BRADFORD VTS · GP TRAINING RESOURCE

Pure Tone Audiometry

A Practical Guide to Hearing Assessment for GPs

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Module: Basic Hearing Assessment | **Series:** Bradford VTS Clinical Teaching Library

1. Measuring Hearing Loss Using Pure Tone Audiometry (PTA)

An **audiogram** is the chart on which a patient's hearing ability is recorded. It plots the **threshold hearing level** (in dB HL) against **frequency** (in Hz), giving a visual picture of exactly where hearing is reduced and by how much.

Hearing loss is classified using the average pure-tone threshold across 250, 500, 1000, 2000 and 4000 Hz. This average does not imply any particular pattern of loss — additional descriptive terms such as "high-frequency loss" may also apply. Hearing levels better than 20 dB HL fall within the normal range, although other factors can still affect hearing quality.

Grade	dB HL Range	Clinical Significance
Mild	20 – 40 dB	Difficulty in noisy environments; may miss soft speech
Moderate	41 – 70 dB	Difficulty with normal conversation; hearing aid likely needed
Severe	71 – 95 dB	Can only hear loud sounds; relies heavily on hearing aids/lip-reading
Profound	> 95 dB	Very little useful hearing without amplification

AKT EXAM TIP — GRADING HEARING LOSS

The AKT commonly tests knowledge of the four grades and their dB ranges. Remember: **Mild 20–40, Moderate 41–70, Severe 71–95, Profound >95**. You may be asked to match a dB value to the correct grade or to identify what grade of loss would indicate a need for hearing aid referral (moderate and above).

The Speech Banana

The banana-shaped zone on the audiogram below marks where the sounds of everyday speech fall during normal one-to-one conversation. If a patient's thresholds lie below this zone, they will struggle to follow speech clearly.

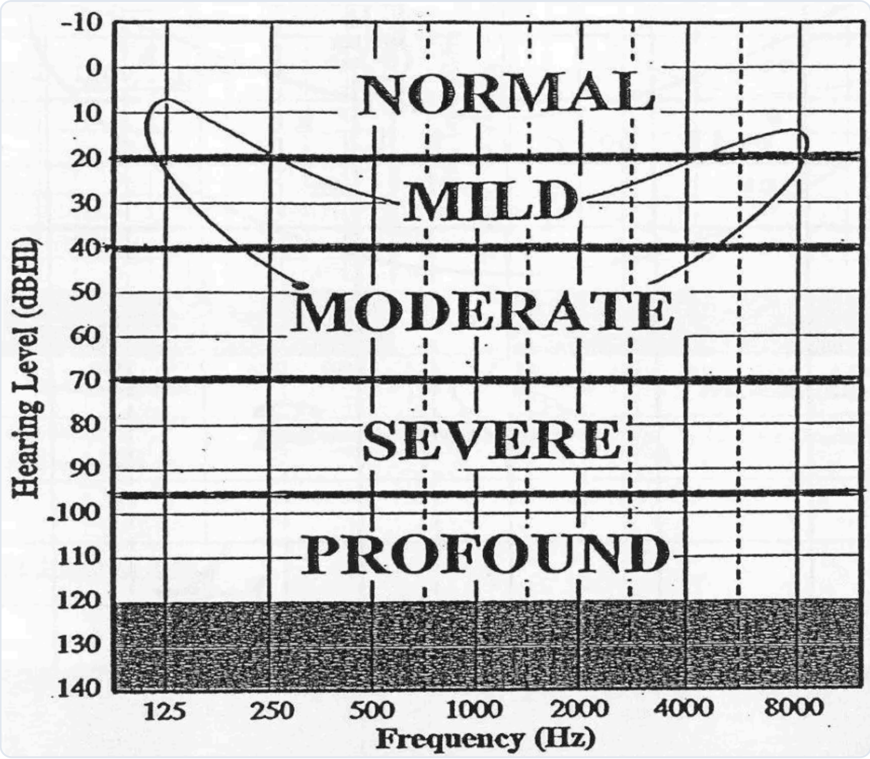


Figure 1: Audiogram with the speech banana — the shaded zone marks where speech sounds occur in normal conversation.

Air Conduction (AC) vs Bone Conduction (BC)

Air conduction (AC) tests hearing through headphones. Sound travels through the external auditory canal, the middle ear, and the inner ear, then along the auditory nerve to the brain. AC thresholds tell us what levels a person can hear sounds in everyday life.

Bone conduction (BC) tests hearing via vibration applied directly to the skull, bypassing the middle ear entirely. Sound travels straight to the inner ear and up to the brain. By comparing AC and BC thresholds, a clinician can determine whether any hearing loss is due to a problem in the middle ear, the inner ear, or both.

KEY POINT — INTERPRETING AC VS BC

- BC thresholds **better** than AC thresholds (i.e. an air-bone gap) = **conductive loss** (middle ear problem)
- AC and BC thresholds **matching** = **sensorineural loss** (inner ear or auditory nerve problem)
- Both AC and BC elevated but AC worse = **mixed loss**

AKT EXAM TIP — CONDUCTIVE VS SENSORINEURAL

This distinction is a favourite AKT topic. Classic causes of **conductive loss**: otosclerosis, cholesteatoma, otitis media with effusion, impacted wax. Classic causes of **sensorineural loss**: noise-induced, presbyacusis, Meniere's disease, acoustic neuroma, ototoxic drugs (aminoglycosides, cisplatin, loop diuretics). Know which type each cause produces.

The Importance of Otoscopy Before Testing

A hearing test should always begin with otoscopy to look for wax and any visible abnormalities. Impacted wax can artificially **raise** (worsen) high-frequency AC thresholds and artificially **lower** (improve) low-frequency BC thresholds, giving misleading results. Wax should be removed before testing where possible.

> **AKT EXAM TIP — WAX AND AUDIOMETRY**
>
> The AKT may present a scenario where wax is found on otoscopy prior to a hearing test. The correct answer is to remove the wax before testing, as it specifically distorts high-frequency AC and low-frequency BC results.

Audiogram Symbols

Ear	Test Type	Symbol
Right	Air conduction (unmasked)	**O**
Left	Air conduction (unmasked)	**X**

2. Examples Using Air Conduction

The following audiograms illustrate the most common patterns of hearing loss you will encounter. Each example shows left and right ears side by side. Becoming familiar with these patterns is essential for both clinical practice and the AKT.

2.1 Normal Hearing

All thresholds fall at or better than 20 dB HL across the frequency range. The audiogram is flat and sits near the top of the chart.

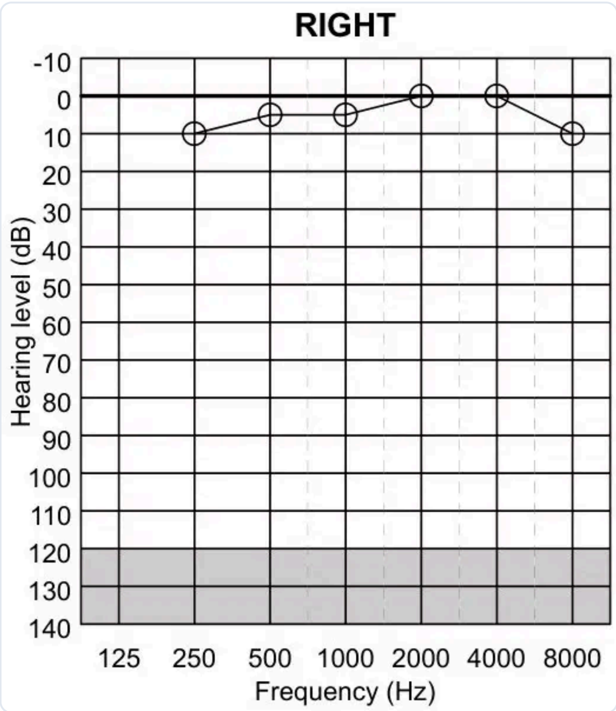


Figure 2a: Normal hearing (left ear)

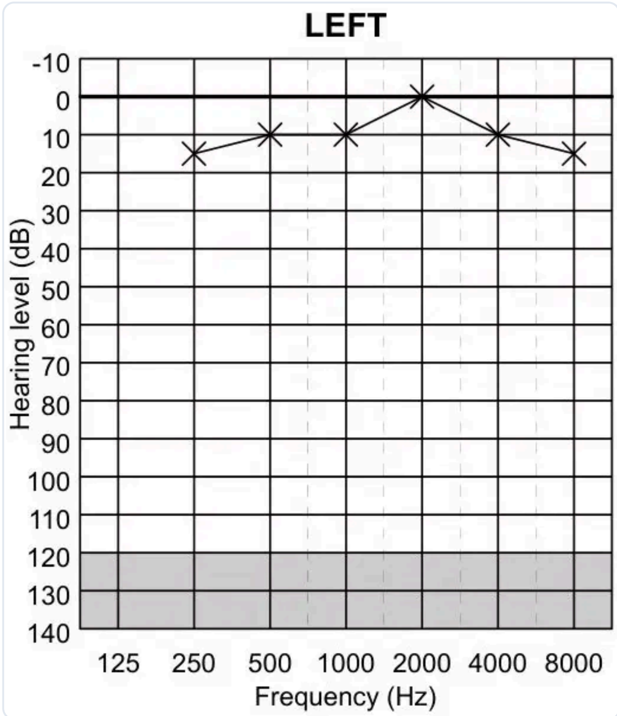


Figure 2b: Normal hearing (right ear)

> **AKT EXAM TIP — NORMAL THRESHOLDS**
>
> Normal hearing is defined as thresholds of **20 dB HL or better**. However, "within normal range" does not guarantee the patient has no hearing difficulties — other factors (e.g. auditory processing disorder) may still be relevant.

2.2 Severe Flat Hearing Loss

Thresholds are elevated uniformly (i.e. "flat") across all frequencies and fall into the severe range. This pattern suggests equal loss at all pitches — no frequency is spared.

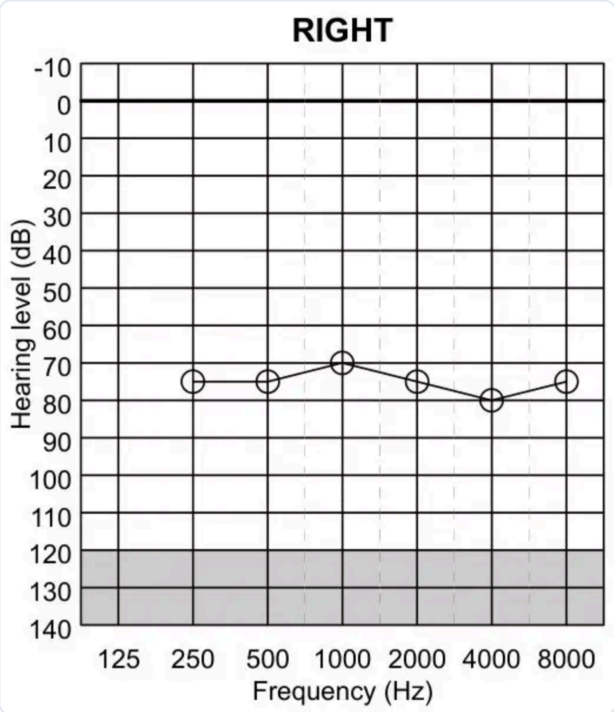


Figure 3a: Severe flat loss (left ear)

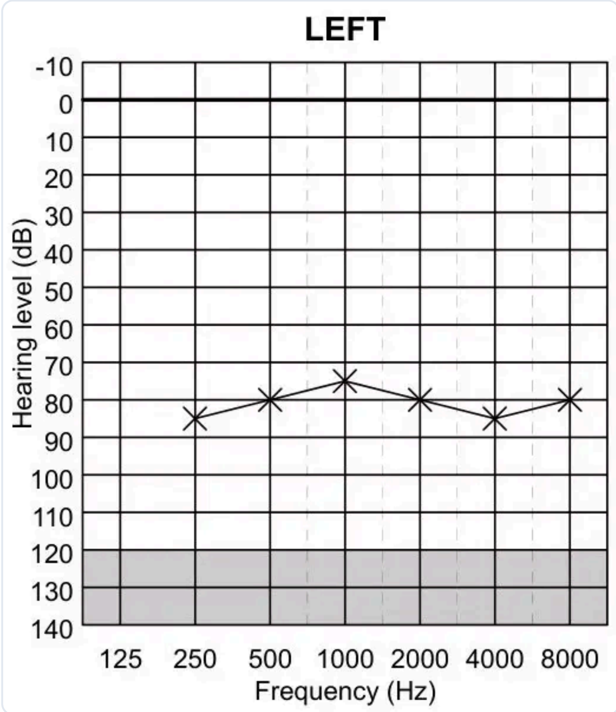


Figure 3b: Severe flat loss (right ear)

2.3 Moderate Sloping High-Frequency Hearing Loss

Thresholds are near-normal at low frequencies and worsen progressively at higher frequencies, producing a downward slope on the audiogram. This is the most common pattern in clinical practice.

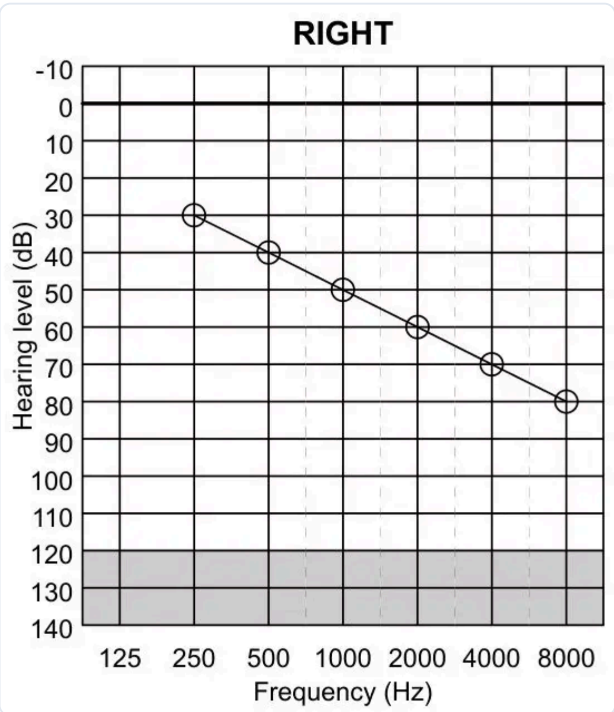


Figure 4a: Moderate sloping high-frequency loss (left ear)

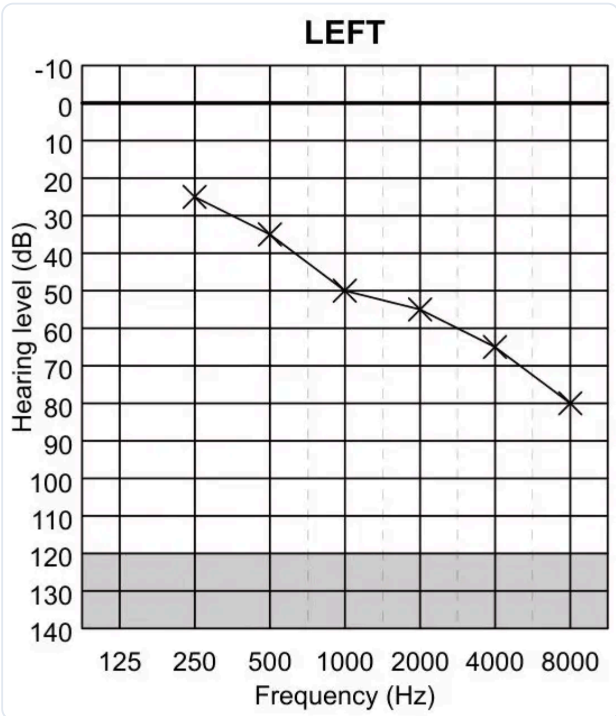


Figure 4b: Moderate sloping high-frequency loss (right ear)

AKT EXAM TIP — HIGH-FREQUENCY SLOPING LOSS

A bilateral, symmetrical, high-frequency sloping loss is the classic pattern of both **noise-induced hearing loss** (typically a notch at 4 kHz) and **presbyacusis** (age-related, gradual slope from 2–4 kHz). Distinguish them by history: noise exposure history points to NIHL; age >60 with gradual onset points to presbyacusis. Noise-induced characteristically shows a 4 kHz dip that partially recovers at 8 kHz.

2.4 Left Corner Audiogram

Only the lowest frequencies (250–500 Hz) show any measurable hearing. All other thresholds are absent or at the limits of the audiometer. This represents profound hearing loss with only residual low-frequency hearing remaining.

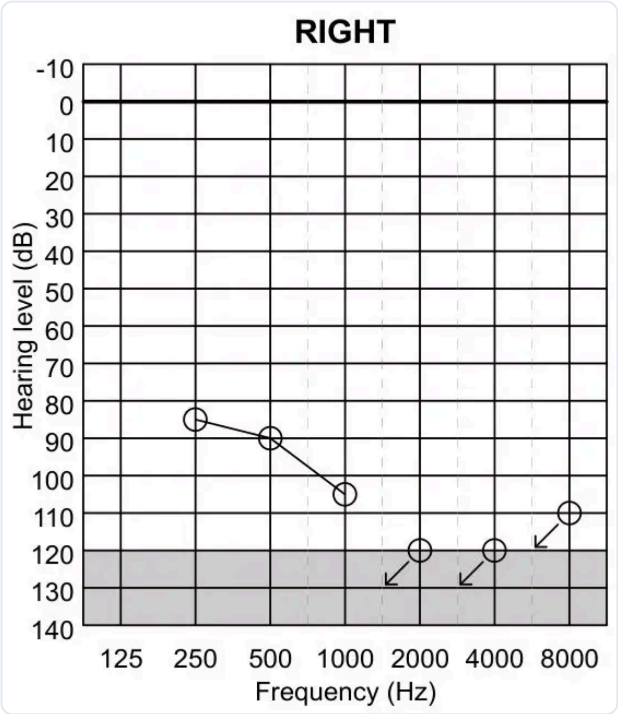


Figure 5a: Left corner audiogram (left ear)

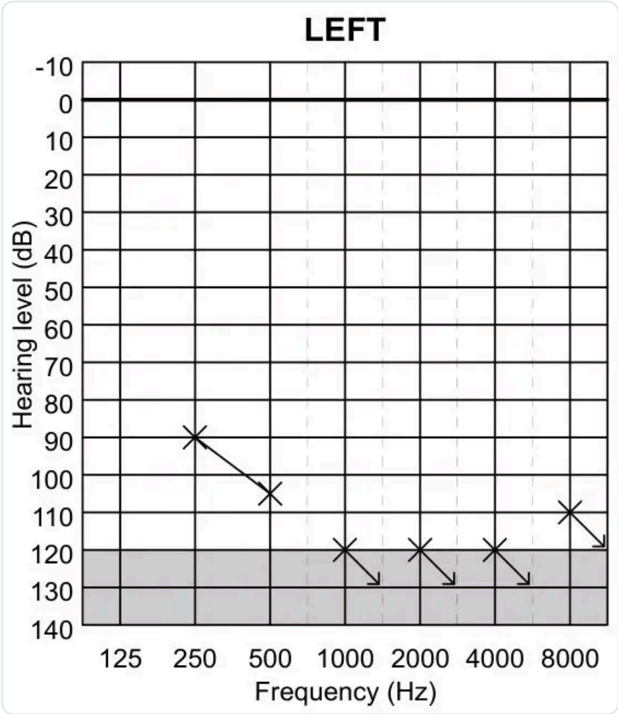


Figure 5b: Left corner audiogram (right ear)

CLINICAL NOTE

Patients with a corner audiogram are candidates for cochlear implant assessment. In primary care, prompt referral to ENT/audiology is appropriate.

3. Bone Conduction

Definition

Bone conduction is the transmission of sound to the inner ear primarily via mechanical vibration of the cranial bones. It bypasses the outer and middle ear, stimulating the cochlea directly.

Why Bone Conduction is Tested

In the human ear, the ossicular chain is finely balanced to minimise bone conduction of internally generated body sounds. As a result, the ear is approximately **60 dB less sensitive** to airborne sound via bone conduction than via air conduction. Despite this, BC testing is invaluable because it allows us to assess cochlear (inner ear) function independently of the outer and middle ear.

The difference between AC and BC thresholds for the same ear is called the **air-bone gap**, and its size indicates the degree of any conductive hearing loss present.

> **AKT EXAM TIP — THE AIR-BONE GAP**
>
> The air-bone gap is central to classifying hearing loss type. A significant air-bone gap (≥15 dB) indicates a **conductive component**. Common AKT causes of conductive loss with an air-bone gap:
>
> - **Otitis media with effusion (glue ear)** — commonest in children
> - **Otosclerosis** — progressive conductive loss in adults; autosomal dominant; worse in pregnancy
> - **Cholesteatoma** — associated with retraction pocket; destructive
> - **Ossicular chain disruption** — post-trauma or infection

Interpreting BC Thresholds

BC thresholds serve as a test of **cochlear integrity**:

- BC thresholds **≤ 20 dB HL**: no sensorineural component
- BC thresholds **> 20 dB HL**: sensorineural hearing loss is present

The two examples below illustrate this principle. The right-ear example shows AC and BC thresholds that match closely — there is no air-bone gap, confirming a purely sensorineural loss. The left-ear example shows masked BC thresholds that are better than the AC thresholds, indicating a conductive component. The size of the gap reflects the degree of conductive loss.

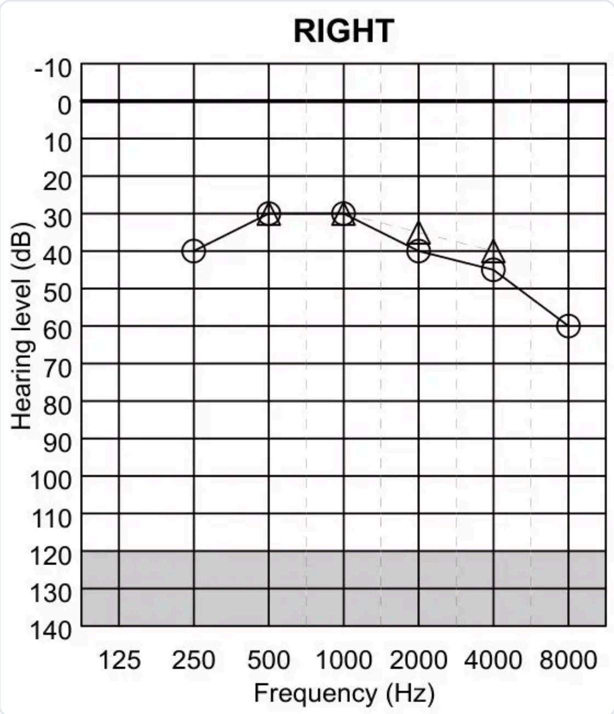


Figure 6a: AC and BC thresholds match — pure sensorineural loss

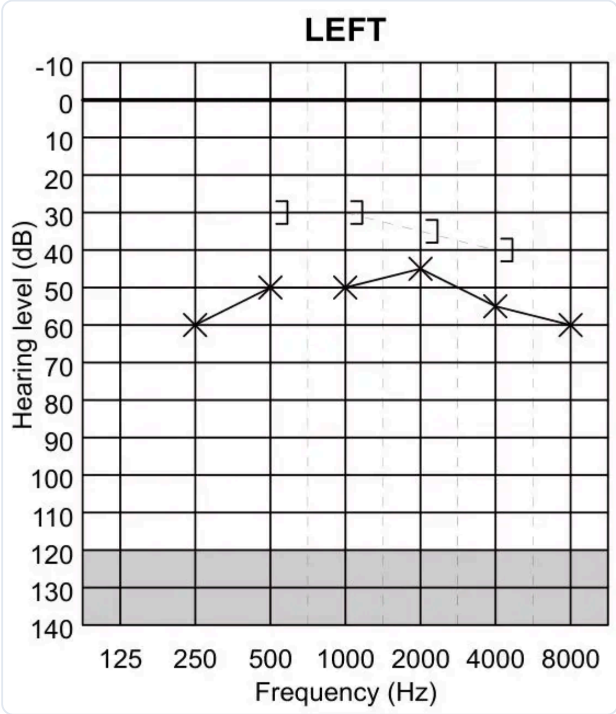


Figure 6b: Masked BC better than AC — conductive element present

Carhart Notch — A Special Case

IMPORTANT — CARHART NOTCH (HIGH-YIELD AKT TOPIC)

BC results are generally assumed to reflect cochlear function, but this assumption is not always correct. One clinically important exception is **otosclerosis**.

In otosclerosis, abnormal bone growth fixes the stapes footplate. This fixation reduces the resonant movement of the ossicular chain and causes an *apparent* reduction in BC sensitivity at **2 kHz** (the resonant frequency of the ossicular chain). This apparent sensorineural dip at 2 kHz — caused by a mechanical, conductive problem — is called the **Carhart notch**.

The Carhart notch is a mechanical artefact, not a true sensorineural loss. It is reversible after successful surgery (stapedectomy).

AKT EXAM TIP — OTOSCLEROSIS AND THE CARHART NOTCH

Key facts tested in the AKT:

- Otosclerosis: progressive **bilateral** conductive hearing loss, typically in young adults
- Paracusis Willisii (better hearing in noisy environments) is a classic feature
- Audiogram shows conductive loss **with a Carhart notch at 2 kHz** on BC
- Tympanometry: **As (shallow) curve** — reduced compliance
- Treatment: **stapedectomy** or hearing aid
- Worsens during pregnancy

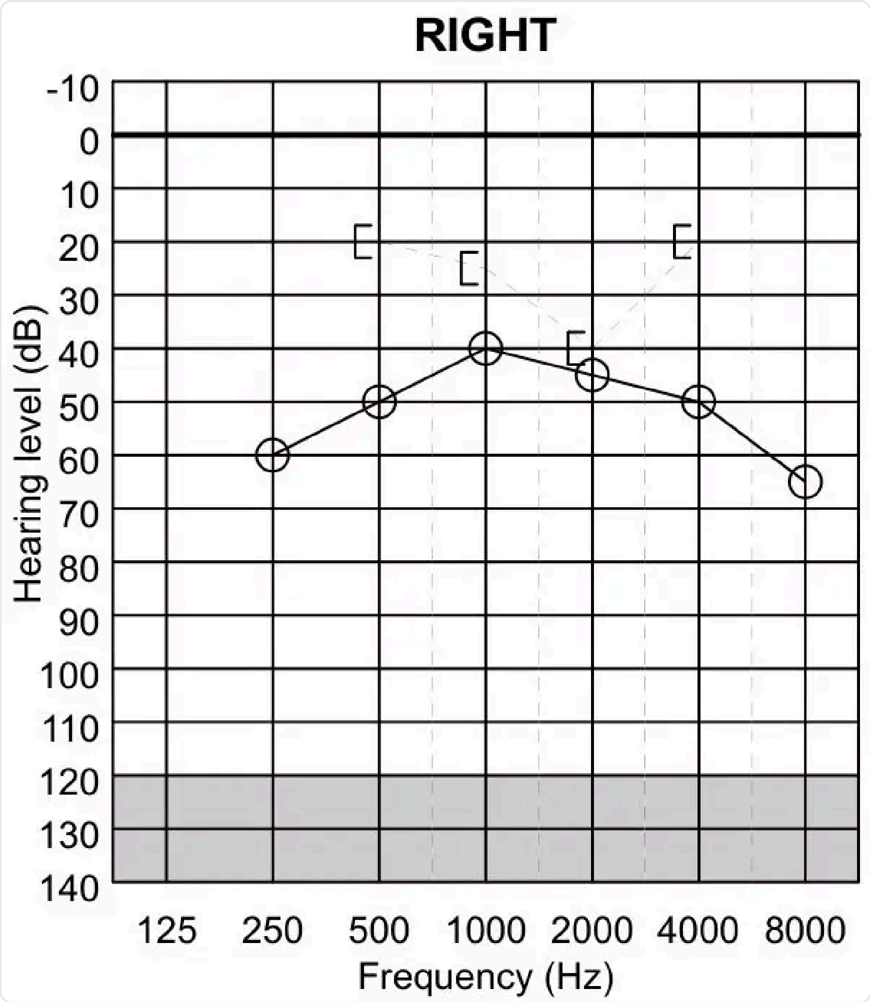


Figure 7: Audiogram demonstrating the Carhart notch at 2 kHz — an apparent BC dip caused by ossicular fixation in otosclerosis.

4. Masking

The Problem of Cross-Hearing

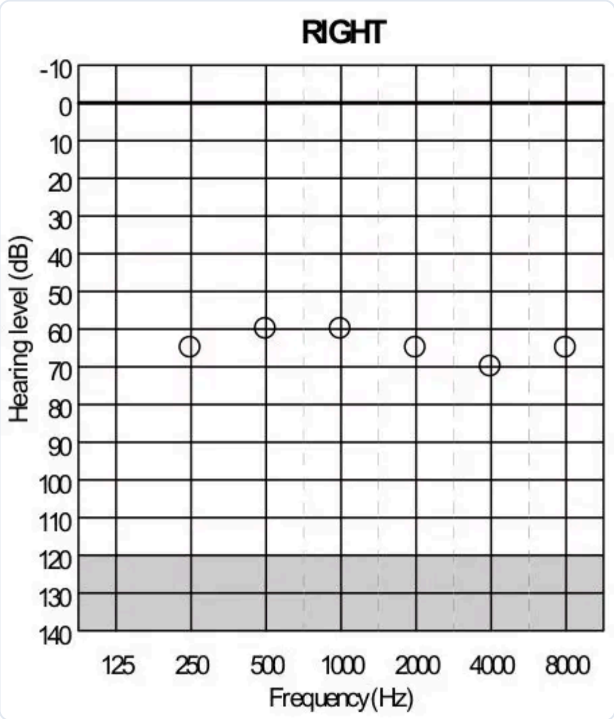
When the two ears have similar thresholds, sound presented to one ear stays in that ear — this is not a problem. However, when one ear hears much less well than the other, sound presented to the poorer ear at high intensities can travel across the skull and be detected by the **better ear's cochlea** instead. The patient responds, but the response reflects the better ear — not the ear being tested. These false responses are called **shadow responses**.

Patients cannot reliably tell you which ear is detecting the tone, so we cannot rely on their report. Instead, we use **masking** — introducing a controlled noise into the non-test ear to prevent it from detecting the test signal. This ensures the results obtained genuinely reflect the ear under test.

> **MINIMUM INTERAURAL ATTENUATION (IA) VALUES**
>
> When predicting cross-hearing, we assume the worst-case (minimum) IA:
>
> - **Air conduction:** IA = 40 dB (i.e. the signal can cross if the test-ear level is 40 dB louder than the non-test ear's threshold)
> - **Bone conduction:** IA = 0 dB (i.e. the signal can cross at any level — BC stimulates both cochleas simultaneously)

4.1 Masking in Air Conduction Testing

Cross-hearing for an air-conducted tone is predicted when the AC threshold of the **worse ear** differs from the AC or BC threshold of the **better ear** by **40 dB or more**. At this difference, the test signal in the poor ear may be loud enough to cross the skull and be heard by the better cochlea.



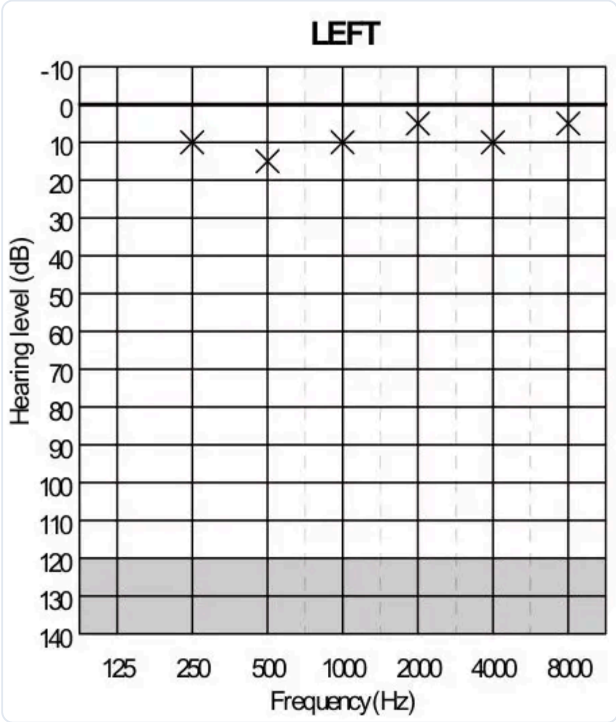
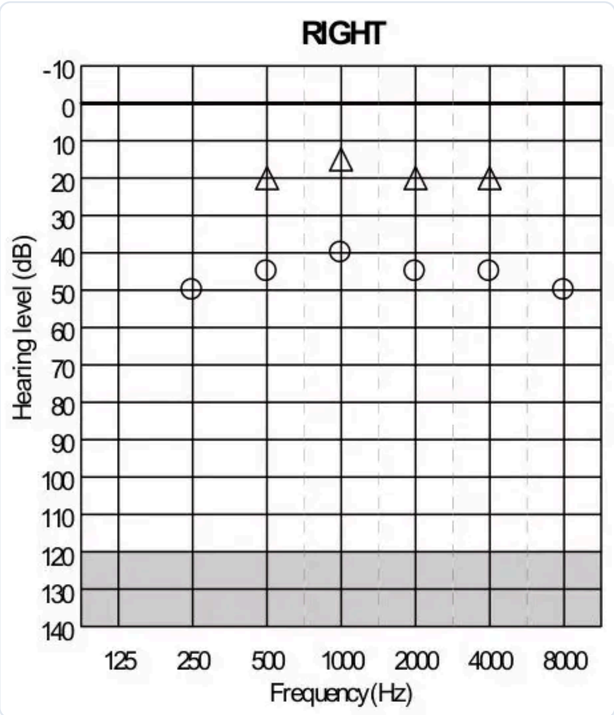


Figure 8a: Masking required for air conduction (left ear)

Figure 8b: Masking required for air conduction (right ear)

Masking is required at all six frequencies (250–8000 Hz) with the right ear as test ear, as the signal in the right ear at these frequencies could have been detected by the left cochlea via cross-hearing.



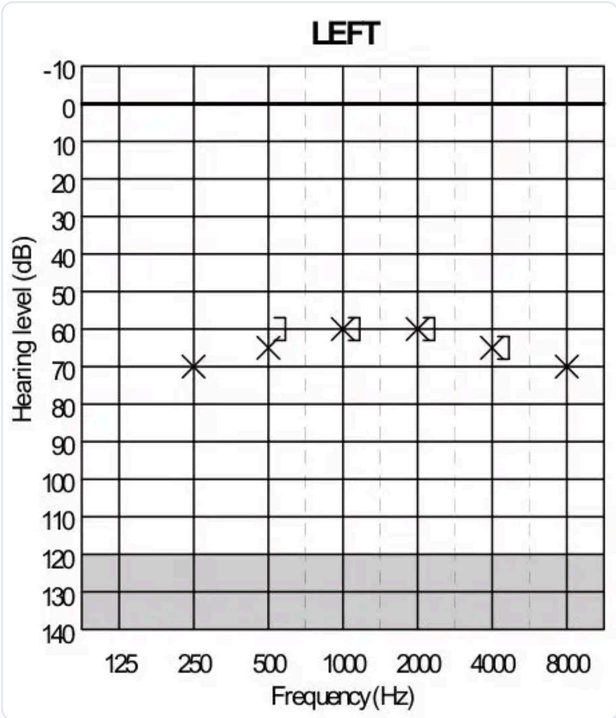


Figure 9a: Masking required (left ear as test ear)

Figure 9b: Masking required (right ear)

Masking is required at 500, 1000, 2000 and 4000 Hz with the left ear as test ear. If significant changes are found, masking should also be applied at 250 and 8000 Hz.

4.2 Masking in Bone Conduction Testing

Because the IA for bone conduction is effectively 0 dB, a BC tone stimulates both cochleas simultaneously. Cross-hearing for a BC signal is predicted when there is a difference of **15 dB or more** between the AC thresholds of either ear and the unmasked BC threshold. This suggests a significant air-bone gap, meaning masking is needed to assign the BC result to the correct ear.

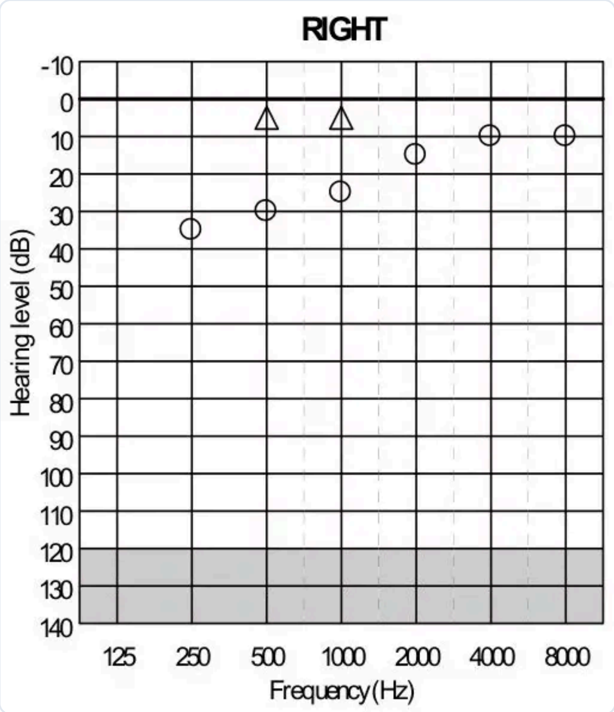


Figure 10a: Masking for bone conduction (left ear)

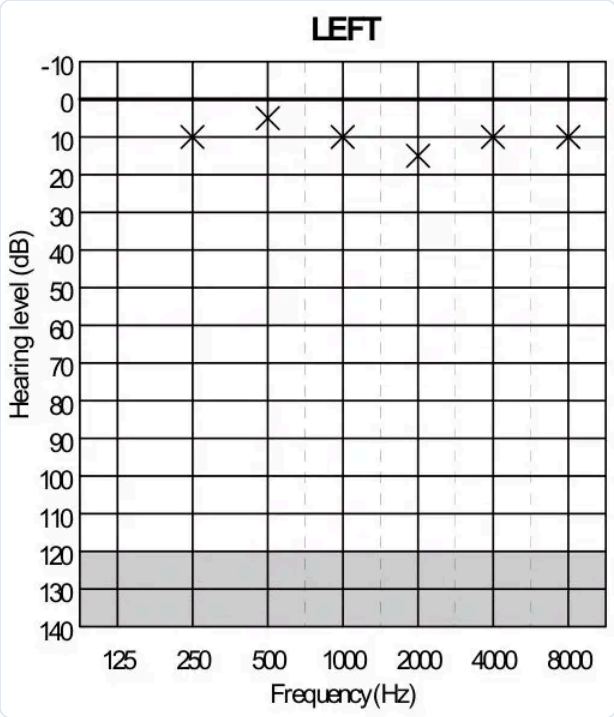


Figure 10b: Masking for bone conduction (right ear)

Masking is required at 500 and 1000 Hz, as the BC presentations at these frequencies on the right side may have been detected by the left cochlea. Until masked BC is obtained, it is unclear whether the right-ear loss is conductive or sensorineural.

5. The Three Rules of Masking

Masking is commonly summarised in three rules that simplify the decision-making process. However, rules have limitations — they can lead to over-masking or missed masking if applied mechanically without understanding the underlying concept of cross-hearing.

Rule	Trigger Condition	Insert Earphones
Rule 1 AC vs AC	Difference between left and right unmasked AC ≥ 40 dB at any frequency	≥ 55 dB
Rule 2 BC vs AC (gap)	Unmasked BC is better than AC (on either ear) by ≥ 10 dB (BSA) or ≥ 15 dB (ISVR)	Same threshold applies
Rule 3 BC vs worse AC	BC of better ear is better than unmasked AC of worse ear by ≥ 40 dB	≥ 55 dB

LIMITATIONS OF MASKING RULES

- Rules can lead to over-reliance on formulae without understanding *why* masking is needed
- They over-generalise and do not cover every clinical scenario
- They can result in unnecessary masking or, more critically, missed masking
- They do not account for all interaural attenuation evidence, especially for bone conduction (current data suggests IA for BC may be up to 20 dB)

Rule 1 — Air Conduction vs Air Conduction

Masking is needed at any frequency where the difference between the left and right *unmasked* AC thresholds is **40 dB or more** (55 dB or more when using insert earphones).

```
Right AC (unmasked) − Left AC (unmasked) ≥ 40 dB  →  Mask
```

After masking, if thresholds worsen, the original (shadow) thresholds are shaded and the new true thresholds are recorded below them. If a masked threshold does not change, the bottom half of the symbol is shaded.

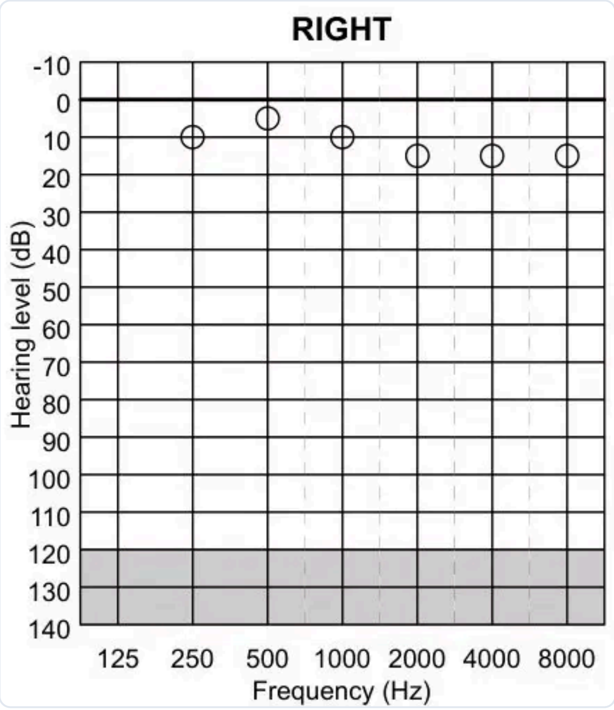


Figure 11a: Rule 1 example (left ear)

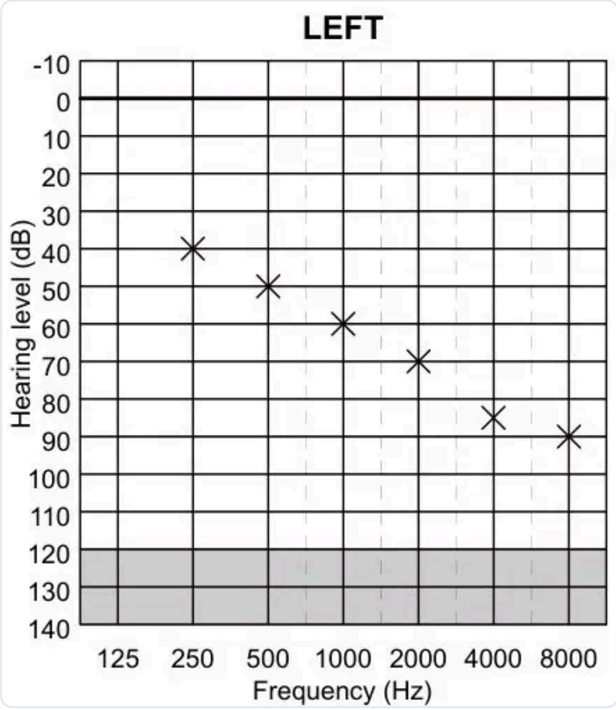


Figure 11b: Rule 1 example (right ear)

The right cochlea is normal and has thresholds 40 dB or more better than the left at every frequency except 250 Hz. Masking of the left ear is therefore required at all frequencies except 250 Hz.

Rule 2 — Bone Conduction vs Air Conduction (Air-Bone Gap)

Masking is needed at any frequency where the *unmasked* BC threshold is better than the AC threshold of either ear by **10 dB or more** (BSA Recommended Procedure) or **15 dB or more** (former ISVR Protocol, still widely used).

```
AC (either ear) − BC (unmasked) ≥ 15 dB  →  Mask
```

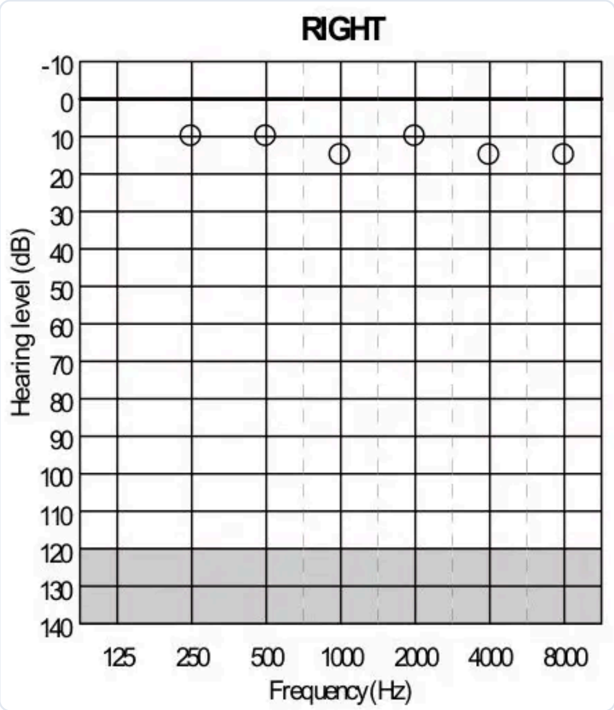


Figure 12a: Rule 2 example (left ear)

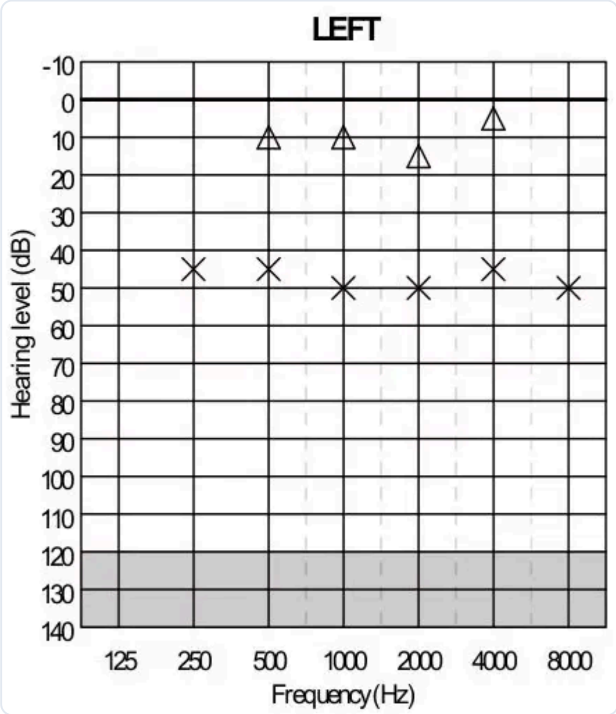


Figure 12b: Rule 2 example (right ear)

The unmasked BC thresholds may belong to the better-hearing right ear. Without masking, we cannot determine whether the left ear's loss is conductive, sensorineural, or mixed. Masking is needed to establish the true BC thresholds of the left ear. An air-bone gap of <15 dB is considered non-significant, and the loss is classified as sensorineural.

A Further Example

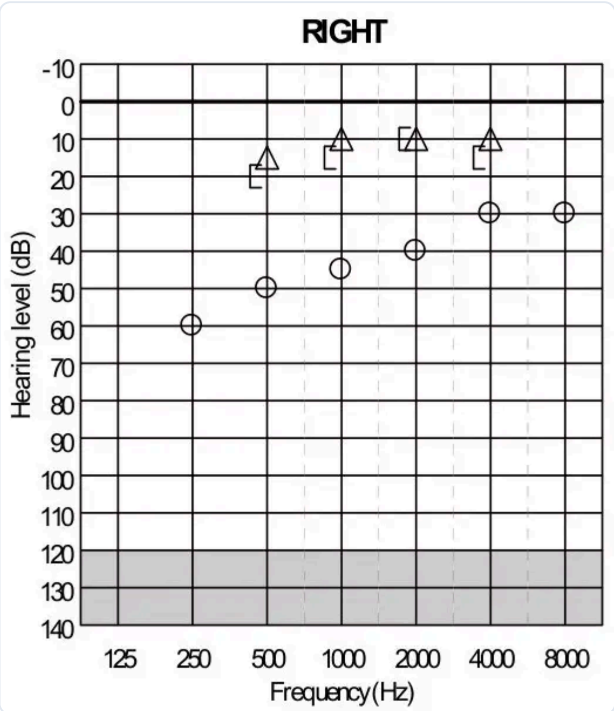


Figure 13a: Rule 2 — further example (left ear)

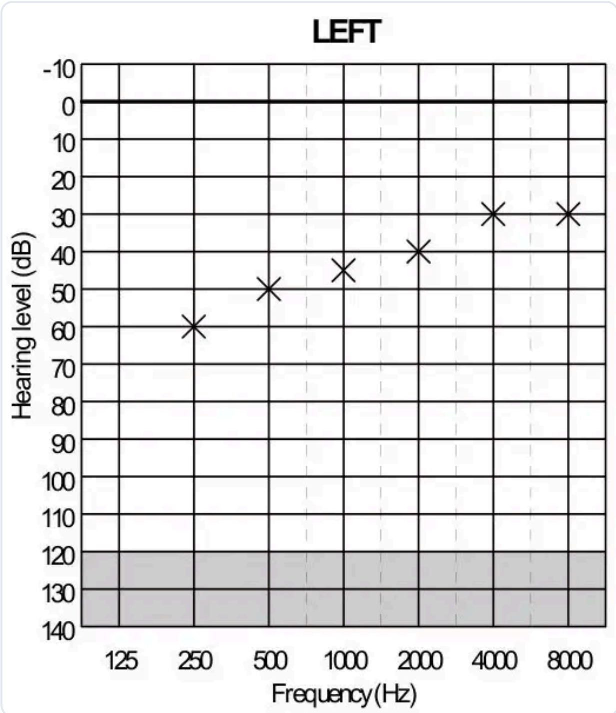


Figure 13b: Rule 2 — further example (right ear)

If masked BC thresholds change by only 5–10 dB, it is possible that the unmasked BC results belonged to the ear with the worse AC thresholds. In this case, it may also be necessary to test the better ear's BC while masking the worse ear, to establish the true BC threshold on both sides. Good practice at 4000 Hz is to use an earplug in the test ear even during BC masking.

NOTE ON INTERAURAL ATTENUATION FOR BC

Rule 2 assumes IA of 0 dB for BC. While this is conservative and prevents missed conductive losses, current evidence suggests IA for BC may be up to 20 dB. This means Rule 2 can occasionally indicate masking is needed when it may not strictly be required — clinical judgement is always necessary.

Rule 3 — Bone Conduction vs Worse Unmasked Air Conduction

Rule 3 applies where Rule 1 has *not* been triggered, but where the BC threshold of the better ear is better than the unmasked AC of the worse ear by **40 dB or more** (55 dB with insert earphones).

```
Better ear BC − Worse ear AC (unmasked) ≥ 40 dB  →  Mask
```

The rationale is similar to Rule 1: if the worse ear has a conductive loss, its cochlea may actually be functioning near-normally. A loud tone delivered to the worse ear could still be cross-heard by the better cochlea on the *other* side, even though that ear also has a hearing loss.

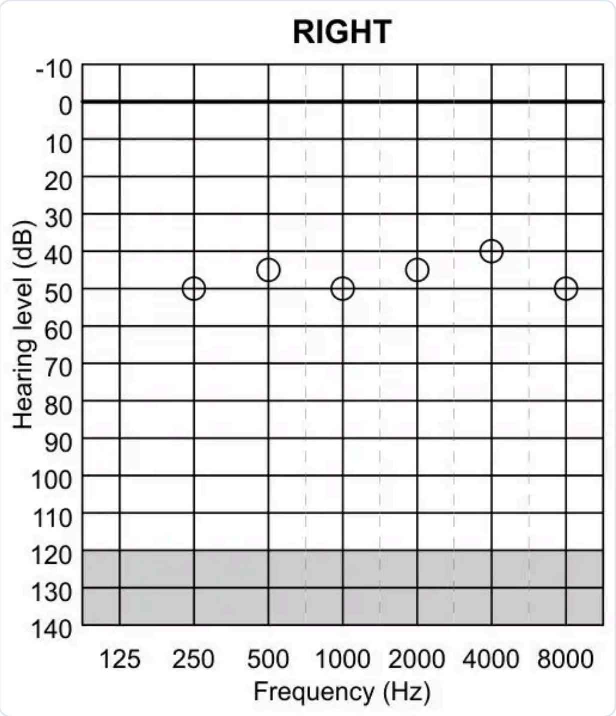


Figure 14a: Rule 3 example (left ear)

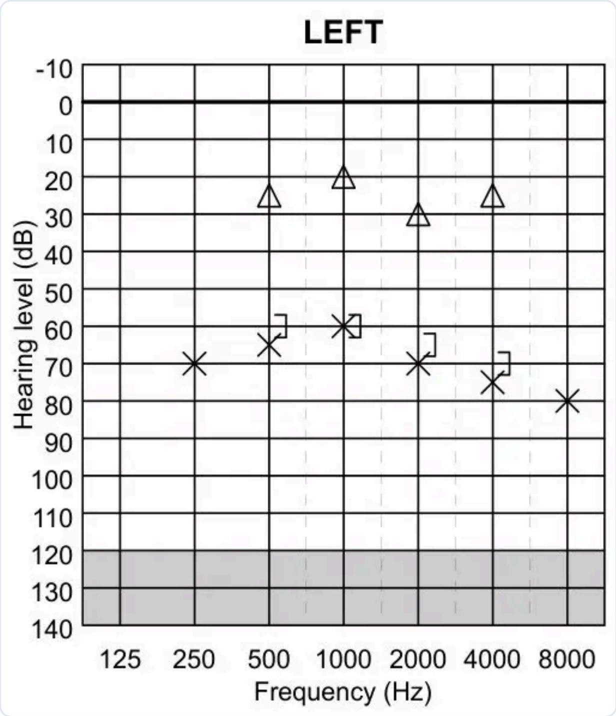


Figure 14b: Rule 3 example (right ear)

Where Rule 3 applies at BC-tested frequencies, masking should also be considered at the remaining frequencies where BC was not tested, as the same cross-hearing principle is likely to apply.

AKT EXAM TIP — MASKING PRINCIPLES

The AKT is unlikely to test the fine detail of masking rules, but may test the underlying concepts:

- Know that masking prevents the non-test ear from responding to a signal intended for the test ear
- Know the minimum IA values: **40 dB for AC, 0 dB for BC**
- Understand that an asymmetric audiogram (one ear much worse than the other) should trigger investigation for a unilateral cause — e.g. acoustic neuroma (vestibular schwannoma)

6. Suspicious Audiograms

Some audiograms are internally inconsistent — the pattern seen is physically or physiologically implausible given the principles of audiometry covered in this module. Recognising these patterns is an important clinical skill. The three examples below illustrate the most common suspicious findings.

6.1 Probable Non-Organic Hearing Loss — Unmask 80 dB Asymmetry

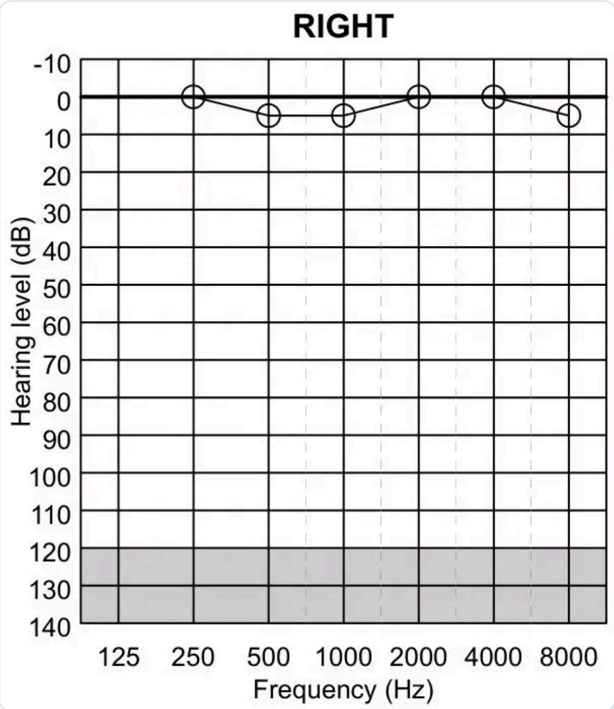


Figure 15a: Suspicious audiogram — unmasked (left ear)

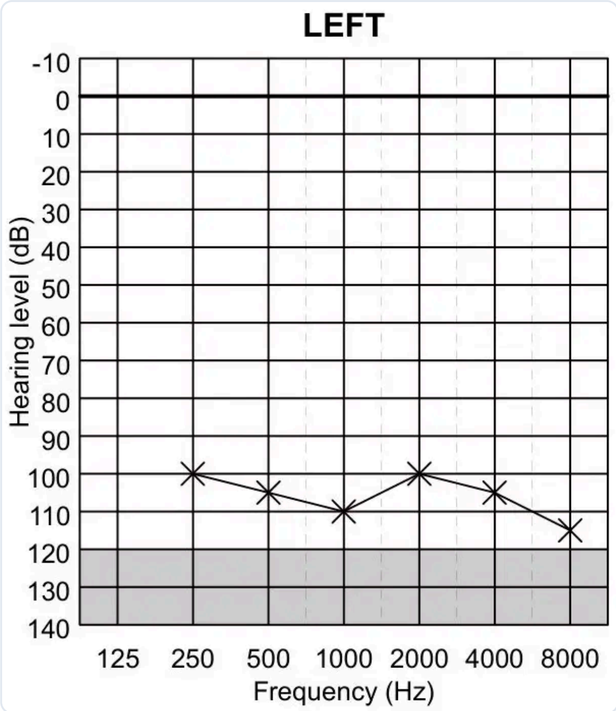


Figure 15b: Suspicious audiogram — unmasked (right ear)

This audiogram has not been masked, yet there is more than 80 dB asymmetry between the ears. Cross-hearing should have occurred at these signal levels, producing better unmasked AC thresholds than are shown here. The fact that this has not happened is a strong indicator of **non-organic hearing loss (NOHL)**.

6.2 Implausible Degree of Conductive Loss

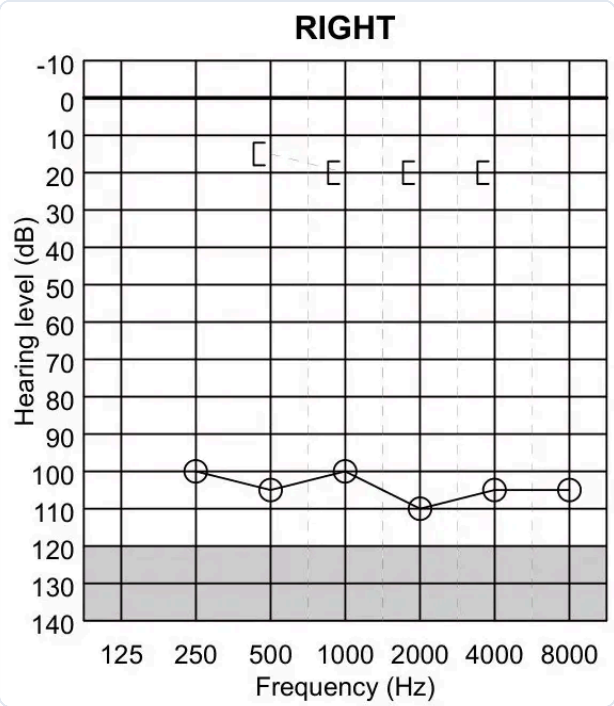


Figure 16a: Suspicious audiogram — excessive conductive loss (left ear)

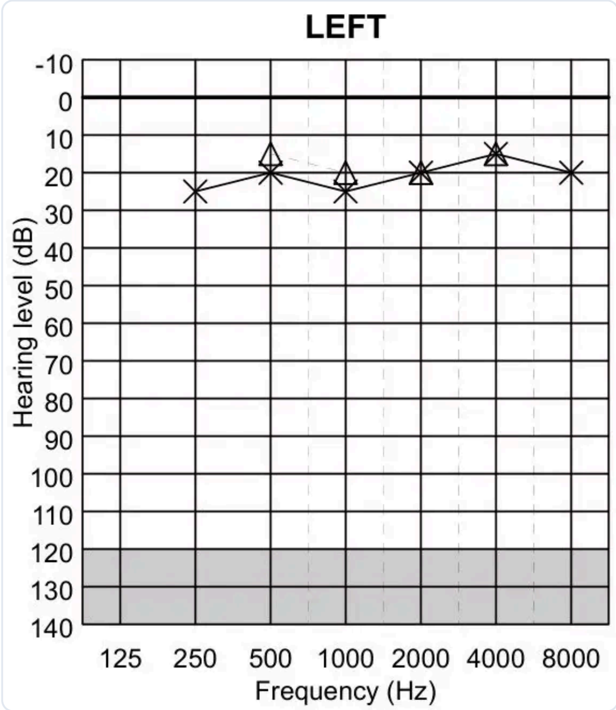


Figure 16b: Suspicious audiogram — excessive conductive loss (right ear)

This audiogram suggests a conductive loss on the right side exceeding the maximum interaural attenuation for most individuals. Furthermore, even in the complete absence of a middle ear (e.g. after radical mastoidectomy), AC thresholds would still be approximately 70 dB — a purely conductive loss of more than 70 dB is not physiologically possible. This pattern is therefore implausible.

6.3 Unmasked Bone Conduction Worse Than Best Air Conduction

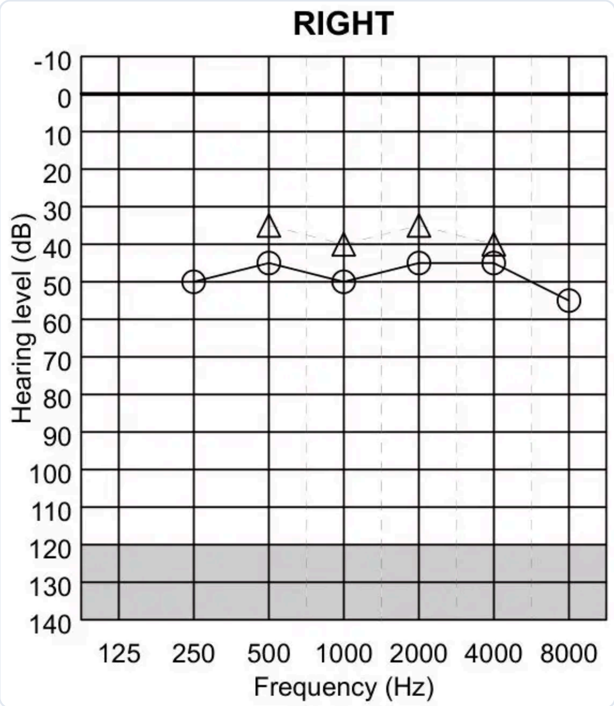


Figure 17a: Suspicious audiogram — BC worse than AC (left ear)

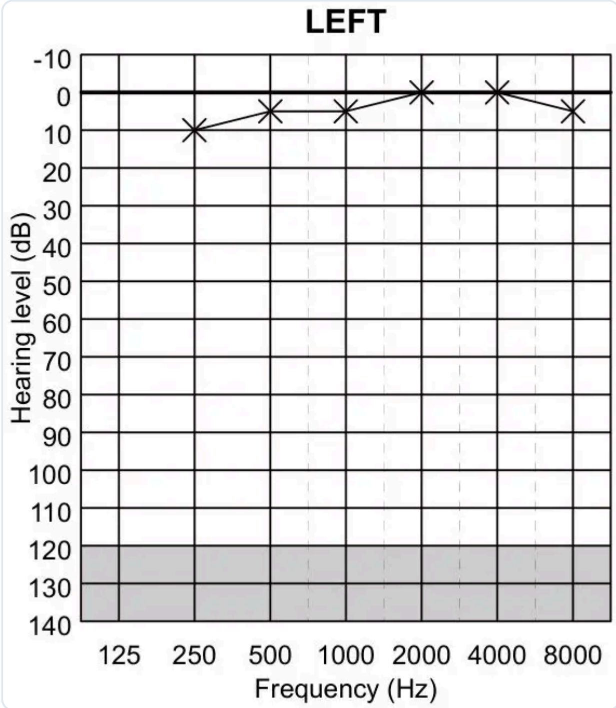


Figure 17b: Suspicious audiogram — BC worse than AC (right ear)

This audiogram shows unmasked BC thresholds significantly worse than the best AC thresholds across the same frequencies. While interaural attenuation for BC may be up to 20 dB, the degree of discrepancy here exceeds this. This is a likely indicator of **non-organic hearing loss**.

AKT EXAM TIP — NON-ORGANIC HEARING LOSS

Non-organic hearing loss (also called functional or psychogenic hearing loss) is an important topic for the AKT and SCA:

- Audiogram inconsistencies (as above) are the key diagnostic signal
- Other clues: poor test–retest reliability, inconsistency between pure-tone and speech audiometry, normal otoacoustic emissions (OAEs) despite claimed hearing loss
- In medicolegal or occupational contexts, consider malingering
- In children, it may reflect psychological distress — address with empathy; do not confront
- Refer to audiology for further objective testing (ABR / ASSR)

KEY POINTS SUMMARY

- Always start with otoscopy — wax distorts audiometry results
- Four grades of hearing loss: mild (20–40), moderate (41–70), severe (71–95), profound (>95 dB HL)
- Air-bone gap ≥15 dB = conductive component present
- AC = BC = sensorineural loss; AC worse than BC = conductive element
- Carhart notch at 2 kHz is the hallmark of otosclerosis
- Masking: IA minimum = 40 dB (AC), 0 dB (BC)
- Unilateral sensorineural loss must prompt acoustic neuroma screening (MRI IAMs)
- Asymmetric audiogram + implausible pattern = suspect non-organic hearing loss