Tinnitus for ENT Physicians

Steve Benton, Au.D.
Tinnitus

- Definition
- Prevalence
- Neurophysiological Model
- Progressive Tinnitus Management
Tinnitus Defined

- Jastreboff and Hazell (2007): “The perception of sound that results exclusively from activity within the nervous system without any corresponding mechanical vibratory activity within the cochlea, and not related to any external stimuli of any kind.”
Tinnitus Defined

- If there is a vibratory component in the cochlea which can be related to the perception of sound, it is categorized as a **somatosound**
- **Somatosounds** are “real” sounds mediated through the normal transmission process within the cochlea
  - Turbulent blood flow within the carotid artery
  - Muscle contractions in the mouth or neck area
  - Clicking jaw bones
Tinnitus Prevalence

- 7 large studies from 4 countries over a 35-year period
  - Only prolonged continuous tinnitus: **10.1% - 14.5%**
  - If definition includes occasional tinnitus: **22%-32%**
- American Tinnitus Association (2008):
  - **17%** of Americans (50 million) experience tinnitus
  - **12 million** seek professional help
  - **1 million** are debilitated by their tinnitus
Tinnitus: Age and Gender

NIDCD (1994-1995): Chronic tinnitus – duration of 3 months or longer

Marked increase for both sexes age 40 to 79 years, declining after age 80 years

More prevalent in males than females ($p < 0.0001$)

Males more likely to be exposed to loud work or leisure noise
Axelsson & Barrenas (2000): **NIPT** – noise-induced permanent tinnitus

Higher Incidence among workers’ compensation claimants than others

**20%-40%** of those exposed to occupational noise experience NIPT.

<table>
<thead>
<tr>
<th>Authors</th>
<th>N</th>
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<td>37</td>
<td>F</td>
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<td>51.3</td>
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Tinnitus & the Military

- Primary causes of tinnitus in the military:
  - #1: Noise exposure: single impulse or accumulation of noise
  - #2: Head and neck injury

- Improvised explosive devices (IEDs) detonate at levels of >140 dBA

- Walter Reed Army Medical Center study: 49% of members exposed to IEDs in Iraq and Afghanistan reported having tinnitus

- The Army is the only branch of the military that requires hearing protection as part of its uniform
Tinnitus and Veterans

• 2009 Most prevalent service-connected disabilities:
  — #1 – Tinnitus (639,012 veterans)
  — #2 – Hearing Loss (570,966 veterans)

• Henry (2003, 2004) estimated that 3-4 million veterans experience tinnitus and up to 1 million require some type of intervention.
Discordant Damage/Dysfunction Theory

- **Outer hair cells (OHCs)** - very susceptible to damage
- **Inner hair cells (IHCs)** – typically unaffected in the presence of even severe OHC damage.
- OHCs and IHCs provide input to the dorsal cochlear nucleus (DCN)
- When normal IHCs provide input to the DCN but their damaged “partner” OHCs do not, the DCN abnormally and spontaneously fires in high-frequency bursts.
  - These abnormal high-frequency nerve-signal bursts are the signal of tinnitus.
Discordant Damage/Dysfunction Theory
Otoacoustic Emissions: the Basics

- Two general types:
  - **Spontaneous (SOAE)**
  - **Evoked (two subtypes)**
    - Transient Evoked OAE (**TEOAE**)
      - (OHCs in ‘relaxed state’).
    - Distortion-Product OAE (**DPOAE**)
      - (OHCs in ‘working state’).

- OAEs are not new. . .
  - Existence hypothesized in 1940’s based on mathematical models of nonlinear cochlear function.
  - Documented in animals in the 1950’s.
  - Spontaneous OAEs first recorded from humans in 1977.
  - Affordable technology allowing routine measurement developed in 1990s.
Types of OAEs: SOAEs

- 40-50% of normal-hearing individuals
  - Hearing thresholds ≤ 25-30 dB HL
- Typically in 1.0-2.5 kHz region
- Typical amplitude: -5 to 15 dB SPL
- More often seen in females than males
- Measurable in neonates
  - (as early as 30 weeks conceptual age)
- **Not** associated with tinnitus!
- Absence of recordable SOAEs essentially meaningless, unless . . .
  - Previously present SOAEs now absent-- may signify change in cochlear mechanics
SOAE Recording

Record
Record
Record
Record
Record
Record
Record
Record

(No Stimulus)

Time

Ear Canal
Middle Ear Ossicular Chain
Cochlea Outer Hair Cells
SOAE

Computer
Microphone
SOAEs

Present or Absent?

- SOAEs at 1025 Hz, 1 dB SPL
- SOAEs at 1470 Hz, 5 dB SPL
- SOAEs at 1895 Hz, 5 dB SPL

Frequency range: 500 Hz to 2500 Hz

SPL levels: +40 dB SPL, 0 dB SPL, -40 dB SPL

SPL differences: 5 dB SPL, 1 dB SPL, -5 dB SPL
Types of OAEs: TEOAE

• Cochlear response evoked by brief, transient broadband click stimuli

• Measurements made during brief silence between clicks
  – OHCs in “relaxed” state (no active cochlear stimulation present during recording).

• Responses averaged over time to reduce noise.
  – Raw response emanates from broad cochlear region.
  – Advanced analysis algorithms are required to separate the response into various frequency bands for interpretation.

• Presence of TEOAEs in a particular band is generally interpreted as indicating hearing sensitivity is 30 dB HL or better in that band.

• Prevalence of DPOAEs in normal ears: 100%.
TEOAE Recording

Stim  →  Record  →  Stim  →  Record  →  Stim  →  Record  →  Stim  →  Record  →  Stim  →  Record  →  Stim

Ear Canal  →  Middle Ear  →  Ossicular Chain  →  Cochlea  
Outer Hair Cells  →  Broadband OAE Response

Computer  →  Speaker  →  Click  →  Microphone
TEOAE Analysis

TEOAE analyzed only by FFT.

TEOAE analyzed in half-octave bands.
Types of OAEs: DPOAE

- Cochlear responses generated by simultaneous stimulation of two pure-tone frequencies (primaries) whose ratio is 1.2 \((f_2 / f_1)\).
- The resulting intermodulation within the cochlea generates components which are not in the input stimuli (distortion products), the most prominent of which is \(2f_1 - f_2\).
- Hair cells in an active state
- Presentation levels generally differ by 10 dB \((L_1 > L_2)\) which allows for better identification of DPs: \(L_1 (f_1) = 65\) dB SPL \(L_2 (f_2) = 55\) dB SPL
- Prevalence of DPOAEs in normal ears: 100%.
- Females have higher DPOAE amplitudes than males.

Example:

\[
\begin{align*}
  f_1 &= 2000\ \text{Hz} \\
  f_2 &= 2400\ \text{Hz} \\
  2f_1 &= 4000\ \text{Hz}
\end{align*}
\]

\[
(2f_1 - f_2) = 4000 - 2400 = 1600\ \text{Hz (DPOAE)}
\]
DPOAE Recording

Stim → Record → Ear Canal → Middle Ear Ossicular Chain → Cochlea Outer Hair Cells

2f1-f2 OAE Response
DPOAE Graph: “DP-Gram”
DPOAE Graph – 1 Data Point

F1 = 65dB SPL @ 2484Hz
F2 = 55dB SPL @ 3000Hz
DP = 6dB SPL @ 1969Hz
NF = -21dB SPL

Accepted Frames = 100
Rejected Frames = 0
Test Status = Accepted

F1

2f1-f2

f1

f2

Noise
## Clinical Utility of OAEs

<table>
<thead>
<tr>
<th>Infants:</th>
<th>Adults:</th>
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<tbody>
<tr>
<td><strong>Neonatal screening</strong></td>
<td><strong>Ototoxicity monitoring</strong></td>
</tr>
<tr>
<td><strong>Children:</strong></td>
<td><strong>Tinnitus evaluation</strong></td>
</tr>
<tr>
<td><strong>Hearing screening</strong></td>
<td><strong>Auditory processing disorders</strong></td>
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<tr>
<td><strong>Ototoxicity monitoring</strong></td>
<td><strong>Difficult-to-test patients</strong></td>
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<tr>
<td><strong>Tinnitus evaluation</strong></td>
<td><strong>Suspicion of non-organic loss</strong></td>
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<tr>
<td><strong>Auditory processing disorders</strong></td>
<td><strong>Hearing conservation programs</strong></td>
</tr>
<tr>
<td><em>(ADHD, ADD, auditory neuropathy)</em></td>
<td><strong>Exposure to hazardous noise</strong></td>
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<tr>
<td><strong>Difficult-to-test patients</strong></td>
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<td><strong>Suspicion of non-organic loss</strong></td>
<td></td>
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<tr>
<td><strong>Exposure to hazardous noise</strong></td>
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</table>
Tinnitus and OAEs

Journal of the Association of Research In Otology (Shiomi et al, 1997)

“In comparison to normal hearing and otologically normal subjects (including no tinnitus), DPOAE amplitudes were consistently reduced among tinnitus patients, even those with audiometrically normal hearing.”

Handbook of Otoacoustic Emissions (Hall, 2000)

“. . . A clear pattern has emerged. OAEs are abnormal, or not detectable, in the frequency region of the tinnitus, even among persons with clinically normal audiograms.”

Auris Nasus Larynx (Paglialonga et al, 2010)

“. . . abnormal OAEs, in particular at higher frequencies, in tinnitus subjects with normal hearing sensitivity . . . outer hair cell dysfunction . . . might thus be assumed in normal hearing tinnitus subjects.”
Tinnitus and OAE Case Study #1

38-year old male with primary complaint of tinnitus.

Noise exposure history:
   Military noise: explosives, artillery, engines, aircraft, firearms.
   Occupational and recreational noise: denied.

Dizziness and/or balance problems: Denied.

Family history of hearing loss: Denied.

Other significant otological history:
   Patient reported that an IED exploded near him in Fallujah and blood poured out of both ears and he couldn't hear for several days.

Tinnitus:
   Ears: Both
   Frequency of occurrence: Always (100% of the time)
   Description: Ringing

   Subjective Tinnitus Severity: Grade 5 (catastrophic):
   a dominating problem that reduces the patient's overall quality of life.

The Tinnitus Severity Index (TSI - Meikle, 1991) was completed. Scores range from 12 to 60. Responses were scored for each item as indicated:

1) Makes veteran irritable or nervous: Often
2) Makes veteran feel tired or stressed: Often
3) Makes it difficult to relax: Always
4) Makes it uncomfortable to be in a quiet room: Always
5) Makes it difficult to concentrate: Always
6) Makes it hard to interact pleasantly w/ others: Often
7) Interferes with required activities: Often
8) Interferes with social activities: Often
9) Interferes with overall enjoyment of life: Often
10) Interferes with ability to sleep: Often
11) Vet has difficulty ignoring tinnitus: Always
12) Vet experiences discomfort from tinnitus: Often

Patient's Tinnitus Severity Index (TSI) score was 52.

TSI scores of 36 or higher are consistent with tinnitus that may benefit from specific treatment.
Tinnitus and OAE Case Study #1

Pure-tone thresholds and DPOAEs
Tinnitus and OAE Case Study #2

40-year old male - compensation & pension examination

“I have difficulty hearing at meetings and trainings if there is background noise. Hearing loss causes frustration/anxiety during conversations. Tinnitus is more noticeable when there isn't any background noise. It's an irritant that sometimes makes falling asleep difficult.”

Pertinent service history: Navy ‘88 – ’92

Noise exposure history:
  Military: Cryptological technician- loud radio static and electronic audio signals through headphones during military service; infantry
  Occupational: denied- student and computer drafter
  Recreational: lawn equipment and power tools

Familial history of hearing loss: denied

Pertinent family and social history: denied

History of ear disease: denied

History of head or ear trauma: denied

Tinnitus:
  Date and circumstances of onset: gradual onset in 1991-1992. Tinnitus is persistent (constant). The tinnitus was described as a high pitched sound paired with a seashell sound which is always present and intensifies at times in both ears.
Tinnitus and OAE Case Study #2

Pure-tone thresholds and DPOAEs
Neurophysiological Model

• *The subconscious auditory filter* (sub-awareness processing center) is responsible for classifying sounds as *significant* or *not significant*
  
  – *NOT SIGNIFICANT* (neutral, of no importance)
    
    • Little, if any, activation of the limbic and autonomic nervous systems
    
    • With repetitive exposure to the particular sound, the subconscious filter will block it and there will be no awareness of the sound:
      
      – *Habituation of Perception*.
  
  – *SIGNIFICANT* (pleasant or unpleasant),
    
    • With repetitive exposure, increasingly strong activation of the limbic and autonomic nervous systems every time a subject is exposed to it.
Neurophysiological Model

Limbic & autonomic systems are engaged

Significance is attached

‘T’ Signal Generated

Subconscious Auditory Filter

No significance is attached

Reaction!
Neurophysiological Model

• **Selective perception**
  – Only one task can **fully** occupy our attention at any one time
  – We must switch rapidly between one attentional focus and another
  – **Prioritization of signals** – more important signals receive more attention
    • Monitoring of tinnitus ensues, and it becomes impossible to perform other tasks requiring attention. **CONCENTRATION DEFICITS RESULT.**
    • Through constant monitoring, the strength of the conditioned reflex and the resulting negative reactions gradually increase, thus resulting in reduction in enjoyment of life. **FRUSTRATION AND DEPRESSION RESULT.**
    • The brain is in an alert state both day and night because of the over-activation of the limbic and autonomic nervous systems. **SLEEP PROBLEMS RESULT,** which further affect concentration and attention and cause mood swings and irritability.
The Problem of Tinnitus

• In patients with disturbing tinnitus, the tinnitus signal is constantly present, resulting in continuous activation of the autonomic nervous system.

• The patient is in a constant state of alertness. Thus, the patient is exhausted and complains of lack of sleep and an inability to focus attention on anything else but the tinnitus.

• There is an overall loss of quality of life.

• Tinnitus “... suppresses or even eliminates positive emotions, resulting in decreased ability to enjoy life... This, in turn, leads to depression" (Jastreboff & Hazell, 2007, p. 39) .
Neurophysiological Model

• **Disturbing tinnitus:**
  – The tinnitus signal is *incorrectly* identified as *significant*
  – The *limbic system* is engaged: negative emotional reactions
    • Fear, anxiety, worry, anger, emotional distress, etc.
  – The *autonomic system* is engaged: negative physiological reactions
    • “Fight or flight” response

• **Non-Disturbing tinnitus:**
  – The tinnitus signal is *correctly* identified as *not significant*
  – The *limbic system* is *not* engaged
  – The *autonomic nervous system* is *not* engaged
  – There is *no* reaction
  – Tinnitus may be heard but there is no disturbance - *no impact on quality of life*
Progressive Tinnitus Management

- Population of all people who experience chronic tinnitus
- Progressively more severe tinnitus problems
- Only education needed
- Non-bothersome tinnitus

Debilitating tinnitus
Progressive Tinnitus Management

Triage Guidelines (for non-audiologists)

- Tinnitus plus ANY of the below
  - Symptoms suggest somatic origin of tinnitus (e.g., tinnitus that pulses with heartbeat)
  - Ear pain, drainage, or malodor
  - Vestibular symptoms (e.g., dizziness/vertigo)
  - No unexplained sudden hearing loss or facial palsy

- Tinnitus plus ANY of the below
  - Physical trauma
  - Facial palsy
  - Sudden unexplained hearing loss

- Tinnitus plus ANY of the below
  - Suicidal ideation
  - Obvious mental health problems

Level 1 Triage

Refer to Mental Health or Emergency Care - report suicidal ideation

Refer to Emergency Care or ENT (if unexplained sudden hearing loss; Audiology referral prior to ENT visit same day)

Refer to ENT (urgency determined by clinician; refer to audiologist for follow-up management)

Refer to Audiology (non-urgent referral)

Tinnitus plus ALL of the below
- Symptoms suggest neural origin of tinnitus (e.g., tinnitus does not pulse with heartbeat)
- No ear pain, drainage, or malodor
- No vestibular symptoms (e.g., no dizziness/vertigo)
- No unexplained sudden hearing loss or facial palsy

Level 2 Audiologic Evaluation

Refer as necessary to ENT, Mental Health, or other specialist

Level 3 Group Education

Refer as needed

Level 4 Tinnitus Evaluation

Refer as needed

Level 5 Individualized Management
Progressive Tinnitus Management

October 1, 2008 – November 30, 2010
2543 “Audiology Hearing Test” referrals

**NonT:** Non-tinnitus subjects. N = 1889
74.3% of all subjects

**T-GrpN:** Tinnitus subjects not referred to Tinnitus Group Education
N = 546. 25.7% of all subjects.

**T-GrpY-IndN:** Tinnitus subjects referred to Group Education who did not continue on to Individualized Management. N = 72. 2.8% of all subjects

**T-GrpY-IndY:** Tinnitus patients referred to Group Education who did continue on to Individualized Management. N = 36. 1.4% of all subjects
**Triage**

- The *Tinnitus Severity Index* (TSI, Meikle et al, 1995) is used at the Atlanta VA to determine if patients may require tinnitus-specific services.
- Scores range from **12-60**.
- Scores of **36 or higher** are consistent with significant tinnitus distress: these subjects may benefit from more intensive services.

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<th>Tinnitus Group</th>
<th>Mean TSI</th>
<th>S.D.</th>
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<td>T-GrpN</td>
<td>34.69</td>
<td>10.25</td>
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<tr>
<td>T-GrpY-IndN</td>
<td>43.14</td>
<td>7.02</td>
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<td>T-GrpY-IndY</td>
<td>49.70</td>
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Audiological Evaluation

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<th>Mean Age</th>
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<td>T-GrpN</td>
<td>56.86</td>
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<td>50.14</td>
<td>12.28</td>
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<tr>
<td>T-GrpY-IndY</td>
<td>54.06</td>
<td>10.84</td>
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Percentage of Subjects in Each Subject Group in Each Age Decade
Audiological Evaluation

Summary Audiometric Data for Four Subject Groups

- Non-T
- T-GrpN
- T-GrpY-IndN
- T-GrpY-IndY

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<tr>
<th>Frequency</th>
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<th>Slope</th>
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<td>dB HL</td>
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Audiological Evaluation

% of Subjects with Various Medical Diagnoses in Each Group

- Mental Health
- TBI
- Headache
- Dizziness
- Substance Abuse

- Non-T
- T-GrpN
- T-GrpY-IndN
- T-GrpY-IndY

Mental Health
- Non-T: 40%
- T-GrpN: 30%
- T-GrpY-IndN: 20%
- T-GrpY-IndY: 10%

TBI
- Non-T: 5%
- T-GrpN: 10%
- T-GrpY-IndN: 15%
- T-GrpY-IndY: 20%

Headache
- Non-T: 10%
- T-GrpN: 15%
- T-GrpY-IndN: 20%
- T-GrpY-IndY: 25%

Dizziness
- Non-T: 5%
- T-GrpN: 10%
- T-GrpY-IndN: 15%
- T-GrpY-IndY: 20%

Substance Abuse
- Non-T: 5%
- T-GrpN: 10%
- T-GrpY-IndN: 15%
- T-GrpY-IndY: 20%
Group Education

Three Uses of Sound for Tinnitus

Interesting sound

Audio Books!
Talk Radio!

TINNITUS

Interesting Music!

Dynamic speech!

Soft breezes
Soothing voice
Babbling brook

TINNITUS

Relaxing music
Running water
Ocean waves

Relaxing sound

Background sound

Sound Plan Worksheet

1. From the Tinnitus Problem Checklist, write down one bothersome tinnitus situation:

2. Check one or more of the three ways to use sound to manage the situation:

   - Interesting sound

   - Talk Radio

   - TINNITUS

3. Write down the sounds that you will try (for help see pp. 28-36)

4. Write down the devices you will use (for help see pp. 37-42)

5. Use your sound plan over the next week

   - Television
   - radio
   - book on CD
   - CD player by bed

6. How helpful was each sound plan after using it for 1 week?

   - Not at all
   - A little
   - Moderately
   - Very much
   - Extremely

7. Comments

   When you find something that works well (or not so well) please comment.
   You do not need to wait 1 week to write your comments.

   Talk radio helped me get to sleep, but I still wake up in the night.

   Adding fan noise helped me get to sleep and helped me stay asleep.

EXAMPLE
Group Education

Pre- and Post-Group Education TRQ Scores and Total Disturbance Scores

Mean TRQ Score / % Total Disturbance

- Pre TRQ
- Post TRQ
- Pre Tot Dist
- Post Tot Dist

Legend:
- T-GrpY-IndN
- T-GrpY-IndY
Tinnitus Assessment

• **Why?**
  – Determining which patients are likely to benefit from specific types of treatment,
  – Establishment of treatment guidelines (e.g., spectrum and/or loudness characteristics of broadband desensitization sounds)
  – Later determination if treatment has had an effect.

• **Tinnitus assessments are completed using standardized methods**
  – Tinnitus quality (e.g., noise- or tone-like)
  – Loudness
  – Perceptual location (e.g., right or left ear, both ears, midline)
  – Minimum masking levels
  – Discomfort levels also are measured to assess loudness tolerance
### Tinnitus Assessment

#### Ranking of Auditory Problems

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<th></th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinnitus</td>
<td>98.3%</td>
<td>1.7%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Hearing Loss</td>
<td>1.7%</td>
<td>73.3%</td>
<td>25.0%</td>
</tr>
<tr>
<td>Loudness Tolerance</td>
<td>0.0%</td>
<td>25.0%</td>
<td>75.0%</td>
</tr>
<tr>
<td>Pitch</td>
<td>2 kHz &amp; lower</td>
<td>3-4 kHz</td>
<td>&gt;4 kHz</td>
</tr>
<tr>
<td>Pitch</td>
<td>7%</td>
<td>33.9%</td>
<td>54.8%</td>
</tr>
<tr>
<td>Quality</td>
<td>Tone-Like</td>
<td>Noise-Like</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>29.0%</td>
<td>71.0%</td>
<td></td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Mean (S.D.)</td>
<td>14.9 (12.5)</td>
<td></td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Right Ear</td>
<td>76.6 (22.8)</td>
<td>78.2 (18.4)</td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Left Ear</td>
<td>75.8 (20.4)</td>
<td>78.2 (18.2)</td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Right Ear</td>
<td>30.7%</td>
<td>32.3%</td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Left Ear</td>
<td>43.5%</td>
<td>24.2%</td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Same Both Ears</td>
<td>27.4%</td>
<td>22.6%</td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Residual Inhibition</td>
<td>Could Not Test</td>
<td>None</td>
</tr>
<tr>
<td>Min. Masking Level (dB SL)</td>
<td>Residual Inhibition</td>
<td>10.0%</td>
<td>15.0%</td>
</tr>
</tbody>
</table>

N = 35
Individualized Management

Two clinically proven methods of tinnitus treatment

Tinnitus Retraining Therapy (TRT)

Neuromonics Tinnitus Treatment (NTT)
Tinnitus Retraining Therapy

- **TRT** uses a combination of low level, broadband sound and counseling (demystification) to achieve the habituation of tinnitus.
  - Detachment of negative limbic and autonomic nervous system reactions from the tinnitus signal.
  - *Habituation of reaction*: decreased tinnitus-induced activation of the autonomic nervous system.
  - *Habituation of perception*: prevention of tinnitus-related neuronal activity from reaching the cortex (area of perception) by the subconscious auditory filter.
  - *Habituation is not a cure for tinnitus*. Tinnitus can still be perceived when attention is focused on it, but there is no reaction.
Tinnitus Retraining Therapy

- **Demystification**: reclassification of tinnitus as a neutral stimulus
  - Involves specific and detailed teaching sessions regarding brain function and the mechanisms of tinnitus generation and of tinnitus disturbance.
  - **Teaching points:**
    - Reaction to the unknown is stronger than reaction to the known.
    - Tinnitus is harmless, not worthy of constant monitoring.
  - The brain reduces and subsequently blocks the spreading of neuronal activity of *neutral stimuli* to the limbic and autonomic nervous systems.
  - Decreased activation of these systems facilitates habituation.
Tinnitus Retraining Therapy

Counseling alone *is not* TRT

Sound generators alone *are not* TRT

Successful outcome can require up to **24** months
Neuromonics Tinnitus Treatment

• FDA-approved tinnitus treatment that utilizes a customized binaural broadband signal embedded in pleasant music to engage the limbic system in a positive fashion, allowing intermittent tinnitus perception and thereby facilitating habituation to the tinnitus.

• In 4 trials involving over 200 people, 80% - 90% of subjects achieved substantial reduction of their tinnitus symptoms.

• In one recent study (Davis et al, 2007), 91% of 35 subjects demonstrated a significant improvement in tinnitus disturbance
  
  – The average improvement in tinnitus disturbance for all subjects was 65%.
  
  – At 6 months, 80% of the subjects' reported tinnitus disturbance was no longer clinically significant.
Neuromonics Tinnitus Treatment

Customized for each patient’s individual hearing profile
Stimulation of a broad range of frequencies (250-12500 Hz)
Use of music as a medium for treatment
Provision of education and counseling
Successful outcome can require 6-10 months
# Neuromonics Tinnitus Treatment

<table>
<thead>
<tr>
<th>Tinnitus Severity &quot;Today&quot;</th>
<th>Average</th>
<th>Better</th>
<th>Worse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>48.2%</td>
<td>14.8%</td>
<td>37.0%</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Interaction Volume</td>
<td>8.96 (2.12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comfortable Volume</td>
<td>7.78 (1.97)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intermittent Interaction Volume</td>
<td>6.72 (2.74)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Results at Comfortable Volume</th>
<th>Interaction (&quot;Blending&quot;)</th>
<th>Relief from Tinnitus</th>
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</thead>
<tbody>
<tr>
<td>Complete</td>
<td>29.6%</td>
<td>22.2%</td>
</tr>
<tr>
<td>High</td>
<td>20.4%</td>
<td>24.1%</td>
</tr>
<tr>
<td>Moderate</td>
<td>40.7%</td>
<td>48.2%</td>
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<tr>
<td>Low</td>
<td>7.4%</td>
<td>3.7%</td>
</tr>
<tr>
<td>None</td>
<td>1.9%</td>
<td>1.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>94.4%</td>
</tr>
</tbody>
</table>
Neuromonics Tinnitus Treatment
Neuromonics Tinnitus Treatment

Our First 8 NTT Patients

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>TRQ: PRE</th>
<th>TRQ: POST</th>
<th>TRQ: Diff</th>
<th>Disturb: PRE Tx</th>
<th>Disturb: POST Tx</th>
<th>Aware: PRE Tx</th>
<th>Aware: POST Tx</th>
<th>Total Disturb: PRE Tx</th>
<th>Total Disturb: POST Tx</th>
<th>Total Disturb: Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>25</td>
<td>19</td>
<td>24.0%</td>
<td>100.0%</td>
<td>10.0%</td>
<td>80.0%</td>
<td>5.0%</td>
<td>80.0%</td>
<td>0.5%</td>
<td>99.4%</td>
</tr>
<tr>
<td>b</td>
<td>58</td>
<td>0</td>
<td>100.0%</td>
<td>15.0%</td>
<td>10.0%</td>
<td>25.0%</td>
<td>20.0%</td>
<td>3.8%</td>
<td>2.0%</td>
<td>46.7%</td>
</tr>
<tr>
<td>c</td>
<td>60</td>
<td>34</td>
<td>43.3%</td>
<td>70.0%</td>
<td>50.0%</td>
<td>90.0%</td>
<td>35.0%</td>
<td>63.0%</td>
<td>17.5%</td>
<td>72.2%</td>
</tr>
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<td>d</td>
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<td>80.0%</td>
<td>35.0%</td>
<td>100.0%</td>
<td>45.0%</td>
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<td>15.8%</td>
<td>80.3%</td>
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<tr>
<td>e</td>
<td>42</td>
<td>15</td>
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<td>80.0%</td>
<td>20.0%</td>
<td>100.0%</td>
<td>30.0%</td>
<td>80.0%</td>
<td>6.0%</td>
<td>92.5%</td>
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<tr>
<td>f</td>
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<td>50.0%</td>
<td>0.0%</td>
<td>50.0%</td>
<td>0.0%</td>
<td>25.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>g</td>
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<td>14</td>
<td>75.4%</td>
<td>90.0%</td>
<td>15.0%</td>
<td>80.0%</td>
<td>75.0%</td>
<td>72.0%</td>
<td>11.3%</td>
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<tr>
<td>h</td>
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<td>0</td>
<td>100.0%</td>
<td>25.0%</td>
<td>0.0%</td>
<td>100.0%</td>
<td>20.0%</td>
<td>25.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>AVG</td>
<td>46.1</td>
<td>10.3</td>
<td>75.9%</td>
<td><strong>63.8%</strong></td>
<td><strong>17.5%</strong></td>
<td><strong>78.1%</strong></td>
<td><strong>28.8%</strong></td>
<td><strong>53.6%</strong></td>
<td><strong>6.6%</strong></td>
<td><strong>84.4%</strong></td>
</tr>
<tr>
<td>S.D.</td>
<td>19.3</td>
<td>12.5</td>
<td>29.8%</td>
<td>30.8%</td>
<td>17.0%</td>
<td>27.2%</td>
<td><strong>23.5%</strong></td>
<td>30.8%</td>
<td>7.3%</td>
<td>18.4%</td>
</tr>
</tbody>
</table>

Habituation of Reaction  Habituation of Perception
Successful NTT outcome is defined as at least a 40% reduction in Tinnitus Reaction Questionnaire (TRQ – Wilson et al, 1991) score and a reduction in tinnitus awareness and tinnitus disturbance.

% Total Disturbance:

(% of waking hours aware of tinnitus) x (% of that time that tinnitus is disturbing)

Mean decrease in TRQ scores: 69.0% (S.D. = 19.7)

Mean decrease in tinnitus disturbance: 72.4% (S.D. = 24.1)
Wrap Up

• Definitions
• Prevalence
• Neurophysiological Model
• Progressive Tinnitus Management
Questions?