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ABCs of Pure Tone Audiometry: A Review Article

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Abstract
Pure Tone Audiometry (PTA) remains the cornerstone of clinical audiological evaluation, often referred to as the gold standard for assessing hearing thresholds. This comprehensive review explores the historical evolution, foundational principles, and clinical relevance of PTA in modern audiology. Beginning with its origins in early tuning fork tests, the paper highlights key technological advancements and contributions from pioneering figures such as Harvey Fletcher, C.C. Bunch, and Raymond Carhart. The review details the acoustic, physiological, and technical principles underlying PTA, including concepts of air and bone conduction, transducer properties, calibration standards, and the threshold of hearing. Pre-testing protocols such as biological calibration, case history intake, and otoscopic examination are emphasised as essential to ensuring reliable outcomes. Testing procedures are elaborated step-by-step, incorporating both air and bone conduction techniques, masking principles, and interpretation of audiometric results. The review also underscores PTA's diagnostic value, utility in monitoring hearing changes, and its pivotal role in hearing aid programming and cochlear implant candidacy assessment. Through historical context and contemporary applications, the review affirms the enduring relevance of pure tone audiometry in audiological science and practice.
Keywords: Pure tone audiometry, Audiometer, Air conduction, Bone conduction, Air-bone gap
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1. Introduction

Hearing is one of the most vital sensory modalities that support communication, language development, and overall quality of life. As such, accurate assessment of auditory function is essential in both clinical and research contexts. Among the various diagnostic tools available in audiology, Pure Tone Audiometry (PTA) has emerged as one of the most widely utilized and universally recognized method for evaluating hearing sensitivity. Referred to as the "gold standard" in behavioral hearing assessment, PTA provides critical information about the degree, type, and configuration of hearing loss through the identification of auditory thresholds across a specific range of frequencies (Carhart & Jerger, 1959; Kutz & Meyers, 2023).

Pure Tone Audiometry is a psychophysical test that determines the softest level of sound a person can detect at discrete frequencies, typically between 250 Hz and 8000 Hz. This range is essential for perceiving and processing speech sounds, which encompasses the frequencies associated with vowels, consonants and other speech elements. The test is performed using calibrated audiometric equipment that delivers pure tones via air conduction (headphones or insert earphones) and bone conduction (bone vibrator), allowing audiologists to differentiate among conductive, sensorineural, and mixed types of hearing loss (Martin & Clark, 2015; Gelfand, 2016).

This review seeks to provide a thorough overview of pure tone audiometry by exploring its historical origins, pioneers, technological evolution, and the core principles that guide its application. Additionally, it outlines step-by-step testing procedures, including pre-assessment protocols, equipment selection, patient instructions, and masking strategies, all of which are critical for ensuring test reliability and validity. Finally, the paper discusses the clinical significance of PTA in diagnosis, treatment planning, hearing aid fitting, and cochlear implant candidacy. Through this detailed analysis, the enduring importance of Pure Tone Audiometry in contemporary audiological practice is reaffirmed.

2. Historical Background

The origin of audiometry can be linked way back to the 1900s where tuning fork tests like Rinne, Weber and Schwabach tests where used which were prone to a lot of errors. These tests lack frequency specificity and loudness control. Also, the interpretations of these tests are totally subjective which means, the results are entirely based on clients responses and clinicians interpretation and these limitations among others led the drive for a more regulated and objective and quantitative approaches. The 20th Century played a transformational role in the world of audiology. The invention of the **Western Electric IA Audiometer** in the early 1920s made room for controlled generation of tones across the frequencies and intensities and was followed by the development of manual audiometry procedure, which brought about the "down 10 dB, up 5 dB" technique for threshold search **(Carhart and Jerger, 1959).**

3. Pioneers of Pure Tone Audiometry

3.1 Harvey Fletcher (1884–1981)

Known as the "father of stereophonic sound," Fletcher was a physicist and an early pioneer in the field of audiology. He worked at Bell Telephone Laboratories and contributed to the development of the Western Electric audiometer, one of the first pure tone audiometers spoken off which helped in the development and advancement of Pure Tone Audiometry. He later developed methods for determining hearing thresholds and masking. (Fletcher and Wegel, 1922)

3.2 Edmund Prince Fowler (1895–1966)

Edmund Prince Fowler is an American otolaryngologist who advanced the understanding and concepts of audiometric techniques. Contributed to the clinical application of PTA, including threshold testing and the use of air and bone conduction. He dedicated part of his carrier, shedding lights on loudness recruitment and other phenomena that pure tone audiometry is assessed with.

3.3 Georg von Békésy (1899–1972)

A Hungarian-born biophysicist, who won the Nobel Prize in Physiology or Medicine in 1961. He invented the automatic audiometer and developed the Bekesy audiometry technique. His work had a great impact on the mechanical properties of the cochlear and laid the basics for understanding frequency selectivity in hearing. (Von Békésy, G., 1960)

3.4 Raymond Carhart (1912–1975)

Because of his crucial contribution to the development of audiology as a distinct clinical and academic field, Raymond Carhart (1912–1975) is commonly referred to as the "father of audiology. He was instrumental in standardising pure tone audiometric procedures, making them more systematic and reliable for diagnosing hearing loss. The Carhart-Jerger method, a popular protocol for audiogram interpretation and thorough audiologic evaluation, was created by Carhart and Jerger. In addition to developing audiometric methods, his work established the foundation for contemporary audiologic practice and instruction (Jerger, 1996).

3.5 CC Bunch (1887–1944)

One of the earliest pioneers in pure tone audiometry was C.C. Bunch (1887–1944), who played a foundational role in the clinical application of audiometric testing. Bunch was among the first researchers to conduct systematic studies on hearing thresholds, and he emphasized the importance of frequency-specific testing in understanding hearing loss. His work significantly influenced the development of early clinical audiometric techniques and helped establish audiometry as a reliable diagnostic tool. His seminal publication, Clinical Audiometry (1929), is recognized as one of the first textbooks in the field, providing structured methodologies for assessing auditory function in clinical settings (Bunch, 1929)

4. Technological Evolution of Pure Tone Audiometry.

Since its inception in the early 20th century, Pure Tone Audiometry (PTA) has experienced considerable technological breakthroughs. Initially, speech tests and tuning forks were used for hearing assessment, which lacked frequency specificity and was subjective. Harvey Fletcher and his colleagues at Bell Telephone Laboratories were largely responsible for the creation of the electrical audiometer in the 1920s, which marked the beginning of PTA's progression. The foundation for contemporary audiometric evaluation was laid by their creation of the Western Electric 1A audiometer, the first commercially available instrument capable of producing pure tones at particular frequencies and intensities (Fletcher & Wegel, 1922).

Audiometers advanced in the 1930s and 1940s with the invention of frequency selectors that increased test accuracy and attenuators for regulating sound intensity. During this time, CC Bunch had a significant influence by incorporating these tools into clinical practice and encouraging frequency-specific testing in audiology (Bunch, 1929).

By the mid-20th century, audiometers witnessed miniaturization and standardisation. By the 1950s and 1960s, audiometers had become more portable and reliable, with frequent calibration standards set by organisations such as the American National Standards Institute (ANSI). During this era, Raymond Carhart contributed significantly by standardising test procedures and promoting the use of bone conduction audiometry to differentiate between types of hearing loss (Jerger, 1996).

Georg von Békésy's invention of Bekesy audiometry (an automatic self-recording audiometer) marked a significant advancement. This tool enable patients to record their own thresholds and regulate stimulus presentation, improving test efficiency and decreasing examiner bias (von Békésy, 1960).

PTA was further transformed in the twenty-first century with the advent of mobile audiometry and tele-audiology. Access to hearing evaluation has improved thanks to portable devices and smartphone-based audiometers, particularly in underserved and distant areas (Swanepoel and Hall, 2010). These solutions increase testing speed and accuracy while extending its reach outside of conventional clinical settings by utilising Bluetooth-enabled transducers, cloud-based data storage, and AI-driven threshold estimate.

5. Principles of Pure Tone Audiometry

5.1 Acoustic Properties of Pure Tones

Frequency: Pure-tone stimuli span the conventional audiometric range of 125 Hz to 8,000 Hz, with octave and often inter-octave steps to map cochlear frequency specificity (ISO 389-1, 2011). Modern audiometers guarantee frequency accuracy within ±1–3 % of the nominal frequency, ensuring that each pure tone stimulates the intended cochlear region (ANSI/ASA S3.6, 2010; BSA, 2011)

Intensity: Intensity is expressed in decibels hearing level (dB HL). Intensity is basically referred to as the volume of a sound. Diagnostic audiometers typically cover ranges of −10 dB HL to at least 110 dB HL, with 5 dB step sizes to precisely determine the listener's threshold (ANSI/ASA S3.6, 2010)

Waveform Purity: To present a precisely single frequency, audiometers generate pure sine waves with total harmonic distortion <1–2 %, avoiding off-frequency energy that could interfere with threshold measurements (ANSI/ASA S3.6, 2010; Martin and Clark, 2015).

Temporal Characteristics: Every single tone is generated with controlled rise/fall times not less than 20 ms and not more than 200 ms. This is to prevent spectral splatter. When a tone is paused, it has a plateau of ≥150 ms with the same rise/fall constraints is standard (ANSI/ASA S3.6, 2010).

Transducer-Related Properties: Supra-aural earphones – these headphones typically cover 250 Hz to 8 kHz and ±3 dB, with interaural attenuation (IA) of 40–80 dB.

Insert earphones - most insert earphones offer higher IA (≈55 dB) and more consistent ear-canal resonance.

Bone vibrators couple ~5 N to the mastoid bone, most effective from 500 Hz to 4 kHz, but with IA ≈0 dB (ISO 389-1, 2011; BSA, 2011).

6. Calibration and Reference Standards

Equipment must comply with ANSI/ASA S3.6-2010 (USA) or ISO 389 series for: Reference equivalent threshold sound pressure levels (RETSPLs), Attenuator linearity, Frequency accuracy, Total harmonic distortion, and Maximum permissible ambient noise levels in test booths (ANSI/ASA S3.6, 2010; ISO 389-1, 2011)

7. Masking Noise

Anytime it is suspected that the interaural attenuation is exceeded, masking noise (e.g. narrow-band noise) is presented to the non-test ear at an effective masking level (EML) to keep the non-test ear from participating in the testing process of the test ear (BSA, 2011).

8. The Concept of Threshold of Hearing

The lowest intensity level at which a person can only notice a sound 50% of the time under controlled settings is known as the threshold of hearing. It is a basic idea in audiology that is used to measure auditory sensitivity, especially in pure tone audiometry. Decibels hearing level (dB HL), which refers to the average hearing sensitivity of young otologically normal people, is used to measure the threshold, which is defined in terms of frequency-specific minimum audibility (ISO 389-1, 2017). It fluctuates depending on the testing setting, individual circumstances, and frequency rather than being a fixed value (Gelfand, 2016). Normal hearing thresholds, for instance, are close to 0 dB HL at 1,000 Hz, however they could be marginally higher or lower at other frequencies. A pure tone stimulus that is provided with increasing and decreasing intensity until the listener responds to the sound at least 50% of the time, is commonly used to measure auditory thresholds (ANSI S3.21, 2004). A popular ascending-descending method for accurately determining this point is the Hughson-Westlake method (Carhart and Jerger, 1959). In order to identify, categorize, and treat hearing loss, thresholds are essential. They serve as the foundation for the audiogram, a visual representation of hearing sensitivity across frequencies that aids in diagnosis and rehabilitation decisions.

9. Conduction Pathways

Air conduction (AC) and bone conduction (BC) are the two (2) primary conduction pathways used in audiology to assess hearing sensitivity and ascertain the type of hearing loss present. Both are employed during pure-tone audiometry, but each tests different parts of the auditory system.

9.1 Air Conduction (AC)

Air conduction evaluates the integrity of the entire auditory pathway, thus, from the outer ear to the brain where interpretation takes place. In this process, sound is delivered through earphones or insert receivers, and the person responds to each sound heard until the faintest response is gotten across a range of frequencies typically 250 Hz to 8000 Hz. The results reflect the combined function of the conductive and sensorineural auditory mechanisms. AC thresholds indicate overall hearing sensitivity. If AC thresholds are elevated, it could be an indicator of either conductive, sensorineural, or mixed hearing loss, depending on bone conduction results (Martin & Clark, 2015).

9.2 Bone Conduction (BC)

Bone conduction test evaluates the sensorineural component of hearing by bypassing the outer and middle ear. Sound is elicited through a bone vibrator, usually placed on the mastoid process or forehead. With this, the cochlea is stimulated directly through skull vibrations. BC thresholds report the function of the inner ear (cochlea) and auditory nerve. If BC thresholds are within the normal range while AC thresholds are elevated, a conductive hearing loss is indicated. If both are elevated and equal, the loss is sensorineural. If both are elevated but AC is worse than BC by more than >10dB SPL, it indicates a mixed hearing loss (Gelfand, 2016; Roeser et al., 2017)

10. Air-Bone Gap

The air-bone gap (ABG) is the difference between AC and BC thresholds. This helps audiologists to differentiate the types of hearing loss present with a patient. An ABG of ≥15 dB at any frequency usually suggests a conductive component (ASHA, 2005).

11. Equipment and Calibration

Audiometer: An audiometer is an electronic device used to assess, evaluate, or determine an individual's hearing acuity. It is the core instrument for conducting pure-tone audiometry, allowing clinicians to evaluate auditory thresholds across a range of frequencies. The audiometer is responsible for producing controlled acoustic signals delivered to the patient through different transducers, and the outcomes form the standards for diagnosing various types of hearing loss (Martin and Clark, 2015)

12. Audiometer Types

Screening audiometers: used in schools or community settings, designed for basic air conduction testing at selected frequencies.
Diagnostic Audiometers: found in clinical settings; it is used for comprehensive testing including air and bone conduction, speech audiometry, and masking.
Computer-Based Audiometers: integrated with software for automated threshold detection, data logging, and reporting.

13. Calibration and Legal Issues

To ensure reliable and accurate results, audiometers must be periodically calibrated in accordance with standards such as ANSI/ASA S3.6-2010 (USA) or ISO 389-1:2017 (international). These standards govern frequency accuracy, intensity linearity, total harmonic distortion, and transducer output (ANSI, 2010; ISO, 2017).

14. Transducers

Supra-Aural Headphones: these rest on the outer ear. They are used during air conduction testing and are sensitive to ear-canal variability and headband pressure. They have a relatively low interaural attenuation of around 40 dB. In cases of unilateral hearing loss, supra-aural headphones can allow cross-hearing (Gelfand, 2016).
Insert Earphones: these are placed into the ear canal and they offer higher interaural attenuation (≈55-70 dB), reducing the need for masking as compared to the supra-aural headphones. They also provide more reliable results due to better placement stability and its ability to substantially reduce external noise (Roeser, Valente, & Hosford-Dunn, 2017).
Bone Conduction Vibrators: these devices are placed on the mastoid process or forehead to assess the cochlea directly by bypassing the outer and middle ear. Bone conduction has low interaural attenuation of 0 to 10 dB (ISO 389-3, 2016; ASHA, 2005).
Sound Field Speakers: these are used in free-field audiometry, especially for patients using hearing aids or cochlear implants. These speakers provide binaural stimuli and are vital in testing individuals who cannot

cooperate with headphones, particularly young children or individuals with certain disabilities (Martin & Clark, 2015).

15. Pre-Testing and Testing Procedures

15.1 Pre-Testing Procedures

To ensure valid and reliable test outcomes, careful pre-testing preparation is vital. This preparation includes biological calibration of instrument, collecting relevant case history, ensuring controlled testing conditions, selecting and positioning transducers appropriately, and giving clear patient instructions. These preparations have a direct impact on the testing procedures as they have the power to influence the general test atmosphere and the results at large. Inadequate and wrong instructions can lead to misdiagnosis and wrong interpretation.

15.2 Biological Calibration

Biological calibration also known as listening checks or functional checks is a crucial process that confirms the accurate and reliable operation of audiometric equipment. Biological calibration uses the human auditory system, usually that of a skilled listener whose hearing acuity is already known to identify anomalies in the audiometer's output, as opposed to electroacoustic calibration, which requires exact instrumentation and technical measurement. Ensuring the everyday functional integrity of audiometric equipment is the main goal of biological calibration (ASHA, 2005). It acts as a rapid and useful check to make sure the audiometer is producing tones with the right intensity, frequency, and clarity for the human senses.

15.3 Case History and Preliminary Evaluation

Before conducting any test on a patient, an in-dept audiological and medical case history is obtained. This helps identify factors that may be potential cause of the present situation such as previous otologic surgeries, ear infections, noise exposure, tinnitus, or use of ototoxic medications, which may affect hearing sensitivity or contribute to the interpretation of test results (Valente, Hosford-Dunn, & Roeser, 2022).

This information serves as the first stage of intervention and provides the audiologist with insight into the patient’s case. It is also critical for the audiologist to consider if modifications to standard testing procedures are needed, identifying contraindications to certain transducers or tests and the precautions to be taken. (e.g., active ear infection). Case history also exposes the overall health of the individual and other health conditions like high blood pressure, diabetes, among others that potentially pose threat to hearing mechanism.

15.4 Otoscopic Examination in Audiology.

Otoscopic examination also known as otoscopy is a fundamental clinical procedure in audiology used to examine the external auditory meatus (EAM) and the tympanic membrane (TM). It is typically the first step in preparing for any audiological assessment, as it provides crucial information about the state of the outer ear and middle ear space. This findings can influence further diagnostic procedures such as pure tone audiometry, tympanometry, and otoacoustic emissions (OAEs) (Valente, Hosford-Dunn, & Roeser, 2022).

An otoscopic examination must be performed to inspect the external auditory canal and tympanic membrane, identify any cerumen impaction, foreign objects, or inflammation before further testing is done. Findings such as perforated tympanic membranes or occlusion require referral or management before proceeding with PTA and other required tests. (British Society of Audiology [BSA], 2018; ASHA, 2020). Otoscopy also help the audiologist to precisely choose the size of universal ear tips and the type of transducer that would best fit the patient. Failure to perform proper otoscopy can result in misdiagnosis, inaccurate hearing threshold measurements, or inappropriate hearing aid fittings (Hall, Swanepoel, & Wilson, 2021).

15.5 Test Environment

The test environment must be a quiet, sound-treated booth that complies with ANSI S3.1-1999 (R2018) standards for permissible ambient noise levels (American National Standards Institute [ANSI], 2018). Surrounding noise can mask soft tones, particularly at lower frequencies leading to artificially elevated thresholds (Hall, Swanepoel, & Wilson, 2021).

15.6 Equipment and Transducer Selection

Appropriate selection and placement of transducers affect the overall accuracy of thresholds. Insert earphones are most preferred for reduced ambient noise and prevention of ear canal collapse (Martin & Clark, 2020). Supra-aural headphones are more suitable if there is ear canal stenosis or if the patient cannot tolerate inserts. Bone conduction vibrators are used assess the sensorineural component. Appropriate positioning of the earphones and bone oscillator is very important, as minor misplacements can cause threshold differ up to 15 dB (Valente et al., 2022).

15.7 Patient Instructions and Cooperation

Because PTA is heavily dependent on patient responses, the patient must fully understand the need to respond to every sound (no matter how soft or loud) and how to respond (e.g., pressing a button or raising a hand) as there are no “right” or “wrong” answers. Verbal and demonstration-based instructions massively improve comprehension and engagement, particularly among children, older adults, and patients with cognitive impairments (Olusanya, Davis, and Hoffman, 2021). Now, a trial tone is usually played before testing to ensure the patient fully understands the procedure (BSA, 2018).

15.8 Physical and Psychological Readiness

During testing, emotional and physical well-being of the patient is crucial. Patients should be awake, focused and avoid every form of distractions (Swanepoel et al., 2023). This helps to minimise the risk of false negatives, inconsistent responses, and test fatigue.

16. Testing Procedures

16.1 Air Conduction Testing

Air conduction (AC) testing is a non-invasive, reliable, subjective and standardized hearing test used for screening and diagnosing hearing impairments. It is also used in routine clinical audiology settings, occupational hearing conservation programs, educational audiology, and preoperative assessments (Roeser, Valente, & Hosford-Dunn, 2011). This test evaluates the entire auditory pathway, from the outer ear to the cortex. Pure tones are presented through earphones or insert phones at frequencies that support the human hearing spectrum usually known as octave frequencies (250–8000 Hz), and at specific loudness levels (decibels). Inter-octave frequencies may be tested if there's a difference of 20 dB or more between adjacent frequencies tested (British Society of Audiology [BSA], 2018).

The standard procedure follows the modified Hughson-Westlake method. This method commonly employed in AC testing, involves a "down 10 dB, up 5 dB" approach to ascertain the lowest intensity at which the individual consistently responds to the tone 50% of the time. (Carhart & Jerger, 1959). During the test, pure tones are delivered into the individual's ear(s) through air conduction transducers, such as insert earphones or supra-aural headphones, placed over or into the patient's ears. The procedure is conducted in a sound-treated environment to eliminate background noise and guarantee accurate results (Katz et al., 2015).

Thresholds are achieved for each ear individually, classically starting with the better-hearing ear or the right ear by convention, unless clinical indications suggest otherwise. If cross hearing is suspected, masking is done to inhibit the better ear from contributing to the test performed on the test ear especially when there is a significant difference of 40dB or more in thresholds between that specific frequency of both ears (Yacullo, 2020). AC thresholds are essential for hearing aid fitting and cochlear implant candidacy appraisals (Roeser, Valente, & Hosford-Dunn, 2011).

If thresholds are elevated (worse than 25 dB HL), it indicates hearing loss. However, AC testing alone cannot reveal the site of lesion. Therefore, AC results are interpreted in concurrence with bone conduction thresholds to differentiate between Conductive hearing loss (elevated AC thresholds, normal BC thresholds, with air-bone gap), Sensorineural hearing loss (both AC and BC thresholds elevated, no air-bone gap), and Mixed hearing loss (both elevated AC and BC thresholds with an air-bone gap) (Gelfand, 2016; Katz et al., 2015).

16.2 Bone Conduction Testing

Bone conduction (BC) testing is performed using a bone vibrator (oscillator), usually stationed on the mastoid process or forehead, depending on clinical preference and patient preference. The bone oscillator generates mechanical vibrations that are transmitted through the skull directly to both cochleae, thereby stimulating the inner ear without demanding sound to travel through the ear canal or middle ear (Katz et al., 2015). Thresholds are typically obtained at frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. The test follows the "down 10 dB, up 5 dB" modified Hughson-Westlake procedure to determine the bone conduction thresholds, defined as the softest intensity level at which a tone is perceived at least 50% of the time (Carhart & Jerger, 1959).

Masking noise is often presented to the non-test ear using air conduction transducers to isolate and test one cochlea. This averts the non-test cochlea from taking in the tone through cross-hearing (Yacullo, 2020).

The principal aim of BC testing is to ascertain the integrity of the inner ear and auditory nerve autonomously of the external and middle ear pathways, that is, when conducting BC testing, the pure tone bypasses the outer and middle ear and goes directly to the inner ear. This type of hearing loss (conductive) may be secondary to a blockage or dysfunction in the outer or middle ear damage to the cochlea or auditory nerve (sensorineural), or a combination of both (mixed) (Gelfand, 2016). The site of lesion determination is only possible when both AC and BC tests are combined using diagnostic audiometers.

16.3 Step by Step Procedure of Pure Tone Audiometry (PTA)

The first step in PTA is to give a clear and precise instruction to the patient. The patient would be instructed that the headset would be placed on his or her ears and tones would be presented to his or her ears. He / she should pay attention and listen for the tone.

Beginners are required to adhere to a set of testing protocol until they have gained enough experience. These step-by-step instructions that follow for conducting a pure tone audiometry in adults and older children are meant to serve as a starting point. An experienced tester may modify the procedures to suit the client and the circumstances.

Step 1: Properly connect the earphones to the apparatus and place them on the client's head. Usually, the red colour is for right ear while the blue colour is for the left ear. Audiologist should ensure that the opening of the earphone is positioned directly over the external ear canal; the height of the phones may be adjusted to allow proper positioning. In addition, Audiologist should be mindful that patient's hair is not interposed between the earphone and the ear. Insert earphones may also be used especially to avoid ear canal collapse.

Step 2: Select the 1000 Hz frequency and set the output switch so that the tone is presented to the better ear. The reason that the test commences with 1000 Hz is because this falls in the middle of the most sensitive area of the hearing spectrum. It is also a clear tone to hear for a person who has never been tested before

Step 3: Initially present the sound at 30 dB HL. If a response is obtained it suggests that 30 dB sound is above the client's threshold. If no response is observed the level is raised to 40 dB and then raised in 10 dB increments until a response is elicited or the limit of the audiometer is reached at that frequency.

Step 4: Once a response is obtained the level is lowered in 10dB steps until the client stops responding. It is then raised in 5dB steps until he/she again responds. The sound is at this stage raised and lowered in 5dB steps until the client indicates 50% of the time that he/she hears the sound. This level is then transcribed onto the audiogram.

Step 5: Switch the frequency to 2000 Hz and repeat the above steps. In most cases the difference between the thresholds of neighboring frequencies does not differ much. Therefore the threshold level at 1000 Hz in Step 5 is used as the starting point for Step 6.

Step 6: Repeat the tests at (4000 and 8000) Hz

Step 7: Repeat the test at 1000 Hz as a control. If the difference between the initial and repeat measures is < 5 dB, it is assumed that the accuracy is satisfactory. If the difference in thresholds between the two tests at 1000 Hz is >10 dB, then the reliability of the test is suspect and it should be repeated from the start.

Step 8: Proceed to test at 250Hz and 500Hz (intermediate frequencies at 750, 1500, 3000 and 6000 Hz are only tested if there are sharp drops >20 dB) in the audiogram at the octave frequencies.

Step 9: Repeat all the above steps on the poorer hearing ear. Determine for every frequency whether it is necessary to mask. In general, if the air conduction threshold of the test ear, and the bone conduction threshold of the non-test ear differ by >40 dB, then the better ear must be masked to ensure that only the responses from the poorer ear are recorded. The reason for this is that interaural attenuation for air conduction is approximately 40 dB. In other words a sound presented to the test ear must be 40 dB louder than the bone conduction threshold of the non-test ear before that ear hears the sound

Step 10: Masking: A signal of significant magnitude presented to one ear may be perceived by the other ear. This is known as crossover of the signal. Air conduction and bone conduction audiometry are often confounded by such crossover or contralateralisation of the signal.

16.4 Pure Tone Bone Conduction Test. The purpose of a bone conduction test is to determine whether an abnormal air conduction test is due to conductive (middle ear), or sensorineural (inner ear or auditory nerve) pathology. Normal bone conduction thresholds with abnormal air conduction indicates a middle ear pathology. When the hearing threshold in both tests is more or less equal, it is likely to be a sensorineural problem.

Step 1. Instruct the client to indicate every time he/she hears the signal by pressing the button. Position the bone conductor on the mastoid bone of the ear detected to have the better hearing sensitivity. The exact placement of the vibrator on the mastoid bone is very important to ensure a good threshold response from the client

Step 2. Start testing at 1000 Hz and at a level 10 dB above the air conduction threshold and follow the threshold search guide for pure tone air conduction. Determine the bone conduction threshold and check whether masking is necessary. Conventionally, it is always necessary to mask when testing bone conduction, because the interaural attenuation for bone conduction is 0 dB. In practical terms it is only important to mask if the bone conduction threshold differs >10 dB from the air conduction threshold.

Step 3. Repeat the above processes for 2000Hz 4000Hz, 500Hz and retest 1000Hz considering masking for each respective frequency. The frequencies to consider during bone conduction testing are 500, 1000, 2000 and 4000Hz.

16.5 Masking Concepts

The introduction of noise to the non- test during a pure tone audiogram is known as clinical masking. The presented tone can then be perceived by the cochlea of the non-test ear and give rise to false-positive results. This occurs less readily when testing air conduction through insert earphones than supra-aural earphones, as insert earphones cause increased interaural attenuation (Munro & Agnew, 1991).

Test ear (TE): ear of which air or bone conduction threshold is being measured

Non-test ear (NTE): opposite or contralateral ear

Interaural attenuation (IA): energy lost as sound travels from one ear to the other. It is one of the most important concepts related to masking. Minimum levels of IA guide the tester as to when crossover is likely to occur. The values differ for air and bone conduction. IA for bone conduction is approximately 0 dB. IA for air conduction (AC) is about 40dB. Because of this, there is no risk of crossover when testing air conduction if the difference between the test ear and the non-test ear bone is 40 dB between the TE AC response and the NTE BC response

17. Relevance in Clinical Audiometry

17.1 Diagnostic Relevance

Pure tone audiometry over the years have proven to be one of the golden hearing assessment tools employed by audiologists especially in the clinical setting to precisely measure the auditory thresholds across the required frequencies (250Hz to 8000Hz). This tool helps clinicians identify the type configuration and degree of hearing loss (Carhart and Jerger, 1959). It also helps to differentiate between the various types of hearing loss available. Thus, conductive, sensorineural and mixed hearing loss by varying the air conduction and bone conduction thresholds which help make informed choices for clinical intervention (Kutz and Meyers, 2023). The results of this test serves as the optimum clinical standard for identifying individuals hearing loss especially in the elderly and cooperative pediatric populations. In the absence of pure tone audiometry, clinicians may find it a bit challenging to accurately report on patients hearing sensitivity which may result in misdiagnosis and inappropriate treatment plans. (NCBI, 2024).

17.2 Monitoring Tool

Pure tone audiometry is very instrumental in monitoring the changes in auditory sensitivity. For patients going through clinical procedures that exposes them to auditory hazards, frequent audiometric testing is very essential in monitoring their hearing ability over time. Subsequent tests are done and compared with the baseline test. The variations are noticed every time and appropriate interventions are rendered. Individuals with progressive disorders like Meniere's disease and presbycusis should not be left out, PTA is also used as a monitory test tool. (ASHA, 2023).

In **occupational audiology**, PTA is vital for detecting early noise-induced hearing loss among workers in high-risk industries like mining, aviation, heavy construction sites, and chain-saw operation sites, among others. Serial hearing screening through PTA helps enhance workplace safety regulations and initiate protective measures (Sliwinska-Kowalska and Davis, 2012).

17.3 Hearing Aid and Cochlear Implant Candidacy

Reliable PTA thresholds or results are most required to program and fit **hearing aids** effectively. Audiologists use the test results to determine the amount of gain and output of amplification devices to match the user's hearing loss (Jerger, 2018). In a study by Olaosun and Ogundiran (2013) on Assistive Technology for Hearing and Speech Disorders, the study emphasizes the importance of assistive technologies in improving communication for people with hearing loss. It concluded that, 'People with hearing loss can be helped and that anyone with some amount of residual hearing can benefit from an assistive listening device'. Also, PTA results helps to determine candidacy for **cochlear implantation** by confirming severe-to-profound sensorineural hearing loss and limited benefit from conventional hearing aids (WHO, 2021).

18. Conclusion

Pure Tone Audiometry (PTA) has stood the test of time as an indispensable tool in the field of audiology. From its humble beginnings with rudimentary tuning fork tests to the development of sophisticated, computerized audiometers and mobile diagnostic platforms, PTA has continually evolved to meet the demands of clinical precision and accessibility. It remains the most standardized and universally accepted behavioral method for evaluating auditory sensitivity, enabling the accurate identification and classification of hearing loss across diverse populations. Pure Tone Audiometry remains an essential procedure in clinical audiology, offering reliable, valid, and clinically actionable data. Its continued relevance in modern practice is not only a testament to its scientific robustness but also to its adaptability in a rapidly advancing field. For clinicians, researchers, and students alike, mastering the ABCs of Pure Tone Audiometry is fundamental to the effective evaluation and management of hearing health.

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