MANSA
Malaysian National Society of Audiologists

# PURE TONE AUDIOMETRY

## RECOMMENDED PROCEDURE

The Working Group on
Pure Tone Audiometry for Adults
Malaysian National Society of Audiologists

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## Recommended Procedure

**Pure Tone Audiometry Recommended Procedure is prepared by:**

The Working Group on Pure Tone Audiometry for Adults, Malaysian National Society of Audiologists (MANSA).

This document describes the recommended procedure of pure tone audiometry conducted on adult clients based on research evidence and recommendations outlined in clinical guidelines by established professional audiology associations worldwide.

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## FOREWORD

Assalamualaikum and Selamat Sejahtera

As many of you know, the Malaysian National Society of Audiologists (MANSA) supports evidence-based and good practice in adults' audiometry assessments. With the current standard in audiometry testing, it is certain that there are several advances in techniques that audiologists need to be aware of. In addition, there is a concern and increased interest in audiologists from different stakeholders to use a standardized technique in pure tone audiometry testing in adults resulting from variations in schools of thought and clinical practices.

With that stand, MANSA Technical Working Group under the Professional Development portfolio has developed and prepared the Adult Pure Tone Audiometry Guideline as a reference for all audiologists. The task force behind these documents consists of experts from three universities, the Ministry of Health, and the private sector. The original work was developed in 2019 but the pandemic has halted the progress. Since then, these guidelines have gone through the process of drafting, content validation by panels, and proofreading by experts.

The specific goal of the document is to describe recommended practices for Pure Tone Audiometry (PTA) testing in adults based on existing practices and research findings. Their intention is not to mandate a single way of conducting a clinical process, but to suggest standard procedures that should improve inter-clinician and inter-clinic comparison of data in the final analysis, thereby allowing for a more effective transfer of information.

In view of the fact that pure tone audiometric results significantly influence the medical, legal, educational, occupational, social, and psychological outcomes, it is critical that these procedures are standardized and made consistent among audiologists. We certainly hope that this document will benefit all audiologists whether they are in the government, private or university sectors.

Without the efforts and assistance of the Technical Working Group, the reviewers, and the proofreaders, the Adult Pure Tone Audiometry Guideline would not be developed and prepared. I applaud the tireless and well-thought effort of all the dedicated audiologists involved in developing these documents. I fervently believe these documents will serve as a stepping stone for more structured and standardized audiological services in Malaysia.

Thank you.

Regards,
Dr. Nurul Huda Bani
President
Malaysian National Society of Audiologists (MANSA) 2020/2022

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# 1 Introduction

This document was developed by the Working Group on Pure Tone Threshold Audiometry for adults under the office of the Malaysian National Society of Audiologists (MANSA). It presents recommended procedures of pure tone audiometry (PTA) testing based on existing evidence and research findings, as well as a consensus of recommendations found in the American Speech-Language-Hearing Association (2005) and the British Society of Audiology (2018). The intention is not to mandate a single way of accomplishing a clinical process, but to suggest standard procedures that in the final analysis should benefit the persons we serve. Although care has been taken in preparing this document, MANSA does not and cannot guarantee its interpretation and application. MANSA cannot be held responsible for any errors or omissions, and MANSA accepts no liability whatsoever for any loss or damage that may arise. The purpose of this document is to describe standard procedures and recommendations for effective PTA in most audiological settings. This document is not intended to provide guidance on specific circumstances or the interpretation of results. The audiologist carrying out the test must use professional judgment when deciding on the particular approach to be used with each person being tested, given the specific circumstances and the purposes of the test.

# 2 Scope

## 2.1 The PTA recommended procedure

The documents presented in this document are intended for clinical diagnostic PTA and do not cover high-frequency audiometry (>8000 Hz), screening audiometry, self-recording audiometry, sound-field audiometry, and the use of signals other than pure-tones during audiometry testing. MANSA does not intend to imply that only one method is correct. Variations in the procedure may be demanded by special clinical problems or regulatory demands, which may require modifications to standard procedures to obtain true and accurate results. This PTA document includes equipment and test environment, preparation of testing, air conduction (AC) and bone conduction (BC) audiometry with and without masking. It also includes recommended format and descriptors for a pure-tone audiogram.

## 2.2 Audiologist

The audiologist described in this document refers to a qualified audiologist. Audiologist is a certified professional in accordance with the Allied Health Profession (AHP) Act 2016 (Ministry of Health Malaysia, 2016) who engages in a practice that promotes healthy hearing, communication competency, and quality of life for persons of all ages through the prevention, identification, assessment, rehabilitation and research of hearing, peripheral or central auditory function, tinnitus, vestibular and balance, and other related systems.

## 2.3 Clients

The client described in this document is referring to an individual who seeks hearing healthcare. This document describes the procedures suitable for routine clinical use with adults and children who are able to perform the task. It may not be appropriate for specific populations (e.g., adults with learning difficulties, cognitive impairment, and younger children). In these cases, some test method modifications may be required depending on the client's condition to obtain reliable results.

# 3 Equipment and Test environment

Audiometric equipment shall be well calibrated and function properly to produce accurate test signals. Audiometric testing should be performed in an acceptable test environment that complies with Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms (MPANL; Frank et al., 1993).

## 3.1 Audiometric equipment and calibration

An audiometer, including the transducers, should be calibrated. Regular calibration ensures the hearing level (dB HL) complies with strict values set by the American National Standards Institute (ANSI) or the manufacturer's specific references for hearing thresholds. There are two types of calibration; exhaustive electroacoustic calibration and biological check. Exhaustive electroacoustic calibration should be performed annually. As for the biological check, the audiologist must make sure that the equipment is working properly by carrying out daily functional inspections, performance checks, and bio-acoustic measurements to verify the equipment's performance before use. The biological check should be done before testing the client or anytime during the day when there is a reason to suspect that the audiometer is not performing properly.

Different types of transducers are used for PTA: headphones (supra-aural and circum-aural), insert earphones, and bone vibrators. The transducers are matched to the audiometer and should not be interchanged without recalibration. Supra-aural and insert earphones are appropriate for AC threshold measurements from 125 Hz through 8000 Hz. In contrast, circum-aural earphones are used for extended high-frequency measurements within their respective frequency and intensity response ranges. It is best recommended to use insert earphones for all cases. Supra-aural headphones are only to be used when insert earphones are contraindicated, e.g., atresia cases or discharging ear. Bone vibrators are used for BC threshold measurements for frequencies within their respective frequency response range. The audiologist should ensure correct placement of the transducers on the client.

## 3.2 Audiometric test environment

### 3.2.1 Test environment and ambient noise level

The audiometric test shall be conducted in audiometric test booths or sound-treated rooms. The use of sound-treated booths/rooms is viewed as a standard practice. Ideally, hearing assessments are performed in a sound-treated booth/room with low background noise. Confirmation of an acceptable test environment shall be documented at least annually.

Generally, the ambient noise of the testing room should not exceed 35 dB (A). It is recommended that the audiometric test should not proceed if the ambient noise is higher than the level, as excessive ambient noise will affect the test results. The problems caused by the ambient noise are more significant when testing by BC as there are no earphones in place to reduce the noise reaching the ears. ANSI (2018) has developed a standard [ANSI S3.1-1999] (R2018) with detailed specifications of the maximum permissible ambient noise levels for audiometric test rooms (Frank et al., 1993).

It is also advisable to equip the test room with i) proper control of temperature, air exchange, and humidity, ii) visual and/or auditory alarm, iii) observation vision panel, and iv) an emergency telephone or a panic button to signal for emergency assistance. To avoid test disruption, mobile phones and other communication devices should be silenced or turned off during the audiometric evaluation. Audiologists should also be alert to the problems of intermittent or transient noise during the test.

# 4 Pre-testing Requirement

## 4.1 Information from client

Before conducting the audiometric testing, information required to determine the testing strategies should be obtained. To obtain the information, the audiologist shall adopt an effective communication strategy with the client. The client's age, hearing status, language skills, and any other possible communication difficulties should be considered. Any significant communication problems shall be recorded, as these may affect the client's performance.

Information on exposure to loud noise during the previous 24 hours by the clients shall be obtained, as this can cause temporary hearing loss. If exposure to loud noise is reported, more details should be obtained regarding the exposure. Further instruction on testing clients with noise exposure is discussed in Section 10.1.

Clients shall be asked if they have better hearing in one ear; if they do, testing should commence with the better ear. Otherwise, testing can be started in either ear. Clients shall be asked if they have tinnitus at the time of testing, as this may affect their ability to detect tones in one or both ears. Further instruction on testing clients with tinnitus is discussed in Section 10.12.

Audiologists are encouraged to ask clients and their significant others about any relevant information that may affect clients' performance during the testing.

## 4.2 Otoscopic examination

Otoscopic examination should be conducted before any audiological testing. It is important to identify the conditions listed below (although not limited to only these conditions):

- Active ear discharge
  - use of insert earphones are contraindicated. Precautions should be taken to prevent cross-infection between ears and between clients. sanitise the headphones before and after each use. The use of disposable headphone covers is recommended.
- Ear canal collapse
  - If there is a possibility of ear canal collapsing with the use of supra-aural headphones, it may lead to a false air-bone gap at high frequencies. Insert earphones (e.g., Etymotic ER3 and ER5) are recommended whenever ear canal collapse is suspected.

- Tympanic membrane perforation/presence of patent pressure equalization tubes
  - Insert earphone is contraindicated as it may result in false AC thresholds in the affected ear.
- Occluded ear canal/external ear anomaly
  - In the case of an occluded ear canal, supra-aural or circum-aural headphones are recommended.
- Indication of recent ear surgery/otalgia
  - Extra precaution should be taken when placing the transducers to avoid discomfort.

**Note:**

*The ear canal should be free of excessive wax before testing. When the ear canal is occluded due to wax, the occluding wax should be removed before audiometry testing. However, if the wax is impacted, the wax removal procedure shall only be undertaken by a professional who is qualified and competent to perform the procedure.*

# 5 Air-conduction Audiometry without Masking

## 5.1 Positioning the client

The client should be seated in a manner to promote safety and comfort as well as valid testing. Such seating considerations may include the following:

- Avoid unintentional visual cues to the client.
- Allow for the monitoring and reinforcement of responses.
- Permit observation of client comfort, safety, and health.

The client's face shall be clearly visible to the audiologist. The client shall not be able to see or hear the audiologist manipulating the audiometer controls during the PTA. When the test is controlled from outside the audiometric test room, the client shall be monitored through the observation panel or a closed-circuit TV system. Communication with the client should also be possible in this setting.

## 5.2 Instructions

The test instructions should be presented in a language or manner that is appropriate for the client. Interpreters (oral or sign) should be used when necessary. Supplemental instructions, including written directives, gestures, and demonstrations, should be provided to enhance understanding (when required). The test instructions shall accomplish the following:

- Indicate the test purpose clearly, which is to find the softest sound (tone) that the client can hear.
- Indicate that the client is to respond (e.g., by pressing the response button or raising a hand) whenever the client thinks a tone is heard, no matter how soft it may be. Reinstruct the client if false positive responses are observed.
- Describe the need to press the response button as soon as the tone is heard and release the button immediately after the tone goes off.
- Indicate that each ear is to be tested separately with tones of different pitches and loudness.
- Indicate that the client must inform the audiologist if he/she experiences discomfort during the test.

- Describe inappropriate behaviours such as drinking, eating, smoking, chewing, or other behaviours that may interfere with the test.

The following is an example of a clear instruction:

> “I will test your hearing by measuring the softest sounds you can hear. Each time you think you hear a tone, no matter how loud or soft it is, regardless of which ear you hear it, press the button. Keep it pressed for as long as you hear the tone, and release the button as soon as it stops. Do not press the button when you do not hear any tone. Please let me know if you feel any discomfort during the test.”.

Providing a concise, printed version of these instructions may also be helpful.

After explaining the test procedure and giving the test instructions, provide an opportunity for any questions the client or accompanying significant others may have. Before the testing begins, remove any hearing aids, glasses, headwear, or earrings that may obstruct the correct placement of the transducers, cause discomfort, or affect the sound transmission. Hair, scarves etc. should not be allowed to sit between the ear and the transducers.

## 5.3 Client's response

The client’s responses to the test tones should indicate whether he/she can hear or no longer hear the tones. Pressing the response button is one of the preferred methods when determining responses from the client. The response button, which is linked to a signal light at the display of the audiometer, should be inaudible during the process.

Noticeable responses are required from the client to indicate that he/she can hear the tones. Any response meeting this criterion is acceptable. Examples of other commonly used responses are raising and lowering the finger or hand, and verbalizing “yes”.

The primary factors used by the audiologists in determining true responses are the onset of the responses (i.e., pressing the response button as soon as the tone is heard), the presence of "on" (keep pressing the response button as long as the tone is still heard) and "off" responses (releasing the response button once the tone is no longer heard), and correct response to non-stimulus trials. The use of no-stimulus trials (i.e., trials with no tone present) is the best way to ensure valid results and reduce false-positive responses. These silent intervals allow the audiologist to observe the client during a specified period to determine if random responses occur without a stimulus present.

The audiologist should reinstruct the client who gives false responses following proper instructions before conducting further assessment.

There are two types of false responses:

i) False-positive: A response when no tone is present, and
ii) False-negative: No response to a tone that the client was observed to have responded to previously.

Either type complicates the threshold-seeking procedures. Reinstruction and refamiliarization of clients may reduce the occurrence rate of false responses. In addition, alternative techniques such as varying the stimulus presentation intervals between audible tones, pulsing or warbling of the signal, or using pulse-counting procedures may also reduce the occurrence of such responses.

**Note:**
*More engaging response methods may be required when testing younger children, adults with learning difficulties or clients with attention difficulties, and if so, this shall be recorded.*

## 5.4 Transducer

A calibrated transducer to an audiometer must be used. Transducers for AC audiometry include supra-aural earphones (e.g., TDH39 and TDH49), circum-aural earphones (e.g., Sennheiser HDA200), and insert earphones (e.g., Etymotic Research ER3 and ER5).

**Note: Contraindications of insert earphones**
*Ears with infections, obstructions, excessive ear wax or abnormalities – Avoid insert earphones as they may cause cross infections or push the obstructions/ear wax further into the canal.*
*Tympanic membrane perforations, including with the presence of pressure equalisation tubes – Use of supra- and circum-aural earphones are recommended as insert earphones are more susceptible to calibration problems and may present higher thresholds at low frequencies (Voss et al., 2000).*

The audiologist must check the placement of transducers for a good fit. Supra or circum-aural earphones shall be held in place by a headband with the earphone's opening directly aligned

with the ear canal entrance. Ensure there is no obstruction between the ears and the transducers. The client should be instructed not to hold or move the earphones. Then the audiologist should ask and check for any sign of discomfort from the client.

If using insert earphones, an appropriate size of foam ear tip should be used. The insert earphones shall be placed comfortably deep in the ear canal and following manufacturer recommendations (e.g., Etymotic ER3C insert earphones user guide; Dean & Martin, 2000). Incorrect placement or fitting may invalidate calibration, lead to leakage of tones out of the ears and provide less attenuation from ambient noise.

There is a risk of vibrotactile sensation when testing AC at 500 Hz and below. The risk is higher when the tone is presented at high-intensity levels. The audiologist should be aware of this possibility and carefully interpret the responses. Note the vibrotactile responses on the audiogram.

## 5.5 Test parameters

### 5.5.1 Stimuli

Continuous or pulsed pure-tone signals should be used for AC audiometry. Pulsed tones have been shown to increase a client's awareness of the stimuli (Burk & Wiley, 2004). Test stimuli that vary over time in either amplitude (pulsed tones) or frequency (warble tones), can be used when testing clients with tinnitus (BSA, 2018).

### 5.5.2 Test order

Start testing at 1000 Hz in the better-hearing/non-pathological ear. Next, test 2000 Hz, 4000 Hz and 8000 Hz, followed by a retest of 1000 Hz before testing at 500 Hz and 250 Hz in that order. The retest at 1000 Hz is a must when testing the first ear. If the difference between the retest and the original values is no more than 5 dB, take the better threshold as the final value.

However, if the value differs by more than 5 dB, the reason for the variation shall be investigated. The audiologist may need to reinstruct or refamiliarize the client and repeat the test for that ear. Remarkably variable results shall be noted on the audiogram. Test the opposite ear in the same order. The retest at 1000 Hz usually is unnecessary when testing the second ear unless tests in the first ear revealed significant variation.

### 5.5.3 Test frequencies

The inter-octave frequencies should be tested when a difference of 20 dB or more exists between threshold values at any two adjacent octave frequencies from 250 Hz to 8000 Hz.

Inclusion of 3000 Hz and 6000 Hz in the audiometric evaluation is strongly recommended as they will provide a complete record of the client's hearing status for prevention and diagnostic purposes (ASHA, 2005). Testing at 3000 Hz and 6000 Hz are required in cases where audiometric results are used to identify noise-induced/work-related hearing loss and/or determination of compensation. When testing for other purposes such as noise induced hearing loss, ototoxicity and medical management, hearing thresholds may be measured at other test frequencies as appropriate. Measurement at 125 Hz should be included in the case of low-frequency hearing loss. Further instruction on test frequencies for special populations is in Section 10 of this document.

## 5.6 Duration and timing of the test stimuli presentation

The tone presentation duration shall vary between 1 and 3 seconds. The interval between successive tones shall be varied but not shorter than the test tone. The audiologist shall not stop the tone as soon as the client responds. The tone presentation must be of the full duration, and the client must respond throughout each one.

The audiologist must ensure that tones are presented in a non-predictable manner as a check against false-positive responses. Refer to Section 5.3 for details on false positive responses.

## 5.7 Threshold measurement procedure

### 5.7.1 Familiarization

Familiarization is a recommended practice for general populations and should be used by the audiologist when there is a concern about the client's mental or physical status. The purpose of familiarization is to ensure the client is familiar with, understands, and is able to perform the response task. Familiarization should be conducted before threshold determination by presenting a tone of sufficient intensity to evoke a clear response.

Familiarization method:

1. Present a 1000 Hz tone to the better ear at a level estimated to be sufficiently audible and comfortable to the client e.g. at 40 dB HL as the initial presentation level for a client with normal hearing or approximately 20 dB above the estimated threshold for a client with a hearing impairment, but never more than 80 dB HL.
2. If a clear response is obtained, begin the threshold measurement.
3. If no response is obtained, increase the intensity in 10-dB steps until a response is obtained.

If the tone is still inaudible at 80 dB HL to the client, the intensity increments of 5-dB steps shall be used until a response occurs.

**CAUTION: The audiologist should monitor any sign of discomfort from the client, especially when testing at high intensity levels.**

### 5.7.2 Threshold determination

The recommended threshold determination method is the Modified Hughson-Westlake technique (Carhart & Jerger, 1959; Hughson & Westlake, 1944).

1. Following a satisfactory positive response from the familiarization process, reduce the presentation level in 10-dB steps until no response is obtained.
2. Increase the tone level in 5-dB steps until a response is obtained again.
3. After the first response using an ascending approach is obtained, repeat Step 1 and Step 2.
4. The hearing threshold is determined when two responses out of three ascending trials at a single level are recorded.

The time taken for audiometric testing shall not cause fatigue to the client as this can affect the reliability of the test results. If the test time exceeds 20 minutes, clients may benefit from a short break.

**Note:**
*If a delayed response to a tone in an ascending series is observed, present a 5-dB higher tone until the immediate response is obtained*.

# 6 Bone-conduction Audiometry without Masking

## 6.1 Instructions

The test instructions for BC audiometry are the same as for AC audiometry (see Section 5.2 for details). Emphasis should be given that the client should respond regardless of the side on which the tone is heard.

## 6.2 Client’s response

Methods of client’s response are the same as for AC audiometry described in Section 5.3.

## 6.3 BC transducer and transducer placement

A calibrated BC transducer to an audiometer must be used, such as RadioEar B71, RadioEarB81, and BHM-Tech BC-2LD bone vibrators.

To begin, place the BC transducer on the mastoid prominence of the poorer ear with the required area of the transducer in contact with the skull. The poorer ear is defined by comparing the averaged AC thresholds for frequencies between 500 Hz to 2000 Hz of right and left ears. The ear with the higher averaged AC thresholds is considered as the poorer ear. The BC transducer shall be placed as near as possible behind the pinna without touching it and without resting on the client's hair (Diagram 6.1). The BC transducer shall be held firmly in place using a headband that holds it against the skull with the required static force. The side on which the BC transducer is placed shall be noted on the audiogram form by using appropriate symbols. See Section 8.2 for details of the use of symbols.

An alternative placement of the BC transducer is on the forehead, provided that calibration issues (i.e., correction values) are accounted for. Refer to Fagelson and Martin (1994), Harkrider and Martin (1998) and BS EN ISO 389-3 (ISO, 2016) for more details on forehead transducer placement. Audiologists should ensure proper placement of the BC transducer throughout the testing.


(A)

(B)


(C)

**Diagram 6.1** (A) RadioEar B71 transducer, (B) BC transducer showing the headband, and (C) Mastoid placement.

## 6.4 Test frequencies and test order

The preferred test order is similar to that used in AC audiometry starting at 1000 Hz (See section 5.5.2 and 5.5.3 for details). Bone-conduction audiometry should only be performed in the frequency range of 250 Hz to 4000 Hz, and it may not be necessary or appropriate to test at all frequencies in every case. No retest is required at 1000 Hz. Due to the individual variability of Interaural attenuation (IAA) that can range between 0 to 15 dB (Studebaker, 1967) the unmasked BC audiometry should be done for the second ear when its AC thresholds are not within the normal range. See Section 6.8 for comments on limitations of BC transducers, the need to use ear plugs, and for test frequencies outside this range.

In cases when separate ear unmasked BC testing is not feasible (e.g. clients with limited attention span), audiologists may perform the unmasked BC (in either ear). The individual variability of IAA for BC transducer (up to 15 dB) may lead to inaccurate interpretation when the BC threshold of the untested ear is assumed to be the same as the tested ear. Therefore, caution needs to be taken when interpreting the result.

## 6.5 Test stimuli

Duration and timing of the test stimuli presentation are the same as for AC audiometry (see Section 5.6). The initial presentation level should be clearly audible to the client (with reference to the measured AC thresholds at each frequency).

## 6.6 Threshold determination method

Ear-specific BC audiometry requires masking of the non-test ear. BC audiometry without masking may be sufficient when an ear-specific measure is not required. The external ear canal must not be occluded when seeking unmasked BC thresholds, as this may artificially improve BC thresholds due to the ’occlusion effect‘ except as described in Section 6.8 (Aazh et al., 2005). If it is occluded, it shall be noted on the audiogram form. Methods to determine BC hearing threshold levels follow the AC threshold determination (see Section 5.7.2)

## 6.7 Vibrotactile threshold

Vibrotactile sensation occurs when the tones reach a sufficiently high intensity and may be perceived through the sense of touch (Boothroyd & Cawkwell, 1970). This poses an issue when the client responds to the tactile sensation instead of auditory sensation. For the mastoid placement of the BC transducer, vibrotactile thresholds may be as low as 25 dBHL as shown in Table 6.1 (Boothroyd & Cawkwell, 1970). However, there is a large inter-client variation in vibrotactile thresholds. Care must be taken not to misinterpret vibrotactile sensation as auditory perception. Any threshold considered to be vibrotactile with the absence of auditory perception shall be noted as ‘VT’ on the audiogram once confirmed by the client (“I feel the stimulus, but not hear the stimulus”). However, if the client indicates hearing the stimulus and feeling the vibration simultaneously, the auditory perception shall be noted as the hearing threshold, not VT.

**Table 6.1:** Minimum vibrotactile thresholds

| **Frequency (Hz)** | 250 | 500 | 1000 |
|---|---|---|---|
| **Vibrotactile threshold (dB HL)** | 25 | 55 | 70 |

## 6.8 Limitations of BC transducers

There is a concern regarding the emission of high-intensity air-borne tone by the BC transducer at higher frequencies, particularly at 3000 Hz and 4000 Hz. To overcome the air-borne sound heard by the client at 3000 Hz and 4000 Hz, consider:

i) inserting an ear plug, e.g. foam plugs used as hearing protector, into the ear canal of the test ear,
ii) covering the test ear with a supra-aural or circum-aural earphone, or
iii) placing the BC transducer at the forehead, as described in Section 6.3.

Although occluding the ear canal would improve the unoccluded BC thresholds, the difference is insignificant at those frequencies (Tate Maltby & Gaszczyk, 2015).

The standard BC transducer used in audiometry has distortion at low frequencies (below 500 Hz) because the client's threshold may relate to hearing the second or third harmonics rather than the fundamental frequency (Lightfoot, 2000). When testing BC at frequency below 500 Hz , the test results should be interpreted with caution.

BC testing at 6000 Hz and above are also problematic due to transducer limitations and should be avoided (Lightfoot & Hughes, 1993). However, there may be exceptional circumstances when tests at the lower and higher frequencies are required, depending on the investigation performed. A check must be made that these frequencies have been included in periodic objective calibration tests, and caution is advised in interpreting the results.

Headband tension has an impact on the sound levels delivered. It is difficult to measure the actual headband tension in situ, but audiologists need to be aware of this source of error (e.g., with a small head) and record any suspected errors.

# 7 Masking

## 7.1 Definitions

1. **Masking**: The process or the amount by which the threshold of audibility for one sound is raised by the presence of another (masking) sound (ANSI, 1994).
2. **Cross-hearing:** A bone conduction phenomenon in which sound that is presented to one ear is perceived by the other ear (Maltby, 2016).
3. **Interaural attenuation (IAA):** The drop in intensity (dB) of an acoustic signal from the test ear (TE) transducer to the non-test ear (NTE) cochlea due to cross-hearing through the vibration of the skull. The IAA values are transducer-specific. Table 7.1 shows the IAA values for different transducers.

**Table 7.1**: Minimum IAA values for different transducers

| Stimulus | Transducer | Minimum IAA across frequencies |
|---|---|---|
| Air conduction | Supraural earphones (Snyder, 1973, Killion et al., 1985) | 40 |
| | Insert earphones* (Gumus et al., 2016) | 50 |
| Bone conduction | Bone vibrator (Snyder, 1973; Nolan & Lyon, 1981) | 0 |
| *Different IAA values were observed at different frequencies. However, only one fixed value (minimum value across frequency) is used for clinical purposes (BSA, 2018). | | |

4. **Plateau**: “plateau” is established when the masker level can be increased over a range of at least 15 to 20 dB without shifting the masked threshold (Katz, 2015) or when three successive levels of masking yield the same threshold, or one threshold shows no more than 5 dB difference than the other two (BSA, 2018).
5. **Overmasking**: Overmasking happens when, after reaching the plateau, any increase in the masking noise on the NTE increases the threshold of the TE.
6. **Undermasking**: Undermasking happens when the tone presented to the TE continues to be perceived in the NTE despite the presence of a masking noise in the NTE.
7. **Central masking:** A phenomenon where a masking noise presented to an ear (i.e. NTE) can cause a threshold shift for a signal presented to the opposite ear (i.e. TE) even though the masker level is too low to cross over to the TE (Gelfand, 2018).

## 7.2 Masking rules

Masking the NTE is needed to eliminate the participation of the NTE whenever there is a possibility of cross-hearing. Masking is required when any of the following rules are met.

### 7.2.1 Air conduction (AC) masking

Rule 1a: The AC threshold of the TE is poorer than the AC threshold of the NTE by the amount of IAA or more.

Rule 1a: ACTE – ACNTE ≥ IAA (AC transducer)

Rule 1b: The AC threshold of the TE is poorer than the BC threshold of the NTE by the amount of IAA or more.

Rule 1b: ACTE – BCNTE ≥ IAA (AC transducer)

### 7.2.2 Bone conduction (BC) masking

Rule 2: The AC threshold of the TE is poorer than the unmasked BC threshold of the TE by the amount of 15 dB or more.

Rule 2: ACTE – BC TE ≥ 15 dB

## 7.3 Masking procedures

The masking procedures follow the plateau-seeking method for masking that is applicable to both AC and BC masking (Yacullo, 1999).

1. Give instructions to the client before the masking procedure. The instructions should emphasize the following points:
    - The client will be given a series of tones and a masking noise.
    - The client needs to ignore the noise but respond to the tone as soon as they hear the tone, even if it is very soft, no matter which side of the ear they hear the tone.
    - The client must not be told to expect to hear the pure-tone in the test ear.

2. Present tone on the TE and masking noise on the NTE at their respective initial presentation levels as indicated below:
    - Masking noise at NTE: AC threshold NTE + 10 dB (Katz, 2015; Martin, 1974; Rahmat, 2010; Yacullo, 1999;).
    - Tone at TE: Unmasked threshold (AC or BC).

3. Increase the tone and masking presentation level according to the client's response:
    - If the client responds: Maintain the tone level in TE while increasing the masking noise in NTE by 10 dB (10-dB steps)*.
    - If the client does not respond: Increase the tone in 5-dB steps until a response is obtained while maintaining the same masking noise level.

    *In cases when there is a potential for overmasking (e.g., large air-bone gap bilaterally), increase the masking level in 5-dB steps rather than 10-dB steps, as this might help to identify a shortened plateau (BSA, 2018).

4. Continue testing until a plateau is obtained. The level at which the threshold remains at least for 2 out of 3 of the plateau range is taken as the correct hearing threshold of the test ear and no further masking is required (BSA, 2018; Katz, 2015).

## 7.4 Consideration for occlusion effect during BC masking

Occluding the NTE with AC transducers (headphones or insert phones) during BC masking may improve the BC threshold. This is known as the occlusion effect. Table 7.2 specifies the amount of BC threshold improvement observed when the ear is occluded during BC testing.

**Table 7.2**: Maximum Occlusion effect (dB)

| **Frequency (Hz)** | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|
| Headphone (Elpern & Naunton, 1963) | 30 | 20 | 10 | 0 | 0 |
| Insert phone (Dean & Martin, 2000) | 10 | 0 | 0 | 0 | 0 |

To account for the occlusion effect during BC masking, correction factor (Table 7.2) need to be applied to the initial presentation level.

- Initial presentation level of tone (TE) = Unmasked BC threshold (obtained when the ear is not occluded) - Maximum occlusion effect (according to the test frequency as shown in Table 7.2)

## 7.5 Overmasking

Overmasking occurs when the masking noise level presented to the NTE is higher than the IAA, causing the noise to cross over transcranially to the TE and mask the test signal instead.

Overmasking can be identified when, after the plateau has been reached, an increase of masking noise is followed by an increase of threshold on the TE by a 1:1 ratio (1 dB per dB). An example of overmasking is shown in Table 7.3.

There is a higher risk for overmasking in cases of testing an ear with conductive hearing loss, with the NTE having moderate hearing loss or worse.

There is also a risk for overmasking in cases where the plateau is shorter than usual, and overmasking is seen after only two consecutive levels of masking noise (instead of the usual three). In this case, 5-dB increments of masking noise instead of 10-dB increments may yield the 'three successive levels of masking' needed to identify a plateau (BSA, 2018).

The risk for overmasking is lower with insert earphones as the IAA for insert earphones is higher as compared to headphones (Munro & Contractor, 2010).

**Table 7.3**: Example of a masking table showing overmasking

| **Masking noise in the NTE (HTL = 10 dB HL)** | **Tone in the TE (HTL = 5dB HL)** | **Phase** |
|---|---|---|
| - | 5 | Undermasking |
| 20 | 15 | |
| 30 | 25 | |
| 30 | 70 | Plateau |
| 40 | 70 | |
| 50 | 70 | |
| 60 | 70 | |
| 70 | 70 | |
| 80 | 75 | Overmasking |
| 90 | 85 | |
| 100 | 95 | |

## 7.6 Central masking

Central masking is thought to be due to an interaction between the masking noise and the signal that happens through central nervous system processes (Katz, 2015). The difference between central masking and direct peripheral masking is that the amount of threshold shift in central masking is less than that of direct masking. Therefore, the ratio of threshold shift-to-masker is less than 1:1 ratio (less than 1 dB per dB). There are 2 conditions where central masking can normally occur; a) central masking in the plateau region, 2) persistent central masking with increasing level of masking noise. An example of potential central masking in the plateau region is shown in Table 7.4. However, the 5 dB shift of tone in the plateau region could also be due to test-retest reliability (Katz, 2015). An example of persistent central masking is shown in Table 7.5.

**Table 7.4** Example of a masking table showing central masking in the plateau region

| **Masking noise in the NTE (HTL = 10 dB HL)** | **Tone in the TE (HTL = 5dB HL)** | **Phase** |
|---|---|---|
| - | 5 | Undermasking |
| 20 | 15 | |
| 30 | 25 | |
| 40 | 30 | Plateau |
| 50 | 30 | Central masking |
| 60 | 35 | |

**Table 7.5** Example of a masking table showing persistent central masking

| **Masking noise in the NTE (HTL = 10 dB HL)** | **Tone in the TE (HTL = 5dB HL)** | **Phase** |
|---|---|---|
| - | 5 | Undermasking |
| 20 | 15 | |
| 30 | 25 | |
| 40 | 30 | Central masking |
| 50 | 35 | |
| 60 | 40 | |
| 70 | 45 | |

If central masking occurs:

1. Determine if a plateau can be obtained. The level at which the threshold remains at least for 2 out of 3 of the plateau range is taken as the correct hearing threshold of the test ear and no further masking is required (BSA, 2018; Katz, 2015).
2. If a plateau cannot be obtained, re-attempt the masking procedure.
3. If the central masking pattern persists, extend the masking procedure to allow evaluation of the slope and rule out over masking. Persistent central masking should show a 5-dB increment in threshold for every 10-dB increment in noise.
4. A true threshold can be estimated by selecting the level near the point where the central masking started. In Table 7.5, the true threshold is estimated at 25 dB HL (BSA, 2018; Katz, 2015).

**Note:**
*If the tester encounters any masking issues as described in 7.5 and 7.6, it is important to specify the issue in the report e.g., "Overmasking", "central masking", or "incomplete masking due to masking noise reaching the audiometric limits".*

## 7.7 Recommended testing flow for AC and BC masking

1. Perform unmasked AC testing in the better ear.
2. Then, perform unmasked AC testing in the poorer ear.
3. Look for the need for AC masking (Rule 1a), and **mask instantly as you go along.**
4. Perform unmasked BC testing on the poorer ear.
5. Look for the need for BC masking (Rule 2), and perform BC **masking if needed ***
6. Perform BC testing in the better ear.
7. Look for the need for BC masking (Rule 2) in the better ear, and perform BC **masking if needed ***
8. Finally, look for the need for additional AC masking (Rule 1b)

*****Even though Rule 2 applies in the better ear, if the unmasked BC thresholds of the better ear differ by ≥ 20dB from the masked BC threshold of the poorer ear, BC masking is not needed

in the better ear. Unmasked BC threshold from the better ear is considered the true threshold as the maximum IAA for BC transducer is ~15 dB (Nolan & Lyon, 1981).

# 8 Audiogram Descriptors

## 8.1 Audiogram symbols

The symbols recommended in this document were taken directly from those specified in appropriate standards which are ANSI S23.21-2004 (R2019) (ANSI, 2019) and ANSI S3.39-1987(R2020) (ANSI, 2020). Refer to Table 8.1 for the recommended audiogram symbols. An example of recommended audiogram format is shown in Diagram 8.1.

**Table 8.1** Recommended audiogram symbols

| Modality | Right | Left | Unspecified |
|---|---|---|---|
| Air conduction (headphones, insert phones) | | | |
| Unmasked | ○ | X | |
| Unmasked (no response) |  |  | |
| Masked | ● | ⧗ | |
| Masked (no response) |  |  | |
| Bone conduction (mastoid) | | | |
| Unmasked | < | > | △ |
| Unmasked (no response) |  |  | |
| Masked | [ | ] | |
| Masked (no response) |  |  | |
| Loudness Discomfort Level | L | ⅃ | |

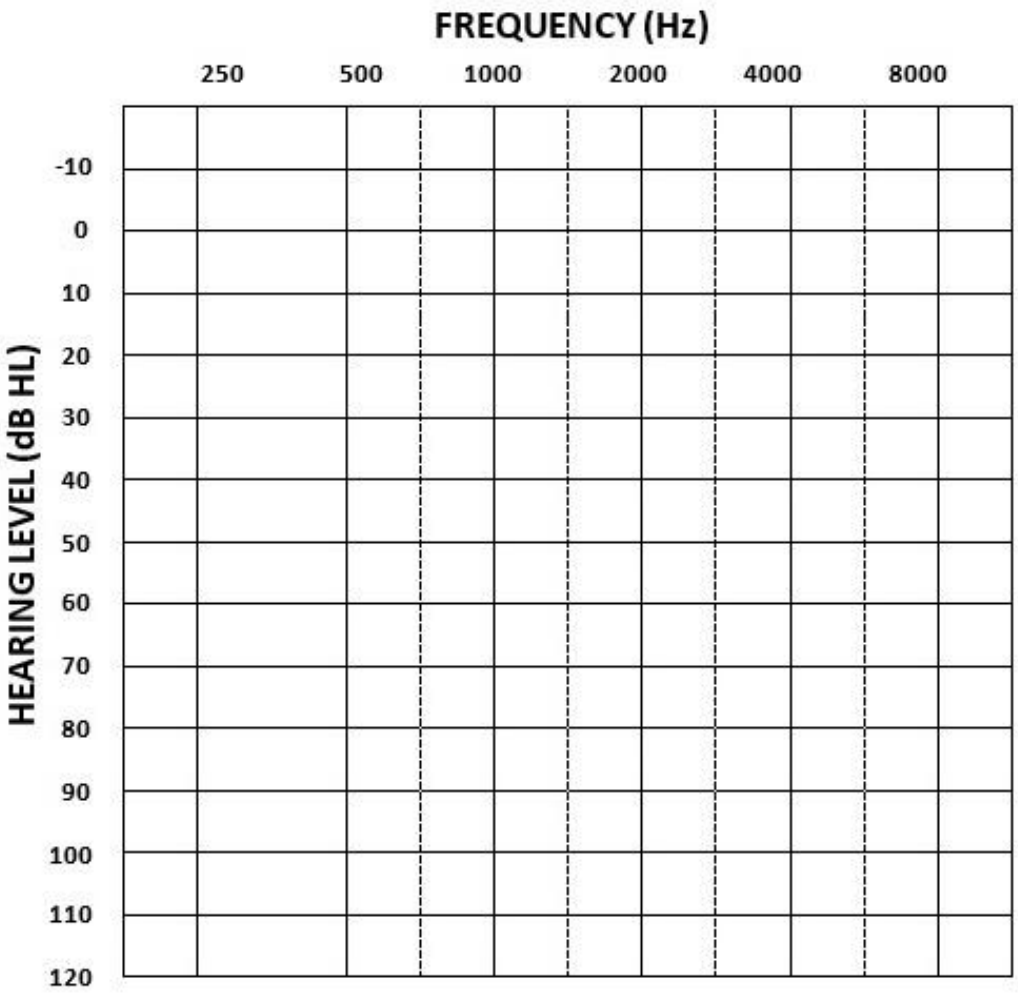


**Diagram 8.1** Recommended audiogram format

## 8.2 Hearing level descriptor

The hearing threshold levels of an individual ear are often described in general severity categories rather than the actual thresholds at different frequencies on a pure-tone audiogram. Recommendations are made below to associate particular level descriptors with ranges of average hearing impairment. Refer to Table 8.2 for the recommended hearing level descriptors.

Four audiometric level descriptors are recommended based on the average pure-tone hearing threshold levels at 250, 500, 1000, 2000 and 4000 Hz. Averages do not imply any particular configuration of hearing loss and do not exclude the usage of additional terms (e.g., profound high-frequency hearing loss).

**Table 8.2** Recommended Hearing Level Descriptor based on the range of average hearing threshold levels in dB HL. Adapted from BSA (2018).

| Hearing Level Descriptor | Average hearing threshold levels (dB HL) |
|---|---|
| Mild | 21-40 |
| Moderate | 41-70 |
| Severe | 71-90 |
| Profound | > 90 |

While hearing level descriptors may provide a useful summary of a client's hearing thresholds, they shall not be used as the sole determinant for the provision of hearing support. They are not reliable indicators of hearing disability and shall not be used as the measure of difficulty experienced with communication in background noise.

## 8.3 Types of hearing loss

Types of hearing loss are determined by comparing the AC and BC thresholds of the same ear at each frequency. Table 8.3 shows a brief description of each type of hearing loss.

**Table 8.3.** Description of the different types of hearing loss.

| Type of hearing loss | Description |
|---|---|
| Conductive hearing loss (CHL) | AC- BC ≥ 15 dB<br>(Significant air-bone gap, AC worse than BC) |
| Sensorineural hearing loss (SNHL) | AC- BC ≤ 10 dB |
| Mixed hearing loss | AC- BC ≥ 15 dB<br>(BC is abnormal > 20 dB)<br><br>Or,<br><br>Combination of CHL and SNHL at different frequencies |

# 9 Loudness Discomfort Level (LDL)

LDL is the intensity of sound at which a client reports sound to be uncomfortably loud. The main purpose of determining LDL is to set the maximum output of a hearing aid to a level that allows for the largest possible dynamic range of hearing while avoiding excessive amplification of loud noises. Similarly, the level can also help audiologists identify clients with decreased sound tolerance levels (hyperacusis).

## 9.1 Instruction

The instructions given to the clients may significantly impact the test outcome. Thus, instructions shall provide clear information about the task. The instruction could be as follows:

> "I will gradually increase the sound in your ear, and you must tell me by pressing the button / raising your hand as soon as you feel the sound becomes uncomfortably loud. This test is not to determine the loudest sound you can tolerate; rather, it determines what level of sound you find uncomfortable. You should press the button only when the sound becomes uncomfortable but make sure you press it as soon as the sound reaches that level."

Alternative wording is acceptable as long as the same instructional principles are included. The instruction shall emphasize that the test does not determine how well the clients can tolerate a loud sound or how strong their ears are. It is only a test to ascertain the point at which they began to experience discomfort from the sound. The tester shall advise the clients that they have the right to terminate the test at any time, especially when they become uncomfortable. The test shall be halted if there is any uncertainty about the client's understanding of the instructions.

## 9.2 Client's response

Overt responses are required from the client to indicate when he or she started to feel the stimulus is uncomfortably loud. Any response task meeting this criterion is acceptable. Examples of commonly used responses are (a) raising and lowering the finger, hand, or arm, (b) pressing and releasing a signal switch, and (c) verbalizing "yes".

The client's facial expression must be observed throughout the testing, thus, it is advisable to ask the client to face the audiologist.

## 9.3 Transducer

Transducers used for this test are the same as the transducers used for air-conduction audiometry. See Section 5.4 for details.

## 9.4 Test parameters

### 9.4.1 Ear

Ear-specific results should be obtained. It does not matter which ear to choose as the initial testing ear. However, audiologists may consider starting with the better-hearing ear (according to the client's account). In addition, if the client has unilateral tinnitus, audiologists may begin the testing with the ear without tinnitus.

### 9.4.2 Stimuli

Continuous pure tone is a common stimulus used in LDL testing, and a warble tone can also be used. However, the usage of stimuli other than pure tones in LDL testing should be recorded with the results. While pure tones may not be the most appropriate stimulus, alternative stimuli are not advised due to the lack of calibration reference values. See section 9.5 for details.

### 9.4.3 Frequency

Similar to the pure tone audiometry, the testing may start at 1000 Hz, then at 2000, 3000, 4000 and 500 Hz, in that order. Testing at two frequencies may be sufficient for some clients, such as a low and high frequency (e.g., 500, and 2000 or 4000 Hz).

### 9.4.4 Duration and timing of the test stimuli presentation

The duration of the presented tone shall be a 1-second-long tone, followed by at least a 1-second quiet period. The client should be given enough time to respond between presentations. It does not matter if the presentation is rhythmic or predictable.

### 9.4.5 Threshold determination method

1. The tester should always observe the client's facial expression. It does not matter if the client can see what the tester is doing.
2. Start at a comfortable level based on the client's audiogram. Unless otherwise specified, the tester may begin testing at 60 dBHL or the client's hearing threshold

level for that ear at that frequency, whichever is higher. For clients with suspected decreased sound tolerance, begin the testing at the client's hearing threshold level.

3. Present the tone for a 1-second duration followed by at least a 1-second quiet period.
4. Ascend in 5 dB steps until the client indicates the uncomfortable level has been reached.
5. Stop immediately if the client shows any distress or flinching during the test.
6. Repeat steps 2 - 4 to check for reliability, then take the second result as the LDL threshold.
7. Repeat procedures for other frequencies.
9. Repeat procedures for the opposite ear.

### 9.4.6 Recording of the results

Other than plotting the results in the audiogram, the results can also be expressed as the thresholds of discomfort (dB HL) or sensation level (dB SL). See Section 8.1 for the LDL symbols.

## 9.5 Limitations

LDL measurement is recommended for tinnitus clients, especially when they complain of decreased sound tolerance. However, some clients may have reactive tinnitus, a subset of the overall tinnitus population. Reactive tinnitus is a type of tinnitus that exacerbates after exposure to sound. In some cases, tinnitus can worsen after exposure to mild sound. Thus, audiologists need to take precautions when performing LDL measurements on tinnitus clients, particularly those who reported that their tinnitus became aggravated due to loud music, traffic noise, et cetera. Audiologists must remind the clients that they are allowed to terminate the test if the stimulus exacerbates their tinnitus.

Another limitation of LDL testing is that the stimulus used during the test does not necessarily reflect the signal that may cause discomfort to the clients in real life. Some clients with decreased sound tolerance may find certain sounds uncomfortably loud or annoying, such as the sound of people chewing, baby crying, and the clanking of cutlery on a plate.

The reliability of the LDL testing is inconclusive. Some studies found that the test is reliable to measure the thresholds of discomfort among clients (Sherlock & Formby 2005; Vidal et al., 2022). Contrary, the National Institute for Health and Care Excellence (NICE)(NICE, 2020) considered LDL testing to have low test-retest reliability.

In conclusion, audiologists must weigh each client‘s potential risk of sound exposure against the potential clinical advantages received from the LDL testing.

# 10 Special Considerations

## 10.1 Pre-testing consideration

### 10.1.1 Noise exposure

Recent noise exposure may cause a temporary threshold shift, and thus may not reflect the client's true hearing thresholds. Therefore, a history of recent noise exposure must be obtained before the hearing assessment. If the client has a recent history of noise exposure, it may be necessary to retest the client at another time. The client should be advised to avoid noise exposure at least 14 hours before the testing (ICOP, 2019; Walker et al., 2013). However, earplugs or other forms of hearing protection devices should not be used as a method to obtain the noise avoidance period. More importantly, test frequencies of 3000 and 6000 Hz must be included as these frequencies are useful in identifying hearing losses due to noise exposure.

If the results may have been affected by recent noise exposure, then it may be necessary to re-test the clients at a time when they have had no recent exposure to noise.

### 10.1.2 Physical or cognitive limitation

Special considerations must also be accorded when evaluating clients with any physical or cognitive limitations that could affect the testing procedures and results. In order to identify the potential difficulty that may arise during the evaluation of these clients, a thorough case history, review of prior evaluation, and clinical observations are recommended (Katz et al., 2015).

### 10.1.3 Compensation

For clients who undergo a hearing test for compensation, familiarization with the test tone before the testing is not recommended. Use strategies such as reinstruction, counselling, and re-examination if reliability of the test results is questionable.

## 10.2 Transducer

Audiologists should carefully consider the best transducer to be used as certain ear disorders can be contraindicators for the transducers.

The contraindicators for headphones include:

- Collapsed ear canals

- Pain or discomfort at the pinna, mastoid or adjacent structures

The contraindicators for insert earphones include:

- Craniofacial anomalies such as microtia, atresia, ear dysplasia, white forelock, and microphthalmia
- Tympanic membrane perforation
- Ear discharge
- Presence of patent pressure equalization tubes

## 10.3 Stimulus intensity

When the clinical history indicates a sensorineural hearing loss, care should be taken when presenting a high intensity stimulus if the client is suspected of having recruitment.

## 10.4 Stimulus duration

Longer test tone duration may be applied when testing clients with cognitive disability.

## 10.5 Stimulus type

Different type of stimulus can be used depending on the need of the clients. For example, clients with tinnitus, especially ringing tinnitus that is present during the test, may confuse between the tinnitus and the test tone. Normally, audiologist should ask the clients to ignore their tinnitus as much as possible. If the clients have difficulty distinguishing between the test tones and their tinnitus, the audiologist may switch to warble or pulse tones at certain affected frequencies or at all frequencies. Audiologists should encourage clients to alert them if the clients experience any difficulty discriminating between their tinnitus and the test tones during the testing. However, audiologists should note that warble tone may yield significantly lower thresholds than pure tone and pulse tone (Lentz et al., 2017). Extra care should be taken when using high levels of masking noise, as this can worsen the tinnitus.

Some children may not pay attention to pure tones, thus, warble or pulse tone can also be used as alternatives. If tones other than pure tones were used during the testing, they should be indicated clearly on the audiogram or in the case report.

## 10.6 Frequency order

Audiologists may choose to start testing at frequency other than 1000 Hz depending on the clients' condition (e.g., mental or physical status of the client), and the availability of previous

hearing tests. For example, in cases with severe or profound hearing loss, the audiologist may begin testing at lower frequency which could be more audible than the higher frequency.

Some clients may find the full test rather tiring, thus it may be appropriate to test fewer frequencies. It is always better to test fewer frequencies accurately than to attempt a complete test on an uncooperative or inattentive client where the accuracy of the results will be in doubt. The reason for the omission of test frequencies will need to be clearly indicated in the client's audiological records (BSA, 2018).

## 10.7 Type of responses

If the client has physical limitations for motor responses, the audiologist should modify the motor response task so that it is appropriate for the client. Alternatively, the audiologist may also use verbal response tasks for the client.

## 10.8 Testing method

If there is a reason to suspect that a client is malingering or exaggerating his/her hearing thresholds, the audiologist may use other threshold-seeking methods such as the ascending thresholds technique or the modified audiometry technique suggested by Cooper & Lightfoot (2000). It is also important to document the reliability of the test results, especially in cases involving medicolegal issues and compensation. If the reliability of the audiometry results is poor or questionable, further testing using objective assessments such as electrophysiological tests must be recommended in the report for hearing threshold confirmation.

## 10.9 Client with disability

Special considerations must be accorded when evaluating clients with any physical or cognitive limitations that could affect the testing procedures and results. In order to identify the potential difficulty that may arise during the evaluation of these clients, a thorough case history, review of prior evaluation, and clinical observations are recommended (Katz et al., 2015).

For testing, audiologists may start with frequencies other than 1000 Hz depending on the circumstances (e.g., mental or physical status of the client, and the availability of previous hearing tests). The audiologist may choose to test 500 Hz immediately after the initial 1000 Hz threshold measurement if there is a question of reliability or inconsistency with other measures such as speech audiometry thresholds or to minimize retesting time if inconsistency for the 1000 Hz retest is evident. If the retest threshold at 1000 Hz differs by more than 5 dB

from the first test, the lower of the two thresholds may be accepted, and at least one other test frequency should be retested (ASHA, 2005).

This group of clients may find the full test rather tiring, thus it may be appropriate to test fewer frequencies. It is always better to test fewer frequencies accurately than to attempt a complete test on an uncooperative client where the accuracy of the findings will be in doubt. Other modifications to the testing techniques may be applied, such as using longer test tones or appropriate alternative response methods. The reason for variation in testing techniques, such as the omission of test frequencies, will need to be clearly indicated in the client's audiological records (BSA, 2018).

## 10.10 Profound hearing loss

An audiologist may begin the familiarization process at a much higher presentation level or at a more audible frequency when the clinical history indicates a profound hearing loss, however, care should be taken if the client is suspected of having recruitment.

## 10.11 Client with noise exposure

Recent noise exposure may cause a temporary threshold shift, thus may not reflect the client's true hearing thresholds. Therefore, a history of recent noise exposure must be obtained before the hearing assessment. If the client has a recent history of noise exposure, it may be necessary to retest the client at another time. The client should be advised to avoid noise exposure at least 16 hours before the testing (Walker et al., 2013). Earplugs or other forms of hearing protection devices should not be used as a method to obtain the noise avoidance period. More importantly, test frequencies of 3000 and 6000 Hz must be included as these frequencies are useful in identifying hearing losses due to noise exposure.

If the results may have been affected by recent noise exposure, then it may be necessary to re-test the clients at a time when they have had no recent exposure to noise.

## 10.12 Clients with tinnitus

Clients with tinnitus, especially ringing tinnitus that is present during the test, should be asked to ignore their tinnitus as much as possible. If the clients have difficulty distinguishing between the test tones and their tinnitus, the audiologist may switch to warble or pulse tones at affected frequencies or at all frequencies. If tones other than pure tones were used during the testing, they should be indicated clearly on the audiogram or in the case report. Clients are encouraged to alert the audiologist if they experience any difficulty discriminating between

their tinnitus and the test tones. Audiologists should note that warble tone may yield significantly lower thresholds than pure tone and pulse tone (Lentz et al., 2017). Extra care should be taken when using high levels of masking noise, as this can worsen the tinnitus.

It is recommended to perform LDL testing on clients with tinnitus as tinnitus is significantly associated with the presence of decreased sound tolerance (Raj-Koziak et al., 2021). Nonetheless, it should be noted that the stimulus used in the LDL testing may not represent the sound that causes discomfort to the clients in real life.

## 10.13 Clients who come for compensation

For clients who undergo a hearing test for compensation, familiarization with the test tone before the testing is not recommended. If there is a reason to suspect that the client is malingering or exaggerating his/her hearing thresholds, the audiologist may use other threshold-seeking methods such as the ascending thresholds technique or the modified audiometry technique suggested by Cooper & Lightfoot (2000). It is also important to document the reliability of the test results, especially in cases involving medicolegal issues and compensation. If the reliability of the audiometry results is poor or questionable, further testing using objective assessments such as electrophysiological tests must be recommended in the report for hearing threshold confirmation.

## 10.14 Craniofacial abnormalities

Audiologists should carefully consider the best transducer for clients with craniofacial anomalies. Craniofacial anomalies include microtia, atresia, ear dysplasia, white forelock, and microphthalmia. In these cases, supra-aural headphones will be required during testing.

# 11 Conclusion

This document describes the recommended procedure of pure tone audiometry to be performed on adult clients. The procedures included are based on research evidence and recommendations outlined in clinical guidelines by established professional audiology associations worldwide. In addition, information regarding the recommended PTA testing procedure in special populations such as clients with a history of noise exposure, tinnitus, and disability is also included.

Besides emphasizing PTA testing, this document also serves to remind audiologists in adhering to universal precautions and appropriate infection control procedures. While audiologists must clean and disinfect instruments that came into physical contact with the client after each use, the implementation of disposable acoustically transparent earphone covers or disposable insert earphone tips is highly recommended. Furthermore, hand washing or sanitizing should be a routine for audiologists before and after consulting each client.

Compliance with the PTA recommended procedures highlighted in this document is envisaged to have a positive impact on the accuracy of hearing diagnosis in adult clients directly, thus enhancing the efficacy of audiological services in Malaysia as a whole.

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