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CONTINUED

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

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CONTINUED

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

Learner Outcomes: *As a result of this Continuing Education Activity, participants will be able to …*

1)List 4 common errors or deficiencies in the clinical measurement of OAEs

2)List 4 common errors or deficiencies in the analysis of OAEs

3)Identify 3 strategies for minimizing errors in OAE measurement and analysis

CONTINUED

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

- Introduction and historical perspective (0 – 5 minutes)
- Six common errors in recording OAEs (6 – 20 minutes)
- Six common errors in analysis of OAEs (21 – 35 minutes)
- Techniques and strategies for avoiding common errors in measurement and analysis of OAEs (36 – 55 minutes)
- Questions and answers (56 – 60 minutes)

5

Historical Perspective: Thomas Gold … OAE Prophet (1948)

6

OAE Historical Perspective: Classic Quote from Yesteryear by Thomas Gold

"I had discussed at length in 1948 with von Bekesy at Harvard that the observations he made on the dead cochlea were unrepresentative. But he wouldn't have that!"

"It is shown that the assumption of a 'passive' cochlea, where the elements are brought into mechanical oscillation solely by means of the incident sound, is not tenable."

" … the nerve ending abstracts much energy from a mechanical resonator."

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.

Discovery of OAEs by David Kemp

(Kemp DT. Stimulated acoustic emissions from within the human auditory system. *JASA 64,* 1978.)

"A new auditory phenomenon has been identified in the acoustic impulse of the human ear…

This component of the response appears to have its origin in some nonlinear mechanism probably located in the cochlea, responding mechanically to auditory stimulation, and dependent upon the normal functioning of the cochlear transduction process…

It is tempting to suggest that one of the functions of the outer hair cell population is the generation of this mechanical energy."

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

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

Examples of Some Current Clinical Practice Guidelines with Recommendations for OAE Measurement

- 2007 Joint Committee on Infant Hearing (JCIH) Position Statement
- 2008 Guidelines on Identification, Diagnosis, and Management of Auditory Neuropathy Spectrum Disorder in Infants and Young Children
- 2010 American Academy of Audiology Clinical Practice Guidelines: Diagnosis, Treatment, and Management of Children and Adults with Central Auditory Processing Disorders
- 2010 American Academy of Audiology Clinical Practice Guidelines: Childhood Hearing Screening
- 2012 American Academy of Audiology: Audiologic Guidelines for the Assessment of Hearing in Infants and Young Children

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

- OAEs are important in clinical audiology as evidence by:
  - Inclusion in many clinical practice guidelines
  - Clinical (FDA-approved) devices from multiple manufacturers
    - Three CPD codes
      - 92558: Screening with automated pass/fail approach
      - 92587: Limited evaluation with 3-6 frequencies
      - 92588: Comprehensive diagnostic evaluation (> 12 frequencies)
  - Research findings in > 5000 peer reviewed journal articles
  - Many clinical applications in children and adults
  - Textbooks devoted to the topic

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)
Many Commercially Available Clinical OAE Devices



Common Errors in Measurement and Analysis 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:

Efferent inhibition of **otoacoustic emissions** in preterm neonates.
Carvallo RM et al. Braz J Otorhinolaryngol. (2015)

Detection of **otoacoustic emissions** in chinchilla when the middle ear contains amniotic fluid.
Akinpelu OV et al. Laryngoscope. (2015)

An active oscillator model describes the statistics of **spontaneous otoacoustic emissions**.
Fruth F et al. Biophys J. (2014)

Switch to our new best match sort order

Search results

Items: 1 to 20 of 5047

1. Universal Hearing Screening in Newborns Using **Otoacoustic Emissions** and Brainstem Evoked Response in Eastern Uttar Pradesh.
Kumar A, Gupta SC, Sinha VR.
Indian J Otolaryngol Head Neck Surg. 2017 Sep;69(3):296-299. doi: 10.1007/s12070-017-1081-x. Epub 2017 Feb 3.
PMID: 28929058

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)
Evidence-Based Clinical Applications of OAEs

- Pediatric Applications
  - Newborn hearing screening
  - Preschool hearing screening
  - Diagnosis of auditory dysfunction
    - Sensitivity to OHC dysfunction
    - Site of dysfunction
  - Identification of ANSD
  - Ototoxicity monitoring
  - Detection of false hearing loss
  - Evaluation of hyperacusis
  - Risk for music induced HL

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)
Evidence-Based Clinical Applications of OAEs

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

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

- Introduction and historical perspective (0 – 5 minutes)
- Six common errors in recording OAEs (6 – 20 minutes)
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- Techniques and strategies for avoiding common errors in measurement and analysis of OAEs (36 – 55 minutes)
- Questions and answers (56 – 60 minutes)

Rationale for Many Evidence-Based Clinical Applications of OAEs in Children and Adults

- General Advantages of OAEs
  - 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

Common Errors in Measurement and Analysis of Otoacoustic Emissions *Common Error in Recording #1*

- Failure to record OAEs with all pediatric patients
  - At least initial diagnostic audiological assessment
  - Any child at risk for hearing loss, e.g.
    - Risk factor for delayed onset/progressive hearing loss
    - Speech and language delay
    - Sound (music) exposure
- Failure to record OAEs in most adult patients
  - Faulty assumption that audiogram is a sensitive and specific measure of auditory function
  - Not aware of multiple evidence-based clinical applications in adults

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Common Errors in Measurement and Analysis of Otoacoustic Emissions *Common Error in Recording #2*

- Under-use of OAEs in clinical audiology, i.e., application of OAE as a hearing screening tool in diagnostic audiological assessment
- Limited and inadequate recording of DPOAEs
  - Without replication of DPgrams
  - With limited number of frequencies per octave (CPT Code 92587: Limited evaluation with 3-6 frequencies)
  - With one intensity paradigm (e.g., L1 = 65 dB; L2 = 55 dB)
- Not recording both TEOAEs and DPOAEs

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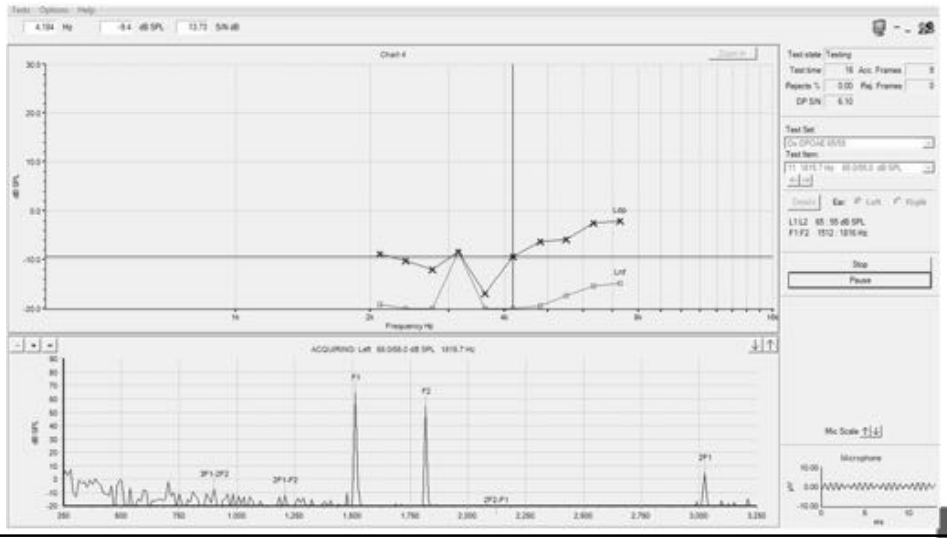
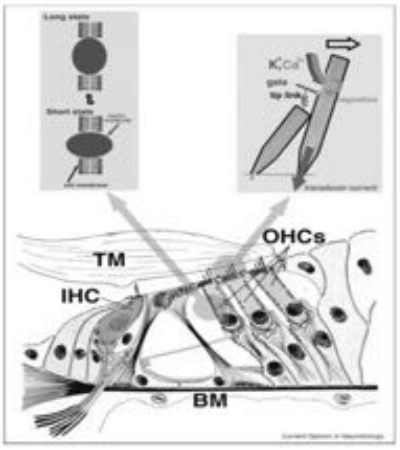
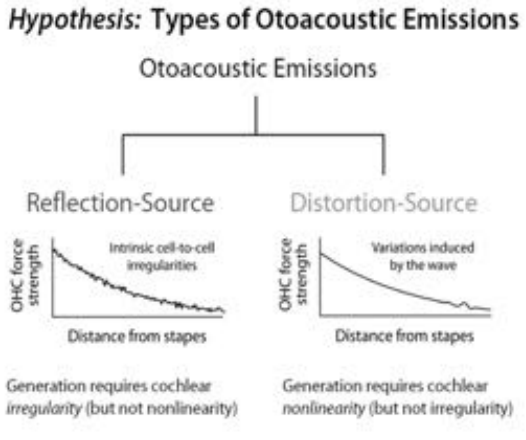
Common Errors in Measurement and Analysis of Otoacoustic Emissions
Recording a Single DPgram (No Replication)



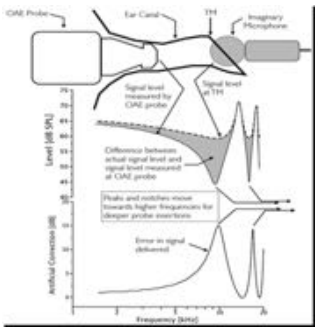
Common Errors in Measurement and Analysis of Otoacoustic Emissions
Not Recording Both TEOAEs and DPOAEs





Common Errors in Measurement and Analysis of Otoacoustic Emissions
Common Error in Recording #3

- Not calibrating 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

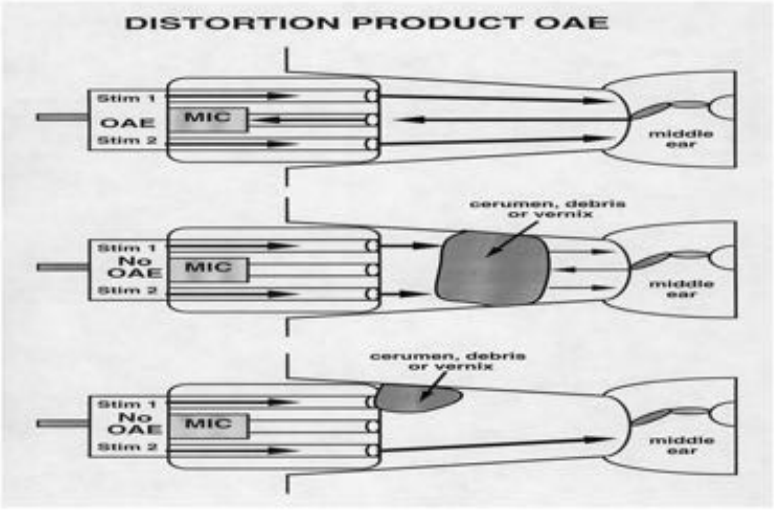


Common Errors in Measurement and Analysis of Otoacoustic Emissions
Common Error in Recording #4

- Not performing otoscopic inspection before OAE recording
  - OAE is recorded in the external ear canal
  - OAE recording may be compromised by:
    - Cerumen
    - Vernix
    - Debris
    - Foreign objects

Common Errors in Measurement and Analysis of Otoacoustic Emissions

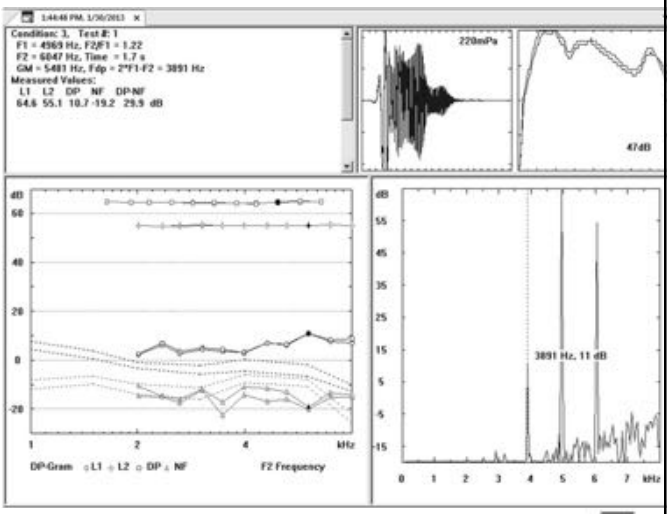
Failure to Inspect the External Ear Canal (Error #4)



Common Errors in Measurement and Analysis of Otoacoustic Emissions

Common Error in Recording #5

- Not monitoring stimulus intensity levels during DPOAE recording
  - L1 and L2 should begin and remain close to target levels (e.g., L1 = 65 dB SPL; L2 = 55 dB SPL)



Common Errors in Measurement and Analysis of Otoacoustic Emissions
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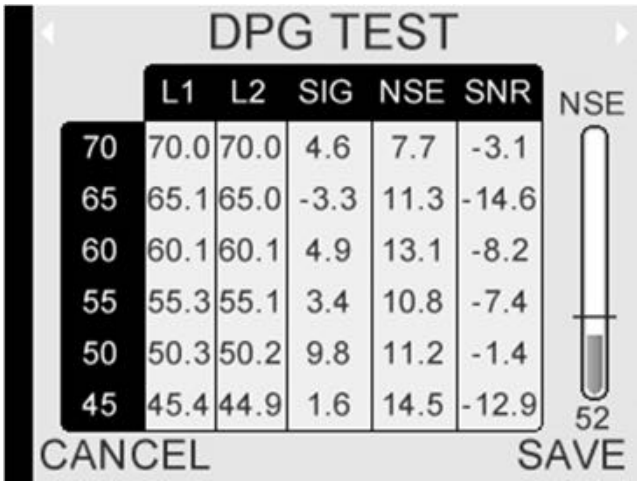
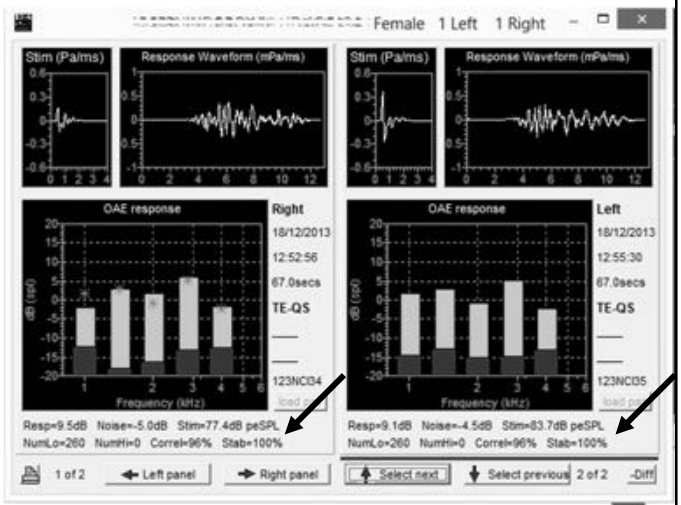


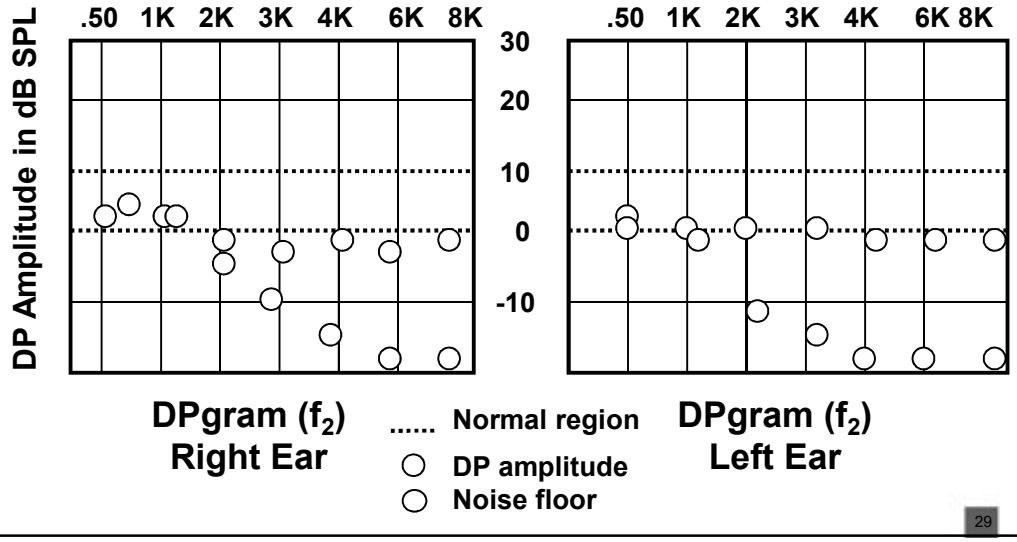
Common Errors in Measurement and Analysis of Otoacoustic Emissions
Common Error in Recording #5

- Not monitoring stimulus intensity levels during TEOAE recording
  - Verify stimulus level (+/- ? dB) and stability (~100%) during TEOAE recording



Common Errors in Measurement and Analysis of Otoacoustic Emissions

Excessive Noise Floor During OAE Recording (Error #6)



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Common Errors in Measurement and Analysis of Otoacoustic Emissions

Steps to Reduce Noise Floor During OAE Recording

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

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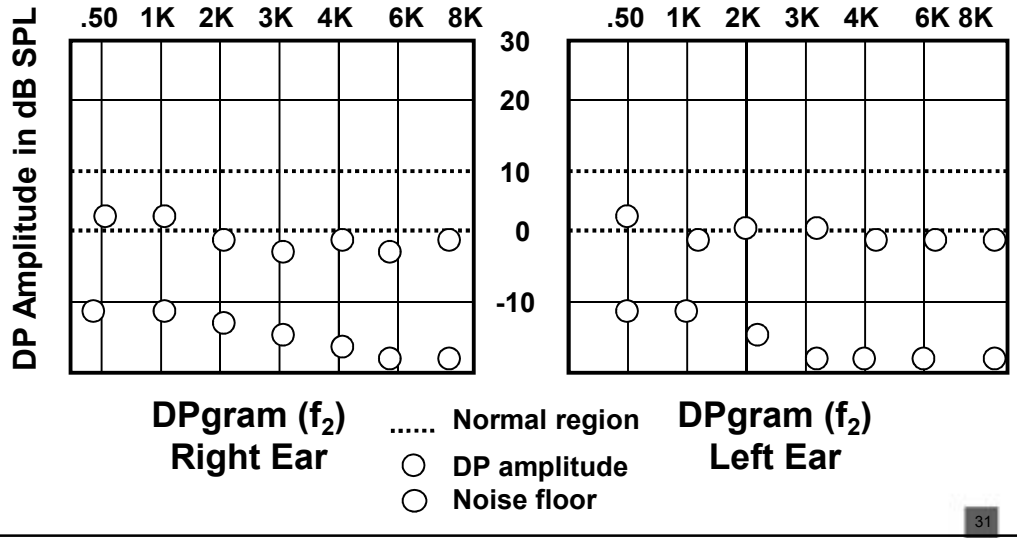
Common Errors in Measurement and Analysis of Otoacoustic Emissions

Reduction of Noise Floor During OAE Recording



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Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

- Introduction and historical perspective (0 – 5 minutes)
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- Questions and answers (56 – 60 minutes)

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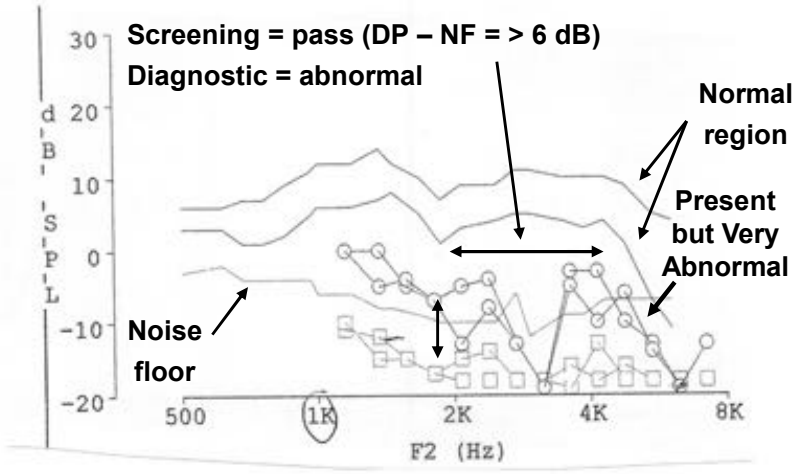
Common OAE Analysis Error #1
Simplistic Overall OAE Analysis of "Pass" or "Present" versus "Fail" or "Absent



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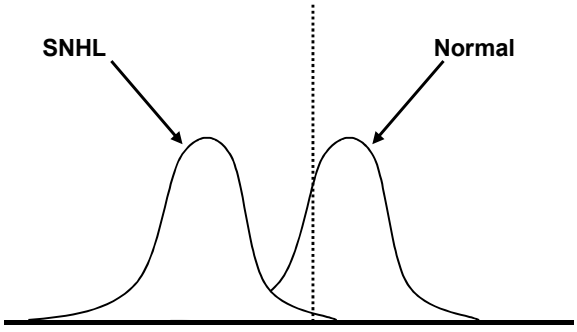
Common OAE Analysis Error #1
Solution to Simplistic OAE Analysis

REFER versus PASS



(Data from Gorga, Stover & Neely, 1996)

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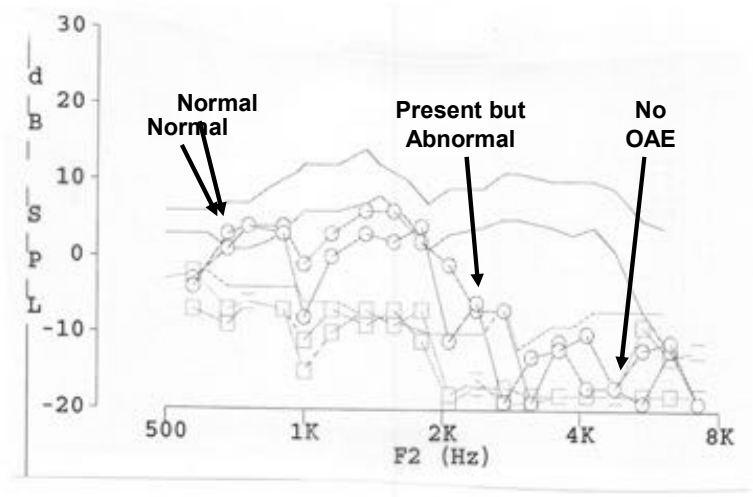
General Steps in Analysis of TEOAE or DPOAE Findings

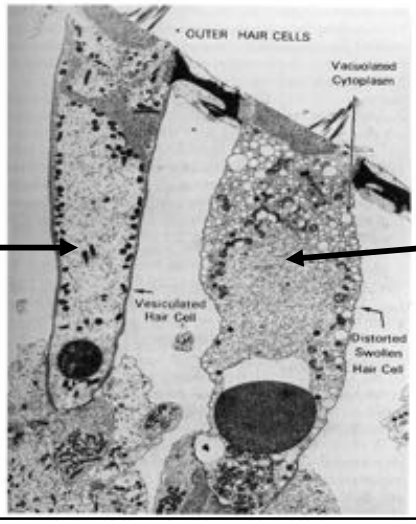
- Verify adequately low noise floor (< 90% normal limits)
- Verify repeatability of TEOAE or DPOAE amplitude
- Perform analysis at all test frequencies
- Three possible outcomes (for any test frequency)
  - Normal
    - OAE amplitude – NF > 6 dB
    - OAE amplitude within normal limits (> ~ 0 dB SPL)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

Solution to Common OAE Analysis Error #1
Three Categories of OAE Analysis



Remember … Abnormally Small OAE Amplitudes (Below Normal Limits) = Outer Hair Cell (OHC) Dysfunction:

Normal OAEs = Normal OHCs



Abnormal OAEs = Abnormal OHCs

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs) *Common OAE Analysis Error #2*

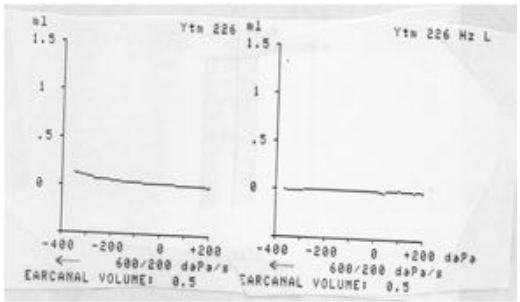
- Failure to evaluate technical explanations for an absent OAEs or highly variable OAE findings, e.g.,
  - Probe that is not calibrated
  - Occlusion of probe ports with cerumen or debris
  - Standing wave interference for test frequencies > 5000 Hz
  - Variable stimulus intensity levels during OAE recording
  - Inconsistent probe fit during OAE recording

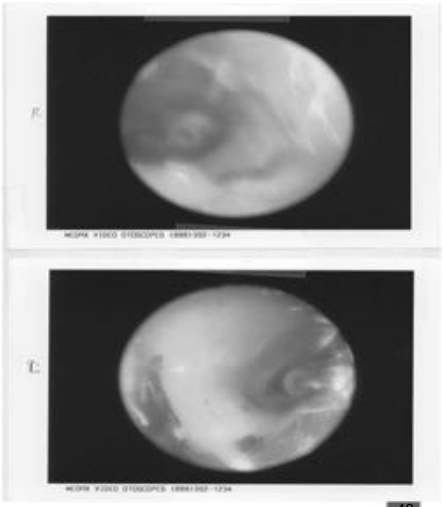
Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs) *Standing Wave Interference for DPOAEs Above 5000 Hz*

- Siegel J. 1994. Ear-canal standing waves and high-frequency sound calibration using otoacoustic emission probes. JASA 95: 2589-2597. [+/- 20 dB error]
- Siegel JH. 1995. Cross-talk in otoacoustic emission probes. Ear and Hearing 16: 150-158.
- Siegel JH & Hirohata ET. 1994. Sound calibration and distortion product otoacoustic emissions at high frequencies. Hearing Research 80: 146-152

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs) *Common OAE Analysis Error #3*

- Failure to evaluate pathologic but non-cochlear explanations for an absent OAE finding, e.g.,
  - External ear canal pathology
  - Middle ear dysfunction





Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs) *Common OAE Analysis Error #4*

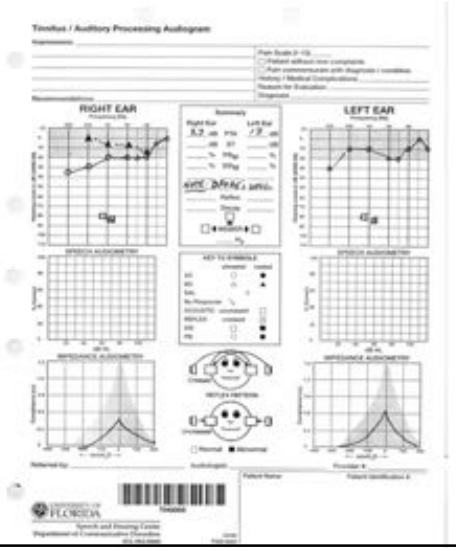
- Failure to require replication and test-retest agreement in OAE recording
  - Inspection of “reproducibility” data in TEOAE recording
  - Taking into account reliability of DPOAE amplitude values for different test frequencies in analysis of replicated DPgrams

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs) *OAE Analysis Error #5*

- Failure to apply the “crosscheck principle in analysis of OAE findings, that is, critical comparison of OAE findings, after close and careful analysis, with findings for
  - Aural immittance measures
    - Tympanometry
    - Acoustic reflexes
  - Pure tone audiometry thresholds
  - Auditory brainstem response (ABR) findings
  - Auditory processing test results

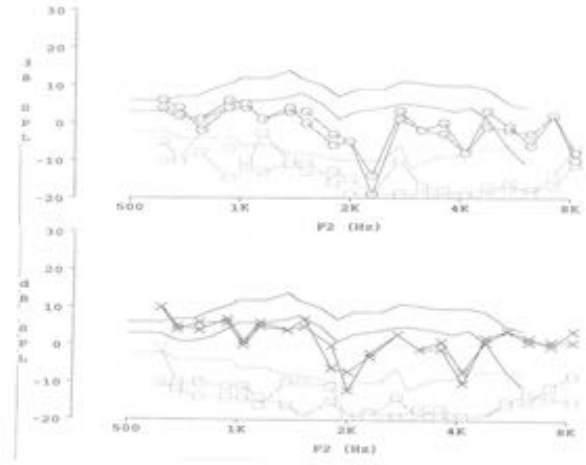
OAE Analysis Error #5: Failure to Apply Crosscheck Principle

Abnormal Hearing Thresholds



OAE Analysis Error #5: Failure to Apply Crosscheck Principle

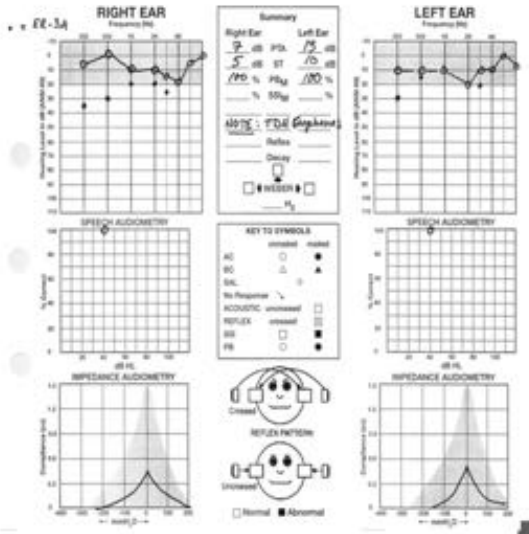
Mostly Normal OAEs



OAE Analysis Error #5: Failure to Apply Crosscheck Principle

Correction of Technical Error (Earphones)

Normal Hearing Thresholds



Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs) *Common OAE Analysis Error #6*

- Poor understanding of the relation between OAE findings versus audiogram findings … misplaced trust in the audiogram as the "gold standard" for auditory function
  - Describing without question "present OAEs" rather than "abnormal OAEs" in patient with normal audiogram
  - Accepting without question a finding of normal OAEs in a patient with pure tone threshold levels > 20 dB HL

To Minimize Common Errors It's Important to Understand 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

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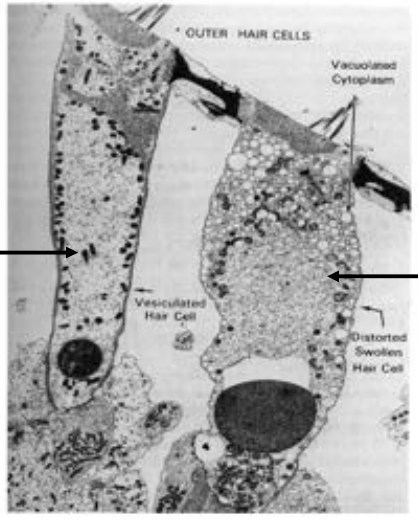
OAEs in Early Detection of Outer Hair Cell Dysfunction: *Rationale Underlying Many Clinical Applications*

Normal OHC (OAEs)



Abnormal OHC (OAEs)

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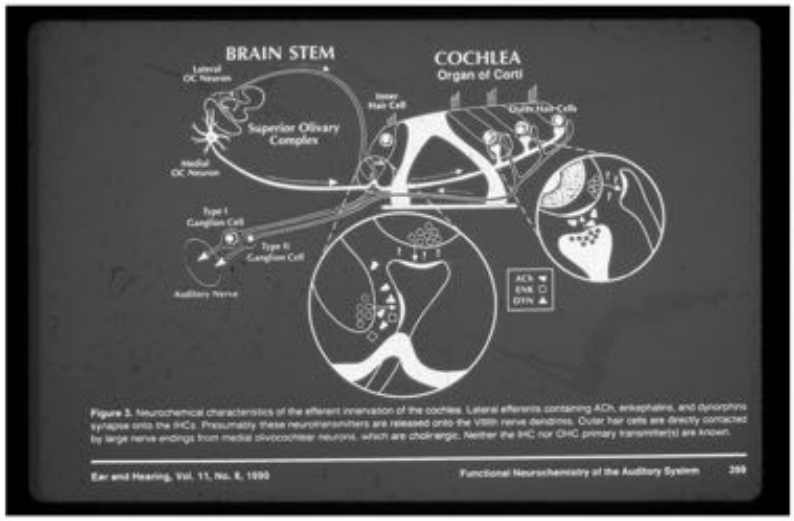
OAEs Reflect Outer Hair Cell Function: *OAEs are Not a Measure of Inner Hair Cell Function and OAEs are "Pre-Neural":*



Relation Between OAE Findings and Audiogram (Pure Tone Audiometry Findings)

- Normal Audiogram (Hearing Thresholds < 20 dB)
  - Normal OAEs?
    - Normal middle ear function
    - Normal cochlear function
  - Abnormal OAEs?
    - Abnormal middle ear function (rule out)
    - Abnormal cochlear (outer hair cell) function

Relation Between OAE Findings and Audiogram (Pure Tone Audiometry Findings)

- Abnormal Audiogram (Hearing Thresholds > 20 dB)
  - Normal OAEs?
    - Possible inner hair cell dysfunction
    - Possible neural dysfunction
    - Possible false hearing loss
    - Possible technical problem with pure tone audiometry
  - Abnormal or Absent OAEs?
    - Rule out middle ear dysfunction
    - Outer hair cell dysfunction if normal middle ear
    - Possible inner hair cell dysfunction if pure tone thresholds > 50 dB HL
    - Possible 8th nerve tumor with compromise of blood flow to the cochlea (unlikely)

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

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- Questions and answers (56 – 60 minutes)

Minimizing Common Errors in the Measurement of OAEs: *Follow Best Practices in OAE Recording*

- Calibrate probe daily
- Do all you can to assure patient is quiet and not moving
- Verify clear external ear canal
- Confirm open ports in the OAE probe assembly
- Obtain secure and deep probe fit in the external ear canal
- Verify that target stimulus intensity levels are met
- Minimize ambient noise in test environment
- Verify noise levels are below normal limits
- Verify that OAE recordings are replicable

Minimizing Common Errors in the Analysis of OAEs: *Careful and Complete Analysis of Findings*

- Compare patient's OAEs versus appropriate normative data
- Rule out middle ear dysfunction for abnormal OAE findings
- Categorize analysis of OAE findings
  - Normal (amplitudes WNL)
  - Present but abnormal
  - Absent (OAE – NF = < 6 dB)
- Analyze OAE findings in context of other test findings, e.g.,
  - Pure tone audiogram
  - Aural immittance measures
  - ABR
  - Speech perception in noise tests

Minimizing Common Errors in the Measurement and Analysis of OAEs: *Remember Limitations of OAEs*

- 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

Common Errors in Measurement and Analysis of Otoacoustic Emissions (OAEs)

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