REVIEW ARTICLE

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Auditory Testing – Interpretation for Physicians

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Hearing is a special sense that allows us to identify objects in the world based on the sound they produce and this makes communication using sound possible. Sound is derived from objects that vibrate producing pressure variations in a sound-transmitting medium, such as air. Thus, a sound wave propagating outward from a vibrating object can reach the tympanic membrane (eardrum) of a listener causing it to vibrate and initiate the process of hearing. The external ear collects sound vibrations from the air and focuses these sounds onto the tympanic membrane. Vibrations are transmitted through the middle ear by the ossicular chain (malleus, incus, and stapes). The stapes transmits these vibrations to the cochlear fluids through the oval window producing motion. The hair cells in the cochlea convert the physical vibrations into action potentials transmitted via the auditory nerve to the brainstem for further processing. Deafness may occur due to interruption at any point along this pathway. Sound can also be transmitted through the bones of the skull directly to the cochlea.

According to WHO, a person is said to have hearing loss if he is not able to hear as well as someone with normal hearing (meaning hearing thresholds of 25 dB or better in both ears). It can be mild, moderate, moderately severe, severe or profound, and can affect one or both ears (Table I). The prevalence of hearing loss varies with age; at least 25 per cent of patients between 51 and 65 years of age, and more than 50 per cent of patients older than 80 years, have objective evidence of hearing loss[1]. The common causes of hearing loss include congenital or early onset childhood hearing loss, chronic middle ear infections, noise-induced hearing loss, age-related hearing loss, and ototoxic drugs that damage the inner ear.

Broadly there are three types of hearing loss: conductive hearing loss (CHL), sensorineural hearing loss (SNHL)and mixed hearing loss. A conductive hearing loss happens when pathology lies in outer and middle ear such as wax in the ear canal, tympanic membrane perforation, middle ear ossicular discontinuity/fixation. Damage to inner ear or nerve pathways from inner ear to brain causes SNHL such as presbycusis (age related hearing loss), oto-toxicity (drug induced hearing loss), noise induced hearing loss, tumours involving/compressing auditory nerve. When there are components of both CHL and SNHL, it is called mixed hearing loss.

It is important for all physicians to pick up hearing loss in their patients due to various systemic diseases and ototoxic drugs. This can effectively be done by hearing tests.

This article will discuss few screening tests which can be used by General Practitioners for hearing assessment. These include Whisper voice test, Finger rub test, Watch ticking test and Scratch test. These screening tests are less reliable and patients can be referred for definitive hearing tests on suspicion of hearing loss. The present article will focus on two such tests: Tuning fork tests and Pure tone audiometry.

Tests for screening of hearing loss (for general practitioners)

1. Whisper voice test

In most Western countries, National Health Guidelines encourage general practitioners to screen elderly people for hearing loss using whispered voice test. Because the tuning fork test evaluates hearing at a single low frequency, it is not appropriate for most elderly patients with presbycusis, who typically have lost the ability to hear high frequencies[2].

Procedure: The examiner stands behind the patient, about an arm's length away, and whispers a series of letters and numbers into one ear while the patient covers the other ear. The patient then repeats what they heard. The test is considered passed if the patient correctly repeats at least three out of the six letters and numbers. To maintain uniformity, the test should be performed after a slow, complete, silent exhalation. The number-letter combination should be different for each ear.

Several studies also examined the reliability or reproducibility of the whispered voice test. Uhlmann *et al*[3] compared the results of an otolaryngologist and an audiologist for 63% of the patients and found a correlation of 0.67 and Macphee *et al*[4] found concordance between a geriatrician and an otolaryngologist of 0.88.

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Limitations of Whisper voice test

1. One area of concern is the reproducibility of the whispered voice test. The results of the studies that measured reliability indicate that the test can be reliable if a standard procedure is used.
2. The most appropriate letters, numbers, or words for testing also needs further investigation. In the elderly population, where presbycusis is the most common type of hearing loss, difficulty in hearing sounds in the higher frequencies is common. As the consonants of speech are usually higher frequency sounds than the vowels[5] using different consonants and vowels in testing could alter the results of the test considerably.
3. The greatest difficulty in standardising the test is the loudness of the whisper. Only few studies mentioned that the whispered sequence occurred after a full expiration. This seems to be an important determinant of the loudness of the whisper.
4. With the test sensitivity much lower in children than adults, it might be argued that the test is of limited value in children[6].

2) Finger rub test

This is a crude and easy test for screening for hearing loss. In the finger rub test, the examiner rubs his or her fingers together near the patient's ear and asks the patient whether they have heard the sound. CALFRAST is calibrated finger rub auditory screening test.

Procedure[7]

With the hand comfortably dry, the CALFRAST sound was produced by briskly rubbing the thumb across the distal fingers. The subject was encouraged to listen carefully so as not to miss the faintest sound. With the subject's eyes closed, the examiner stood nose to nose, 6 to 10 inches in front of the subject, and extended both arms straight laterally so that the moving fingers would be equidistant from the examiner's and subject's ears, a distance of approximately 70 cm. First, a strong finger rub (CALFRAST–Strong 70), as strong as one can perform without snapping the fingers, was presented to each side separately and was repeated three times. If the subject reported accurately, the next test was the faint finger rub (CALFRAST–Faint 70), the softest rub that the examiner could hear with arms fully extended. If the participant heard CALFRAST–Faint 70 bilaterally, the testing was complete.

If the participant did not hear CALFRAST–Strong 70 with either ear, still louder stimuli were produced by bringing the strong rub closer to the tested ear at standard intervals of approximately 35, 10, and 2 cm. Halving the stimulus distance to approximately 35 cm was conveniently estimated by flexing the elbow to 90 degrees (CALFRAST–Strong 35). One hand breadth was conveniently used to mark the 10 cm distance (CALFRAST–Strong 10). The 2 cm distance stimulation was presented as close to the tragus as possible, without touching the earlobe (CALFRAST–Strong 2). The CALFRAST level for each ear was the weakest stimulus perceived.

3) Clock ticking test

During this test, an examiner places a watch next to the patient's ear and ask them to note when they can no longer hear the ticking.

4) Scratch test

This test was decribed as a means of diagnosing an acute post-operative dead ear, alternative to the Weber test[8], when the tuning fork is not available.

Procedure: In the post-operative period, the bandage was scratched in the midline and patient was asked whether he can hear the sound[9].

Tuning fork tests

Tuning forks (Fig. 1) are used as a simple test in the OPD to establish the probable presence or absence of a significant conductive element to hearing loss. The sound is produced by setting the tuning fork into vibration. They are typically used to provide early diagnostic information when audiometry is not available or possible[10]. The most preferred tuning fork is a 512Hz tuning fork. At this frequency, in comparison to the 256Hz and 1024 Hz tuning forks, the tone does not fade too quickly, produces limited overtones and is not vibrotactile[11]. The practitioner shall hold the tuning fork by its stem and strike one side of the tines, two thirds of the way along the tine from the base, on a padded surface or the practitioner's elbow or ball of hand. Do not strike on a hard surface as this will introduce harmonic overtones and may damage the tuning fork. The test should be undertaken in a quiet room.

Air conduction and bone conduction

Before we discuss the types of tuning fork tests, let us understand two important terms called as air conduction and bone conduction testing. In tuning fork tests, we test for air conduction as well as bone conduction. Air conduction means when sound is given through the External auditory canal. It is transmitted through tympanic membrane, middle ear ossicles and then reaches cochlea. It tests both conductive and sensorineural pathways. For air conduction testing, after striking, the tuning fork is held in front of the ear canal. Bone conduction testing is done by placing the tuning fork over the mastoid process after striking. Here, the sound is transmitted to cochlea through skull bones. It directly measures cochlear function. Air conduction is always better than bone conduction in normal individuals.

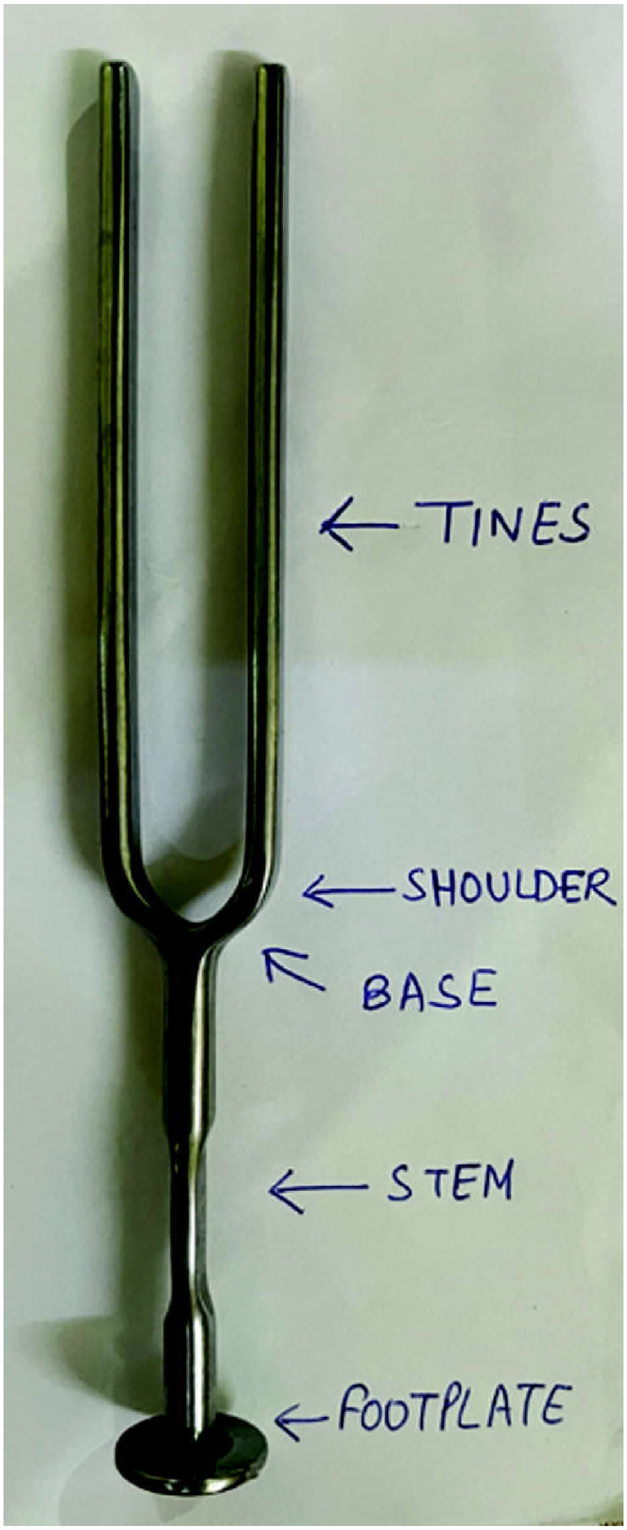

Fig. 1: *Tuning Fork.*

The main tuning fork tests are Rinne, Weber and Absolute bone conduction (ABC). The practitioner shall instruct the patient on each of the tests. Tuning fork tests are particularly subjective and response bias must be accounted for when determining their validity as diagnostic tools. Clear and concise instructions will limit misinterpretation by the patient. Tuning fork tests have been the mainstay of otologic examination in OPD. The Weber test has been mainly used to establish a diagnosis in patients with unilateral hearing loss to distinguish between conductive and sensorineural hearing loss[12].

The Weber Test

The Weber test is a test of lateralisation of the sound and is more commonly preferred in asymmetric hearing loss.

Procedure[13]: Strike the tuning fork (512 Hz) and place it on the midline, typically on the patient's forehead but it can also be placed on the vertex, bridge of the nose or chin. Stabilise the patient's head using other hand. Hold the tuning fork in place for up to 4 seconds (Fig. 2). After giving the patient listening time, ask them where the tone is heard: is it equal in both ears (central), or towards the left or right ear. The patient is asked to which ear the sound feels lateralised.

Interpretation

1. With symmetrical hearing or a symmetrical hearing loss the sound should be central.
2. With an asymmetrical sensorineural loss, the sound should be heard in the better ear.

Fig. 2: *Weber Test.*

3. With an asymmetrical conductive hearing loss the sound should be heard in the poorer ear.

Principle: In normal individuals (without hearing loss), the inner ear is more sensitive to sound via air conduction than bone conduction (in other words, air conduction is better than bone conduction).

In the presence of a purely unilateral conductive hearing loss, there is a relative improvement in the ability to hear a bone-conducted sound. This can be explained by the following:

- ***Masking effect:*** The sound heard via the affected ear has less environmental noise reaching the cochlea via air conduction compared to the unaffected ear, which receives sounds from both bone conduction and air conduction. Therefore, the affected ear is more sensitive to bone-conducted sound[14].
- ***Occlusion effect:*** Most of the sound transmitted via bone conduction travels to the cochlea. However, some of the low-frequency sounds dissipate out of the canal. A conductive hearing loss will prevent external dissipation of these frequencies and lead to increased cochlear stimulation and loudness in the affected ear[15].

In the presence of sensorineural hearing loss, the sound will be perceived louder in the unaffected ear, which has a better cochlea. Thiagarajan and Arjunan[16] reported that the Weber test can determine a difference of 5 decibels between two ears in terms of bone conduction thresholds.

The Rinne Test

This test is commonly done by loudness comparison method. We compare loudness of air conduction testing with bone conduction.

Procedure[13]: The practitioner should start with the ear to which the Weber has lateralised to. Place the vibrating tuning fork approximately 25 mm from the ear canal entrance with its tines parallel for about 2 seconds. Now without any interruption and without touching the tines, press the footplate of tuning fork firmly against the mastoid (without any hair getting between the footplate and the mastoid). The tuning fork is held in place for another 2 seconds (Fig. 3). After giving the patient listening time, ask them whether the tone is louder next to the ear or behind the ear. The patient should respond verbally.

Interpretation

1. If air conduction (next to the ear canal) is louder, it is interpreted as Rinne positive result indicating either normal hearing or a Sensorineural hearing loss (AC >BC).
2. If bone conduction (held on mastoid) is louder, it is a Rinne negative result, indicating a Conductive Hearing loss (BC >AC).

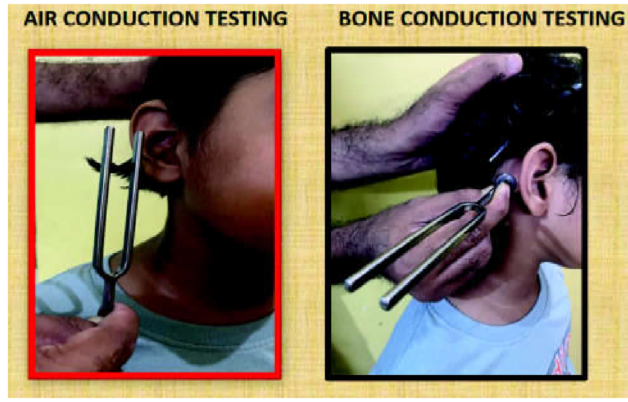

Fig. 3: *Rinne Test.*

Principle

Rinne Positive: The patient is positive on that side (the ossicular chain is doing what it should be doing, acting as an amplifier).

Rinne Negative: If the bone conduction through the mastoid process is heard louder than through the air, the patient is Rinne negative. This is seen in CHL. This is because air vibrations are not transmitted across the external auditory canal, the tympanic membrane, the ossicular chain, or the oval window.

Rinne False Negative: This occurs with a severe sensorineural loss predominantly on the test side. This occurs when the bone conduction transmits through the skull to the opposite ear and is detected through cross hearing by the better cochlea (in the non-test ear). It can be distinguished by considering if the Weber test result is contradictory and asking the patient which ear the bone conduction part of the test was heard in.

Absolute Bone Conduction Test (ABC)

This is a test of cochlear function.

Procedure

In this test, bone conduction is tested by placing the vibrating tuning fork over the mastoid region with occlusion of external auditory canal (EAC) to prevent air conduction sounds interfering with bone conduction. The patient is asked to inform when he stops hearing the sound. Then the same vibrating tuning fork is placed over the mastoid bone of examiner himself. The examiner then hears the sound.

Interpretation

1. If the examiner is also not able to hear any sound then it is interpreted as 'Same as Examiner' and indicates normal cochlear function.
2. If examiner is still able to hear sound the sound of tuning fork when patient has stopped hearing it is interpreted as 'Shortened' and indicates SNHL.

Table I: Classification of hearing loss[20].

Grade Of Impairment	Pure Tone Audiometric Threshold[a,B]
Normal Hearing	0 - 25 dB
Mild Hearing Loss	26 - 40 dB
Moderate Hearing Loss	41 - 60 dB
Severe Hearing Loss	60 - 80 dB
Profound Hearing Loss	>80 dB

[a]In the better ear; [B]Average of 500, 1000, 2000 and 4000 Hz.

Table II: Summary of Tuning Fork Tests.

	Rinne	Weber	ABC
Normal	Positive	Central	Same as examiner
CHL	Negative	Lateralised to deaf ear	Same as examiner
SNHL	Positive	Lateralised to normal ear	Shortened (as compared to examiner)

Pure Tone Audiometry

The tuning fork tests give us an idea of presence or absence of hearing loss and type of hearing loss. But to find the degree of hearing loss, Pure tone Audiometry (PTA) is performed. It is done with the use of an audiometer. The graph thus plotted is called an audiogram. The advantage of an audiogram is that it provides information about the type and degree of hearing loss. Also, it provides a permanent record which can be included in the patient's file for future reference and comparison and is essential for documentation especially for medicolegal cases. Audiometry is more challenging in patients younger than five years.

Pure tone testing is the measurement of an individual's hearing sensitivity to pure tones at different frequencies. A pure tone audiology threshold at a specific frequency is the decibel level at which a sound is perceived 50% of the time. The decibel scale used in pure tone audiometry is *dB Hearing Level (dB HL)*. The dB HL intensity scale is based on normal human hearing with 0 dB HL representing the median threshold for otologically normal young adults[17]. The basic audiological assessment focuses on pure tone air conduction thresholds in the frequency range 0.25 - 8 KHz.

Pure tone thresholds at each frequency are plotted on a graph called an *audiogram*, which depicts the type, degree and configuration of the hearing loss(Fig. 4). The x-axis denotes the frequency being tested and the y-axis denotes the decibel level at which the patient perceives the pure tone sound. Using specific symbols, a mark is placed on the graph at the decibel level where the patient perceives the particular frequency of sound being tested. This is done separately for both ears.

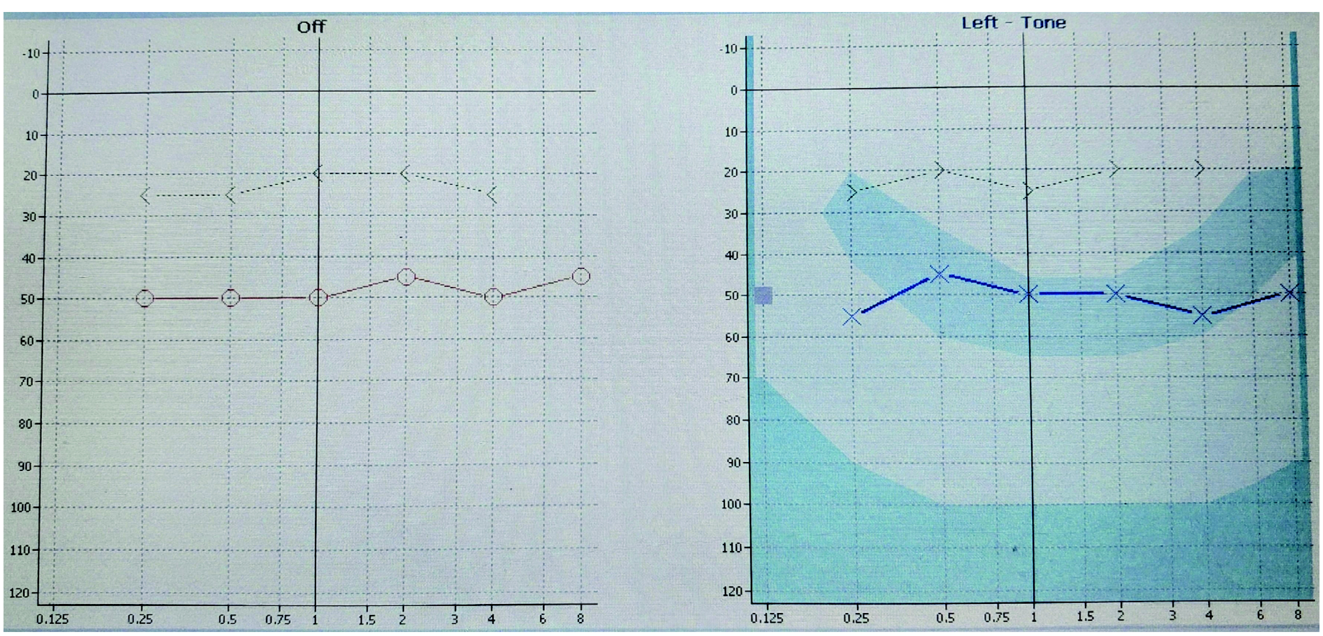

Fig. 4: *Audiogram.*

For air conduction testing, sound is given using head phones. Whereas for bone conduction testing, sound is given by a bone oscillator placed over the mastoid bone. Testing is done separately for both ears. There are specific symbols to record air conduction and bone conduction thresholds on an audiogram for both ears as shown below.

	Umasked Air	Unmasked Bone	Masked Air	Masked Bone
Right	0	<	△	[
Left	X	>	□	]

Usually, the symbols for right ear are drawn in red colour and left ear are in blue colour on an audiogram.

Masking

If the pure-tone threshold difference or asymmetry between ears at any frequency is equal to or greater than 40 dB, the sound energy from the test ear can stimulate the nontest ear, causing the nontest ear to respond to the stimulus. To prevent this crossover of sound from one ear to the other, narrow band noise is presented to the nontest ear and thresholds are recorded as masked. This procedure in audiology is called as Masking.

Interpretation

The values of the thresholds are inserted into the audiogram blank sheet. The tone frequency expressed in Hertz is recorded on the horizontal axis, while the vertical axis shows the tone intensity expressed in Decibels[18].

A normal audiogram displays air and bone conduction lines with thresholds of ≥25 dB HL at each of the tested frequencies in both ears. An air-bone gap is noted on the audiogram, which is present when the difference between air conduction and bone conduction thresholds at a specific frequency is greater than 15 dB HL and is indicative of CHL. With a pure CHL, the bone conduction thresholds are normal, but the air conduction thresholds indicate hearing loss. On an audiogram, pure SNHL is indicated by overlapping of the lines representing air conduction and bone conduction without the presence of any air-bone gaps >10 dB[19] (Fig. 5).

The audiogram gives a fundamental description of auditory sensitivity. According to the international classification of hearing loss, to calculate the degree of hearing loss, it is necessary to summarise the four values, i.e., the lowest audible sound intensity using the frequencies of 500, 1,000, 2,000 Hz, and 4,000 Hz and then to divide the sum by 4 to get the arithmetic average using the following formula:

I(500) + I(1000) + I(2000) + I(4000)/4

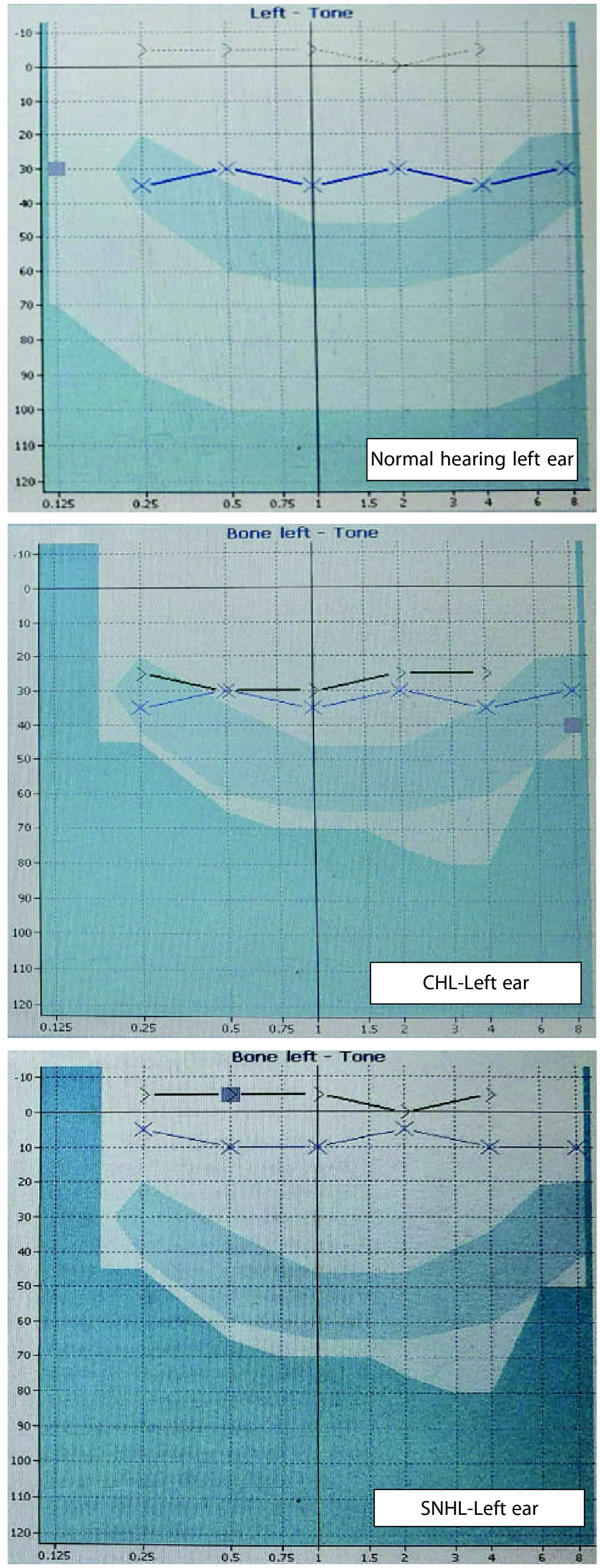

Fig. 5: Various Types of Audiogram.

References

1. Walker JJ, Cleveland LM, Davis JL *et al*. Audiometry Screening and Interpretation. *American Family Physician* 2013; 87: 41-6.
2. Pirozzo S, Papinczak T, Glasziou P. Whispered voice test for screening for hearing impairment in adults and children: systematic review. *BMJ* 2003; 327 (7421): 967.
3. Uhlmann RF, Rees TS, Psaty BM. Validity and reliability of auditory screening tests in demented and non-demented older adults. *J Gen Intern Med* 1989; 4: 90-6.
4. Macphee GJ, Crowther JA, McAlpine CH. A simple screening test for hearing impairment in elderly patients. *Age Ageing* 1988; 17: 347-51.
5. Fleming KC, Evans JM, Weber DC. Practical functional assessment of elderly persons: a primary-care approach. *Mayo Clin Proc* 1995; 70: 890-910.
6. Pirozzo S, Papinczak T, Glasziou P. Whispered voice test for screening for hearing impairment in adults and children: systematic review. *BMJ* 2003; 327 (7421): 967.
7. Torres-Russotto D, Landau WM, Harding GW *et al*. Calibrated finger rub auditory screening test (CALFRAST). *Neurology* 2009; 72 (18): 1595-600.
8 Buckland JR, Geyer M, Maleki N. The use of the weber tuning fork test and 'scratch test' in post-operative tympanomastoid surgery. *Clinical Otolaryngology* 2006; 31 (6): 581.
9. Iacovidou A, Giblett N, Doshi J. How Reliable Is the "Scratch Test" Versus the Weber Test After Tympanomastoid Surgery. *Otology and Neurotology* 2014.
10. Turton L, Batty S. Recommended procedure rinne and weber tuning fork tests. *British Society of Audiology* 2022.
11. Khanna S, Tonndorf J, Queller J. Mechanical parameters of hearing by bone conduction. *J Acoustic Soci Amer* 1976; 60 (1): 139-54.
12. Blakley BW, Siddique S. A qualitative explanation of the Weber test. *Otolaryngol Head Neck Surg* 1999; 120 (1): 1-4.
13. Recommended procedure rinne and weber tuning fork tests BSA 2022.
14. Surendran S, Stenfelt S. The Outer Ear Pathway During Hearing By Bone Conduction. *Hear Res* 2022; 421: 108388.
15. Goldstein DP, Hayes CS. The occlusion effect in bone conduction hearing. *J Speech Hear Res* 1965; 8: 137-48.
16. Thiagarajan B, Arjunan K. Tuning fork tests. *Webmedcentral Otorhinolaryngol* 2012; 3: WMC003279.
17. Recommended procedure Rinne and weber tuning fork tests BSA 2022.
18. Soer M. Open access guide to audiology and hearing aids for otolaryngologists. The Open Access Atlas of Otolaryngology, Head & Neck Operative Surgery.
19. Pure-tone Audiometer. Kapul AA, Zubova EI, Torgaev SN. IOP Conf. Series: *Journal of Physics*: Conf. Series 881, 2017, 012010.
20. Olusanya BO, Davis AC, Hoffman HJ. Hearing loss grades and the International Classification of functioning, disability and he health. *Bull World Health Organ* 2019; 97 (10): 725-8.