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Managing the Musician With Hearing Loss: Fundamentals and Diagnostics

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Disclosures

- Dr. Fligor owns Boston Audiology Consultants, Inc., a private clinical and technical consulting practice.
- Dr. Fligor is a consultant to Lantos Technologies, Inc., a privately-owned early-commercial medical device company. Dr. Fligor has ownership interest in Lantos Technologies, Inc.
- Dr. Fligor is chair of the WHO/ITU working group making recommendations for manufacture of personal audio systems (portable listening device, portable music player).
- Dr. Fligor receives an honorarium from AudiologyOnline for presenting.

Learning Outcomes

- Describe the limitations of applying occupational noise safety standard to musical exposures.
- Explain the relative risk for developing music-induced hearing disorders for specific musicians based on a detailed history and sound survey.
- Detail audiological evaluation considerations for musicians.
- Prescribe custom hearing protection devices based on the patient's individual relative risk for music-induced hearing disorders.

Topics

- Terminology
- Diagnostics
- Hearing Protection

Who is a Musician?

- Self-selected population
- Formal training?
- Paid for performance?
- Narrow view vs. wide view…

S. Benjamin "Benj" Kanters, M.M., "Music Professionals need an audiologist the way everyone else needs a dentist."

(www.HearTomorrow.org)

http://www.colum.edu/Academics/Audio_Arts_and_Acoustics/Faculty_and_Staff/bkanters.php

Who is a "Musician"?

- Professional, pre-professional, hobby musician, music teachers
- "Non-musician" producer
  - Audio engineer (post-production, Front of House, Monitor)
  - Disc Jockeys
  - Music producer
  - Music promoter
- Consumer (avid, occasional)
  - Live venue
  - Recorded

Holistic view of exposure

Music-Induced Auditory Injuries/Disorders (MIHD)

NIPTS (also NITTS):

- "Noise Notch": hearing threshold decrease poorest in the 3000 – 6000 Hz range

Other noise injuries:

- Tinnitus
- Abnormal pitch perception (diplacusis)
- Loudness intolerance (hyperacusis)

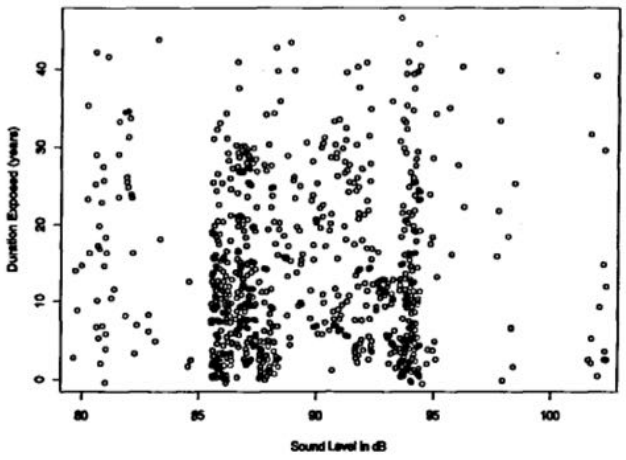
How Does Noise Damage Hearing?

- Gradually Developing Noise-Induced Permanent Threshold Shift (NIPTS)
  - 78 dBA – 130 something (?) dBA
  - Outer hair cells
  - Metabolic overload after duration of exposure
  - Gradual loss in sensory hearing
  - NITTS: recovery after a rest period

How Does Noise Damage Hearing?

- Acoustic Trauma (AT)
  - 140 dB Peak SPL (132 dB SPL - Price, 1981)
  - Usually from impulse: brief, fast rise time
  - Can result from marked “overdose”
  - Mechanical Damage after single exposure
  - Immediate loss of sensory hearing

ONHS 1968-1972, NIOSH



Scatter Plot of Noise Exposure (level and years) of 792 workers

Risk for a "Material Hearing Impairment"

OSHA (1981): Minimum Standard for Safety

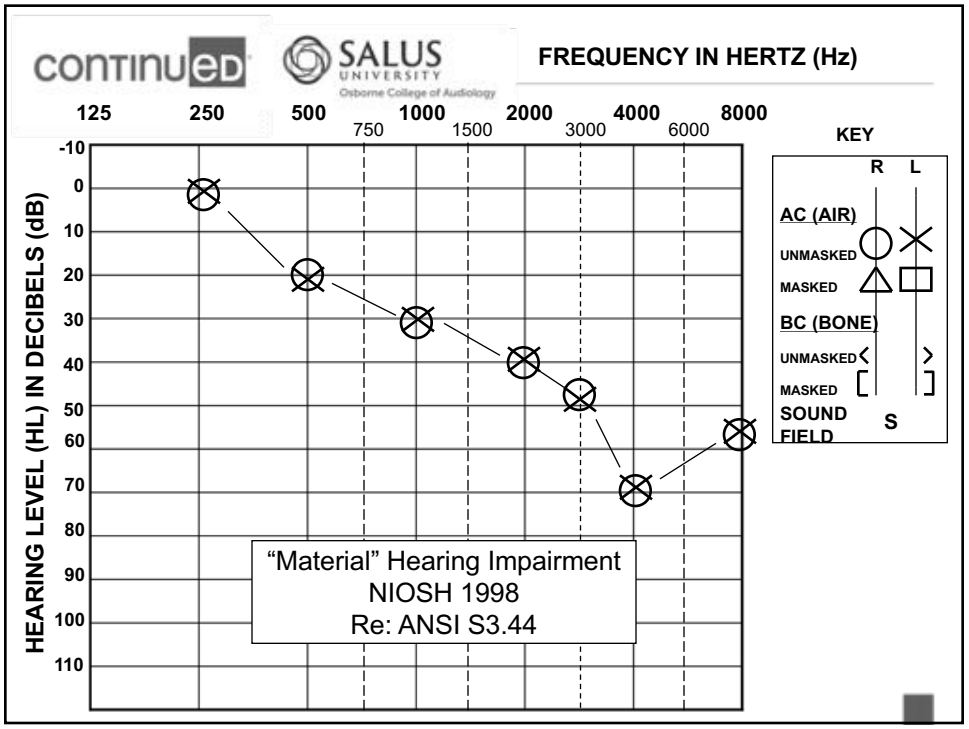
Organization	TWA Noise Exposure	Estimated % at Risk
ISO	*90 dBA*	*21%*
	85 dBA	*10%*
	80 dBA	*0%*
EPA	*90 dBA*	*22%*
	85 dBA	*12%*
	80 dBA	*5%*
NIOSH	*90 dBA*	*29%*
	85 dBA	*15%*
	80 dBA	*3%*
Prince, et al 1997	**85 dBA**	**8%**

Material Hearing Impairment?

NIOSH 1998 Definition:

> 25 dB HL Avg. 1k, 2k, 3k, and 4kHz

(What's that like?)



Damage Risk Criteria

OSHA
- 90 dBA, 8-hr TWA*
- 5 dB ER*

90 dBA | 8 hrs
95 dBA | 4 hrs
100 dBA | 2 hrs
105 dBA | 1 hr

NIOSH
- 85 dBA TWA
- 3 dB ER

85 dBA | 8 hrs
88 dBA | 4 hrs
91 dBA | 2 hrs
94 dBA | 1 hr

- **EPA / WHO**
  - 80 dBA TWA
  - 3 dB ER

80 dBA | 8 hrs
83 dBA | 4 hrs
86 dBA | 2 hrs
89 dBA | 1 hr

LIBERAL ⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯→ CONSERVATIVE

* "TWA" = Time-Weighted Average
* "ER" = Exchange Rate

Deep Dive into Music as a Source of Noise

- Is Music "noise"?
  - Time varying: rests (quiet) but also transients (Thiery and Meyer-Bisch, 1987)
  - Dynamic range
    - Music, perhaps 30 dB SPL (pppp) to 120 dB SPL (fff)
    - Speech, range 30-35 dB
  - Crest factor (RMS to peak)
    - Speech, RMS = 65 dB SPL, peaks ~12 dB higher
    - Music, RMS = ? (instrument dependent); peaks 18-20 dB higher (Chasin, 2007)
- Damage Risk Criteria (DRC) are based on occupational (steady-state) noise exposures…
  - There is no DRC for music

MIHD in Musicians

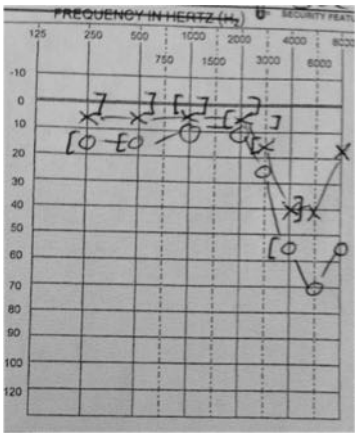
- Kahari et al (2003)
  - 139 rock and jazz musicians in Sweden (25 years experience)
  - "Hearing disorders" found in 74%
- Santos et al (2007): DJs in Brazil
  - Exposures: $L_{avg}5$ = 93.2 – 109.7 dBA)
  - 11 of 30 had NIPTS (presumed) at baseline
  - TTS and OAE reduction post-vs. pre-exposure
- Royster et al (1991): Chicago Symphony Orchestra
  - 68 noise exposure measures: 79-99 dBA (L_{eq} = 75-95 dBA; mean = 85.5 dBA)
  - 52.5% had "notched" audiograms
  - 32 musicians with good exposure history HTLs correlated with L_{eq} measures

Evaluation for MIHD in Musicians

- Diagnostic evaluation of music-induced hearing disorders:
  - When to refer or further medical evaluation, when to manage in-house
  - Evaluation for tinnitus reaction, hyperacusis, and diplacusis
- Prioritization of treatment: tinnitus, hyperacusis, diplacusis, and pure-tone threshold shift

Case Study, MIHD in Musicians

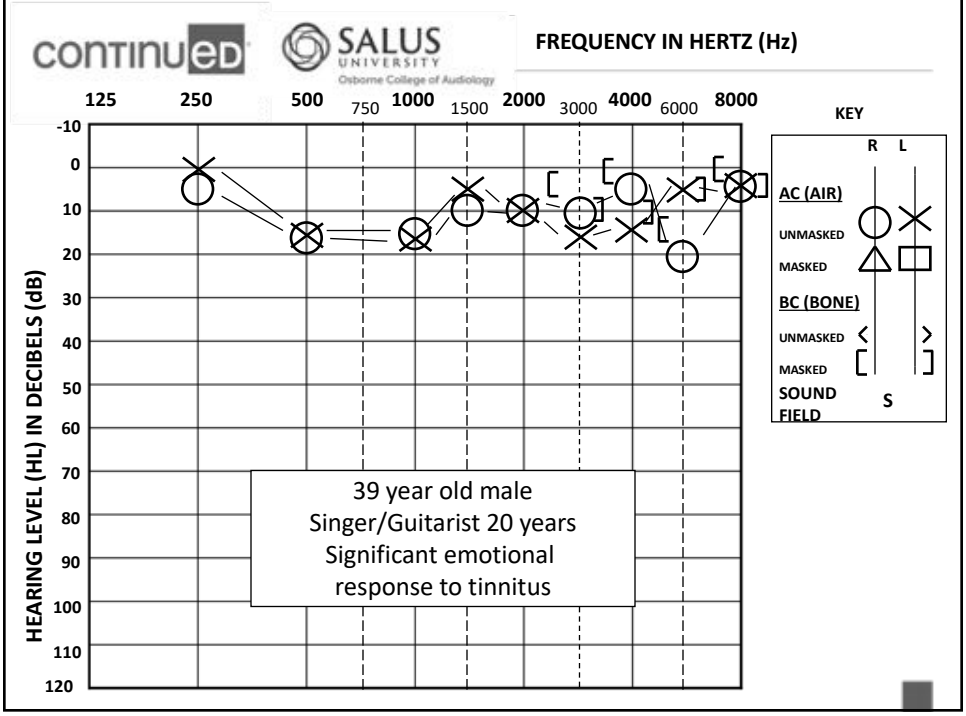
- 59 year old trial attorney
  - 4 years ago picked up bass guitar
  - 3 weeks before seeing me,
    "loud" practice,
    "crickets" in ears got louder
  - Why the asymmetry?



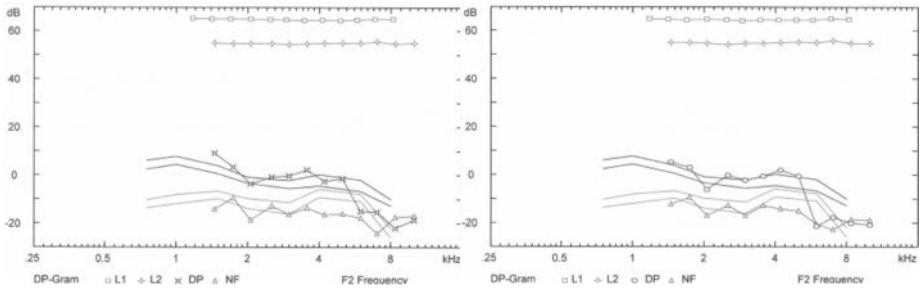
Normal Tympanograms and Middle-ear muscle reflexes
Excellent Word Recognition Scores bilaterally

Case Study, MIHD in Musicians

- 39 year old singer/guitarist
  - 20 years experience as semi-pro musicians
  - Radiology technician by trade
  - Chronic subjective tinnitus
  - Audiograms have historically shown normal hearing sensitivity (normal tymps, excellent WRS)
  - Using Shooters Muffs with foam earplugs during practice
  - Quit one band due to loud drummer
  - Significant emotional response to tinnitus



Case Study, MIHD in Musicians



- Absent DPOAEs at F2 = 6000 – 10,031 Hz Bilaterally
- Reduced DPOAEs at other discrete frequencies re: 95% normals (Gorga, et al., 1997)
- **Emotional Response to tinnitus significantly reduced in light of diagnostic process**

Evaluation for MIHD in Musicians

<u>Pure-tone air/bone and Speech testing:</u>

- Comprehensive audiometry (air, bone, speech) including 3k and 6k Hz
- +/- Extended-high frequency (EHF) audiometry (9k Hz – 20k Hz): Le Prell et al (2013)
- Immittance, +/- MEMR
- DPOAEs, 1500-10k Hz, 4 freq's per octave

At least annually, or as needed to evaluate TTS

Evaluation for MIHD in Musicians

Additions to evaluation for tinnitus complaint:

- Tinnitus Functional Index (Meikle et al 2011), Tinnitus Reaction Questionnaire (Wilson et al 1991), or Tinnitus Handicap Inventory (Newman et al 1996):
  - Meet criteria for "clinically significant"?
  - At intake and end point of therapy
- Minimum masking level
- +/- loudness and pitch matching, residual inhibition
- Informational Counseling

Evaluation for MIHD in Musicians

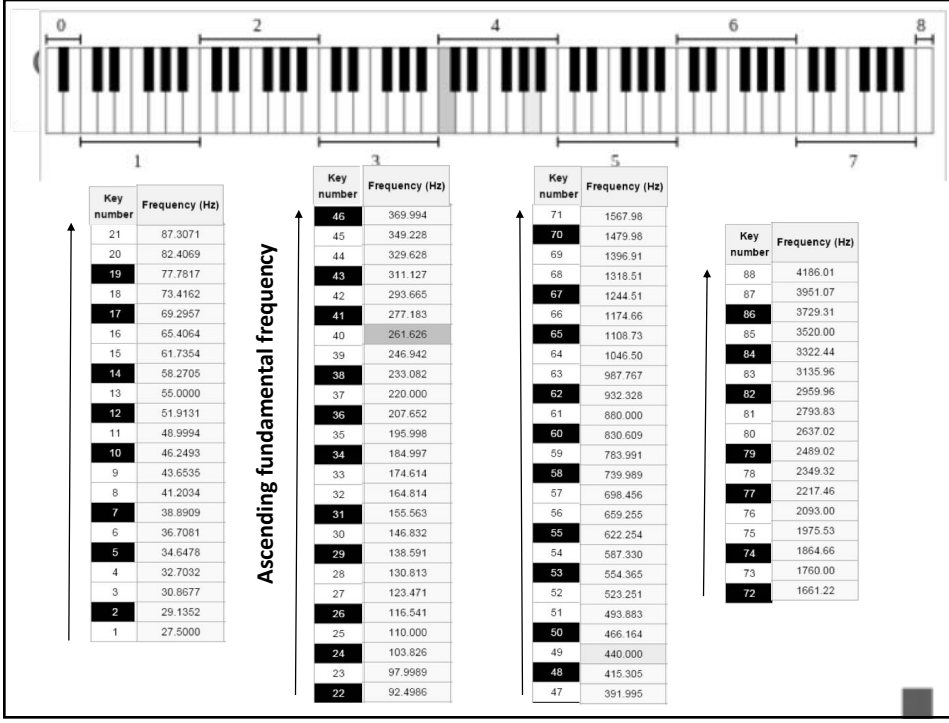
Additions to evaluation for loudness tolerance complaint:

- Measure UCL/LDL: cannot tell if "pain point" vs. "guarding"
  - Technique and instruction-specific
  - Establish trust
- Ipsilateral acoustic reflex: if patient can tolerate
- (DP) OAEs to determine possible latent cochlear damage/dysfunction
- Consider modifying tinnitus self-assessment questionnaire to illustrate hyperacusis challenges

Evaluation for MIHD in Musicians

Additions to evaluation for pitch perception (or distortion) complaint:

- Challenging in the clinical setting to assess
  - History might illuminate
  - Consider signal generator and tuner
- Possible concomitant poor speech-in-noise or WRS
- Might be level-specific (only obvious at high intensities)



Key number	Frequency (Hz)
21	87.3071
20	82.4069
19	77.7817
18	73.4162
17	69.2957
16	65.4064
15	61.7354
14	58.2705
13	55.0000
12	51.9131
11	48.9994
10	46.2493
9	43.6535
8	41.2034
7	38.8909
6	36.7081
5	34.6478
4	32.7032
3	30.8677
2	29.1352
1	27.5000

Key number	Frequency (Hz)
46	369.994
45	349.228
44	329.628
43	311.127
42	293.665
41	277.183
40	261.626
39	246.942
38	233.082
37	220.000
36	207.652
35	195.998
34	184.997
33	174.614
32	164.814
31	155.563
30	146.832
29	138.591
28	130.813
27	123.471
26	116.541
25	110.000
24	103.826
23	97.9989
22	92.4986

Key number	Frequency (Hz)
71	1567.98
70	1479.98
69	1396.91
68	1318.51
67	1244.51
66	1174.66
65	1108.73
64	1046.50
63	987.767
62	932.328
61	880.000
60	830.609
59	783.991
58	739.989
57	698.456
56	659.255
55	622.254
54	587.330
53	554.365
52	523.251
51	493.883
50	466.164
49	440.000
48	415.305
47	391.995

Key number	Frequency (Hz)
88	4186.01
87	3951.07
86	3729.31
85	3520.00
84	3322.44
83	3135.96
82	2959.96
81	2793.83
80	2637.02
79	2489.02
78	2349.32
77	2217.46
76	2093.00
75	1975.53
74	1864.66
73	1760.00
72	1661.22

Evaluation for MIHD in Musicians

Diplacusis:

AudioTools App
Metronome/Tuner

Evaluation for MIHD in Musicians

Medical Referral (when to refer, when to manage):

- Hearing Loss
  - Sudden hearing loss (even acoustic trauma)
  - *Unexplained* asymmetry (particularly if doesn't look like a notch)
  - Conductive component (especially with abnormal tympanometry or elevated reflexes)
  - Poor WRS, especially unilateral
  - Concomitant dizziness, especially with intense sound (e.g., Tullio phenomenon)

Evaluation for MIHD in Musicians

Medical Referral (when to refer, when to manage):

- Tinnitus
  - Any indication that the patient might harm himself (or others)
    - Ask the question, document the answer
  - To a lay person, do they seem anxious or depressed?
    - Past history of seeing behavioral health professional
  - Sleep disturbance, anxiety or depression that is not improving
  - *Unexplained* unilateral tinnitus
  - Concomitant dizziness
  - Poor WRS on affected side
  - Elevated or absent acoustic reflexes on affected side

Evaluation for MIHD in Musicians

Medical Referral (when to refer, when to manage):

- Hyperacusis (and Diplacusis)
  - Any indication that the patient might harm himself (or others)
    - Ask the question, document the answer
  - To a lay person, do they seem anxious or depressed?
    - Past history of seeing behavioral health professional
  - Sleep disturbance, anxiety or depression that is not improving
  - Concomitant dizziness
  - Poor WRS on affected side
  - Elevated or absent acoustic reflexes on affected side

Prioritization of Hearing Care

Why did he/she come in?

1. Tinnitus almost always is the reason
2. If not tinnitus, then hyperacusis
3. If hyperacusis and tinnitus, address hyperacusis first
4. Hearing Protection Devices (standard recommendation, and always custom)
5. Treat the patient, not the audiogram

Hearing Protection Devices

Why custom?

Open ear (unprotected)

Non-Custom

Custom (15 dB)

Sound quality

Consistency of fit, predictability of protection

PAR vs. NRR of non-custom vs. custom (Neitzel, et al., 2004)

Comfort, likelihood to use

Can we fit HPDs Prescriptively? Exposure Calculation

$$T = \frac{8 \text{ hours}}{2^{(L-Lmax)/ER}}$$

L = Exposure Level dBA
T = Time to 100% Noise Dose
Lmax = Maximum allowed dBA in 8 hrs
ER = Exchange Rate (e.g., 3 or 5)

$$\text{Noise Dose} = C / T$$

C = Exposure Time

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Exchange Rate: 3 dB or 5 dB?

85 dBA TWA, 3-dB trade

L dBA	*T* min 100%
85	480
86	381
87	302
88	240
89	190
90	151
91	120
92	95
93	76
94	60
95	48
96	38
97	30
98	24
99	19
100	15

90 dBA TWA, 5-dB trade

L dBA	*T* min 100%
85	960
90	480
95	240
96	209
97	182
98	158
99	138
100	120
101	104
102	91
103	79
104	69
105	60
106	52
107	45
110	30

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HPD: Can we prescriptively fit?

Theoretical Noise Survey (let's use "safer" 85 dBA, 3dB-ER)

- 97 dBA for 8 hours, daily
- Need to hear self and bandmates (and crowd)

Noise dose = C/T

T = 8 hrs/2^((97-85)/3) = 8 hrs/2^4 = 0.5 hrs (30 min)

Noise Dose = 8hrs/0.5hrs = 16 (as in, 16X allowable) = 1600%

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HPD: Can we prescriptively fit?

Theoretical Noise Survey (let's use "safer" 85 dBA, 3dB-ER)

- 97 dBA for 8 hours, daily
  - Let's try **15 dB** attenuator (e.g., ER-15 Musicians Earplug)

Noise dose = C/T

T = 8 hrs/2^((**[97-15]**-85)/3) = 8 hrs/2^((82-85)/3)

= 8 hrs/2^(-1) = 16 hrs

Noise Dose = 8hrs/16hrs = 0.5 (as in ½ allowable) = 50%

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HPD: "Flat Frequency Attenuators"

"They told me these were flat, but I don't think they are."

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HPD: Verification (probe mic)

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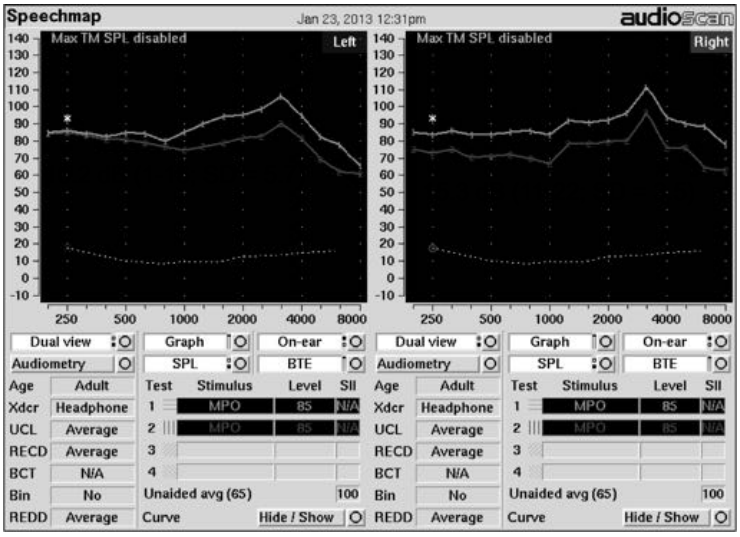
MIRE Verification of Flat Attenuation



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Custom In-Ear Monitors

Benefits over Earplugs and Floor Wedge Monitors:

1. Signal-to-noise ratio
   - Stage volume = ~105 dBA
   - Level under ER-15 = 90 dBA
   - ("More ME!"… levels creep up)
2. Sound quality

Risks: Incredibly powerful hearing damaging device

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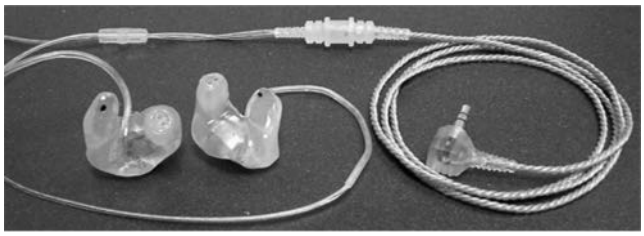
Custom In-Ear Monitors

Retrofit Custom mold on non-custom IEM

dB Check (Sensaphonics) Acoustic "speedometer"



Full custom IEM

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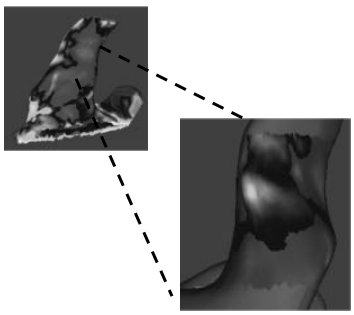
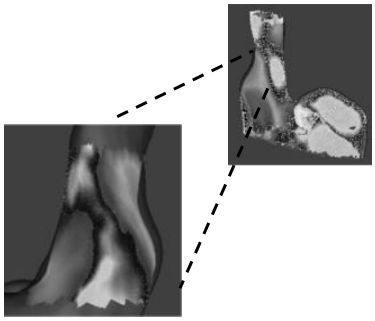
Earmold Impression Technique

- Open vs. Closed Jaw?
- EMI as they play their instrument





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Direct Ear Scanning Technique

- Dynamic Shape Change – not commercially available (yet!)

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Conclusions

- Music is capable of causing Sound-Induced (Music-Induced) Auditory Injuries
- Damage-Risk Criteria suitable for occupational noise exposure is tenuous, but the best we have
- Diagnostic testing, tinnitus questionnaire, and detailed history elucidates our plan of care
- Custom HPDs and Custom IEMs work better than non-custom
- Treat the patient, not the audiogram!

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