Otoacoustic Emissions Overview

James W. Hall III, Ph.D.

Professor
Salus University and University of Hawaii

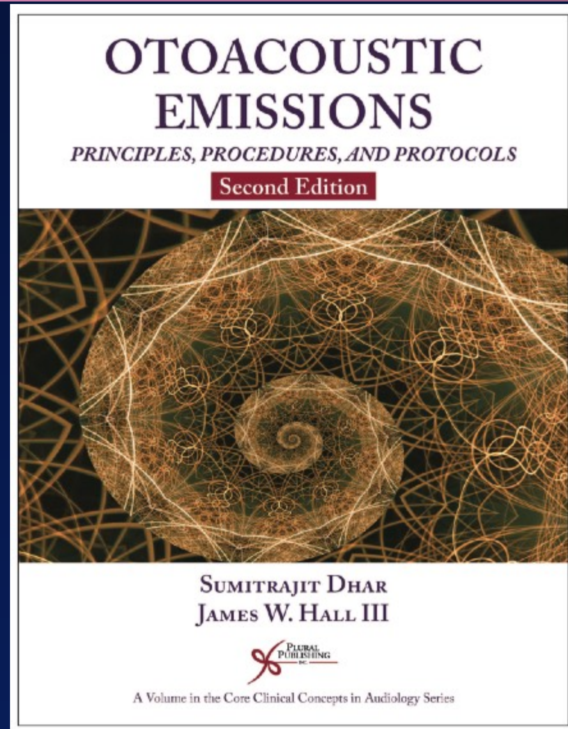
Visiting Professor
American University of Beirut

Extraordinary Professor
University of Pretoria South Africa

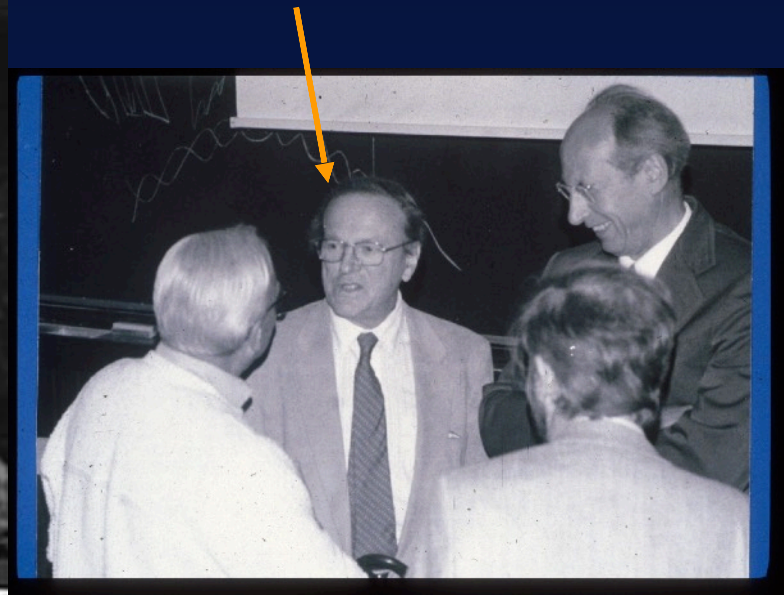
jwhall3phd@gmail.com   *www.audiologyworld.net*

Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- ❑ Brief historical overview
- ❑ Update on anatomy and physiology
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



Historical Perspective:
Thomas Gold … OAE Prophet (1948)



David Kemp, PhD
Discoverer of OAEs in 1970s
From: Hall JW III *Introduction to Audiology Today* (2014). Boston: Pearson Educational

LEADERS AND LUMINARIES

David Kemp

David Kemp is a Professor at the University College London who founded the Ear Institute. Dr. Kemp is known for his discovery and scientific exploration of otoacoustic emissions (OAEs) as well as his invention of practical technologies for their application in screening and diagnosis. A physicist by training, Dr. Kemp gained experience in electronics and audio-frequency signals at London University England in the 1960s while researching extremely low-frequency radio waves. He found his acute hearing useful in analyzing signals and diagnosing instrument faults. Moving into audiology Kemp studied low-level auditory perceptual aberrations experienced by normally hearing subjects, concluding they were due to reflections and distortions inside the cochlea. His findings were totally at variance with contemporary auditory theories but his observations predicted acoustic emissions. Dr. Kemp subsequently recorded otoacoustic emissions. The discovery led to the identification the cochlear amplifier, nonlinear compression, a new clinical tool, and indeed a new industry. You can learn more about Dr. Kemp and this very important test technique by downloading the Story of Otoacoustic Emissions from the Otodynamics website.

Bill Brownell, PhD
"Discoverer of Outer Hair Cell Motility"

Brownell W (1990).
Outer hair cell electromotility and otoacoustic emissions.
***Ear & Hearing, 11*, 82-92**

Current Clinical Application of OAEs
Many Commercially Available Clinical OAE Devices

Current Clinical Application of OAEs:
Large and Still Growing Literature
www.nlm.nih.gov "otoacoustic emissions"

PubMed | otoacoustic emissions

Format: Summary **Sort by**: Most Recent **Per page**: 20

Best matches for otoacoustic emissions:

Children with autism spectrum disorder have reduced **otoacoustic emissions** at the 1 kHz mid-frequency region.
Bennetto L et al. Autism Res. (2017)

Otoacoustic emissions in young adults: Effects of blood group.
Chow KT et al. Hear Res. (2016)

Otoacoustic emissions from ears with **spontaneous** activity behave differently to those without: Stronger responses to tone bursts as well as to clicks.
Jedrzejczak WW et al. PLoS One. (2018)

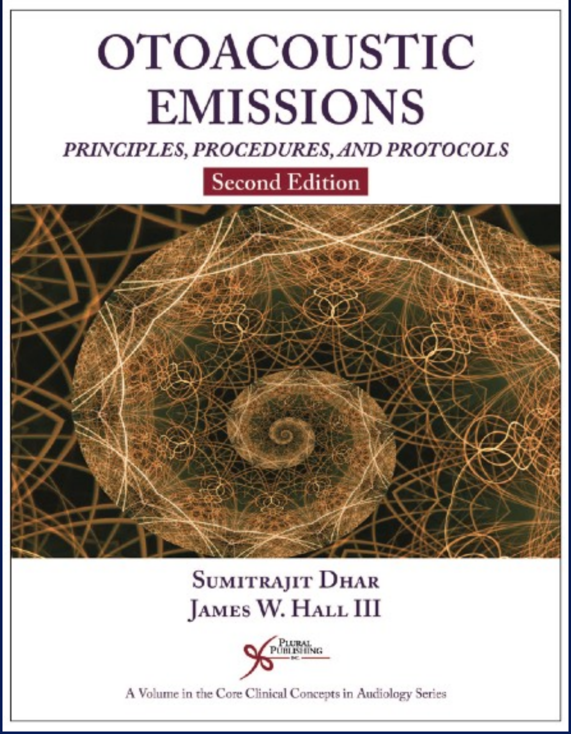
Switch to our new best match sort order

Search results

Items: 1 to 20 of 5341

Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- ❑ Brief historical overview
- ❑ **Update on anatomy and physiology**
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



Otoacoustic Emissions Today: *Overview of Anatomy*
(From Dhar & Hall, 2018)

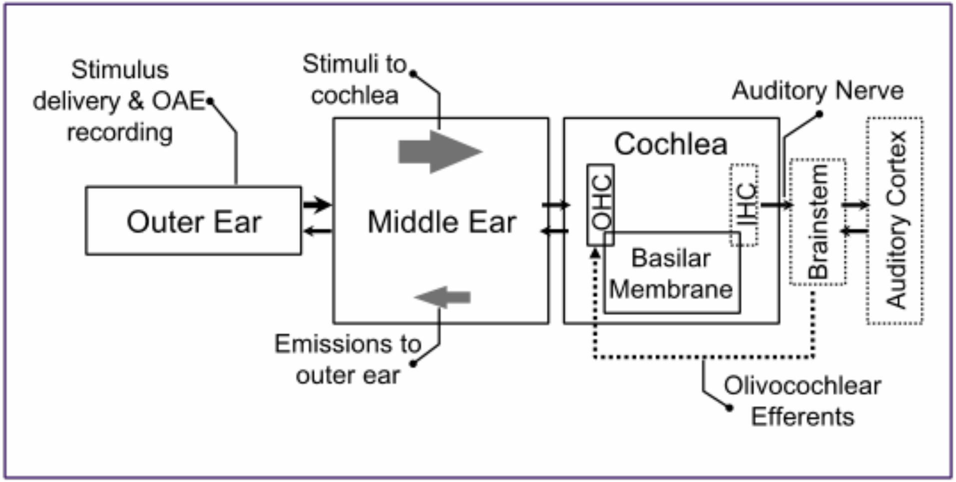
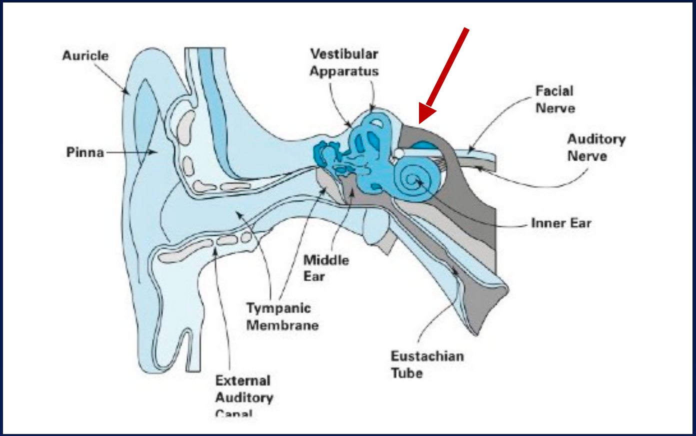


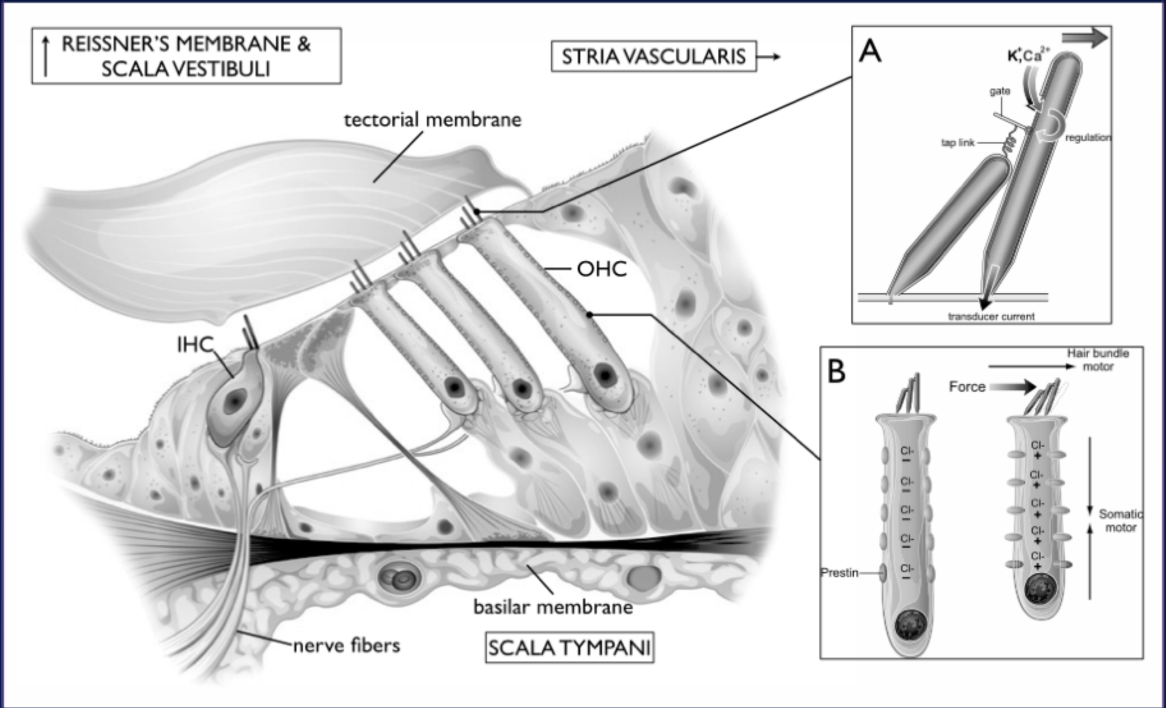
FIGURE 1–4. A simple block schematic of the major regions of the auditory system that influence the measurement of otoacoustic emissions. Note the directional arrows in the middle ear depicting the bidirectional energy transfer through this space. The size of the arrows is representative of the relative magnitudes of the energy traveling into and out of the cochlea. Structures outlined in dashed lines play a secondary role in modulating OAEs.

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 propagation)
- External ear canal
  - Stimulus presentation
  - OAE detection

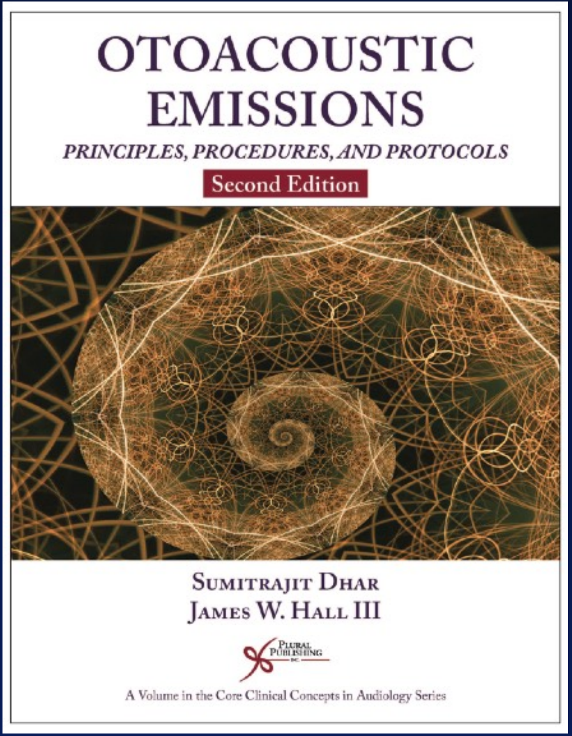


Generation of OAEs: Role of Outer Hair Cells
(From Dhar & Hall, 2018)



Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- ❑ Brief historical overview
- ❑ Update on anatomy and physiology
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



Conventional OAE Taxonomy …Stimulus Based

(From Dhar & Hall, 2018)

Traditional Classification of OAEs

- Spontaneous OAEs
  - No stimulus necessary. Synchronizing stimulus allows for fast recordings.
- Evoked OAEs
  - Transient Evoked (TEOAEs): OAEs recorded using extremely short duration clicks. Broadband spectrum.
  - Distortion Product (DPOAEs): OAEs recorded using two pure tones presented simultaneously.
  - Stimulus Frequency (SFOAEs): OAEs recorded in response to a single tonal stimulus.
  - Other: OAEs can be evoked by other stimuli as well. Examples include amplitude modulated tones, tone bursts, etc.

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]

Reflection Source Emissions
Shera & Guinan (1999). JASA, 105, 782-798

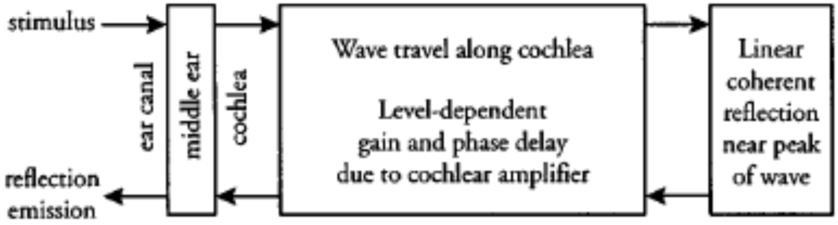


FIG. 11. Simplified conceptual model for the generation of reflection-source emissions. Reflection-source emissions arise from a region of linear coherent reflection near the peak of the traveling-wave envelope. Incident and reflected waves undergo level-dependent gains and phase delays while traveling to, from, and within the scattering reigon. At medium and high stimulus levels, reflection-source emissions therefore exhibit a nonlinear growth with sound level. Note that although they appear separated here for clarity, the regions of coherent reflection and maximal gain overlap within the cochlea. Figure 12 fleshes out this conceptual model (by including phase shifts due to wave propagation) and extends the model to illustrate the mixing of reflection- and distortion-source emissions that occurs during the generation of DPOAEs.

Reflect Source Emissions
(From Dhar & Hall, 2012)

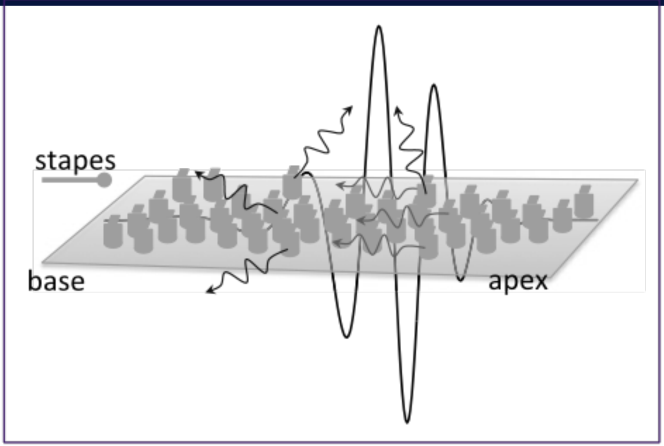
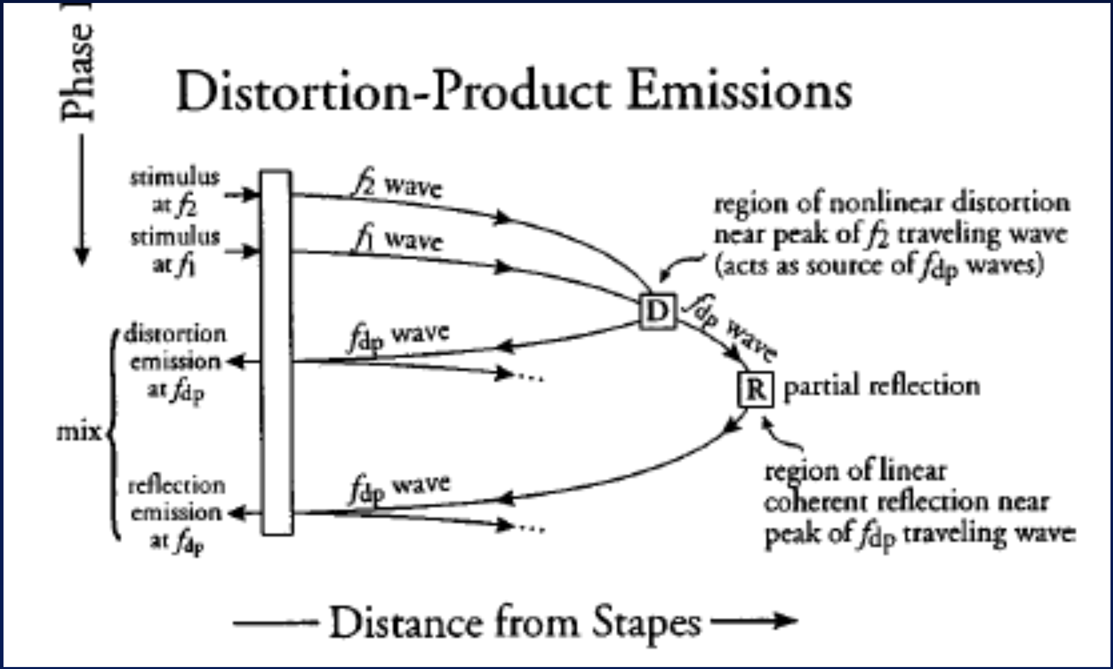


FIGURE 3–5. Schematic of "thought" model of reflections from random perturbations on basilar membrane (following Shera, 2003; Shera & Guinan, 1999). A simplified picture of the cochlear partition is presented with the stapes representing the source of energy input into the cochlea. The traveling wave pattern in the background reminds the reader that the magnitude of vibrations of the cochlear partition increases from base to apex, peaking at the CF region. The silhouettes in the shape of outer hair cells represent random perturbations that act as "reflectors" of this incoming energy. Note that the phase of the individual reflections (*represented by direction of the arrows*) are random. A few reflections from around the CF region happen to be in the same direction (have coherent phase).

Distortion Product Emissions
Shera & Guinan (1999). JASA, 105, 782-798



Distortion Production OAEs: Two Sources
(From Dhar & Hall, 2012)

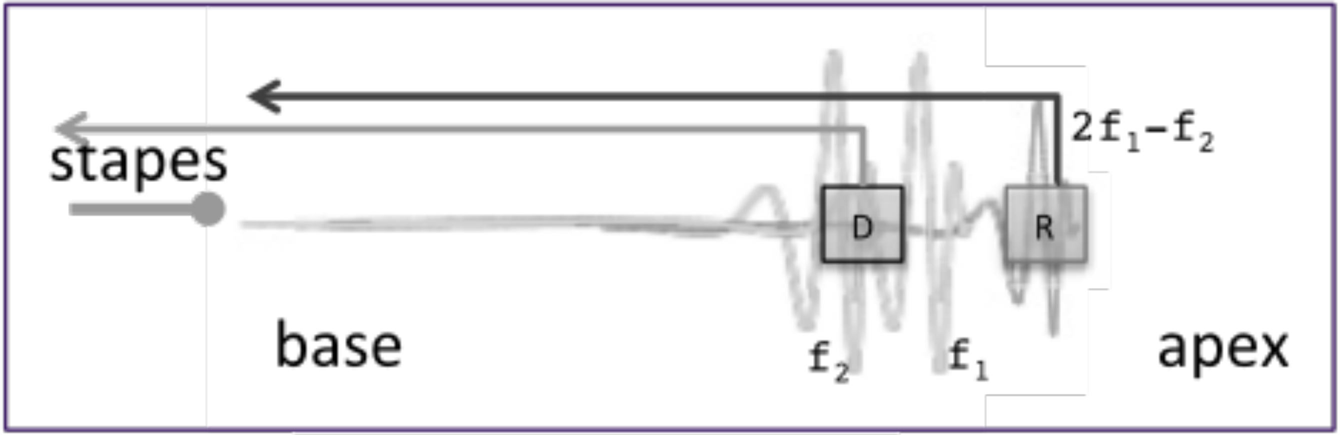
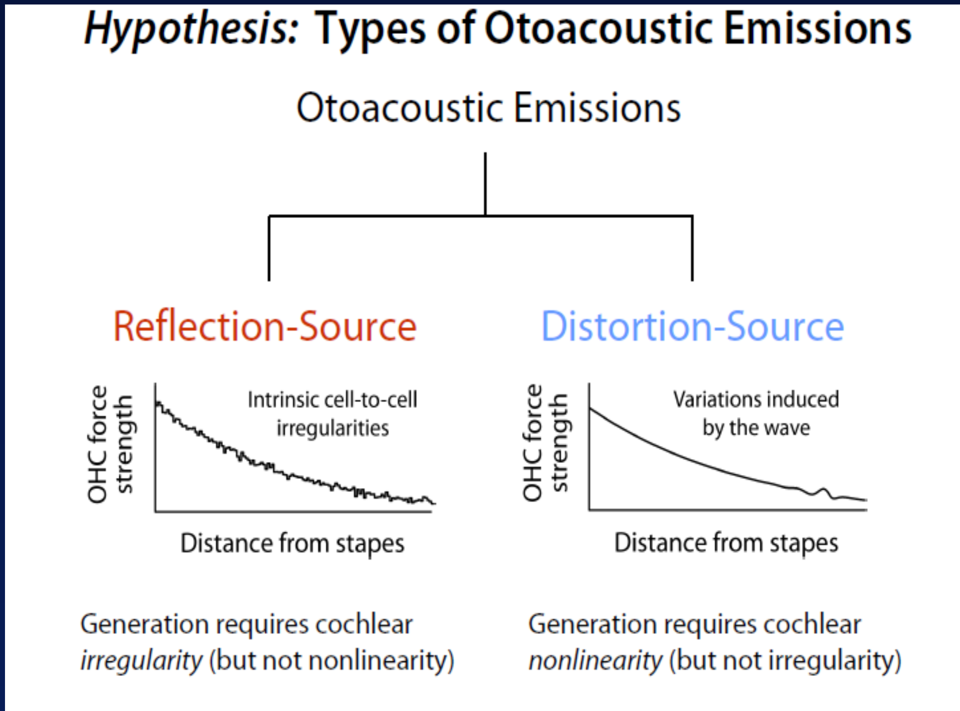


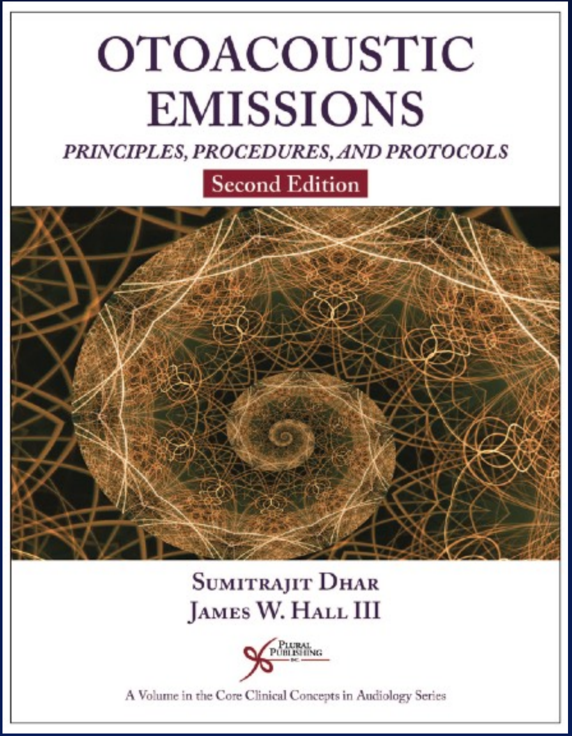
FIGURE 3–7. Schematic of two-component model of DPOAEs. See text for details.

OAE Anatomy, Physiology, and Mechanisms: *Reflection versus Distortion Source*



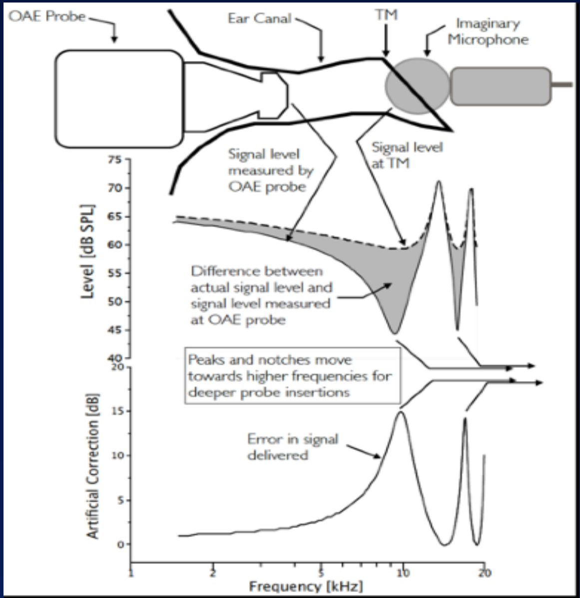
Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- ❑ Brief historical overview
- ❑ Update on anatomy and physiology
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



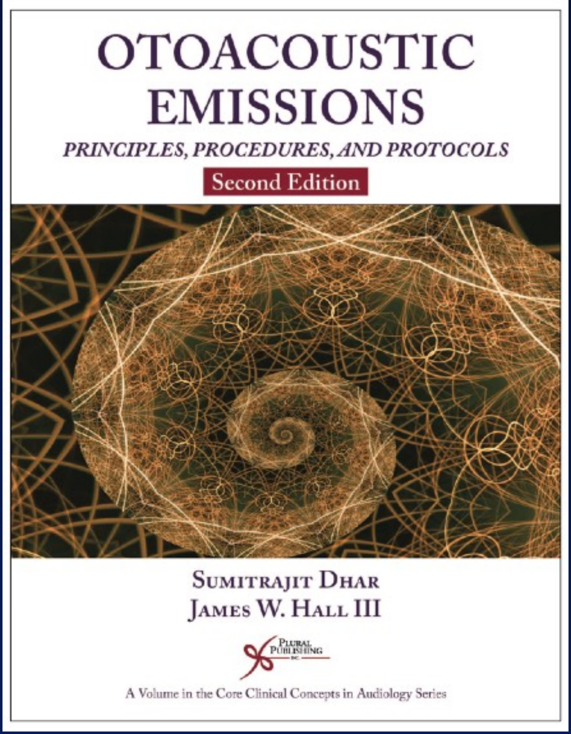
Measurement of Otoacoustic Emissions
Calibration is Important

- Calibrate OAE equipment at the beginning of each clinic day
  - Hard walled cavity is supplied with OAE device
  - Components in OAE probe assembly are delicate
  - Cerumen and debris can occlude tiny ports



Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- ❑ Brief historical overview
- ❑ Update on anatomy and physiology
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



Guidelines for Measurement of Otoacoustic Emissions in Clinical Audiology

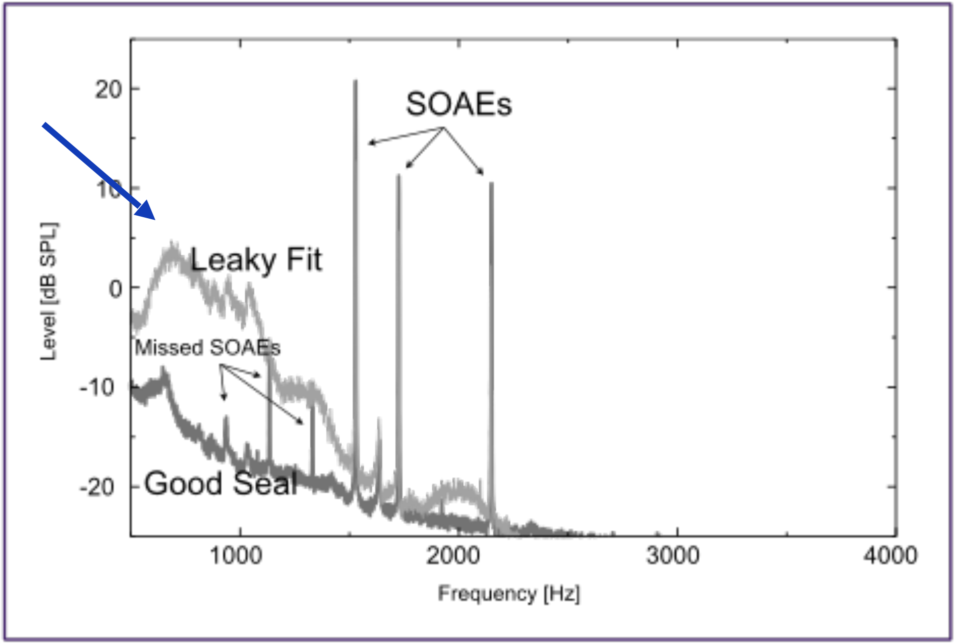
- Perform otoscopic inspection before OAE recording
- OAE is recorded in the external ear canal
- OAE recording may be compromised by ear canal:
    - Cerumen
    - Vernix
    - Debris
    - Foreign objects

Guidelines for Measurement of Otoacoustic Emissions in Clinical Audiology

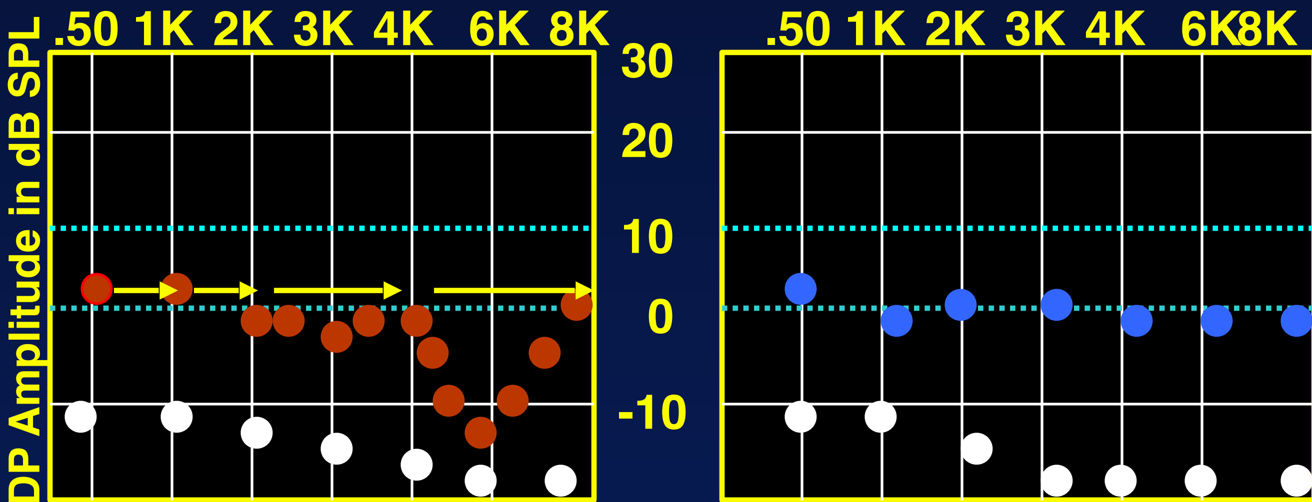
- Two sources of noise
  - Acoustical
  - Physiological
- Techniques for minimizing noise in the EAC
  - Reduce ambient noise
  - Tight probe fit
  - Deep probe insertion
  - Locate patient away from OAE equipment
  - Modify test protocol

Secure and Deep Probe Fit is Important for Valid Measurement of OAEs

(From Dhar & Hall, 2018)



OAEs are Highly Frequency Specific: Probe Inter-Octave Cochlear Function with DPOAEs

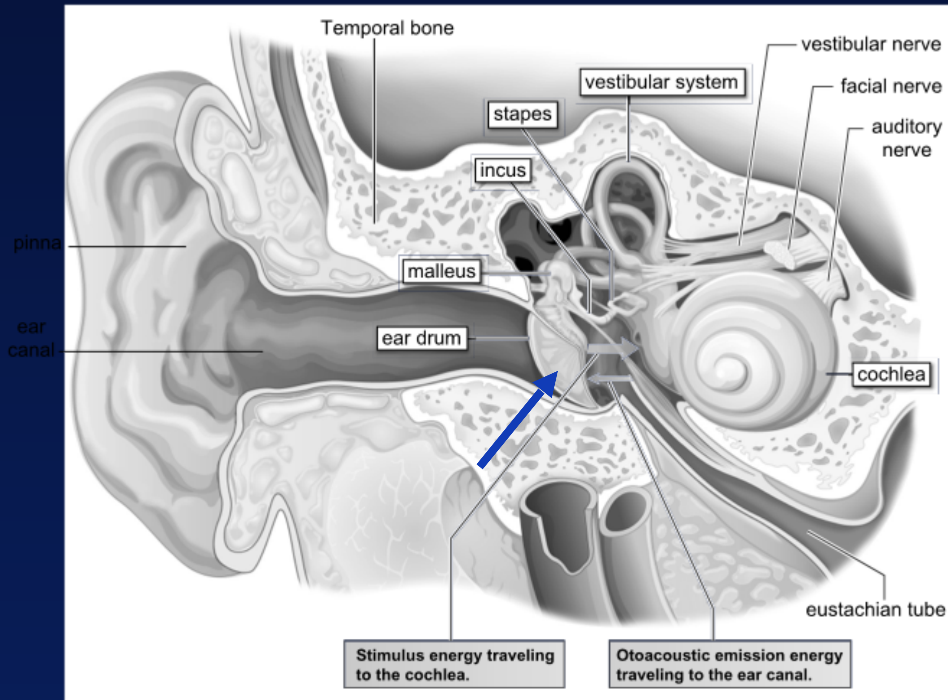


DPgram (f_2)
Right Ear

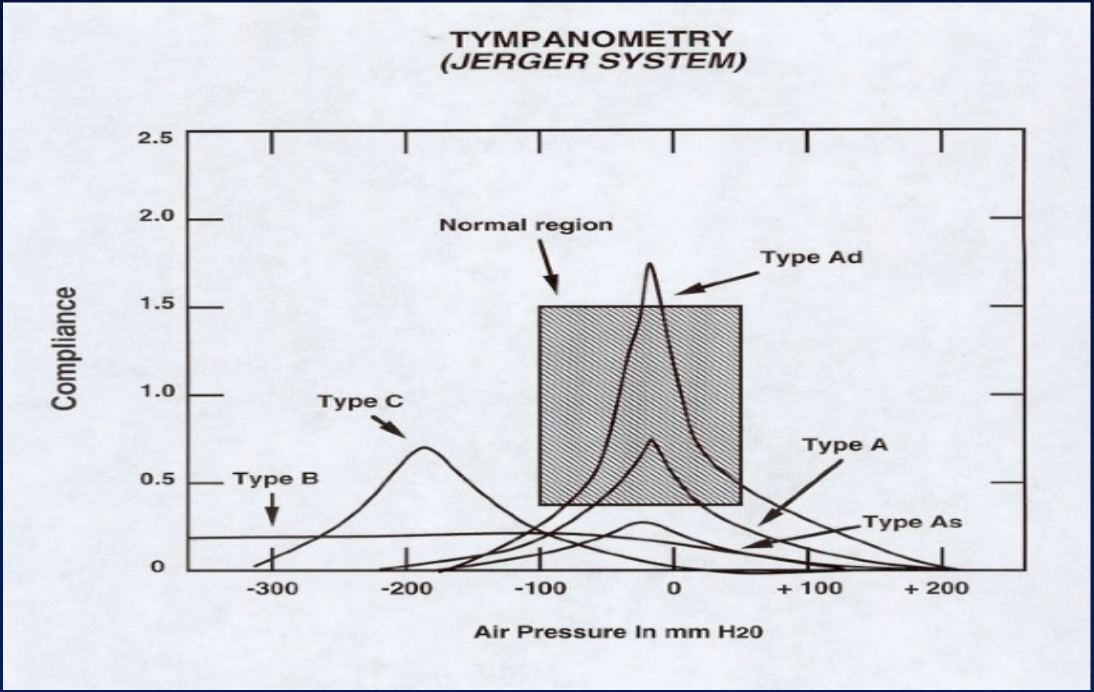
Normal region
DP
amplitude

DPgram (f_2)
Left Ear

The Two Way Middle Ear Link in Recording OAEs



Acoustic Immittance Measurements and OAEs: *Perform Tympanometry*



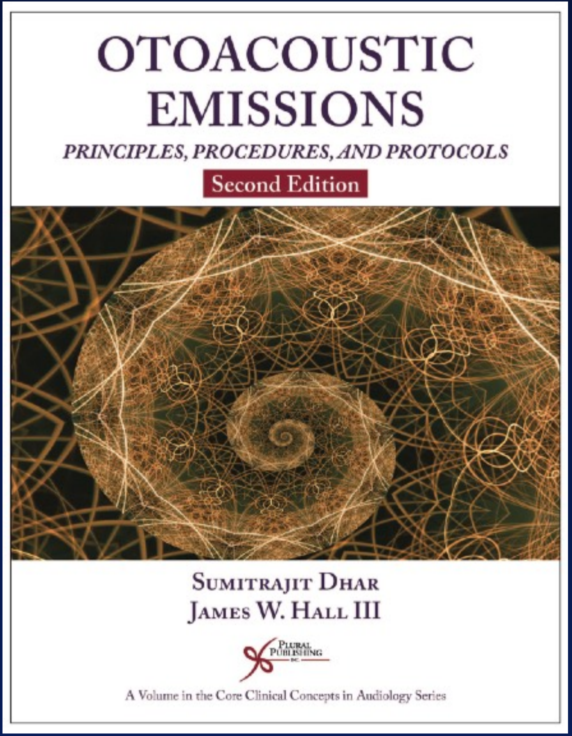
Diagnosis of Hearing Loss: Protocol for Confirmation of Hearing Loss in Infants and Toddlers (0 to 6 months)

Year 2007 JCIH Position Statement

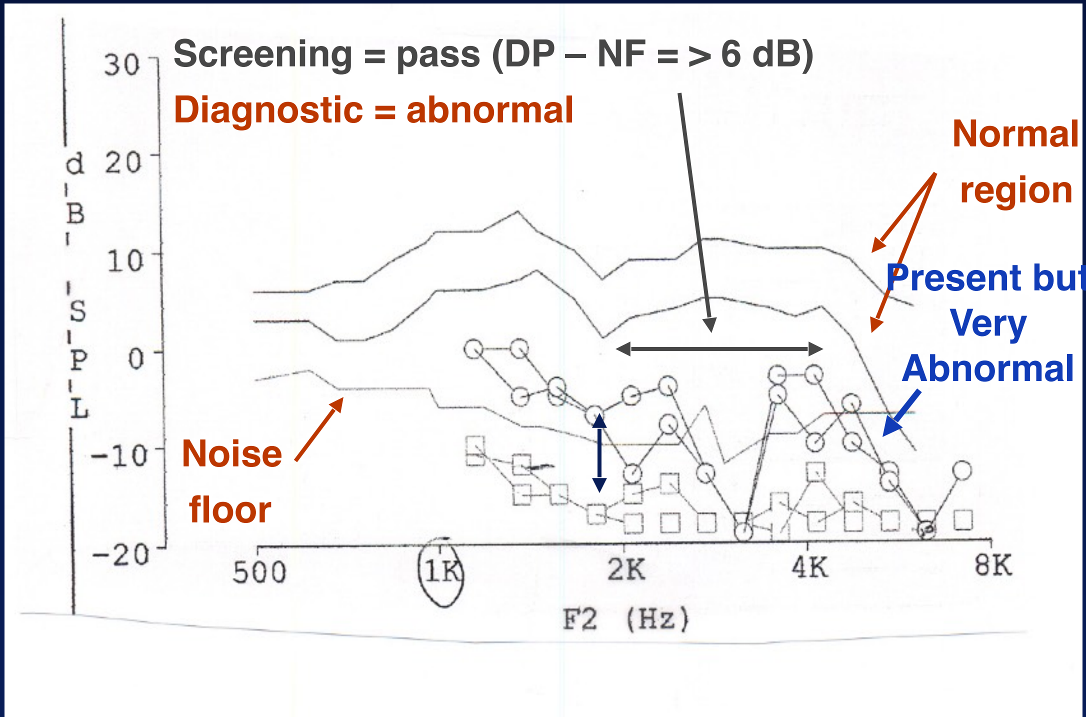
- Child and family history
- Otoacoustic emissions
- ABR during initial evaluation to confirm type, degree & configuration of hearing loss
- Acoustic immittance measures (including acoustic reflexes) *using high frequency (1000 Hz) probe tone*
- Supplemental procedures (insufficient evidence to use of 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)*
- Parental report of auditory & visual behaviors
- Screening of infant's communication milestones

Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

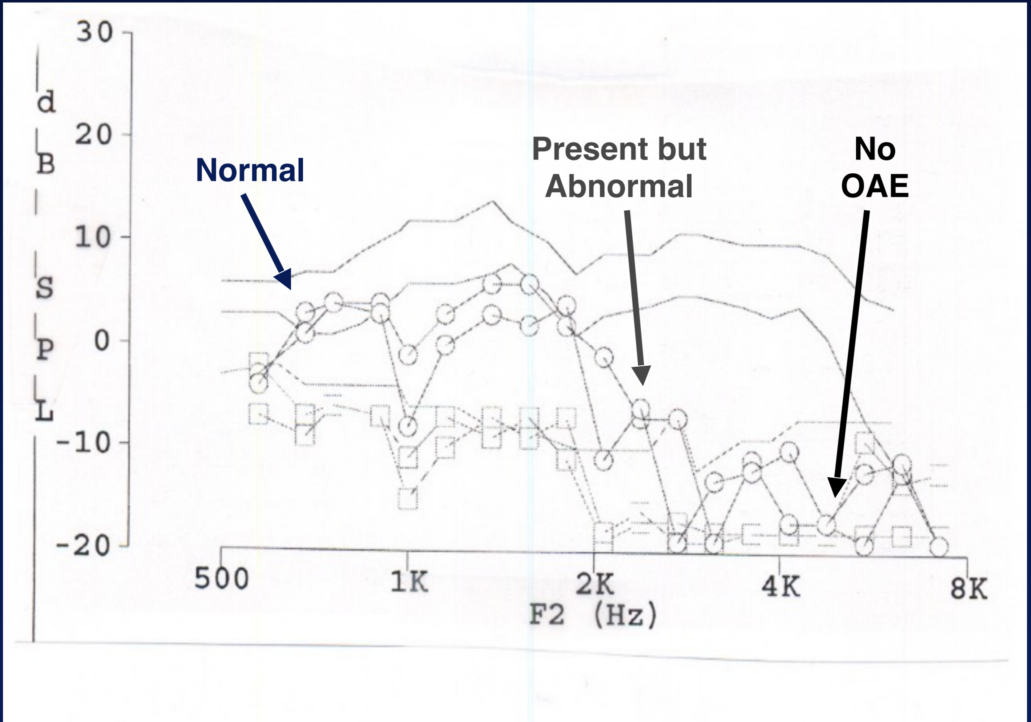
- ❑ Brief historical overview
- ❑ Update on anatomy and physiology
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



OAE Analysis:
Not "Present" versus "Absent" but …
1. Normal, 2. Present but Abnormal, or 3. Absent

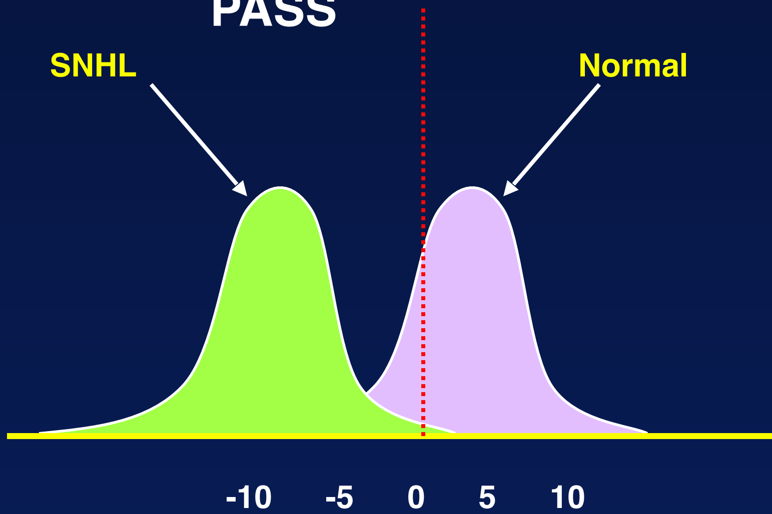


OAE Analysis:
Not "Present" versus "Absent" but …
1. Normal, 2. Present but Abnormal, or 3. Absent



OAE Analysis for Preschool and School Age Hearing Screening: *“Pass” = DP amplitude > 0 dB SPL*

REFER versus PASS



DP Amplitude (dB SPL)

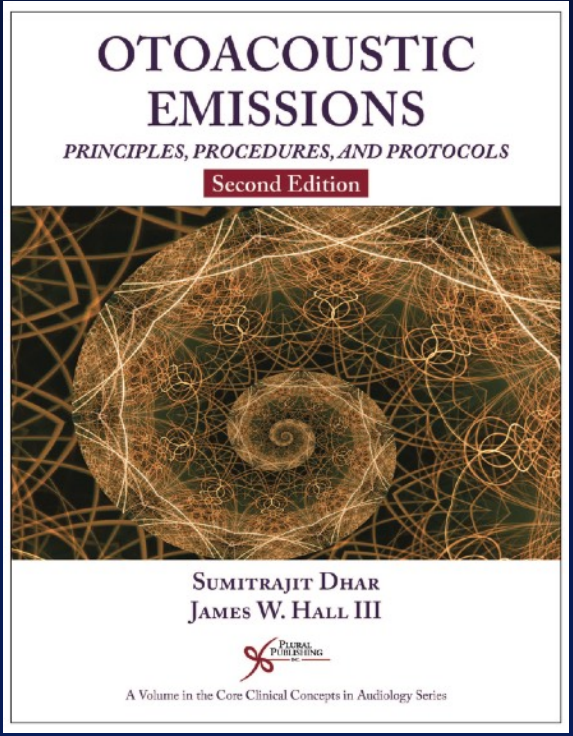
(Data from Gorga, Stover & Neely, 1996)

Review …
General Steps in Analysis of OAE Findings

- Verify adequately low noise floor (< 90% normal limits)
- Verify repeatability of TEOAE or DPOAE amplitude
- Perform analysis at *all* test frequencies
- Three possible outcomes (for any test frequency)
  - Normal
    - ✓ OAE amplitude – NF > 6 dB
    - ✓ OAE amplitude within normal limits (> ~ 0 dB SPL)
  - Present but abnormal
    - ✓ OAE amplitude – NF > 6 dB
    - ✓ OAE amplitude below normal limits (< ~ 0 dB SPL)
  - Absent
    - ✓ OAE amplitude – NF ≤ 6 dB

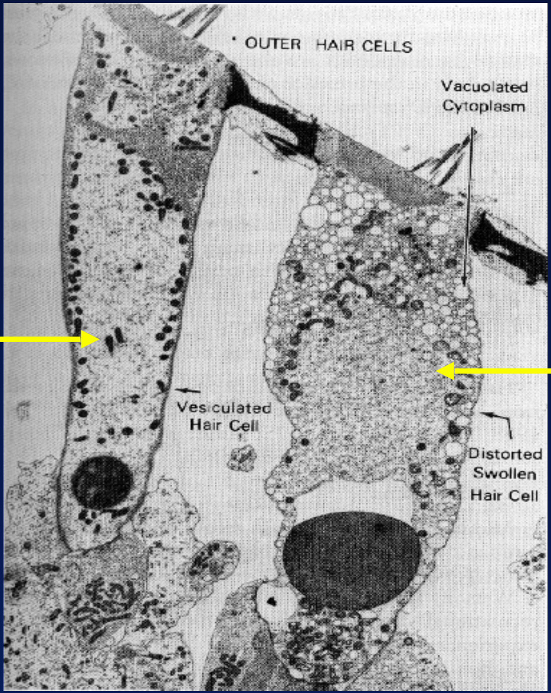
Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- ❑ Brief historical overview
- ❑ Update on anatomy and physiology
- ❑ New classification of OAEs
- ❑ Calibration is important
- ❑ Practical protocol for measurement
- ❑ Simple guidelines for analysis
- ❑ Clinical applications in children
- ❑ Clinical applications in adults
- ❑ Conclusions



OAEs in Early Detection of Outer Hair Cell Dysfunction:
Rationale Underlying Many Clinical Applications
(Remember: OAEs may be abnormal with normal audiogram)

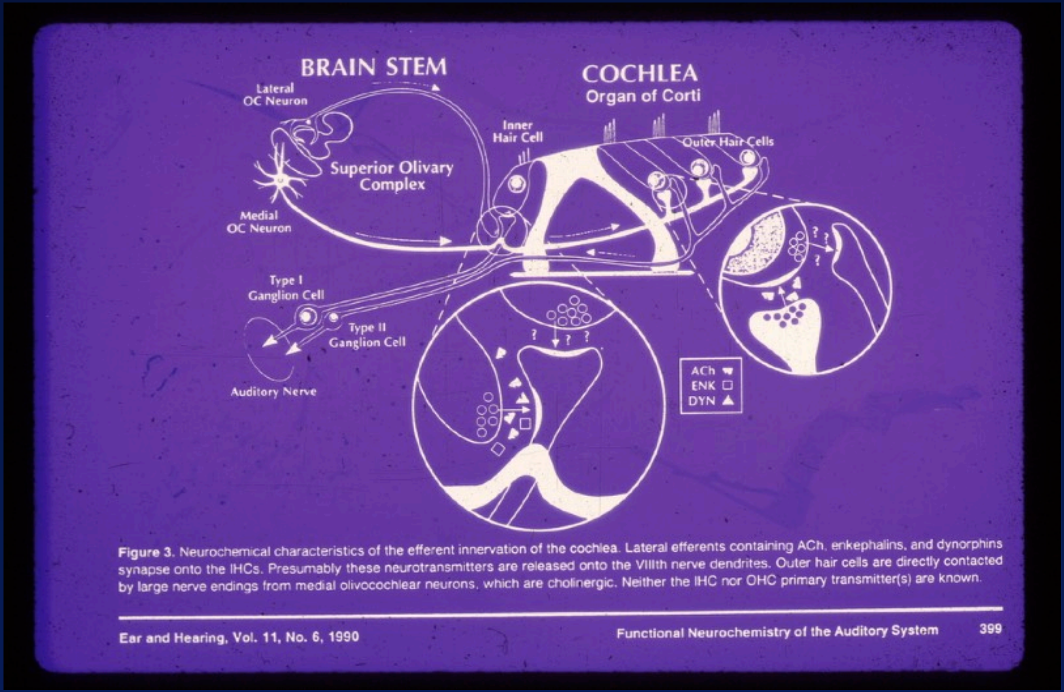
Normal OHC (OAEs)



Abnormal OHC (OAEs)

OAEs and Auditory Function: Generation of OAEs is "Pre-Neural"

(Very Important for Identification of ANSD)



The Cross-Check Principle is Important in Diagnostic Audiology with Children and Adults

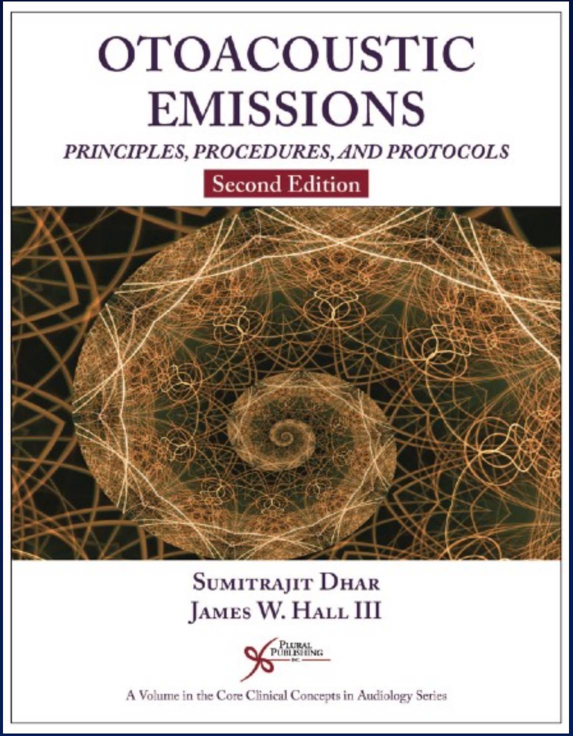
(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)

Analysis of Otoacoustic Emissions (OAEs)
Importance of Crosscheck Principle

- Apply the "crosscheck principle in analysis of OAE findings,
- Critically compare OAE findings, after close and careful analysis, with findings for
  - Aural immittance measures
    - ✓ Tympanometry
    - ✓ Acoustic reflexes
  - Wideband reflectance/absorbance
  - Pure tone audiometry thresholds
  - Auditory brainstem response (ABR) findings
  - Auditory processing test results

Las emisiones otoacústicas y su aplicación en el diagnóstico y manejo de las patologías otológicas

- Brief historical overview
- Update on anatomy and physiology
- New classification of OAEs
- Calibration is important
- Practical protocol for measurement
- Simple guidelines for analysis
- Clinical applications in children
- Clinical applications in adults
- Conclusions



Clinical Applications of Otoacoustic Emissions
Advantages and Disadvantages

Dhar & Hall (2018) OAE Textbook Table 7.1

	Advantages	Disadvantages
Otoacoustic Emissions	• No behavioral response required • Appropriate for all ages • Preneural auditory response • Ear-specific information • Brief test time • Frequency-specific information • High site specificity (outer hair cells) • Does not require sound-treated room	• Not a true test of hearing • Does not assess neural pathways • Invalidated by middle ear dysfunction • Limited value in estimating hearing level

Clinical Applications of OAEs in Children

- Newborn hearing screening (> 880 peer reviewed publications)
- Preschool hearing screening
- Diagnosis of auditory dysfunction
- Identification of ANSD
- Ototoxicity monitoring
- Detection of false hearing loss
- Evaluation of hyperacusis
- Risk for music induced HL

Clinical Applications of OAEs in Children

- Newborn hearing screening (> 750 peer reviewed publications)
- Preschool hearing screening
- Diagnosis of auditory dysfunction
- Identification of ANSD
- Ototoxicity monitoring
- Detection of false hearing loss
- Evaluation of hyperacusis
- Risk for music induced HL

Positive Clinical Experiences with Hearing Screening in Pre-School Populations

(Head Start Programs)

Pediatric Applications of Otoacoustic Emissions: Pre-School Hearing Screening

(Send me an email to request a reprint)

JEHDI
The Journal of Early Hearing Detection and Intervention
NCHAM National Center for Hearing Assessment and Management Utah State University

2016; 1(1): 2-12

Effective And Efficient Pre-School Hearing Screening: Essential For Successful Early Hearing Detection And Intervention (EHDI)

James W. Hall III, PhD[1,2,3]

[1]Osborne College of Audiology, Salus University

[2]Department of Communication Sciences and Disorders, University of Hawaii

[3]Department of Audiology and Speech Pathology, University of Pretoria

Abstract

An unacceptable number of infants failing newborn hearing screening do not receive necessary follow-up services in a timely fashion as a result of loss to follow-up problems. In addition, a high proportion of children who pass newborn hearing screening later acquire hearing loss during the preschool years. Systematic pre-school hearing screening offers a logical strategy for detection of hearing loss among these children.

Pure tone hearing screening of older preschool children has questionable test performance and validity. And, there is consensus that a behavioral technique is not feasible for routine hearing screening of younger preschool children. Otoacoustic emissions (OAEs) offer the most promising option for systematic hearing screening of the preschool population. Multiple advantages of OAEs are cited in support of their role in preschool hearing screening. This paper summarizes a new evidence-based and clinically feasible strategy for effective and efficient preschool hearing screening that relies on objective auditory tests.

Acronyms: AAA = American Academy of Audiology; ABR = auditory brainstem response; AABR = automated auditory brainstem response; ASHA = American Speech-Language-Hearing Association; ANSD = auditory neuropathy spectrum disorder; BBN = broadband noise; CDC = Centers for Disease Control and Prevention; DHH = deaf or hard of hearing; DP = distortion product; DPOAE = distortion product optoacoustic emissions; EHDI = Early Hearing Loss Detection and Intervention; HL = hearing level; LTFU = loss to follow-up; NIH = National Institutes of Health; OAE = otoacoustic emissions; SPL = sound pressure level; UNHS = universal newborn hearing screening

Rationale For Pre-School Hearing Screening

Serious Loss to Follow-Up Problems

Clinical Applications of OAEs in Children

- Newborn hearing screening (> 750 peer reviewed publications)
- Preschool hearing screening
- Diagnosis of auditory dysfunction
- Identification of ANSD
- Ototoxicity monitoring
- Detection of false hearing loss
- Evaluation of hyperacusis
- Risk for music induced HL

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN

POLICY STATEMENT

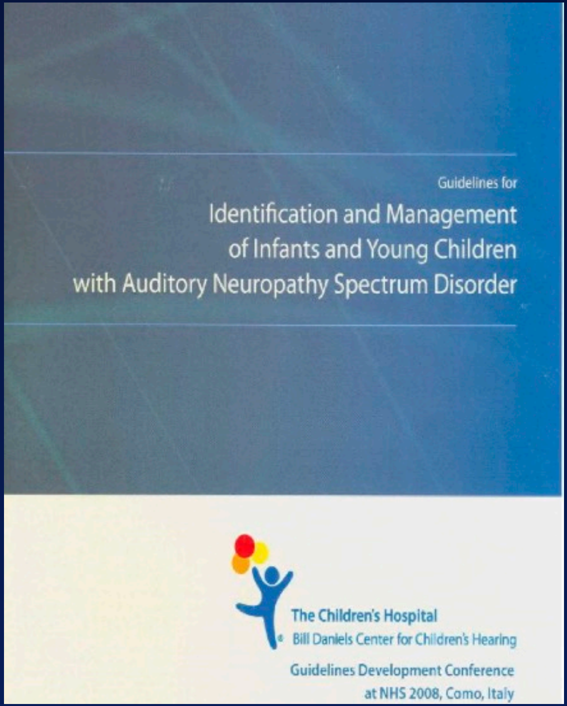
Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

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 and configuration of hearing loss
- ❑ Immittance measures *using high frequency (1000 Hz) probe tone*
- ❑ Supplemental procedures
  - Auditory steady state response (ASSR)
  - Acoustic middle ear reflexes for infants < 4 months
  - Broad band reflectance
- ❑ Behavioral response audiometry *(if feasible)*
- ❑ Parental report of auditory & visual behaviors
- ❑ Screening of infant's communication milestones

Clinical Applications of OAEs in Children

- Newborn hearing screening (> 750 peer reviewed publications)
- Preschool hearing screening
- Diagnosis of auditory dysfunction
- Identification of ANSD
- Ototoxicity monitoring
- Detection of false hearing loss
- Evaluation of hyperacusis
- Risk for music induced HL

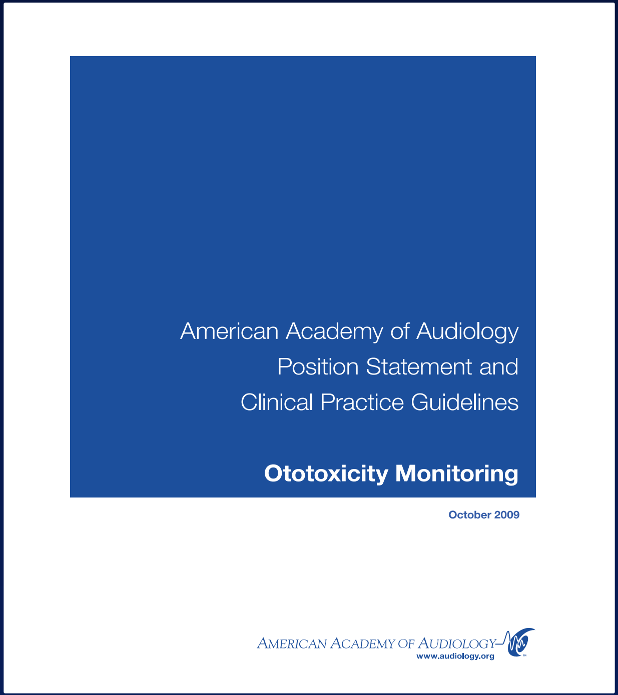


Identification and Diagnosis of Auditory Neuropathy Spectrum Disorder (ANSD): Minimal Test Battery (2008 ANSD Guidelines)

- 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)

Clinical Applications of OAEs in Children

- Newborn hearing screening (> 750 peer reviewed publications)
- Preschool hearing screening
- Diagnosis of auditory dysfunction
- Identification of ANSD
- Ototoxicity monitoring
- Detection of false hearing loss
- Evaluation of hyperacusis
- Risk for music induced HL



American Academy of Audiology
Position Statement and
Clinical Practice Guidelines

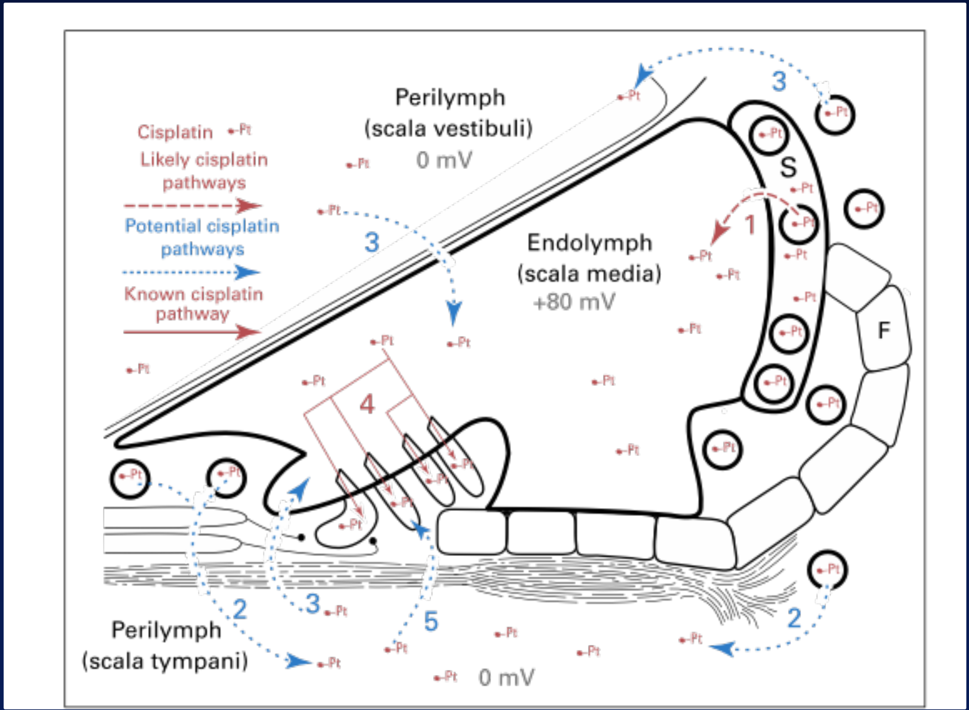
Ototoxicity Monitoring

October 2009

AMERICAN ACADEMY OF AUDIOLOGY
www.audiology.org

Mechanisms of Ototoxicity (Cisplatin)

From Brock et al. Journal of Clinical Oncology 30, 2012



Clinical Applications of OAEs in Children

- Newborn hearing screening (> 750 peer reviewed publications)
- Preschool hearing screening
- Diagnosis of auditory dysfunction
- Identification of ANSD
- Ototoxicity monitoring
- Detection of false hearing loss
- Evaluation of hyperacusis
- Risk for music induced HL

Strong Rationale for Detection and Diagnosis of False Hearing Loss in Children with OAEs

(Dhar & Hall, 2918, Table 7.5)

Strengths	Weaknesses
• Do not require a behavioral response from the patient • Results are not influenced by motivation • Results are not influenced by cognitive status • Results generally are not influenced by state of arousal • Measurements can be made with patient sedated or anesthetized • Results are not influenced by the patient's native language • Patient is not required to follow detailed verbal instructions • Results not influenced by motor status • High degree of sensitivity to peripheral (outer hair cell) auditory dysfunction • Site-specific information on auditory dysfunction • Valid measures are possible from infants and young children • Reasonable test time	• Do not measure "hearing" • Abnormal finding does not invariably indicate hearing loss • Single measure generally provides limited information on hearing status • No information on speech perception or understanding

Clinical Applications of OAEs in Children

More Applications and Populations in Chapter 7

7

OAEs and Cochlear Pathophysiology: Children

INTRODUCTION

Crosscheck Principle Revisited and Revised

gained by incorporating OAEs into the test battery. Application of the crosscheck principle also, in some cases, involves additional objective test procedures, such as electrocochleography (ECochG), auditory steady-state response (ASSR), and cortical auditory evoked responses. Readers interested in more information on this important clini-

Clinical Applications of OAEs in Adults

- Industrial hearing screening
- Risk for noise or music induced auditory dysfunction
- Tinnitus evaluation and counseling
- Ototoxicity monitoring
- False or exaggerated hearing loss
- Cochlear vs. retrocochlear diagnosis
- Meniere's disease
- Hidden hearing loss
- Monitoring intracranial pressure in concussion injury

Clinical Applications of OAEs in Adults

More Applications and Populations in Chapter 8

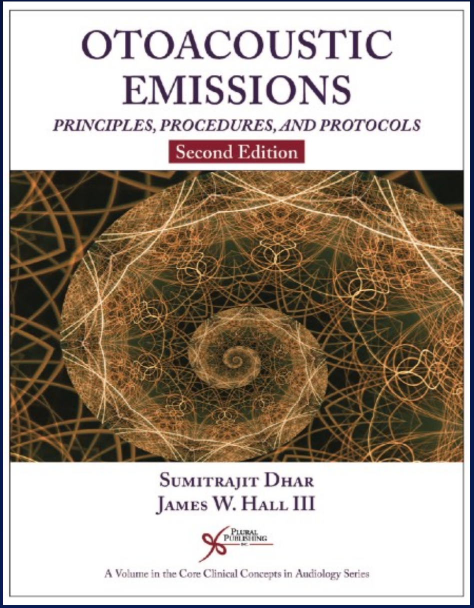
8

OAEs and Cochlear Pathophysiology: Adults

INTRODUCTION

Otoacoustic emissions are not just for pediatric patients. The review in the previous chapter unusual or rare disorder or disease, but more typically results from independent investigations are reported in many articles for patients with commonly encountered disorders or diseases, such as noise-induced hearing loss, ototoxicity, tinnitus, or systemic diseases affecting the auditory system.

- Conclusions
  - OAEs are a highly sensitive measure of cochlear (outer hair cell function) … more sensitive than the audiogram
  - Normal OAEs = amplitude > 0 dB SPL
  - Always rule out middle ear dysfunction in patients with abnormal OAEs
  - OAEs must be included in diagnostic test battery for children
  - There are important clinical applications of OAEs in adults



Plural Publishing

2018