Otoacoustic Emissions As A Test Of Noise-Induced Hearing Loss

Brenda L Lonsbury-Martin PhD

Department of Otolaryngology--Head & Neck Surgery
Loma Linda University Medical Center
blonsbury-martin@llu.edu

Research Service
VA Loma Linda Healthcare System
Loma Linda CA
brenda.lonsbury-martin@va.gov
Detecting NIHL Using OAEs

presentation outline

• brief review of types of OAEs re their clinical utility for NIHL detection
• present a few case-study examples illustrating some clinical applications re NIHL
Detecting NIHL Using OAEs

presentation outline

• brief overview of some studies using OAEs to detect occupational NIHL
• review current research findings that hold promise for ability of future clinical OAE tests to detect early NIHL
Otoacoustic Emissions

all types discovered by David Kemp by 1978

sounds emitted from the cochlea either naturally or in response to acoustic stimulation

- spontaneous OAEs
- transient-evoked OAEs
- distortion-product OAEs
- stimulus-frequency OAEs
Otoacoustic Emissions

sounds emitted by the cochlea

- clinical interest in OAEs:
  their promise in providing an objective measure of behavioral audiogram

- newborn hearing screening

- screening toddlers, very ill patients for ototoxicity monitoring, confused elderly, multiply handicapped, workers in hearing-conservation programs
Auditory Input
anatomical pathway

- OHC Cochlear Amplifier
- Descending Efferent System
## Types of OAEs

*current consensus of field*

### Primary Generator Sources

- **TEOAEs, SFOAEs, SOAEs:**
  - coherent linear reflection primarily from irregularities around test-frequency place
- **DPOAEs:**
  - nonlinear distortion primarily from $f_2$ place with reflection from DP-frequency place
OAEs Sources

*a common view of field*

- reflection--OHC lateral wall electromotility
- distortion--nonlinearities in opening and closing of transduction channels at tips of stereocilia likely introduce basic cochlear nonlinearity
Otoacoustic Emissions

**beneficial clinical features**

- measure functional status of the hearing receptor type (OHC) that is most sensitive to cochlear dysfunction:
  - external agents: noise, ototoxins
  - internal agents: bacteria, viruses
  - genetic factors: familial disorders, aging
Otoacoustic Emissions

*beneficial features*

- measured non-invasively and objectively thus allowing for:
  - simple set-up time
  - rapid response acquisition
  - systematic assessment re stimulus frequency and level domains
Otoacoustic Emissions

simple equipment set-up

(Kemp '78)
Otoacoustic Emissions

beneficial clinical features

• operate at low to moderate stimulus levels:
  - thus have the potential to detect the onset stages of cochlear dysfunction
Otoacoustic Emissions

*beneficial features*

• measurement instrumentation is:
  – commercially available
  – relatively inexpensive
  – easy to operate
Transient Evoked Otoacoustic Emissions

ILO88 display
Transient-Evoked Otoacoustic Emissions advantages for clinical use

• measurement procedure based on familiar evoked response methodology: click-based synchronous (time) averaging

• easily measured with most successful device that was commercially available early on:
  Otodynamics Ltd ILO88 (1988)
Transient Evoked Otoacoustic Emissions

*normative data*

(normal)

(Whitehead et al ‘96)

(NIHL)
Distortion Product Otoacoustic Emissions

human $2f_1 - f_2$

\[ f_1 = 3.165 \text{ kHz}, \quad 70 \text{ dB SPL} \]
\[ f_2 = 3.833 \text{ kHz}, \quad 63 \text{ dB SPL} \]
\[ 2f_1 - f_2 = 2.498 \text{ kHz}, \quad 12 \text{ dB SPL} \]
\[ \text{NF} = -34 \text{ dB SPL} \]

MEAN OF 16 BINS
Distortion Product OAEs

(normal vs abnormal ear)
Noise-Induced Hearing Loss

Symmetrical loss

49 y/o M with 25-y Hx of exposure to factory noise
Noise-Induced Hearing Loss
asymmetrical loss

37 y/o M with 20-y Hx as lathe operator with R ear (open circles) nearest to equipment
Noise-Induced Hearing Loss

early stages

21 y/o M ex-US Coast Guard artillery specialist with R ear (open circles) nearest to gun barrel of deck-mounted artillery
relating hearing thresholds to DP-gram levels has mostly failed

(Meinke et al '05)
Stimulus-Frequency Otoacoustic Emissions

*normal-hearing human*

- fine structure
Site of $2f_1-f_2$ DPOAE Generation
OAE Generation Mechanisms
clinical implications of basic research

clinical measurement of both types of emission sources (ie, reflection, distortion) or only 1 source may be needed to maximize the power and specificity of OAEs as probes of cochlear function and estimators of behavioral hearing
DP-Gram

eliminating fine structure

- Heitmann, Janssen et al (‘96):
  - developed single-generator DP-grams (sigDPOAE)
  - suppressing DP-frequency place with higher-frequency suppressor
Distortion Product OAEs
response growth I/O function

22 y/o F

RESPONSE GROWTH (I/O) FUNCTION

-25 -20 -15 -10 -5 0 5 10 15
DPOAE Amplitude (db SPL)

25 35 45 55 65 75
Primary levels (dB SPL)
DPOAE I/O Function
approaches for estimating ‘threshold’

• fixed signal-to-noise ratio (SNR) criterion:
  — eg, 6 dB measurement-based stopping rule
• simple linear regression to extrapolate DPOAE threshold
• resulted in modest correlations between audiometric thresholds and DPOAE ‘thresholds’
OAEs
detecting early NIHL

- Marshall, Lapsley Miller and colleagues
- large-scale studies in military personnel:
  - 6-mo noise exposure re aircraft carrier duty
- significant reductions in average OAE levels without changes in average audiometric thresholds indicating early detection
Early Detection of NIHL

recreational rifle shooter (R)

43 y/o normal-hearing F complains of:
- decreased sensitivity
- tinnitus
- difficulty in hearing in background noise
Temporary Threshold Shift in Humans

DPOAE paradigm: $L_1-L_2$

Noise Exposure:
- test DPOAE = 4 kHz
- exposure = 2.8 kHz at 105 dB SPL for 3 min

(Sutton et al '94)
Average DPOAE Recovery From TTS effects of $L_1$-$L_2$

- lower levels with $L_1$-$L_2=25$ dB most sensitive to TTS
- relevant to hearing-conservation program monitoring

(Sutton et al '94)
Temporary Threshold Shift
recovery of hearing vs DPOAE levels

(Sutton et al ‘94)
DPOAEs in Ear-Canal

‘total space’

FIG. 1.

A. "Traditional" 2f₁-f₂ DP-Gram

B. Traditional DP-gram

DPOAE level

DPOAE Phase

C. 75.75 dB SPL

D. 75.75 dB SPL
Site of $2f_1 - f_2$ DPOAE Generation

distributed
generator
sources
Translate Human DP-gram onto L/P Map
Rabbit low frequency loss
ADP-gram
Low frequency loss
ADP-gram vs ABR

Low-Frequency Loss Ear

ABR Threshold Difference (dB)

$L_1 = L_2 = 70 \text{ dB SPL}$

$f_2$ Frequency (kHz)

DPOAE Level Difference (dB)

- $\text{ABR}$
- $\text{ADP-gram}$
Notch Loss
ADP-gram improvement
Notch Loss

ADP-gram vs ABR

Notched-Loss Ear

$L_1, L_2 = 60, 55 \text{ dB SPL}$

ABR Threshold Difference (dB)

DPOAE Level Difference (dB)

$f_2$ Frequency (kHz)
Other Applications of OAEs

noise-induced hearing loss

- efferent system evaluation:
  - resistant vs susceptible ears
- identifying pseudohypacusis
- contribute towards decision(s) re habilitative approach:
  - optimizing digital hearing-aid fitting
Pseudohypacusis Testing

**earphone emission in L ear**

35 y/o M telephone operator

<table>
<thead>
<tr>
<th>PTA</th>
<th>SRT</th>
<th>DISCRIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGHT</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>LEFT</td>
<td>125+</td>
<td>DNT</td>
</tr>
</tbody>
</table>

---

![Graphs](image-url)
Pseudohypacusis Testing

35 y/o M - earphone emission in L ear
Conclusions

**most promising application of OAEs to NIHL**

- devising effective protocol for early detection of OHC dysfunction:
  - incorporation into civilian and military hearing-conservation programs
Research on Otoacoustic Emissions

supported by

- NIH/NIDCD: DC00613.21
- NIH/NIDCD: DC003114.23
- VA/RR&D: CL212L.2
- VA/RR&D: C4494R.4