Hearing loss

By F. Ahmadzadeh MD; occupational & environmental medicine specialist
It is estimated that over 22 million workers are exposed to hazardous noise on the job and an additional nine million are at risk for hearing loss from other agents such as solvents and metals.

Noise-induced hearing loss is 100 percent preventable but once acquired, hearing loss is permanent and irreversible.
Occupational hearing loss may be partial or total unilateral or bilateral, and conductive, sensorineural, or mixed.

In the workplace, hearing loss can be caused by blunt or penetrating head injuries, explosions and thermal injuries such as slag burns sustained when a piece of welder's slag penetrates the eardrum.
Ear anatomy

- Eardrum
- Malleus
- Incus
- Stapes
- Semicircular canals
- Auditory nerve
- Facial Nerve
- Vestibular nerve
- Cochlea
- Eustachian tube
Physiology of Hearing

Sound pressure level: dynes/cm²

Decibels hearing level [dBHL]

The finest sound that is sensible by human has 0.00002 pa spl = 0 dBHL

\[
\text{dB} = 20 \log \frac{p_1}{p_0}
\]

If SPL = 0.0002 then dBHL = ?

\[
\text{dBHL} = 20 \log \frac{0.002}{0.0000002} = 40
\]
Relation of decibels to energy

- 10 dB  10 x increase in power
- 20 dB  100x increase in power
- 30 dB  1,000x increase in power
- 60 dB  1,000,000x increase in power
- 120 dB 1 trillion x increase in power
Steady-State Noise Examples

- Conversation 60dB
- Automobile 70dB
- Alarm Clock 80dB
- Screaming Child 90dB
- Pneumatic Drill 100dB
- Helicopter 110dB
- Live Concert 130dB
WAYS TO CHARACTERIZE OF NOISE

- **FREQUENCY** - perceived as pitch
- **INTENSITY** - perceived as loudness
- **NATURE** - steady-state vs. impulse/impact
- **DURATION** - length of time exposed
0-120 dB is range of faintest noise to painful stimulation.

The normal human cochlea is capable of detecting and encoding sound waves across the frequency range extending from approximately 20 hertz (Hz) to 20,000 Hz.

The most important range for human speech reception is between 500 Hz and 3000 Hz.
-Cochlear duct (1) which contains endolymph,
-Scala vestibuli (2)
-scala tympani (3) which contain perilymph.

*The red arrow is from the oval window, the blue arrow points to the round window. Within the modiolus, the spiral ganglion (4) and auditory nerve fibres (5) are seen
Sound Localization in the Cochlea
EVALUATION OF HEARING

- Test of spoken word
- Tuning fork tests (rinne, weber)
- Pure tone audiometry
- Speech audiometry (SRT, SDS)
- Impedance audiometry (Tympanometry, Acoustic R)
- Stenger test
- Evoked response audiometry
- Otoacoustic emissions
Test of spoken word

The patient is asked to repeat spoken words of increasing intensity while competing noises.

Test results may be expressed as the ability to hear:
1. soft whisper
2. loud whisper
3. soft spoken voice
4. loud spoken voice
5. shout
Tuning fork tests

- Rinne’s test
- Weber’s test
Striking the fork

- On bony prominence
- Not on hard surface
Rinne’s Test

**Purpose**
- Compare AC to BC

**How**
- Strike tuning fork
- Place TF alternately on mastoid process and opening of ear canal
Rinne interpretation

- Normal or Bilateral SNHL
  Positive Rinne – louder at opening ear canal
  AC > BC

- Abnormal
  Negative Rinne – louder on mastoid process
Rinne interpretation

If Rinne Negative, masking is Essential
Weber

Purpose:
Conductive vs. SNHL in unilateral losses

How:
Strike fork
Place midline of head
Incisors > Vertex > Forehead
Weber - interpretation

Normal - Midline sensation of hearing
= equal hearing both sides of same type
= equal loss of same type

Abnormal – Tone louder in one side
= Conductive loss – tone louder on affected side
= SNHL – tone louder on contralateral side
Pure tone audiometry

Air conduction

Bone conduction
How they do it (briefly)

1. Otoscopy + explanation
2. Best ear?
3. Start with AC on best ear
4. Start at 1000Hz at 60dB
5. Down by 10dB until no response
6. Then up by 5dB until response
7. Up and down frequencies
8. Same for bone
Pure tone audiometry

Sensitivity to pure tones are measured at 250, 500, 1000, 2000, 3000, 4000, and 8000 Hz for both air conduction (head phones) and bone conduction.
Normal PTA
Conductive Loss
Sensorineural Loss
Mixed Loss
The speech reception threshold (SRT) is the intensity (in decibels) at which the listener is able to repeat 50% of balanced two-syllable words.

The threshold is usually in close agreement (usually within 6-10 dB) with an average of the pure tone thresholds for frequencies between 500 and 3000 Hz.
Speech reception threshold

NL: 0-20

Mild: 20-40

Moderate: 40-60

Sever: 60-80

>80: Profound
SPEECH DISCRIMINATION SCORE

- Also referred to as word *recognition score*
- Monosyllabic words are presented at intensities SRT plus 25-40 dB
- Results are expressed as a percentage of words correctly repeated.
- The normal range of SDS is 88-100%.
Tympanometry

Is a measure of the stiffness of the eardrum and thus evaluate middle ear function. This test can be helpful in detecting:

- fluid in the middle ear
- negative middle ear pressure
- disruption of the ossicles
- tympanic membrane perforation
- otosclerosis.
Tympanometry

Measure of compliance of TM at varying pressure
Normal tympanogram (Type A)

Peak at 0daPa

Best movement of drum when no extra pressure on either side of TM
Other Type A tympanograms

- Peak at 0dPa
- Unusually high amplitude
- Ossicular disruption
Other Type A tympanograms

- Peak at 0dPa
- Low amplitude
- **Stapes fixation**
Flat tympanogram (Type B)

- No Peak
- No best TM movement at any pressure
Flat tympanogram (Type B)

When tymp is flat, usually means 1 of 3 things:

1. Artefact
2. Fluid in ME
3. Perforation

Look at ear canal vol. If large = perf
If normal = fluid
Negative tympanogram (Type C)

Peak at < 0dPa
ACOUSTIC REFLEX TESTING

Contraction of the middle ear muscles in response to a loud noise results in a measurable rise of middle ear impedance.
Evoked Response Audiometry (Brain Stem Audiometry)

In patients who demonstrate unilateral or asymmetric sensorineural hearing loss, retrocochlear lesions (lesions of the eighth cranial nerve, brain stem, or cortex) must be ruled out.

Evoked potentials, which are typically elicited in response to clicking noises and recorded via scalp electrodes, provide information about the location of sensorineural lesions.
five electroencephalographic waves may be detected, representing the central auditory system from the eighth cranial nerve (wave 1) to the inferior colliculus (wave 5).
Stenger Test

This test is useful for detecting feigned unilateral hearing loss.

when two tones of the same frequency but of different loudness are presented to both ears simultaneously, only the louder tone will be heard.
Stenger Test

When the louder tone is presented to the ear with a feigned hearing loss, the patient stops responding.

Patients with true unilateral loss indicate that they continue to hear the sound in the opposite ear.
Otoacoustic Emissions

If an individual generates OAEs, but does not admit to hearing, a nonorganic origin must be assumed.
DIFFERENTIAL DIAGNOSIS OF SENSORINEURAL HEARING LOSS

Non occupational Hearing Loss

Noise-Induced Hearing Loss
PRESBYCUSIS

Hearing loss is a gradual, symmetric, progressive high frequency sensorineural associated with gradual deteriorating speech discrimination.
HEREDITARY HEARING IMPAIRMENT

Distinguished by a family history and early age at onset; however, there are delayed-onset forms of HHL.

can be conductive, mixed, or sensorineural.

Otosclerosis is an example of a progressive autosomal dominant hearing loss that can be conductive, mixed, or sensorineural hearing loss.
METABOLIC DISORDERS

DM, thyroid dysfunction, renal failure, autoimmune disease, hyperlipidemia, and hypercholesterolemia.

May result in a sensorineural hearing loss that is bilateral, progressive, and high frequency.
Sudden SNHL

- Sudden onset, usually within 1 or 2 hours, in the absence of precipitating factors.
- Almost always unilateral

Sensorineural hearing loss (SNHL)
- Can be exhibited at low frequencies with improvement in the high frequencies, flat, or high frequency with good low-frequency hearing.
SUDDEN SNHL

- Ranging from mild to severe

- The etiology of SNHL is unknown; speculation as to viral, vascular insult, or inner ear membrane rupture.
Infections

- meningitis and encephalitis
- syphilis and Lyme

Congenital syphilis sufferer may develop symptoms in infancy or later in life that may also be associated with vestibular symptoms similar to Meniere syndrome; the hearing loss is usually bilateral.
Late syphilis may present a slowly progressive sensorineural hearing loss and may also exhibit associated vestibular problems.

Mumps may cause a severe, most typically **unilateral** sensorineural hearing loss
Cerebellopontine angle tumors, especially acoustic neuroma, may present progressive sensorineural hearing loss that is unilateral.

Demyelinating diseases (e.g., multiple sclerosis) may present a **sudden unilateral hearing loss** that typically recovers to some degree.
MENIERE DISEASE
(ENDOLYMPHATIC HYDROPS)

- fluctuating low frequency or flat unilateral sensorineural hearing loss
- fullness or pressure in the affected ear
- tinnitus
- episodic disabling vertigo
- In early stage usually low frequency sensorineural but over time it may progress to a flat severe hearing loss.
NONORGANIC HEARING LOSS

- Functional hearing loss for purposes of secondary gain is quite frequent.

- Poor correlation between the SRT and the average of the air conduction thresholds at 500, 1000, and 2000 Hz is the most common indication of functionality.

- Test-retest variability is also suggestive.

- In cases of suspected uni-lateral functional hearing loss, the Stenger test is useful.
NOISE-INDUCED HEARING LOSS

Results from trauma to the sensory epithelium of the cochlea.

Vascular, chemical, and metabolic changes occurring in the sensory cells

Initially the vascular, chemical, and metabolic changes are potentially reversible, and, given time, the hearing will recover. This is known as a temporary threshold shift (TTS)
continued noise exposure results in permanent loss of stereocilia which are replaced by scar tissue, is known as permanent threshold shift (PTS)

Because TTS may mimic PTS, individuals should be given audiometric tests after a recovery period of 12-24 hours following exposure to hazardous levels of noise.
NOISE-INDUCED HEARING LOSS

PTS may be caused by a brief exposure to extremely high-intensity sounds (>140dB) but it is more commonly caused by prolonged repetitive exposure to lower levels of hazardous noise.

Susceptibility to NIHL is highly variable.
Risk of permanent hearing impairment is related to the duration and intensity of exposure as well as genetic susceptibility to noise trauma.

Prolonged exposure to sounds louder than 85 dBA is potentially injurious.

Most severe around 4000 Hz, with extension toward the "speech frequencies" (500-3000 Hz) occurring only after prolonged or severe exposure.
ACUTE NOISE INDUCED HEARING LOSS

Result from a brief exposure to extremely loud noise (explosion)

May also occur following single periods of exposure to continuous noise. (For example, several hours of unprotected exposure to a jet turbine producing sounds in the 120-140 dB )

Acute NIHL can result in temporary or permanent damage
Clinical Findings

- Bilateral, predominantly high-frequency sensorineural hearing loss with a maximum drop of the pure tone thresholds occurring at or around 4000 Hz.
- Asymmetry can exist.
- Frequently complain of gradual deterioration in hearing.
Clinical Findings

- Difficulty in comprehending speech, especially in the presence of competing background noise.
- Vowel sounds are heard better than consonant sounds.
- Frequently accompanied by tinnitus:
  1. High freq. Tonal (ringing)
  2. Low freq. Tonal (buzzing, blowing, hissing)
  3. Non tonal (popping, clicking)
Clinical Findings

Tinnitus frequency matches the frequency of the hearing loss seen on the audiogram and is about 5 dB above that threshold in loudness.

SDS is normal in the early stages but may deteriorate as the loss becomes more severe.
85 dBA has been characterized as the approximate biologic threshold above which permanent shifts in hearing are possible.

OSHA: the presence of occupational noise at or above an 8-hour TWA exposure of 85 dBA is the threshold that triggers the need to HCP.
A time-weighted average is used to calculate a workers daily exposure to a hazardous substance (such as chemicals, dusts, fumes, mists, gases, or vapors) or agent (such as occupational noise), averaged to an 8-hour workday, taking into account the average levels of the substance or agent and the time spent in the area.

This is the guideline OSHA uses to determine permissible exposure limits (PELs) and is essential in assessing a worker's exposure and determining what protective measures should be taken. A time-weighted average is equal to the sum of the portion of each time period (as a decimal, such as 0.25 hour) multiplied by the levels of the substance or agent during the time period divided by the hours in the workday (usually 8 hours)
A hearing conservation program (HCP) is the recognized method of preventing noise induced hearing loss in the occupational environment.
hearing conservation program (HCP)

1. noise monitoring
2. engineering controls
3. administrating controls
4. worker education
5. Hearing Protection Devices (HPD)
6. Periodic audiometric evaluation
The noise must be characterized:
1. Frequency (predominantly high, predominantly low, or mixed)
2. Intensity (how loud it is)
3. Type (continuous, intermittent, or impulse)

Anytime there is any change in production, process, equipment, or controls, all noise monitoring tests must be repeated.
Continuous noise

Fluctuating noise

Intermittent noise

Impulse noise
Noise Measurement

- **Sound level meter:**
  - measures ambient noise levels in decibels

- **Dosimeter:**
  - sound level meter that integrates constant or fluctuating sound over time
Sound level meters
Noise dosimeter
A Scale

شبکه A

گوش انسان به فرکانس‌های بیم حساسیت کمتری دارد. بعبارت دیگر آستانه شنوایی در این فرکانس‌ها بالاتر است. در شبکه A مقادیر تراز فشار صوت متناسب با حساسیت گوش dBa انسان در ترازهای پایین توزین می‌شود. تراز اندام‌گیری شده در این وضعیت بر حسب بیان می‌گردد. استاندارد های مواجهه به این مبنا هستند، لذا اندام‌گیری صدا بمنظور تعیین حدود مواجهه کارگر نیز با این مقياس می باشد. منحنی توزین فرکانس در شبکه A منطبق با منحنی درک شنوایی انسان خصوصاً در ترازهای کمتر از ۶۰ دسیبل است.
این شاخص بیانگر درک شنوایی انسان در تراز‌های بالا است. لذا برای اهداف تجزیه‌فارق‌سازی صوت، کنترل صدا و ترازوی فشار بالاتر از 85 dB از این مقياس استفاده می‌شود.

همچنین بر اساس نظر ACGIH\(^1\) برای تعیین حدود صاف‌یک‌های ترازو فشار پیک صدا کوبه‌ای نیز از این شاخص استفاده می‌گردد.
جمع ترازهای صوتی

هر موج صوتی که به گوش می‌رسد نتیجه انتشار صوت منابع مختلف و تراز فشار صوت در فرکانس‌ها می‌تواند اثر افزایشی بر هم‌داشت باشد و ایین بمعنای جمع چند جبری تراز‌ها نیست. اصولاً تراز های صوت را به دلیل ماهیت لگاریتمی نمی‌توان جمع چند جبری نمود. اما حاصل چنین تراز موجود چه در فرکانس‌های مختلف و چه در اثر منابع مختلف یک تراز است که به آن تراز کلی صوت \( SPL \) می‌گویند. در هنگام اندازه‌گیری صوت که معمولاً تراز صوت کلی در هر استیت‌گاه اندازه‌گیری می‌شود و مبنای ارزیابی مواجهه کارگر قرار می‌گیرد، خود نتیجه اثر تراز فشار صوت منابع و اثر تراز فشار صوت در هر یک فرکانس‌ها منابع می‌باشد. رابطه زیر نحوه جمع تراز های فشار صوت را بیان می‌کند:

\[
LP_T = 10 \log \left[ \sum_{i=1}^{n} \left( \frac{P}{P_0} \right)^2 \right] = 10 \log \left[ \sum_{i=1}^{n} \text{anti log} \left( \frac{LP_i}{10} \right) \right]
\]

\[
LP_T (dB) = 10 \log \left[ \sum_{i=1}^{n} 10^{LP_i/10} \right]
\]

\( LP_T \) : تراز مجموع (کلی) فشار صوت
\( LP_i \) : تراز فشار صوت هر منبع یا تراز فشار صوت در یک فرکانس خاص منبع
\( dB \) : تراز فشار صوت هر منبع یا تراز فشار صوت در یک فرکانس خاص منبع
در بررسی یک منبع صوتی معلوم شده است که در تجزیه یک اکتاو باند تراز های زیر از صدا توسط منبع منتشر شده است تراز فشار صوت را محاسبه نمایید:

<table>
<thead>
<tr>
<th>Freq (Hz)</th>
<th>SPL (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>73</td>
</tr>
<tr>
<td>125</td>
<td>74</td>
</tr>
<tr>
<td>250</td>
<td>80</td>
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<tr>
<td>500</td>
<td>86</td>
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<tr>
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<td>86</td>
</tr>
<tr>
<td>8000</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>66</td>
</tr>
</tbody>
</table>

\[
LP_T (dB) = 10 \log \left( \sum_{i=1}^{n} 10^{\frac{LP_i}{10}} \right)
\]

\[
LP_T = 10 \log \left[ 10^{7.7/10} + 10^{7.7/10} + 10^{7.6/10} + 10^{8.0/10} + 10^{8.0/10} + 10^{8.5/10} + 10^{8.4/10} + 10^{6.8/10} \right] = 90.9 dB
\]

مثال

اگر تراز دو منبع صوتی 90 دسیبل باشد تراز مجموع حاصل از این دو منبع در هنگامی که هر دو روشن باشند چند دسیبل است؟

\[
LP_T (dB) = 10 \log \left( 10^{9/10} + 10^{9/10} \right) = 93 dB
\]
<table>
<thead>
<tr>
<th>تفاصل ذو تراز (dB)</th>
<th>عددی که باید به تراز بزرگتر اضافه نمود</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2/6</td>
</tr>
<tr>
<td>2</td>
<td>2/1</td>
</tr>
<tr>
<td>1</td>
<td>1/8</td>
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<tr>
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<td>6</td>
<td>1</td>
</tr>
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<td>7</td>
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<td>8</td>
<td>0/6</td>
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<tr>
<td>9</td>
<td>0/5</td>
</tr>
<tr>
<td>10</td>
<td>0/4</td>
</tr>
<tr>
<td>12</td>
<td>0/3</td>
</tr>
<tr>
<td>14</td>
<td>0/2</td>
</tr>
<tr>
<td>16</td>
<td>0/1</td>
</tr>
<tr>
<td>19/4</td>
<td>0/0</td>
</tr>
</tbody>
</table>

جمع تراز های صوتی با استفاده از جدول
Engineering controls

- Based on the information collected during noise monitoring.

- Possible engineering solutions:
  - The source
  - The path
  - The receivers
Engineering controls

The noise controls may involve the use of enclosures (to isolate sources or receivers), barriers (to reduce acoustic energy along the path), or distance.

In general, engineering controls are preferred but are not always feasible because of their costs and limits in technology.
Administrative controls

Reducing the amount of time a given worker might be exposed to a noise source in order to prevent the TWA noise exposure from reaching 85 dBA, and establishing purchasing guidelines to prevent introduction of equipment that would increase worker noise dose.
Workers must understand the potentially harmful effects of noise.

In general, the use of HPDs by employee exposed to TWA noise levels of 85 dBA or greater is recommended.
A good worker education program describes

(1) Program objectives
(2) Existing noise hazards,
(3) How hearing loss occurs,
(4) Purpose of audiometric testing, and
(5) What workers can do to protect themselves.
There are three basic types of HPDs:

- **Ear plugs** or "aurals" (premolded, formable, and custom molded)
- **Caps** or "semiaurals" (with a band that compresses each end against the entrance of the ear canal)
- **Ear muffs** or "circumaurals"
Although the HCP is triggered by the presence of noise levels equal to or greater than an 8-hour TWA of 85 dBA, HPDs must attenuate worker exposure to an 8-hour TWA at or below 90 dBA

Hearing protection devices
Premolded ear plugs

- (NRR)=23dB
- 5 color-coded sizes:
  - White (Extra Small)
  - Green (Small)
  - Orange (Medium)
  - Blue (Large)
  - Red (Extra Large)
Formable ear plugs

Foam  Fiberglass  Silicone
1. Using clean hands, roll and compress the entire earplug into a thin cylinder.
2. To make insertion easier, pull back and up on outer part of ear.

3. Insert earplug into ear canal and hold in place for a few seconds until it expands and blocks out noise.
4. Properly inserted.

5. Not properly inserted.
Straighten the ear canal before inserting the plug.
Custom molded earplugs

Custom Molded

Portion that enters ear canal
Ear muffs

Noise Reduction Rating (NRR)=23dB
Ear muffs
Noise Reduction Rating

- All HPD are assigned a standardized as NRR.
- NRRs are based on laboratory attenuation data and achieved under ideal conditions.
- Adjustment of the assigned NRR based on:
  A- Weighting scale adjustment
  B- Derating
  C- Combining HPDs
**Weighting scale adjustment**

If workplace noise levels are determined by using the "C" scale (dBC), the assigned NRR may be subtracted directly from the actual measured TWA noise levels.

If workplace noise levels are determined by using the "A" scale (dBA) on the monitoring instrumentation, the assigned NRR must be reduced by 7 dB before being subtracted from the actual measured.
Derating

- OSHA derates the assigned NRR (after weighting scale adjustment) for all types of HPDs to relative performance by 50%.

- NIOSH recommendation:
  - *Earmuffs* are derated 25%
  - *Formable earplugs* are derated 50%
  - *Other earplugs* are derated 70%
If a device has an NRR of 21 and workplace noise measurements were made using the "A" scale, then the predicted field attenuation or "relative performance" of the device would be:

\[
\frac{(21 - 7)}{2} = 7 \text{ dBA}
\]

- (Such a device would be expected to provide protection where 8-hour TWA noise levels up to 97 (90 + 7) dBA are present.)
Combining HPDs

OSHA advises its inspectors that 5 dB are to be added after the weighting scale adjustment is applied to the device with the higher NRR.
Only quantitative means of assessing the overall effectiveness of a hearing conservation program.

Results of audiometric testing must be shared with employees to ensure effectiveness.
## OSHA permissible noise exposure level

<table>
<thead>
<tr>
<th>Duration/Day</th>
<th>Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 hrs</td>
<td>90 dB(A)</td>
</tr>
<tr>
<td>6 hrs</td>
<td>92 dB(A)</td>
</tr>
<tr>
<td>4 hrs</td>
<td>95 dB(A)</td>
</tr>
<tr>
<td>2 hrs</td>
<td>97 dB(A)</td>
</tr>
<tr>
<td>1 hr</td>
<td>100 dB(A)</td>
</tr>
<tr>
<td>.25 hr</td>
<td>115 dB(A)</td>
</tr>
<tr>
<td>Sound level resulting from the use of the protector (dBA)</td>
<td>Protection outcome</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>85+</td>
<td>Insufficient</td>
</tr>
<tr>
<td>80–85</td>
<td>Acceptable</td>
</tr>
<tr>
<td>75–80</td>
<td>Optimal or Ideal</td>
</tr>
<tr>
<td>70–75</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Less than 70</td>
<td>Overprotection</td>
</tr>
</tbody>
</table>
**calculation of impairment**  
**AAO-79 method**

<table>
<thead>
<tr>
<th>Hertz (Hz)</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right ear (dB)</td>
<td>25</td>
<td>35</td>
<td>35</td>
<td>45</td>
<td>50</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>Left ear (dB)</td>
<td>25</td>
<td>35</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>50</td>
</tr>
</tbody>
</table>

1. **Unilateral impairment:**  
  (Average dB at 500, 1000, 2000, 3000 Hz) − 25 dB (low fence) × 1.5% = Percentage of unilateral impairment  
  Right ear = \((25 + 35 + 35 + 45 \div 4) − 25 \times 1.5\%) = 15\%  
  Left ear = \((25 + 35 + 40 + 50 \div 4) − 25 \times 1.5\%) = 18.8\%  

2. **Bilateral impairment:**  
  (Percentage of unilateral impairment in better ear × 5) + (Percentage of unilateral impairment in poorer ear) ÷ 6 = Percentage of bilateral impairment  
  \((15 \times 5) + (18.8\%) ÷ 6 = 15.6\%\)
Criteria need to action

- **Baseline audiogram:**
  
a- Average HL at 500, 1000, 2000, and 3000 Hz > 25 dB in either ear.
  
b- Difference in average HL between the better and poorer ears > 15 dB at 500, 1000, and 2000 Hz or > 30 dB at 3000, 4000, and 6000 Hz.

- **Periodic audiogram:**
  
  - Change for the worse in average HL in either ear compared to the baseline audiogram > 15 dB at 500, 1000, and 2000 Hz or > 20 dB at 3000, 4000, and 6000 Hz.

- **Other criteria:** ear pain, drainage, dizziness, tinnitus, fluctuating or rapidly progressive hearing loss, and ...
Thanks