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Audiometric Testing and Audiogram Interpretation

Audiology: Science to Practice by Kramer & Brown (2019)

Chapters 6 and 7

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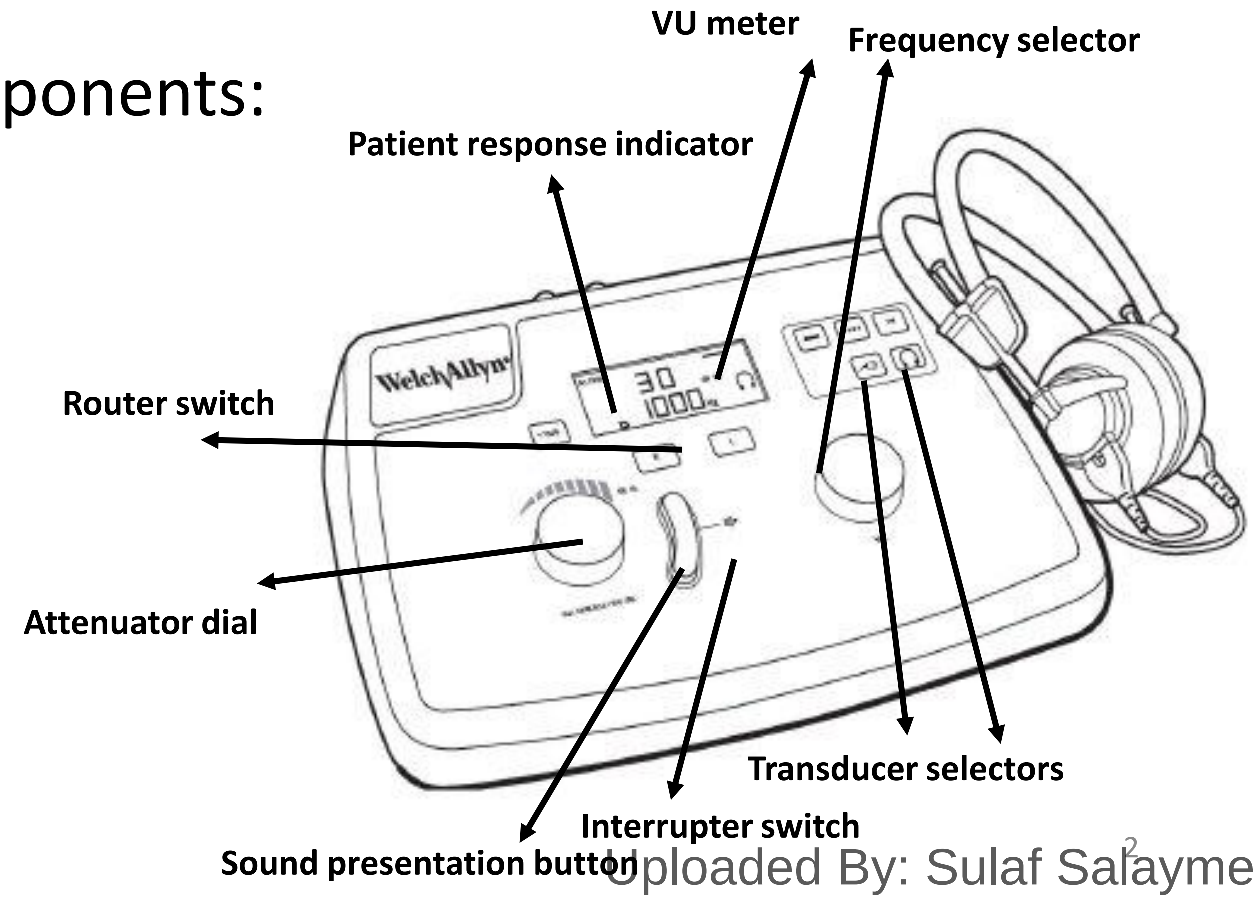
The audiometer and its components

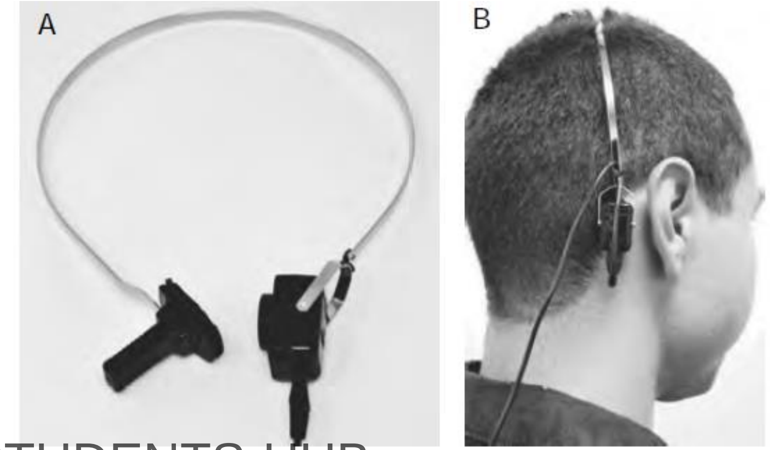
- The audiologist uses an instrument called an audiometer for many of the hearing tests.
- The audiometer has several components:

Function	Component
Selects the frequency of the pure tone	Frequency selector
Changes sound pressure level of signal	Attenuator dial
Selects how the signal is delivered	Transducer selector
Directs signal to desired location	Router switch
Presents the signal to the patient	Interrupter switch
Indicates whether patient responded	Patient response indicator
Monitors/calibrates input level	VU meter



Audiometric transducers

- The function of transducers is to deliver sound to the patient.
- Three types:
- Supra-aural earphones (TDH-39)
- Insert earphones
- Bone conduction earphones (bone vibrator)



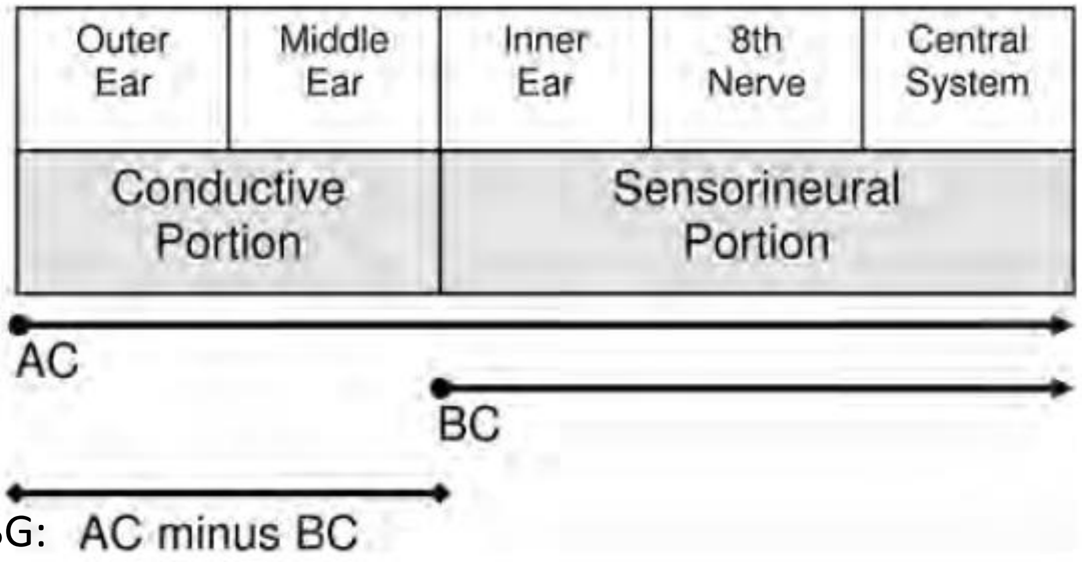
Audiometric transducers

- Sound field / free-field transducers
- Extended high-frequency supra-aural headphones (for frequencies > 8 kHz)

FIGURE 6–5. A. A set of extended high-frequency earphones (Sennheiser HDA200). **B.** Extended high-frequency earphones properly placed for testing.

Air conduction vs. bone conduction testing

- When earphones are used to deliver sounds to the patient, this is referred to as air conduction (AC) testing.
- When the bone conduction vibrator is used to deliver sounds to the patient, it is called bone conduction (BC) testing.
- Testing by AC stimulates the entire auditory system
- testing by BC delivers the vibrations through the skull and are picked up by the inner ears(BC testing essentially bypasses the portions of the auditory pathway.
- The difference in thresholds between AC and BC is referred to as the air-bone gap (ABG).



ABG:

Let's watch

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- https://www.youtube.com/watch?v=Mwz3dU3Tl9M

Audiometric test environment

- Diagnostic hearing testing must be done in a specially designed sound-attenuating test room (also called a sound-proof booth).
- Contains sound absorption material and small holes in the inside wall to absorb the sounds and reduce reflections.
- The test room can be single-walled or double-walled.
- Test rooms can be arranged so that the equipment/ tester is outside of the patient test booth, or as a two-room test suite that has one room for the patient and a separate room for the equipment

Patient positioning in the test room

- The position of the patient in the test booth can be varied **depending on the situation**.
- The arrangement must be such that the patient is unable to discern any inadvertent cues by the tester, such as hand, head, or eye movements, facial expressions, or visible reflections.
- In order to reduce the possibility of inadvertent cues.
- The typical orientation would have the patient facing 45º to 90º away from the observation window.
- Patients may respond by raising their hand or by clicking on a button (response appears on audiometer screen).

Instructions to patients

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- Provide some clear instructions to the patient.
- For example: “We are interested in finding the faintest level at which you are able to hear sounds of different pitches. Listen carefully and be sure to press the response button (or raise your hand) as soon as you think you hear a sound and release the button (or lower your hand) as soon as the sound goes away. We will be testing each ear separately. Do you have any questions?”

Placement of transducers

- Place the appropriate transducer on the patient in the proper position (remember Red = Right).
- Do not allow the patient to put the transducer on or move it.
- Improper placement will result in inaccurate thresholds.
- Test AC before BC and begin AC testing in the better-hearing ear if known or as reported by the patient.

Familiarisation Stage

- Begin testing with a familiarization phase.
- This involves presenting a 1000 Hz pure tone at a relatively easy level to hear (e.g., 30 to 40 dB above the estimated threshold of the patient), in order to allow the patient to become familiar with the task and to show the tester that the patient understands the task.
- If the patient does not hear the pure tone at the initial level, the level is increased in 20 dB steps until a response is obtained.
- Often, the familiarization phase is continued by decreasing the level of the pure tone in 10 dB steps until the patient no longer responds.

Frequency selection

- Select the desired frequency: Testing usually begins with 1000 Hz because it is a mid-range tone that is generally easier to perceive, and is the frequency used for the familiarization phase.
- The order of frequencies tested is not critical; however, the order suggested by ASHA (2005) is 1000, 2000, 3000, 4000, 6000, 8000, 500, 250 Hz.
- Retesting 1000 Hz in the first ear is recommended in order to account for improvement due to practice effects with the other frequencies.

Frequency selection

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- The inclusion of 125 Hz for AC testing is recommended in cases when there is a **low frequency hearing loss or** when interested **in better characterizing residual low frequency hearing.**
- 750 and 1500 Hz should be tested if there is more **than a 20 dB difference in thresholds** between the **adjacent octave frequencies**.
- For BC testing, the recommended testing sequence is 1000, 2000, 500, and 4000 Hz.

Tone presentation

- Present the pure tone by pressing and releasing the interrupter button.
- The presentations of the tones or series of pulses should be 1 to 3 s in duration.
- There should be variable pauses (1 to 3 s) between presentations so that the patient is not able to predict the rhythm of the presentations.

Procedures for obtaining pure-tone thresholds

- **Hearing threshold** is defined as the lowest intensity level that the patient can hear 50% of the time.
- Begin the threshold search phase using the up-5 down-10 procedure.
- This means that when the patient does not respond, the level of the pure tone is increased in 5 dB steps until he or she does respond, and decreased by 10 dB (presumably below threshold) until the patient does not respond.
- These bracketing steps are repeated until a threshold for that frequency is established.

Procedures for obtaining pure-tone thresholds

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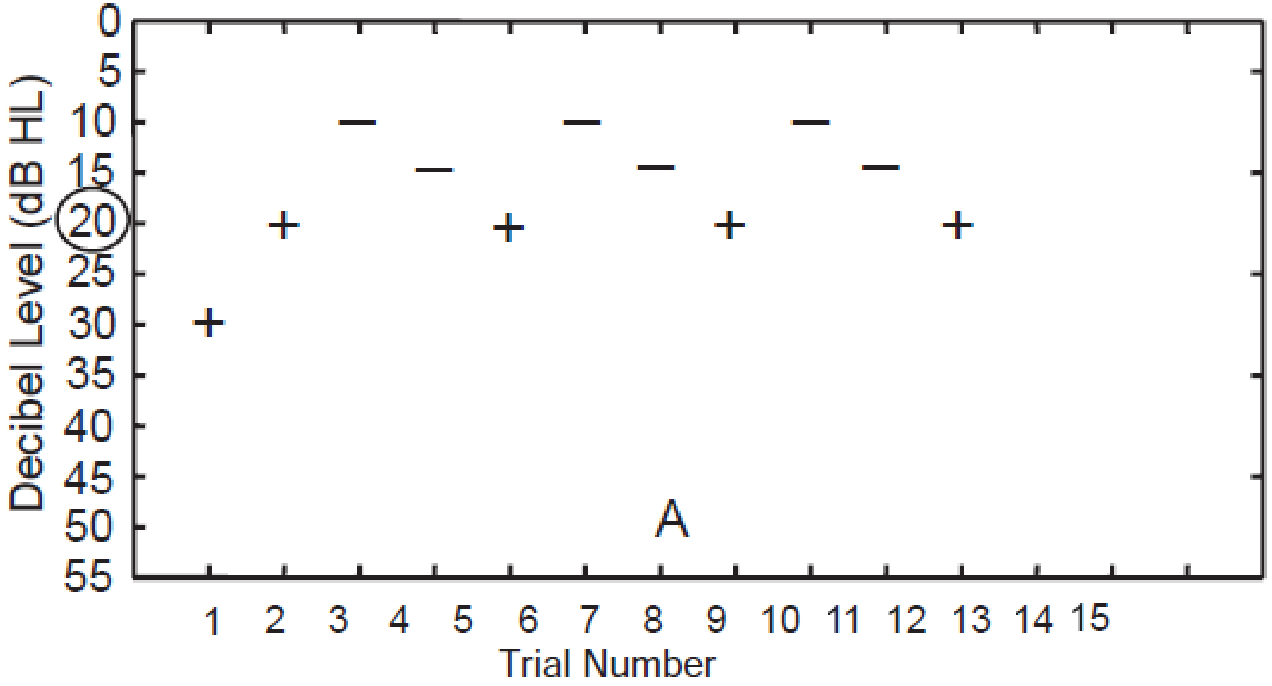
- Continue the tone presentations, using the up-5-down-10 procedure, until the threshold is established based on the following definition.

- **A pure-tone threshold is defined**: as the **lowest intensity level** that the patient responds to at **least 50%** of a **series of ascending presentations**, with at least two responses out of at **2 or 3 or 4 trials for a single level** (i.e., 2/2 or 2/3 or 2/4 correct ascending responses).

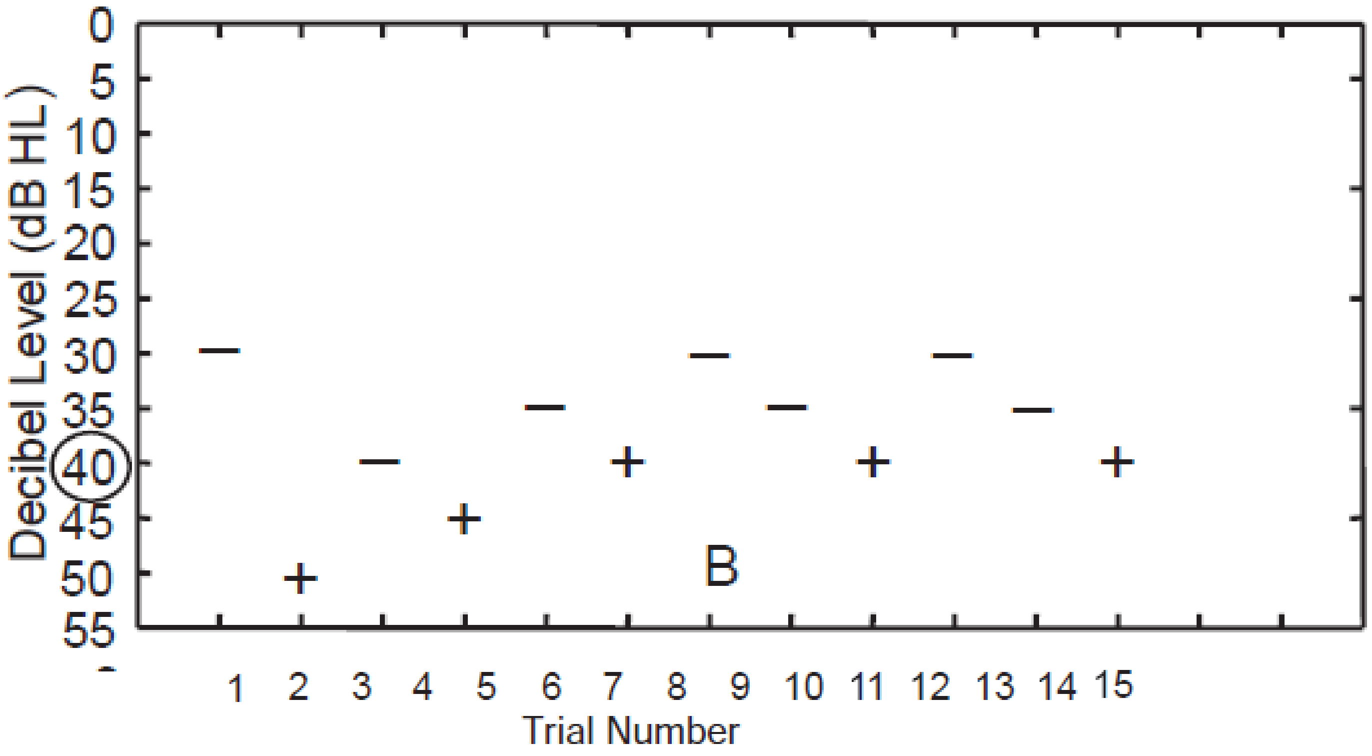
Example 1

+ : the patient hears
- : the patient does not hear



Example 2

+ : the patient hears
- : the patient does not hear



Variables influencing thresholds

- Background noise
- Cognitive abilities (concentration/ attention ..)
- Motor response (e.g. elderly)
- Tinnitus
- Patient cooperation (false responses)

Test-retest variability

- Typically (+/- 5 dB) for PTA (but can be worse)
- Unusually worst at:
  - Extreme frequencies (e.g. 8000 Hz); harder to perceive less familiar sounds.
  - In young children
  - In sub-optimal acoustic conditions
  - Patients with tinnitus
  - Uncooperative patients with false responses.

The audiogram

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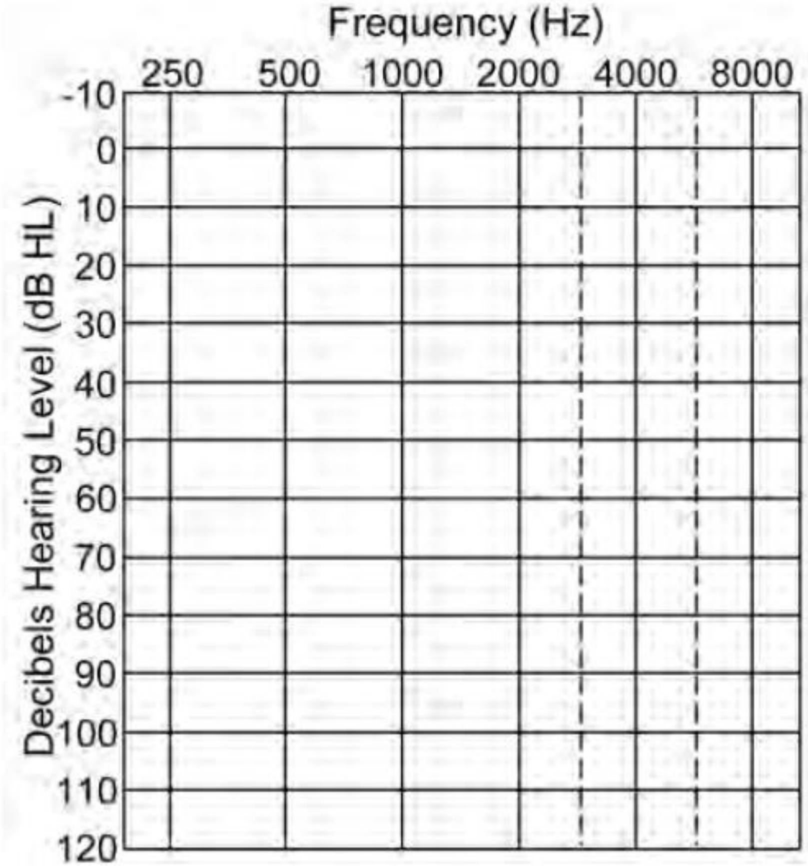
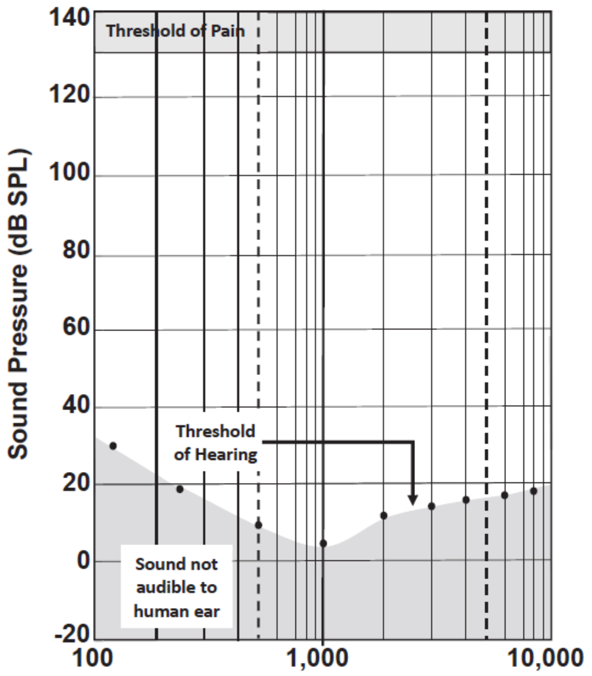


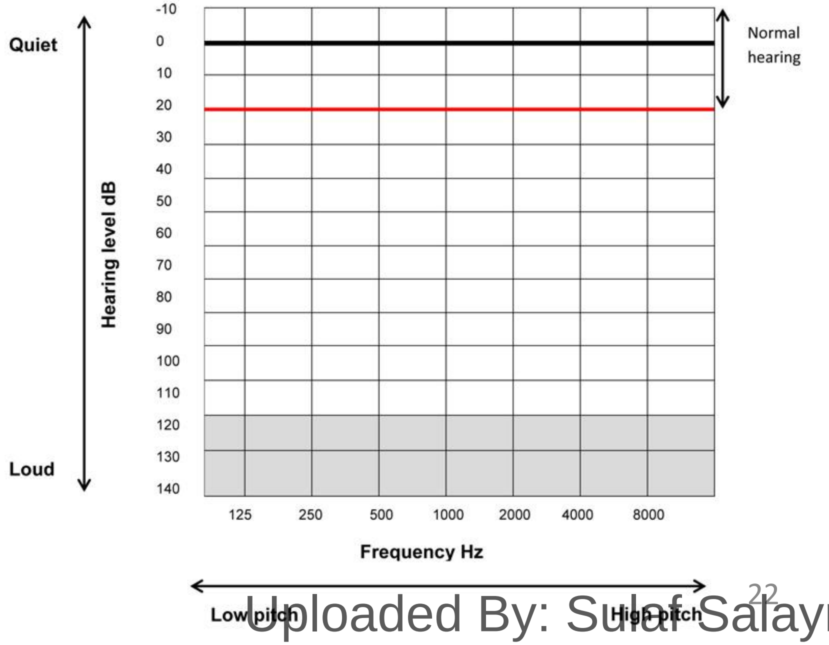
Audiogram Key	Right Ear	Left Ear
AC unmasked	O	X
AC masked	△	□
BC unmasked	<	>
BC masked	[	]
No response	↙	↘
Sound-field	S	

FIGURE 7–1. An example of an audiogram used to record pure-tone thresholds. An audiogram key, as shown on the right, is usually included with an audiogram to identify the symbols. AC, air conduction; BC, bone conduction.

Decibel Hearing Level (dB HL)

- The y-axis of the audiogram represents the decibel level of sounds, in units of dB hearing level (dB HL).
- For clinical purposes, it would be somewhat cumbersome to use a dB SPL scale for the audiogram, since the same amount of hearing loss at different frequencies would be represented by different values of dB SPL.
- The threshold of audibility curve is “straightened out” by creating a 0 dB HL for each frequency that is equal to the average amount of dB SPL needed for normal hearing listeners to hear each frequency





Decible sensation level (dB SL)

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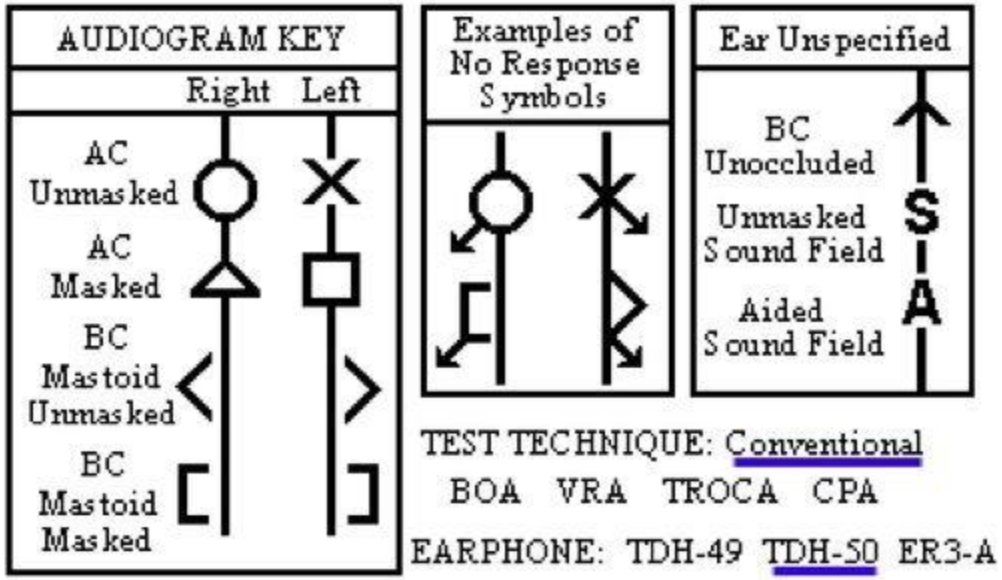
- The magnitude of sound level that is above the patient’s hearing threshold.
- Example 1: If a patient’s hearing threshold at 1000 Hz is 20 dB HL and a sound is presented at 50 dB HL, this sound is equivalent to 30 dB SL.
- Example 2: If the threshold of hearing is 40 dB HL and a sound is presented at 90 dB HL, this sound is equivalent to 50 dB SL.

Audiogram symbols



Describing audiograms

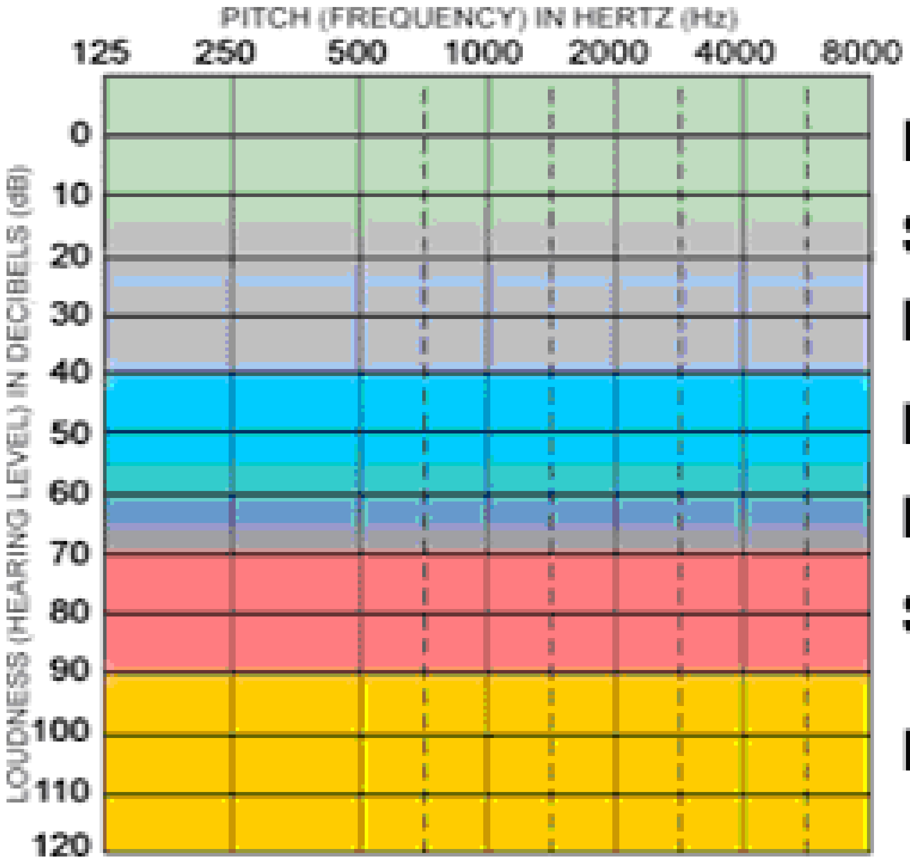
- When describing the pure-tone audiogram, the following three types of information should be conveyed:

✓ Degree (amount) of hearing loss

✓ Type of hearing loss

✓ Shape of hearing loss

Degrees of hearing loss I



Normal Hearing	00 - 15 dB HL
Slight Loss	16 - 25 dB HL
Mild Hearing Loss	26 - 40 dB HL
Moderate Loss	41 - 55 dB HL
Moderately Severe	56 - 70 dB HL
Severe	71 - 90 dB HL
Profound	> 90 dB HL

Degrees of hearing loss II

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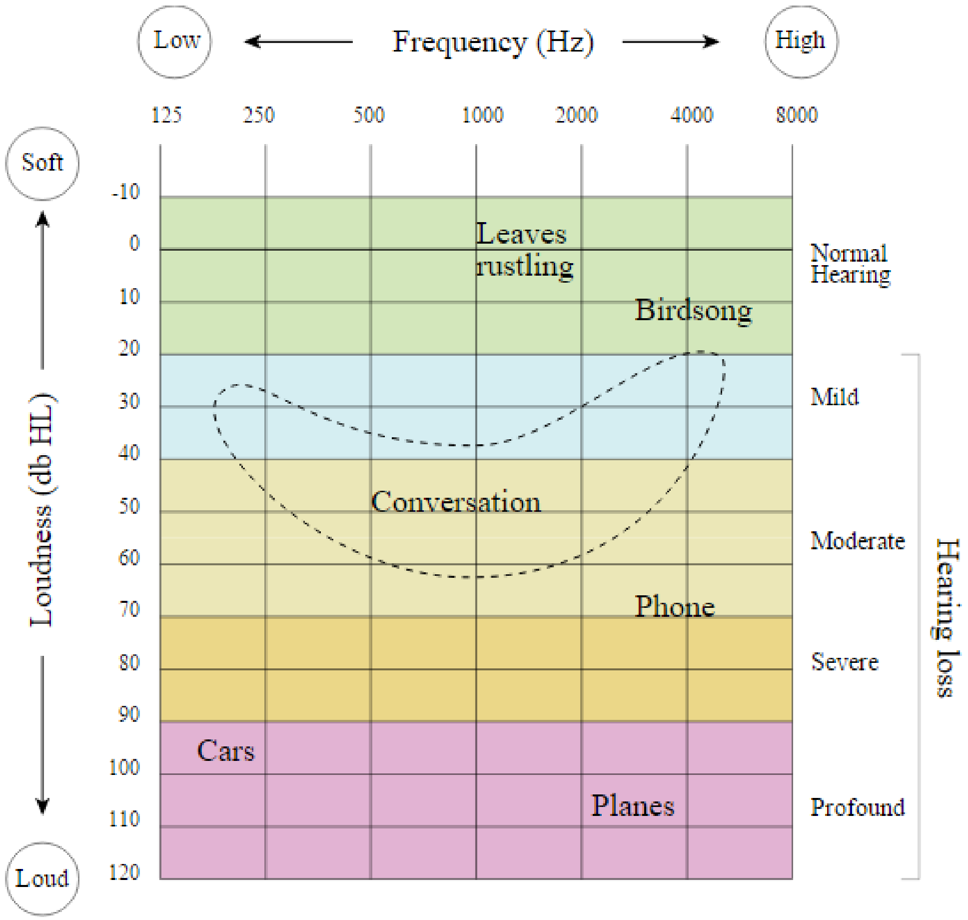

Let us test a patient online

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- https://www.counselear.com/Controls/Pages/Public/index.aspx?page=Simulator/Audiometer

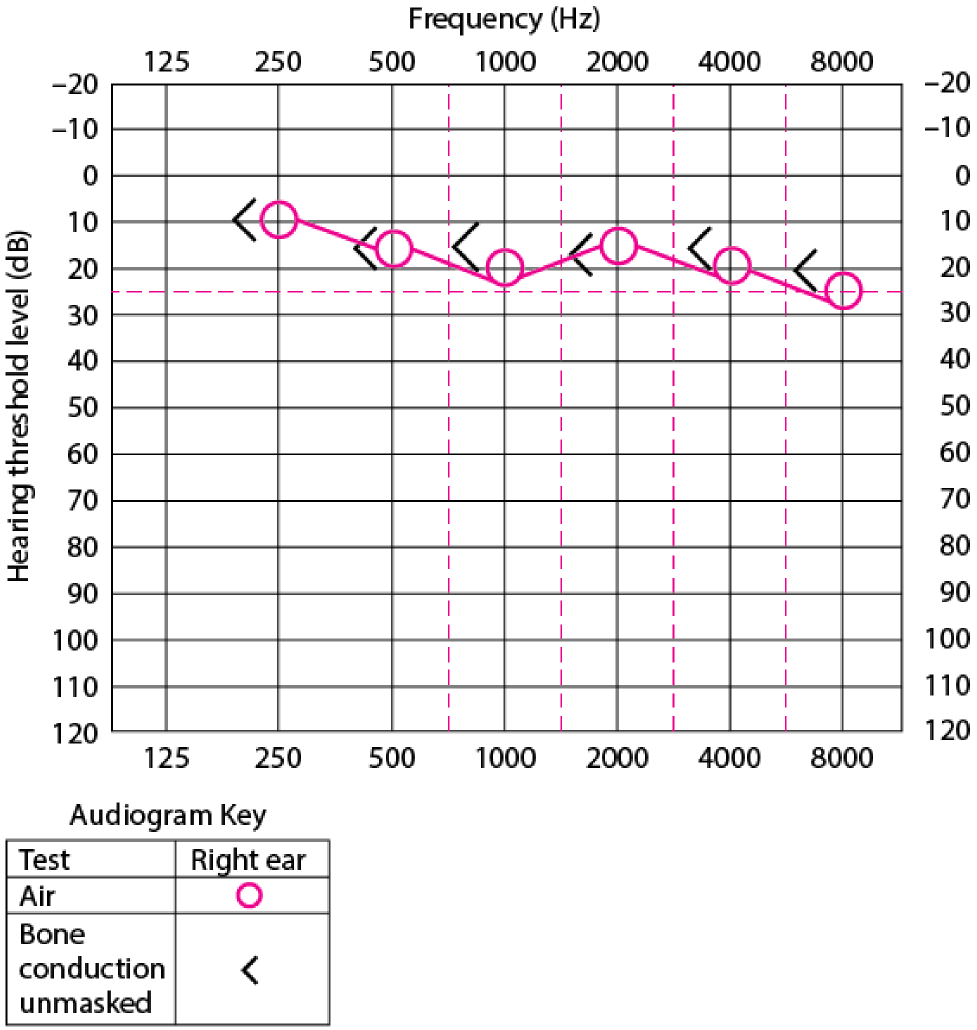
Types of hearing loss

TABLE 7–3. Common Audiometric Definitions of Types of Hearing Loss

Type of Hearing Loss	Audiometric Definition
Sensorineural	Abnormal AC, abnormal BC, ABG $\leq$ 10 dB
Conductive	Abnormal AC, normal BC, ABG > 10 dB
Mixed	Abnormal AC, abnormal BC; ABG > 10 dB

Note. AC = Air conduction thresholds; BC = Bone conduction thresholds; ABG = Air-bone gap (>10 dB difference between the thresholds by AC and BC).

Normal hearing audiogram



Conductive hearing loss audiograms

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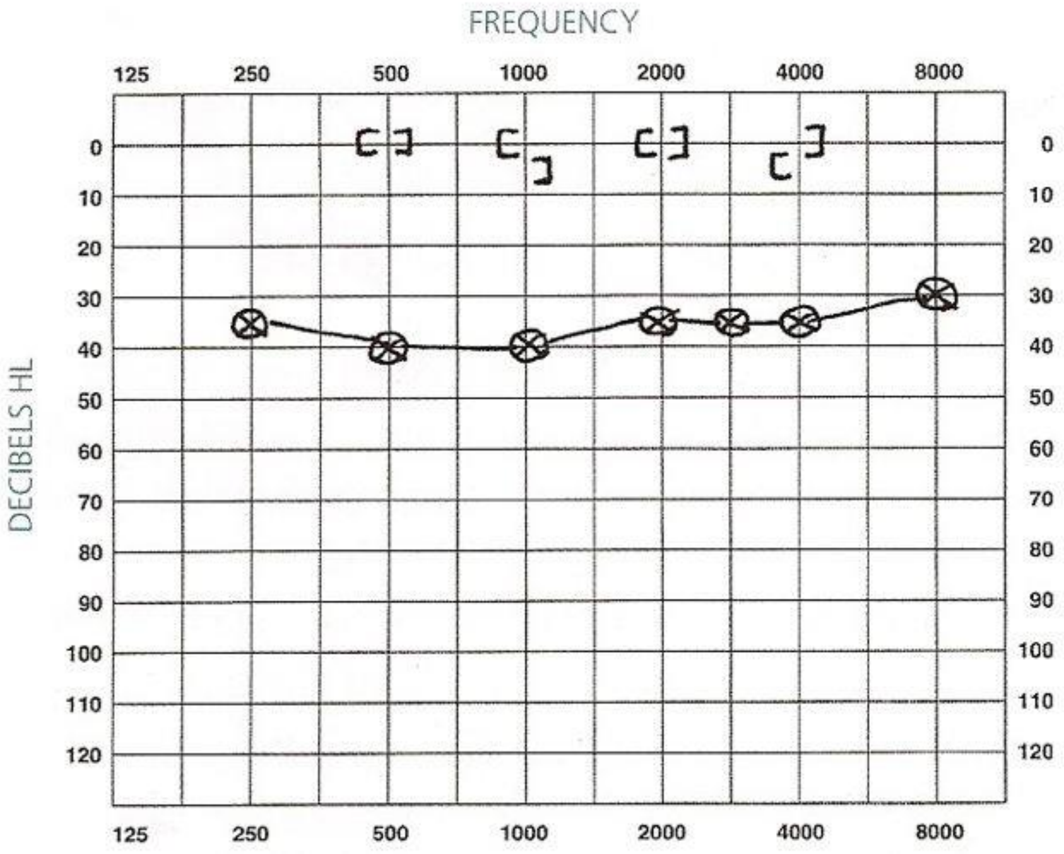
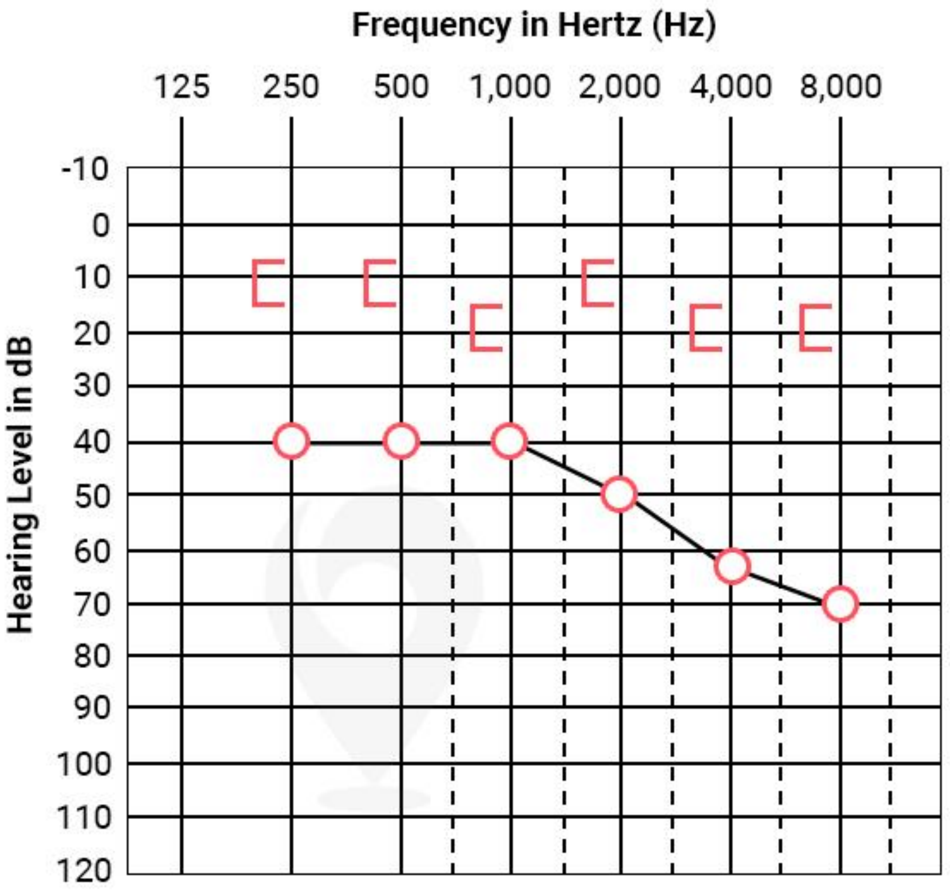
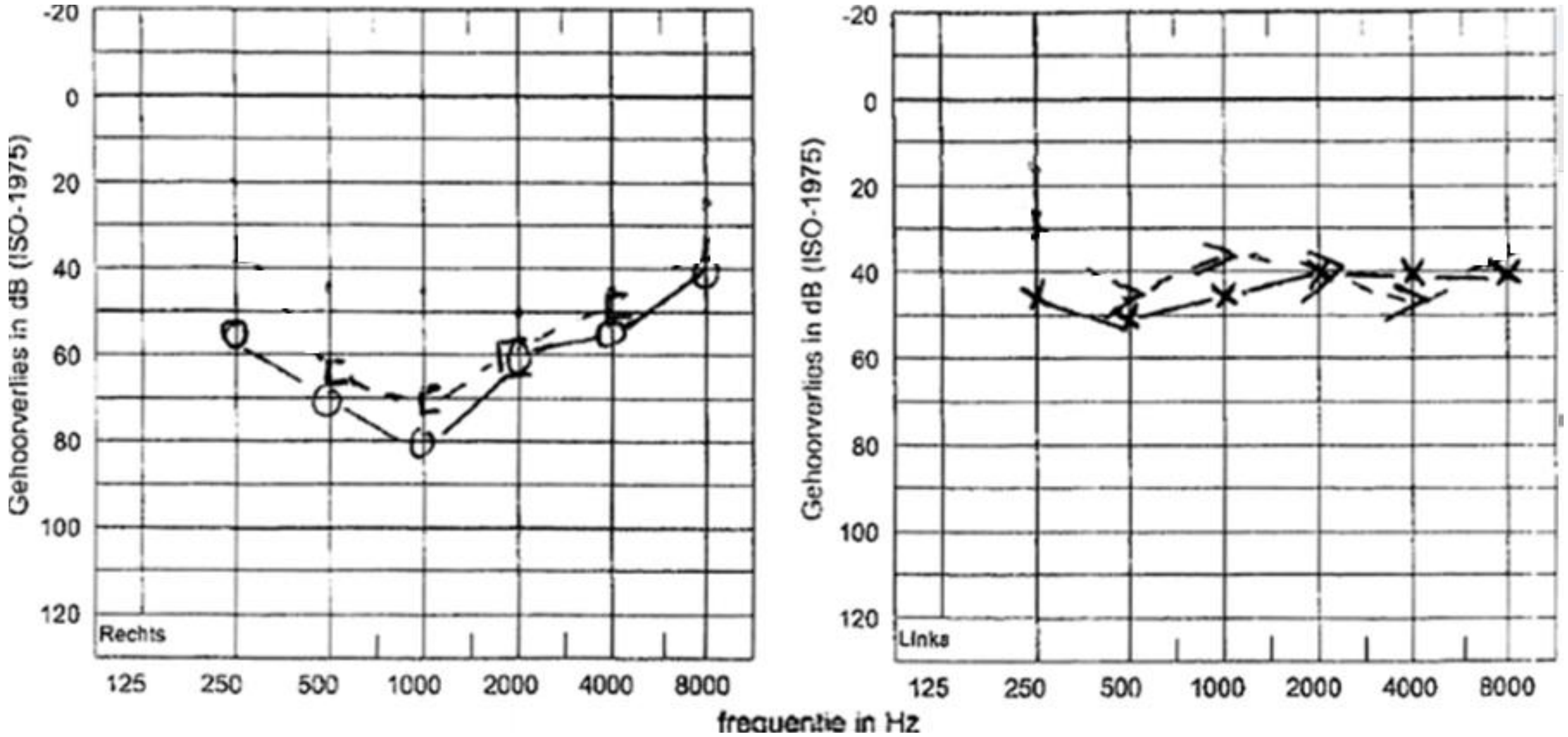




Sensorineural hearing loss audiograms



Mixed hearing loss audiograms

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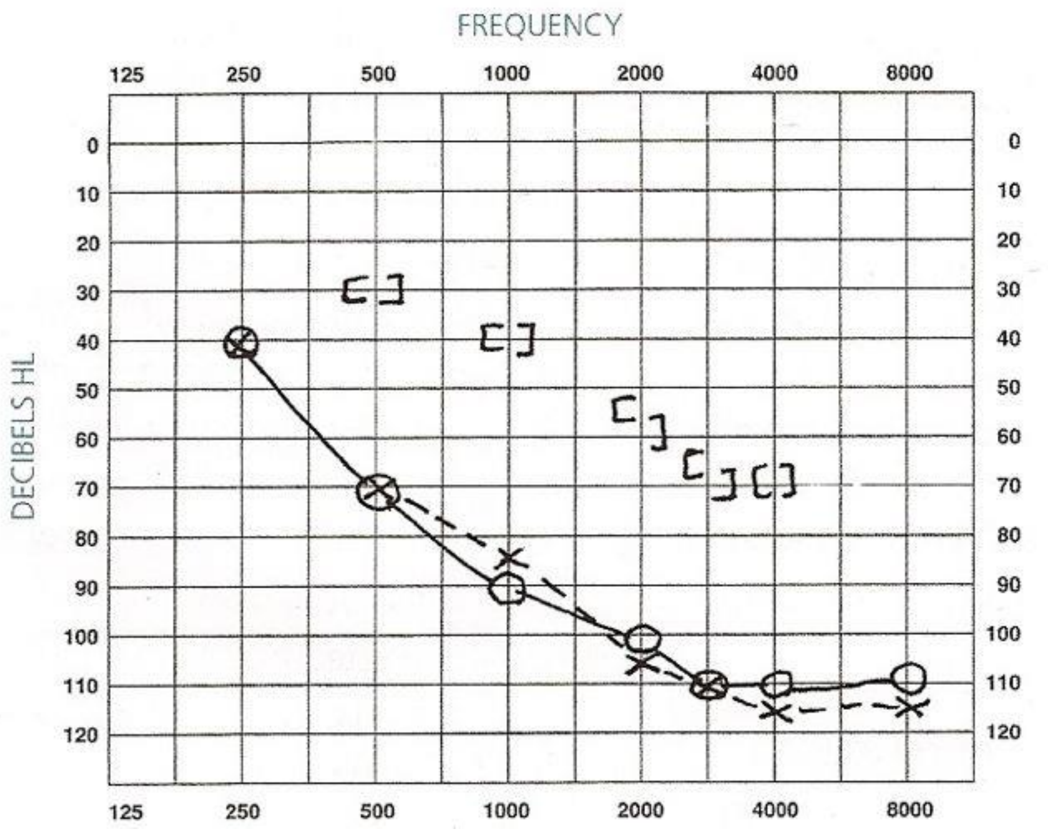

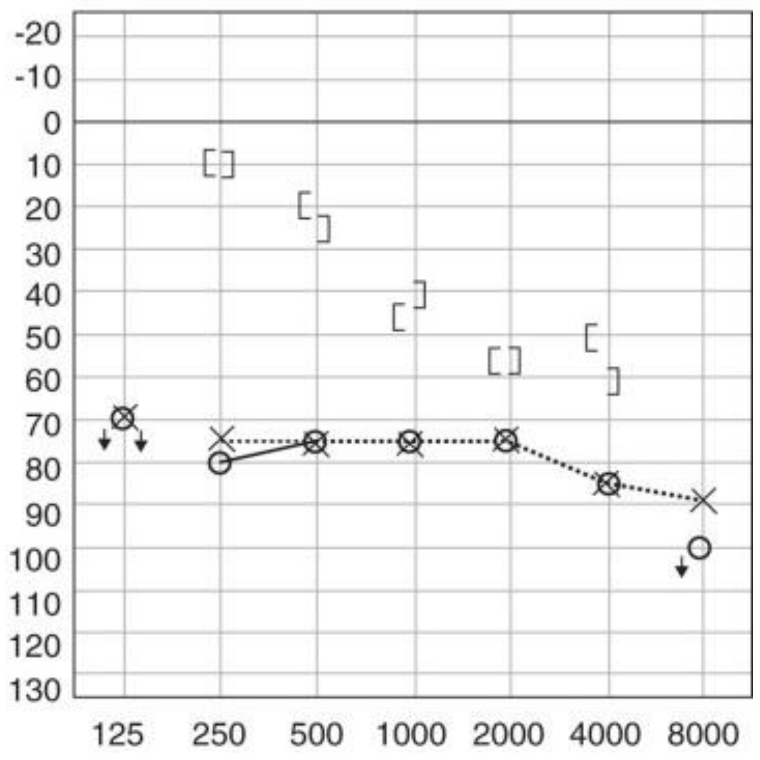

Unilateral vs. bilateral hearing loss

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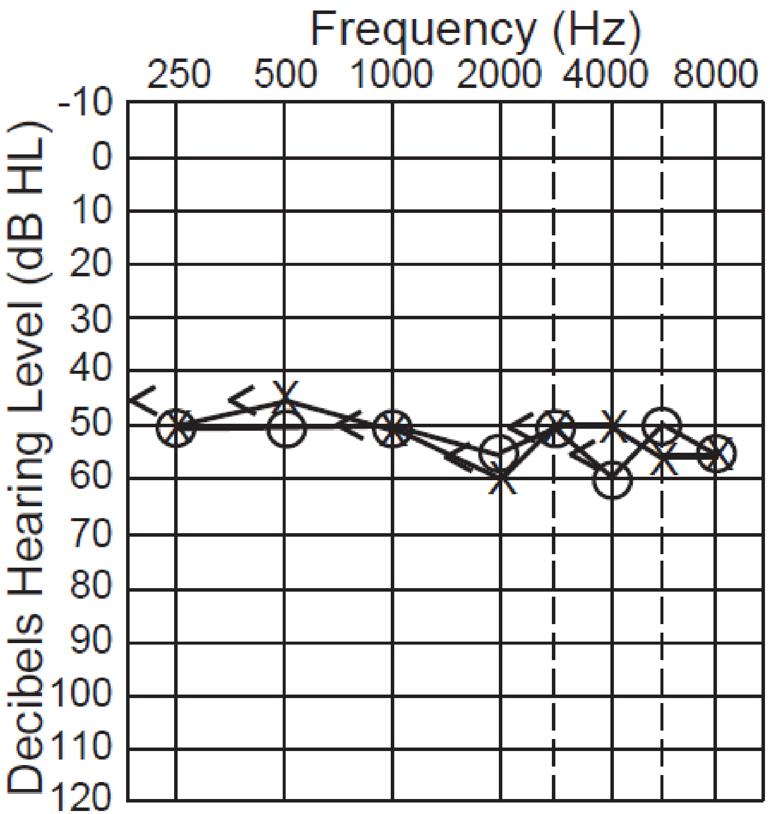
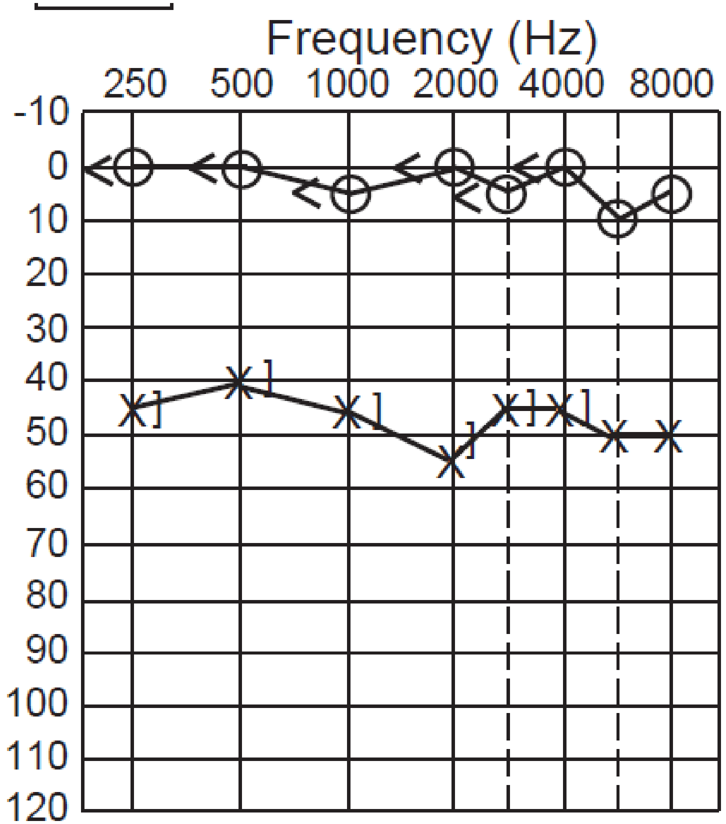
- Symmetrical vs. asymmetrical

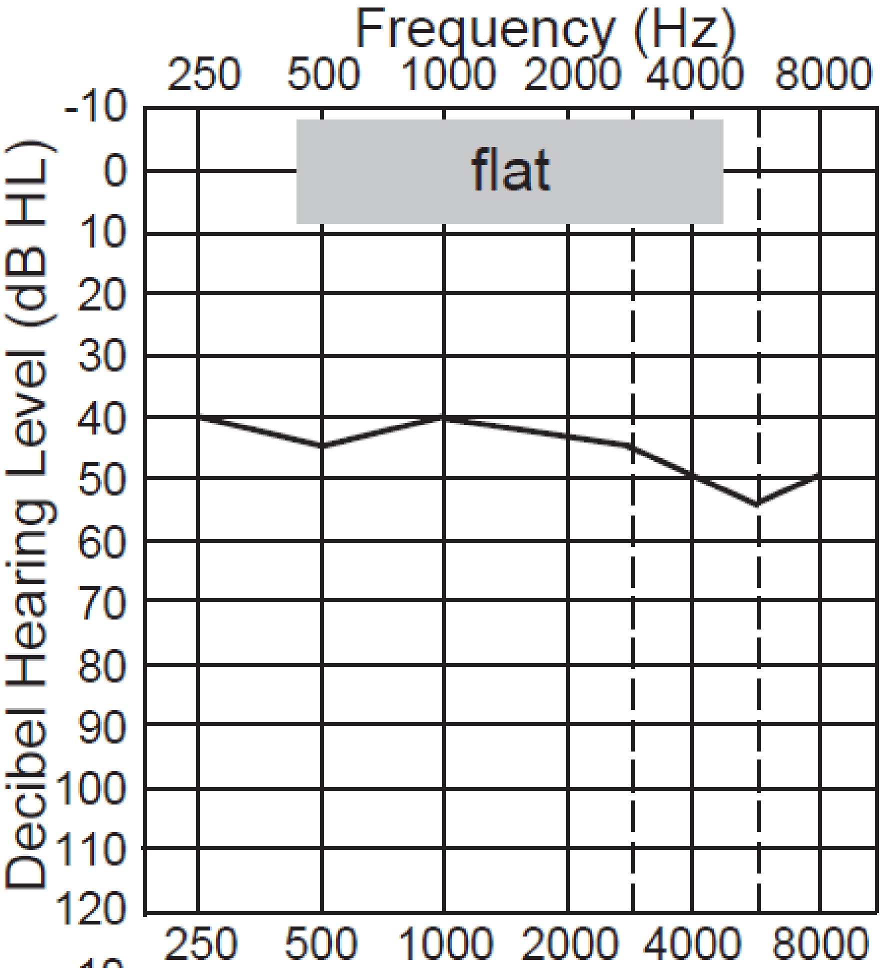


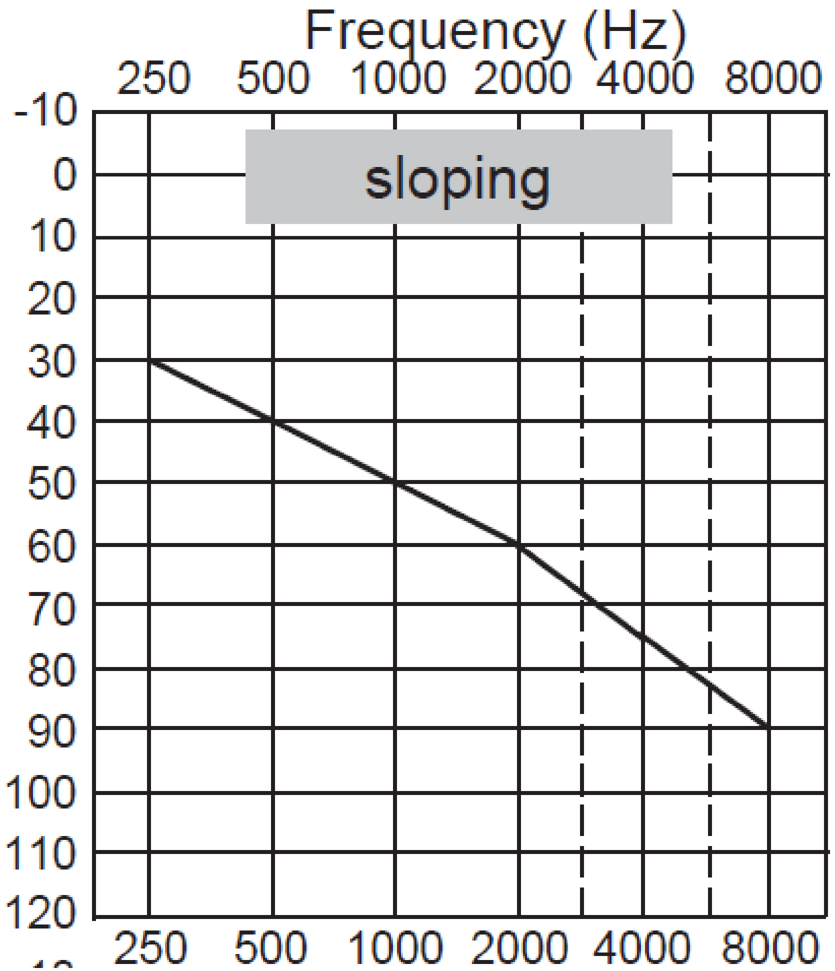
Bilateral Symmetrical
(could be asymmetrical)



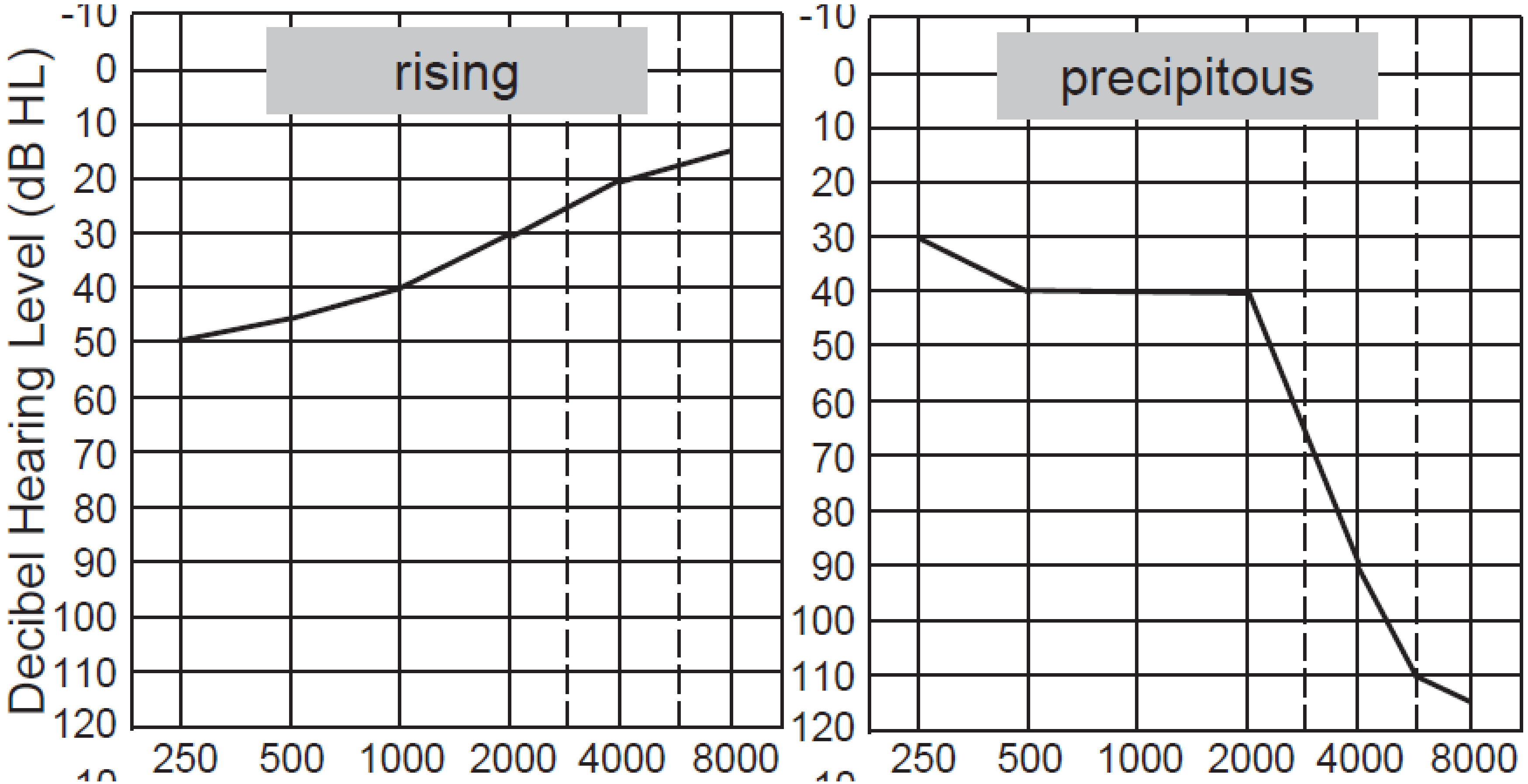
Unilateral (LE)

Audiometric configurations

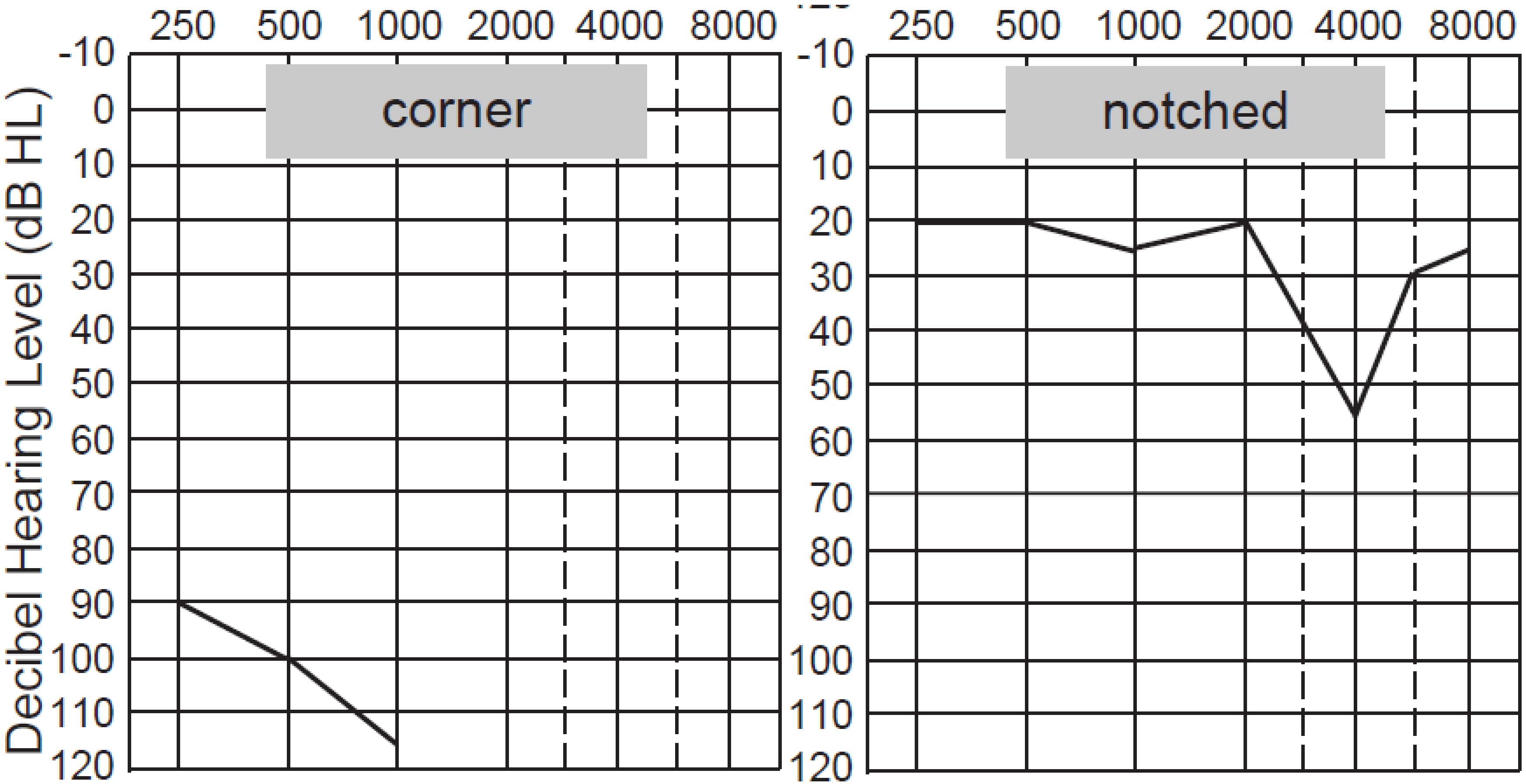




Audiometric configurations



Audiometric configurations



Audiometric configurations

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TABLE 7–4. Commonly Used Descriptions of Audiogram Shapes

Shape	Audiometric Threshold Characteristic
Bilateral	Similar in both ears
Relatively flat	Within 20 dB across the audiogram
Sloping	>20 dB per octave change toward high frequencies
Precipitous	Steeply sloping (e.g., >40 dB/octave) toward high frequencies
Rising	Improving >20 dB from low toward high frequencies
Notched	Worse in a narrow frequency region (typically 3000–6000 Hz)
Saucer/ cookie bite	Worse in mid frequencies; shallow concave appearance
Corner	Residual hearing ability only in the low frequencies

The pure-tone average

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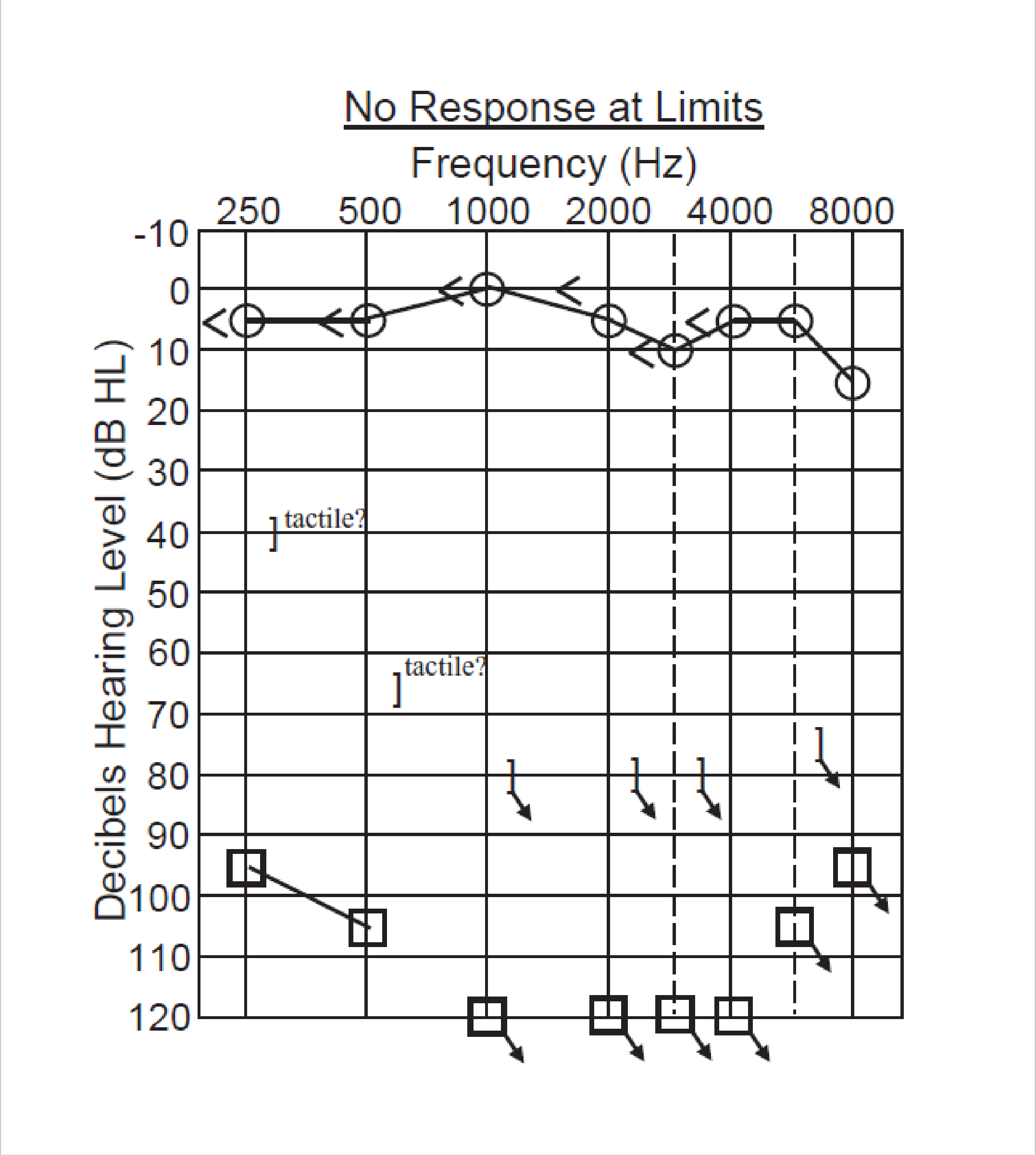
- Calculating a pure-tone average (PTA) for each ear is often done to provide a summary of the pure-tone thresholds over a particular frequency range.
- The PTA is calculated from the AC thresholds because the AC route includes all portions of the auditory system.
- The traditional PTA is the average of the thresholds at 500, 1000, and
- 2000 Hz or 500, 1000, 2000, and 4000 Hz.
- The PTA is sometimes used as an average value for describing the degree of hearing loss.
- A single number (average) does not adequately reflect how the degree of hearing loss changes across the audiogram.

Vibrotactile responses

- Tactile Responses (or vibrotactile) responses are a result of the patient feeling the vibrations rather than hearing the sound.
- **Bone conduction** vibrotactile thresholds can be as low as:
  - 30 dB HL at 250 Hz
  - 55 dB HL at 500 Hz
  - 70 dB HL at 1000 Hz.
- **Air conduction** vibrotactile thresholds (using circumaural headphones) can be as low as:
  - 80 dB HL at 250 Hz
  - 90-100 dB HL at 500 Hz.

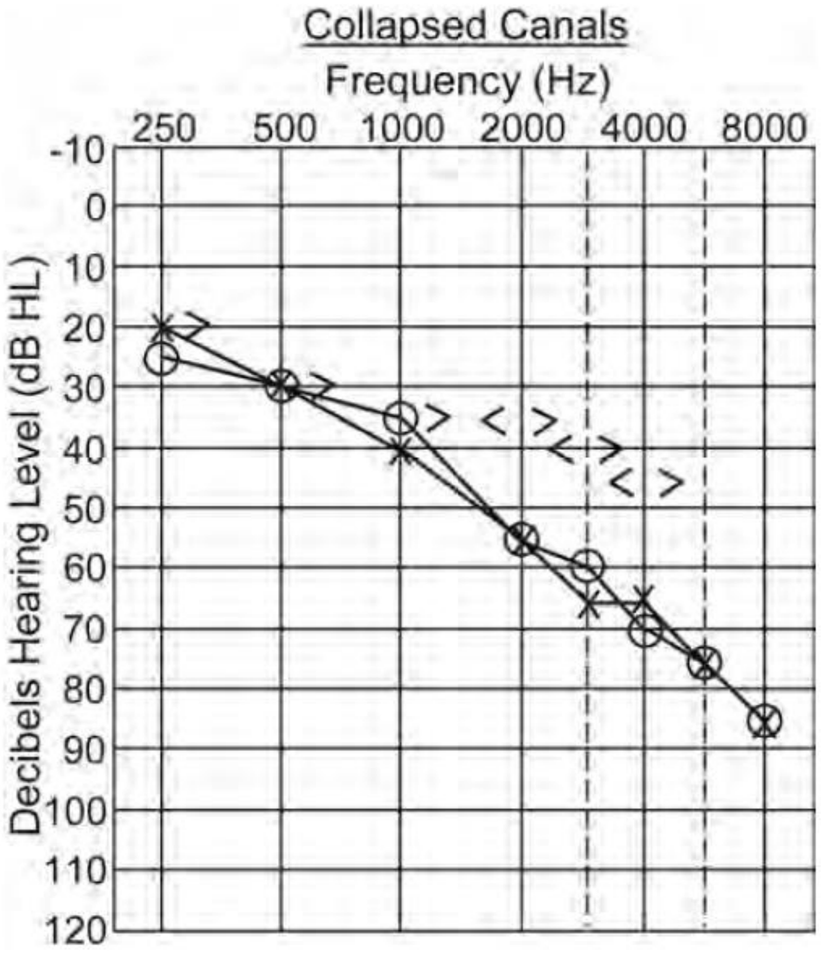
No response at audiometer output levels

- When the upper limits of the audiometer's output levels are reached and the patient does not respond, the appropriate symbols for AC and/ or BC are plotted on the audiogram with arrows



Collapsed ear canals

- Collapsed canals can occur in some individuals with reduced elasticity in the cartilaginous portion of the external ear canal (e.g. older adults) when supra-aural earphones are used for testing.
- This creates “fake” conductive hearing loss.
- Use insert earphones to solve this problem.



Audiogram interpretation examples I

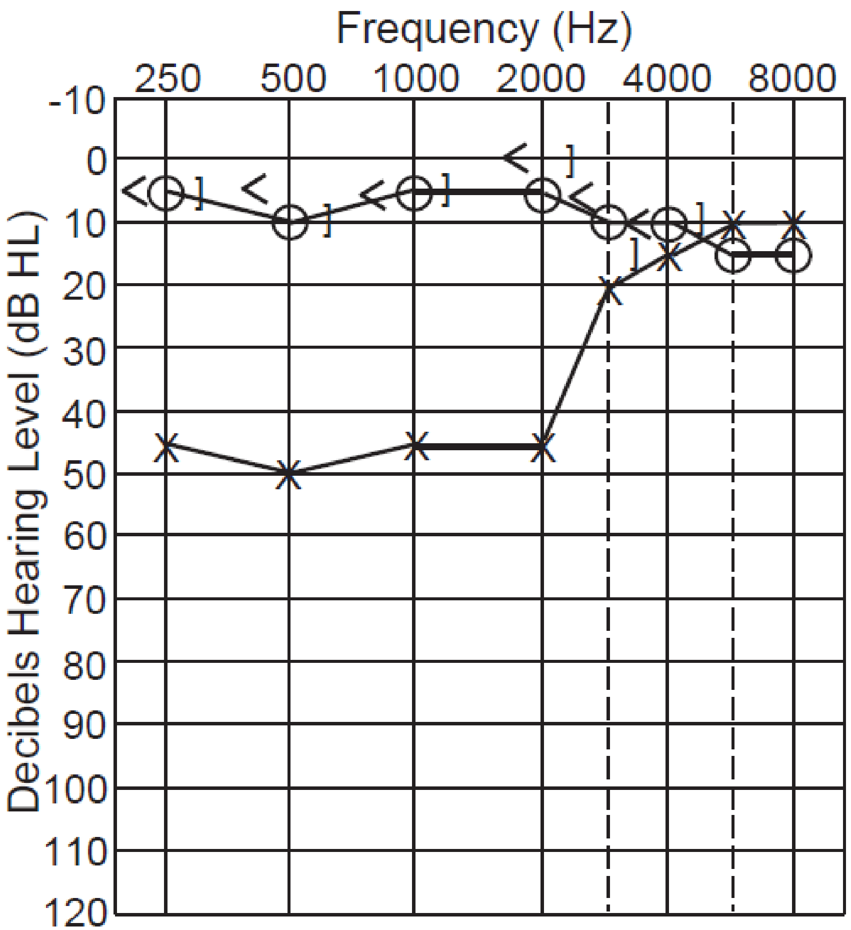
- Right ear:

- Hearing is within normal limits
PTA$_4$: 7.5 dB HL

- Left ear:

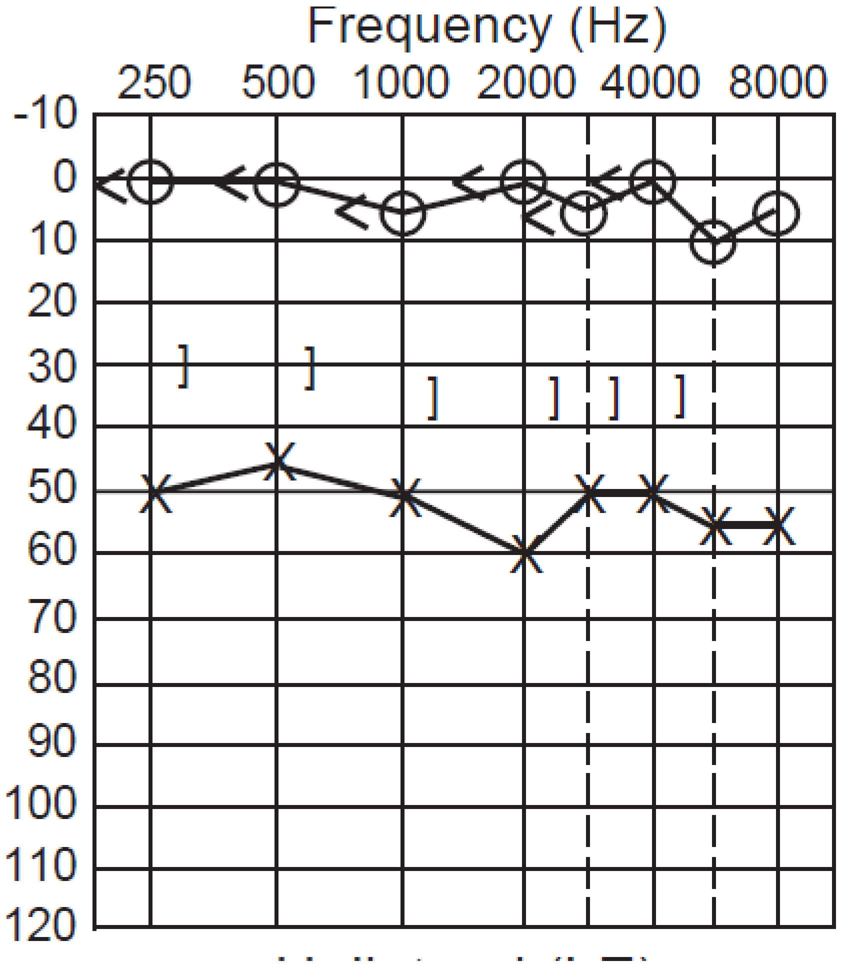
- Moderate conductive hearing loss from 250-2000 Hz, rising to within normal limits at 4000-8000 Hz.
PTA$_3$ (at 500,1000, and 2000) = 46.7 dB HL

Example 1



Audiogram interpretation examples II

- Right ear: within normal limits at 250-8000 Hz.
  PTA_4: (0+5+0+0)/4 = 1.25 dB HL
- Left ear:
  - Mixed moderate flat hearing loss.
  PTA_4: (45+50+60 +50)/4 = 51.25 dB HL



Audiogram interpretation examples III

- Right ear:

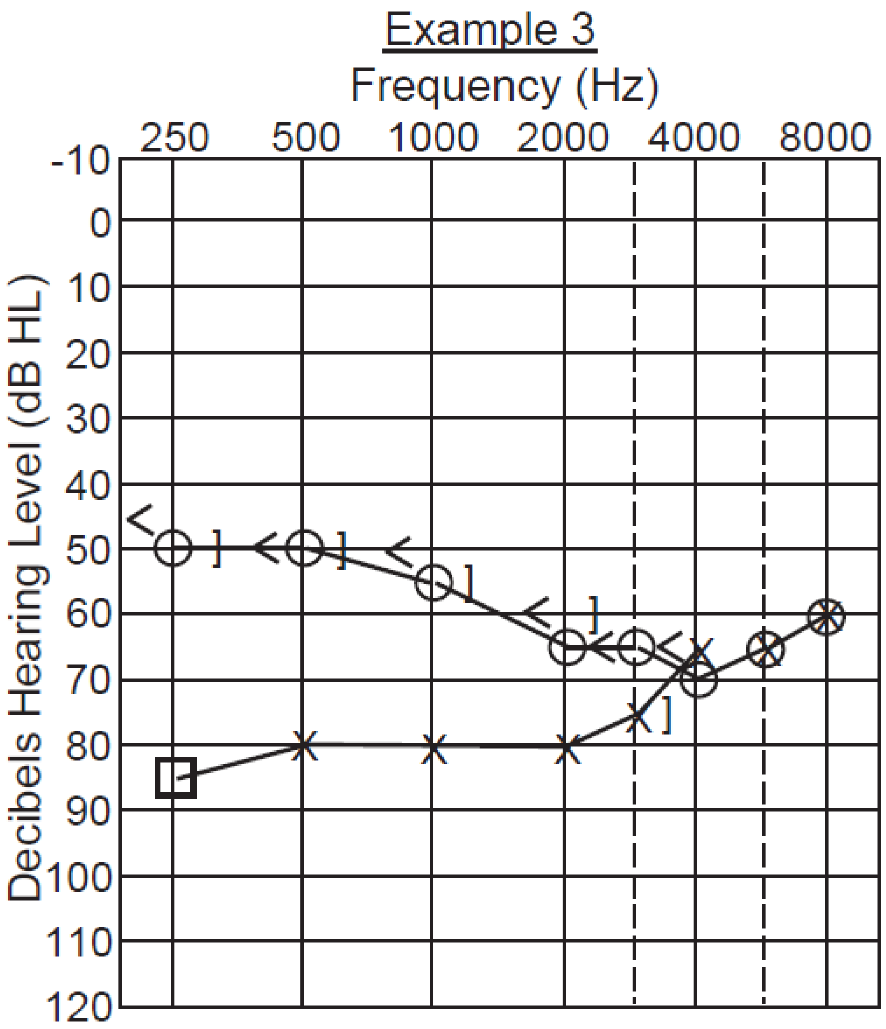
- Sensorineural moderately severe flat hearing loss

PTA_4: (50+55+65+70)/4= 60 dB HL

- Left ear:

- Mixed severe rising hearing loss

PTA_4: (80+80+80+65)/4 = 76.25 dB HL



At home task

- Right ear:

- Left ear: