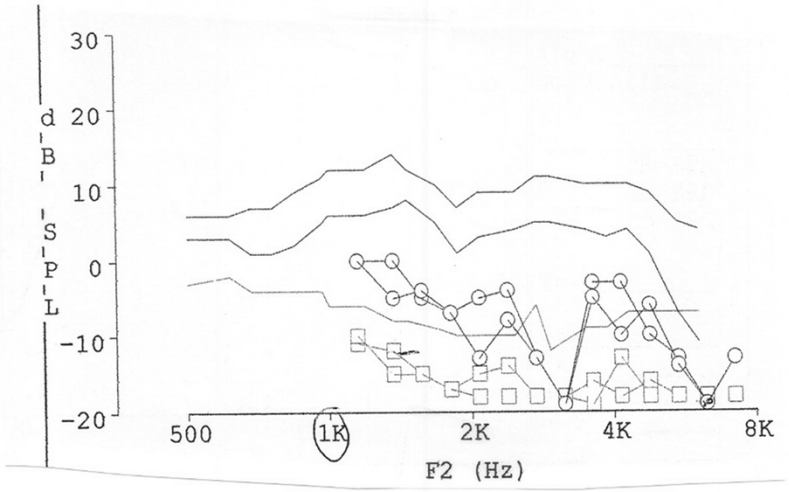
OAEs and Music Exposure: Case Study

- 62 year old female
- Professional violinist and violin teacher
- Bothersome tinnitus bilaterally, left > right ear
- Hyperacusis (LDLs = 70 to 80 dB HL)
- Sound level measurements when playing violin
  - Right ear = 81- 86 dBA SPL
  - Left ear = 91 - 97 dBA SPL (peak > 100 dB SPL)

Case Report: 62 year old female violinist



Music Induced Hearing Loss and OAEs:
62 year old violinist and violin teacher (right ear)



Music Induced Hearing Loss and OAEs:
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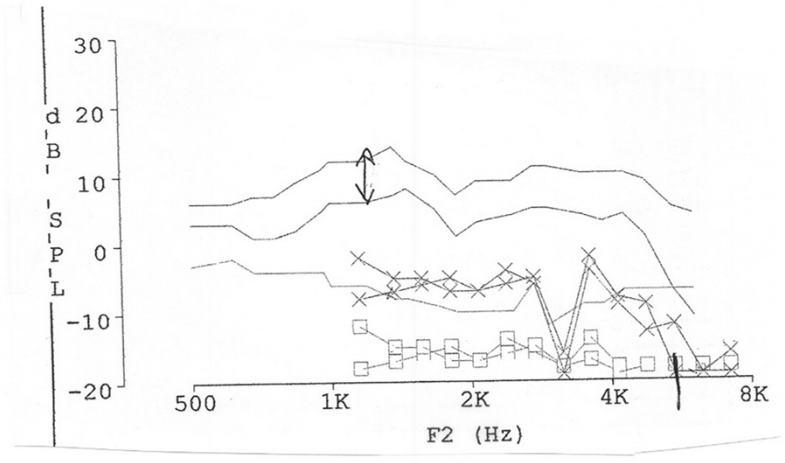
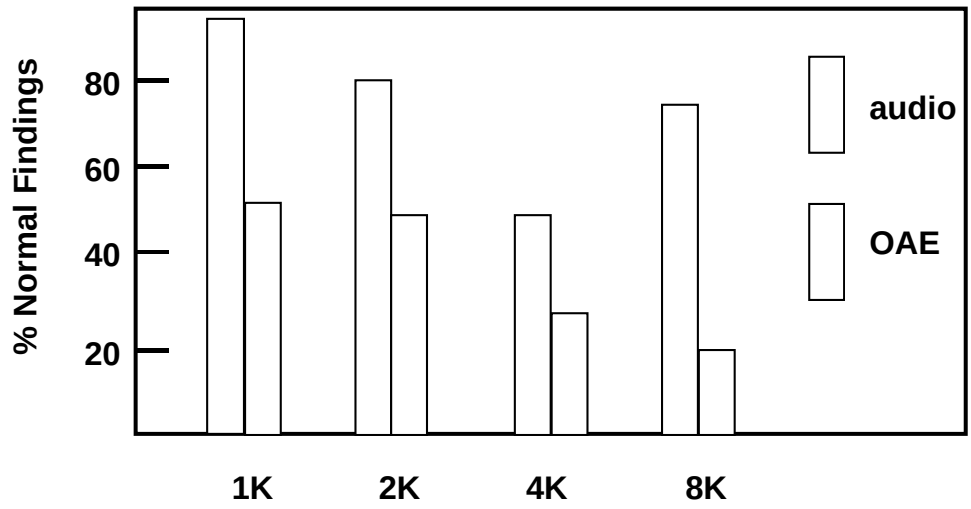
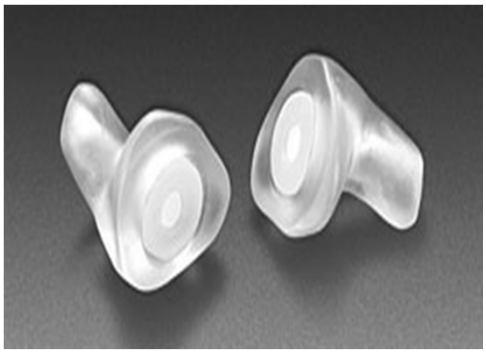


Music Induced Auditory Dysfunction: Audiogram versus DPOAE (N = 37 Professional Musicians)



Preventing Music Induced Hearing Loss: Musician's Earplugs and Ear-Level Monitors



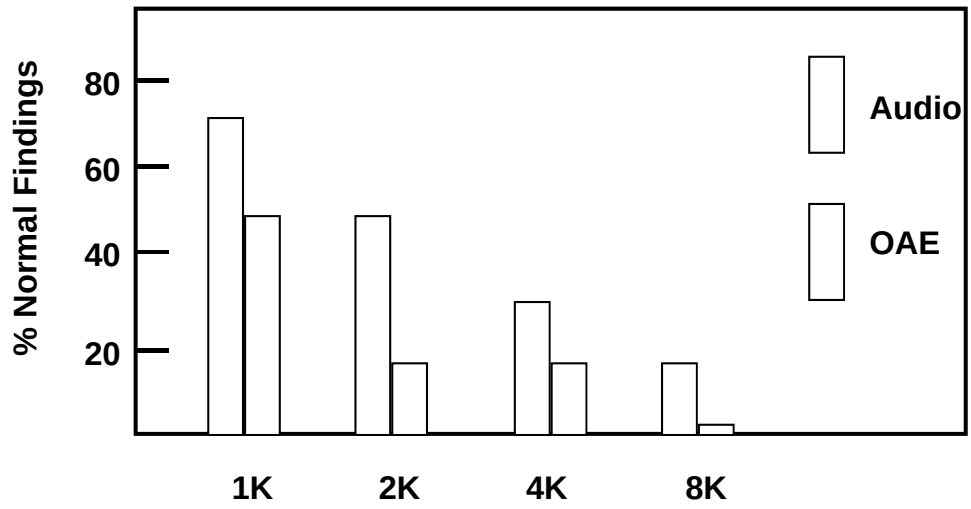
Conclusion:
OAEs Can Play an Important Role in Hearing Conservation

- Rationale for OAEs
  - Highly sensitive to cochlear deficits
  - Objectively and quickly administered
  - Easily administered by non-audiology personnel
- Possible protocol
  - Baseline audiologic assessment with OAEs
  - Monitor auditory status with OAEs
  - Pure tone audiometry only with change in OAEs
- New research (Universities of Michigan and Florida)
  - Early detection of cochlear dysfunction with OAEs (including iPod users)
  - Immediate preventive treatment with micronutrients
    - ✓magnesium
    - ✓vitamins

OAEs in Diagnosis and Management of Tinnitus:
Documentation of Cochlear Origin

- Origin in cochlea
  - Hair cell damage
  - Imbalance between OHC and IHC function
- Eighth cranial nerve
  - increased or changed resting potential
- Auditory brainstem, thalamus, and cortex
  - Perception of sound in primary auditory cortex
  - Inappropriate subcortical neural circuitry
- Non-traditional auditory regions
  - Limbic system
  - Autonomic nervous system
- Efferent auditory system
  - Reduced activity

TINNITUS ASSESSMENT AND MANAGEMENT: Audiogram versus DPOAE



New Evidence for Five Clinical Applications of OAES in Adults: Hearing Conservation

- Rationale for OAEs
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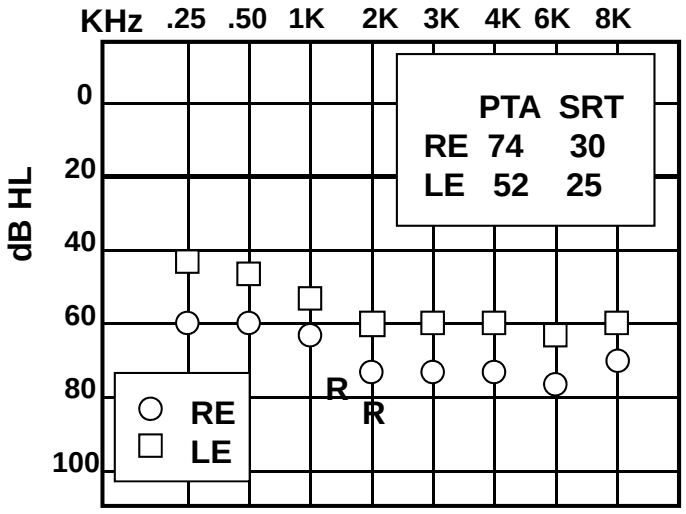
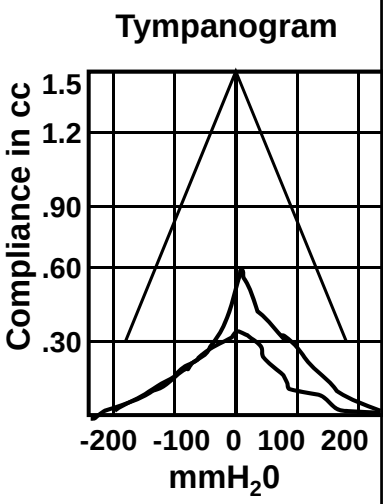
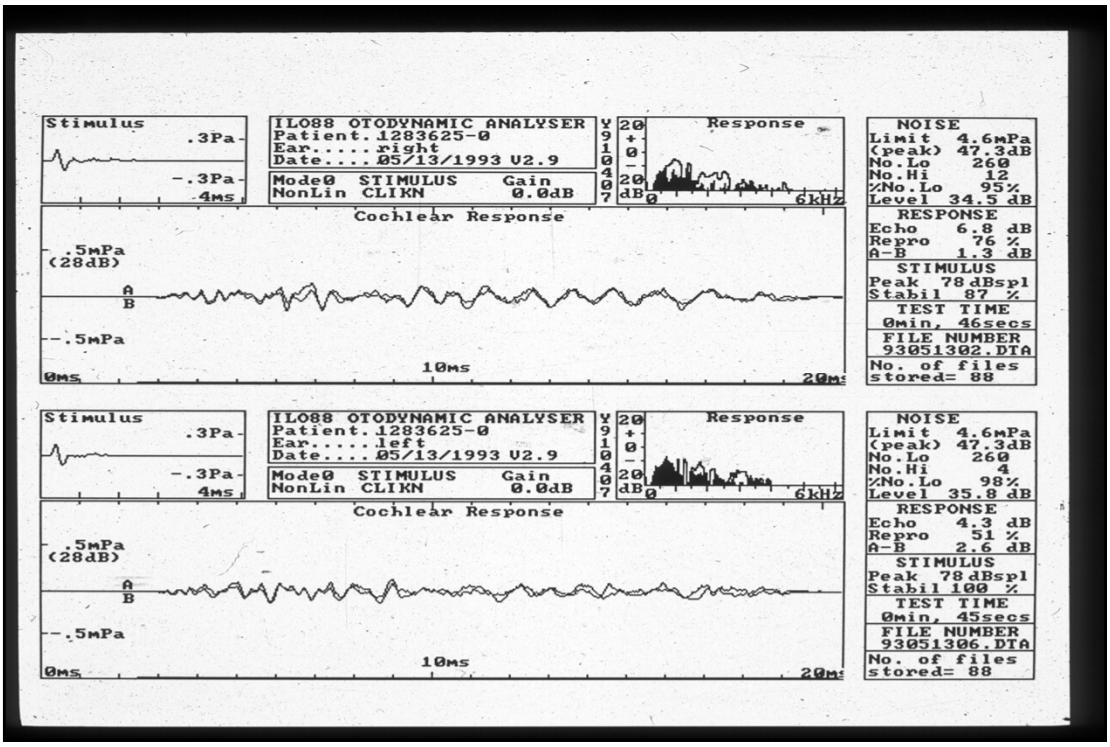
OAEs and False/Exaggerated Hearing Loss: Case Study of a Malingerer (Early 1990s)

- 49 year old male
- Referred for assessment by U.S. Dept. of Labor
- History of noise exposure in work place
- Complained of bilateral hearing loss

Case Study of a Malingerer (Early 1990s): Audiogram #1 (before OAEs)

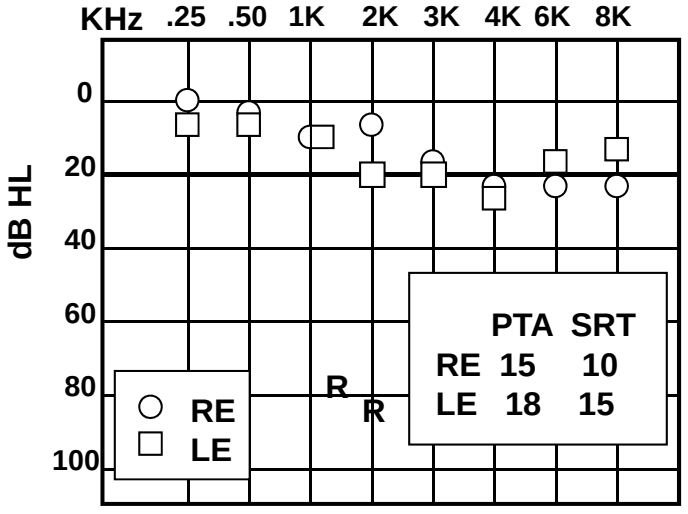




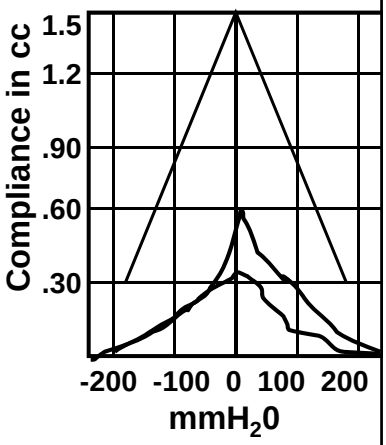


Malingerer: Audiogram #2 (after OAEs)

We should charge for OAE treatment …



Tympanogram



OAEs: Selected Meniere's Disease Literature

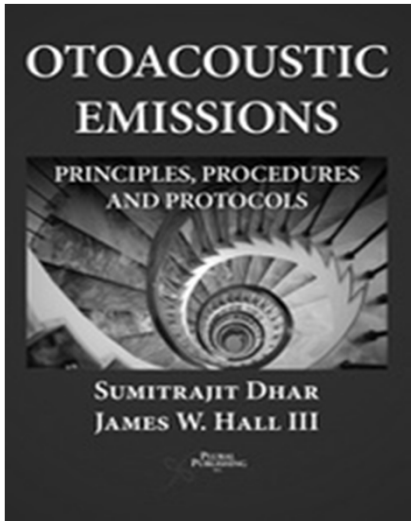
- Magliulo et al. Distortion product otoacoustic emissions and glycerol testing in endolymphatic hydrops. Laryngoscope 111: 102, 2001. *[DPOAEs detect minimal dysfunction in early MD]*
- Fetterman B. Distortion product otoacoustic emissions and cochlear microphonics: relationships in patients with and without endolymphatic hydrops. Laryngoscope 111: 946, 2001. *[18% of hydropic ears had DPOAEs unexpectedly with HTLs > 50 dB HL]*
- Haginomori et al. Spontaneous otoacoustic emissions in humans with endolymphatic hydrops. Laryngoscope 111: 96, 2001. *[SOAEs returned in some ears with gylcerol test]*
- Herschfelder et al. Diagnosis of endolymphatic hydrops using low frequency modulated distortion product otoacoustic emissions. *HNO 53*, 2005 *[The registration of low-frequency modulated DPOAEs is comparable to the generally applied transtympanic electrocochleography in its diagnostic validity. The method is fast and non-invasive and could be applied to monitor the course of the disease]*

OAEs in Monitoring for Ototoxicity in Adults: *Substantial Published Research*

- Knight et al. Early changes in auditory function as a result of platinum chemotherapy: use of extended high-frequency audiometry and evoked distortion product otoacoustic emissions. *J Clinical Oncology 25*, 2007.
  - "Pilot data suggest that EHF thresholds and DPOAEs show ototoxic changes before hearing loss is detected by conventional audiometry."
- Jacob et al. Auditory monitoring in ototoxicity. *Rev Brasilian Otorhinnolaryngol 72, 2006*
  - "For the early detection of auditory lesions induced by ototoxic pharmaceutical drugs, high-frequency audiometry and evoked otoacoustic emissions both allow early identification of hearing disorders before changes are seen in conventional pure-tone audiometry."

Thank You!

Questions?



William James Finn McNeal
(Born April 8, 2015)