Audiometer: Impedance (Tympanometry)

Purpose الغرض

An impedance audiometer is a device designed to test the functional status of the middle ear and mobility of the tympanic membrane (eardrum) and the conduction bones. The technique is also known as tympanometry. The test enables the audiologist to measure how well the eardrum is vibrating when sound strikes it and how well the tiny bones of the ears are functioning to transmit those vibrations. The other purpose of the test is to assess acoustic reflex pathways including the auditory brainstem and the cranial nerves. This test, however, does not evaluate auditory sensitivity directly. Tympanometry is an important part of the audiometric evaluation as abnormal finding on this test may suggest a conductive loss.

Principle

Impedance audiometry, or most commonly referred as tympanometry, is based on pro- ducing variations of air pressure in the ear canal by means of a probe measuring the middle ear's acoustic resistance. Acoustic impedance is considered to be a response to acoustic admittance, which involves the measurement of air pressure or energy flow in the eardrum and associated structures. The reciprocal of acoustic admittance is acoustic impedance. As these measurements are performed in terms of impedance rather than admittance, the technique is often known as impedance audiometry. As admittance implies how energy is transmitted through the middle ear, the instrument is designed to measure the reflected sound that is expressed as an admittance or compliance. The results are plotted on a chart known as a tympanogram, which is a graphic representation of the relationship of external auditory canal air pressure to impedance.

Acoustic Reflex Measurement

Acoustic reflex threshold of the middle ear (contraction of stapedius muscle) is a response to loud noise presented to the auditory pathway. When the stapedius muscle contracts in response to a loud sound, there is a change in the middle ear admittance due to this contraction. This change in admittance is reflected as a deflection in the recording. The test is performed by presenting stimulus tones of varying intensities at 500, 1000, 2000, and 4000 Hz at short bursts. Reflex measurements are normally carried out with air pressure in the outer ear canal set for maximum compliance. Usually this test is conducted after performing routine tympanometry. The reflex measurements along the impedance curve measurement forms the basis for study of the integrity of the complete middle ear system, which is of great diagnostic value.

Multiple Frequency Tympanometry

In addition to the standard 226 Hz probe tone tympanogram, a higher frequency probe tone can also be employed for tympanometry. However, there are different screening protocols for different frequencies of the high probe tone. A tympanogram recorded using high probe tones is generally considered better suited for screening of neonates than tympanograms recorded using the conventional 226 Hz probe tone. In high frequency test, measurements are made through a series of frequencies ranging from 250 to 2000 Hz. Figure 1 illustrates the block diagram of acoustic impedance audiometer. A hand- held probe with a flexible and soft tip is inserted into the ear canal to obtain an airtight seal. The inside of the handheld probe contains three tubes. These tubes contain a loud speaker to deliver pure tone signal and a microphone to receive reflected sound and another one for air delivery from an air pressure pump. A pure tone is sent to the tympanic membrane, and the response of the tone sent back from the eardrum is recorded through the tube connected to the microphone. The air pump generates air pressure in the external ear canal that can be varied from -400 to +400 mm H2O. The air pressure pump assembly consists of a DC step motor. The pressure is measured using a strain gauge type transducer whose output goes to an A/D converter, processor, and display screen. In this way, the impedance of the eardrum can be calculated. Any disease process in the middle ear can result in either increase or decrease in the flexibility of the eardrum and may be an indication of hearing loss. A tympanometry typically has a signal generator and transducers that can be used to deliver high intensity tones at various frequencies for the purpose of acoustic reflex testing. A tone of 226 Hz is generated by the tympanometer and delivered into the ear canal, where the sound strikes the tympanic membrane, causing the vibration of the middle ear. This in turn results in the conscious perception of hearing. Some of this sound is reflected back and picked up by the microphone. From the middle ear, the acoustic transmission is maximum when the air pressure in the ear canal and middle ear is equal. This implies that the lowest impedance will be observed when the air pressure will be equal on both sides of the tympanic membrane. This would be indicated by the highest compliance to the sound waves and is also referred to as a compliance peak. Mobility of the tympanic membrane is indicated by the height of the compliance peak on the tympanogram. Low compliance is indicated by stiffness of the middle ear and tympanic membrane.

Tympanometry is an objective test of middle ear function and is not a hearing evaluation, but is rather a measure of energy transmission through the middle ear. The results of the test should always be viewed in conjunction with pure tone audiometry.

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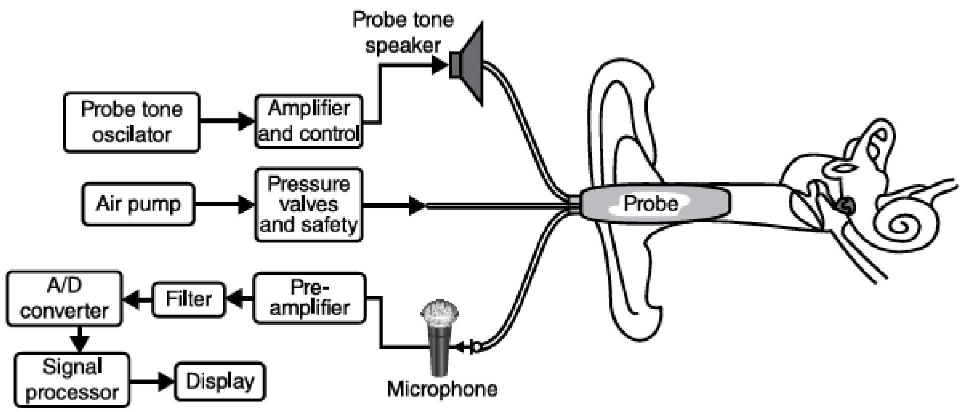
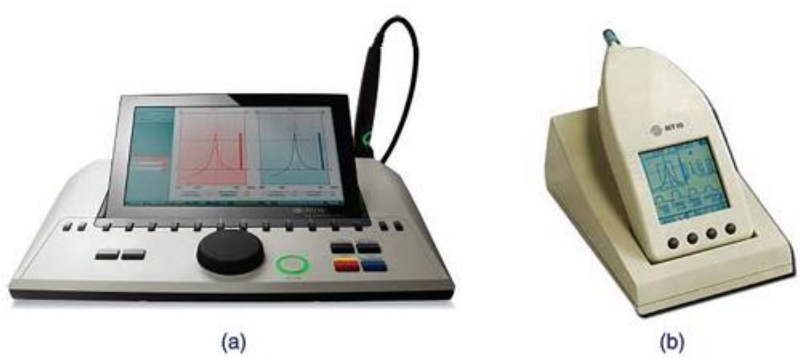
Commercial instruments for tympanometry are available both as desktop and as handheld portable type.



1 Block diagram of an acoustic impedance audiometer.

The two examples are shown in Figure 2. The instruments provide a versatile combination of testing capability for tympanometry alone, tympanometry combined with screening acoustic reflex measurements, and screening audiometry. They also allow storing of data by printing or by transferring data to a computer.



.2 Typical models of impedance audiometers: (a) table model and (b) handheld tympanometer. *Source*: Reproduced with permission from Interacoustics, Denmark.

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Specifications

- Tympanometry: Probe tone: frequency: 226Hz for all functions; 678, 800, 1000 Hz for traditional curve tympanometry; level: 85 dB sound pressure level (SPL)
- air pressure: -400 to +400 mm H_2O; function: automatic, where pump speed start and stop pressure can be user-programmed
- Acoustic reflex functions: Automatic testing with four stimuli to each ear; stimulus duration 1.0 second
- intensity (maximum): 110 dB HL
- Audiometer: Screening audiometry; intensity: 10-50dBHL; frequency: 0.5, 1, 2, 3, and 4kHz

Applications

Impedance audiometry tests are mostly performed in good hospitals.

Audiometer PureTone

Purpose

Pure tone audiometer is a device that is generally used to perform the key hearing test to assess the nature, degree, and configuration of hearing loss. Thus, the test provides the basis for diagnosis and plans the most appropriate interventions for management of the problem. The test is, no doubt, subjective because for determining the hearing threshold, the clinician has to rely on the patient's response to pure tone stimuli. The test is suitable for adults and children old enough to cooperate and respond to the test procedure.

Principle

Pure tone audiometry involves assessing the hearing response of an individual to the pure tones. A pure tone is a tone that has a single specific frequency. The frequency of the tone is determined by the rate or speed at which the sound source vibrates. Intensity of sound is defined as the amount of energy transmitted per second over an area of 1 m2. For the purpose of audiometry, the loudness of the tone can be considered as the intensity of the pure tone. Sound intensity is expressed in decibels (dB). In audiometry, different dB scales are used for different applications that include the dB hearing level (HL) scale, the dB sound pressure level (SPL) scale, and the dB sensation level (SL) scale.

However, the most common dB scale used in audiology is the dB HL scale.

Pure tone audiometry employs both air and bone conduction techniques to assess the hearing loss. An air-conducted signal travels through the air and reaches the ear in the same way as we normally hear on daily basis. Thus, air conduction audiometric threshold measurements are indicative of a person's hearing for air-conducted sounds as much as the same manner by which humans typically hear most sounds. Bone conduction, on the other hand, stimulates the cochlea directly with pure tone signal, bypassing the outer and middle ear. This type of testing helps to evaluate whether a hearing loss measured via air conduction reflects a cochlear/neural deficit or an outer or middle ear dysfunction. The results of pure tone audiometric testing representing an individual's hearing status are plotted on a graph commonly called as the audiogram. Frequency, measured in hertz (Hz), is plotted on the horizontal axis, generally from 250 up to 8000 Hz, whereas the intensity level of the sound in dB HL is represented on the vertical axis of the audiogram. Audiograms generally represent lower intensities at the top and higher intensities at the bottom, increasing in 5 dB steps.

Instrumentation

Pure tone audiometers vary from simple, inexpensive screening devices used in public health programs to more sophisticated and expensive diagnostic audiometers used in hospitals and clinics. However, some components are common to all audiometers, which include the following:

1- Oscillator: An audio oscillator is required in all pure tone audiometers to generate pure tones of different frequencies. The frequency variation may be of continuous type, but it is usually in discrete steps of 125, 250, 500, 750, 1000, 2000, 3000, 4000, 6000, and 8000 Hz
2- Amplifier: The output power available from the power amplifier determines the maximum SPL available from the headphones and the bone vibrator. The amplifier amplifies the oscillations to a fixed intensity level, e.g. 110 dB HL. The amplifier must have low distortion and a good signal-to-noise ratio to meet the standard requirements.
3- Attenuator: The attenuator is used to control the intensity of the amplified

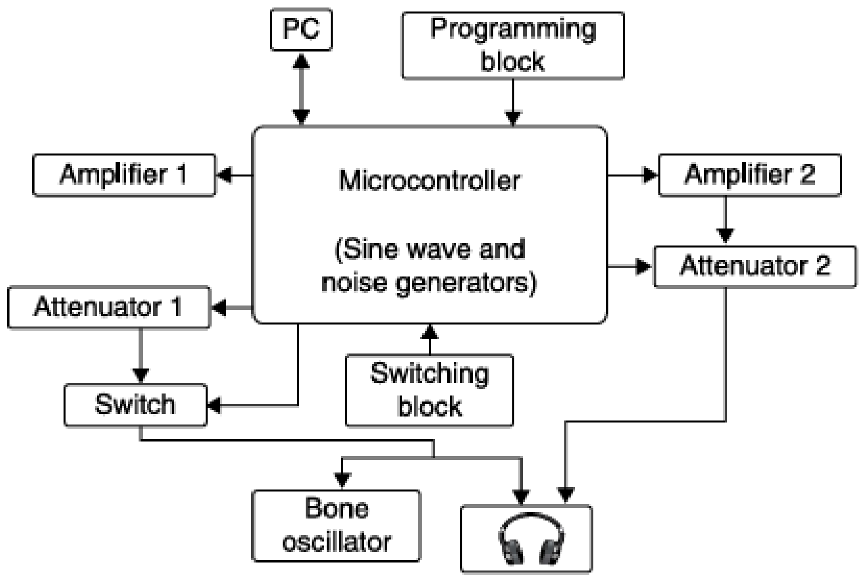
oscillations with a view to vary the energy reaching the ear. The range of variation is from 0 to110dB HL in 5dBHL steps. The audiometers generally display the maximum intensity that is allowed at each frequency.

4- Earphones: Earphones are transducers that convert electrical energy into acoustic energy that is presented to the ear. Rubber cushions are usually fitted to the ear- phones or insert earphones may be used, which are inserted into the ears. For bone conduction studies, the sound is sent directly to the inner ear via the skull.

5- Masking: Most audiometers have facilities to generate a masking noise, which is especially required when the hearing thresholds differ significantly between the ears. For the masking purpose, the noise generator should provide wide band noise, which has energy spectrum equally distributed over the test frequency range, i.e. up to 8kHz. There is a facility for narrow band noise whose output should be distributed around the test frequency.

Modern instruments are mostly microprocessor based in which the software controls the hardware, stores the data, and prints a standard audiogram report.

The Figure belowe shows a block diagram of an audiometer. It consists of two channels, namely, pure tone generator and noise generator, each channel having an attenuator, equalization circuit, and power amplifier. The tone generator or oscillator has a controllable frequency range from 250 Hz to 8kHz. The equalization circuit is required to provide frequency-dependent attenuation in order to calibrate the output sound levels in dB HL and also to provide different amounts of attenuation for different output devices used (headphone, loudspeaker, and vibrator). The attenuator, known as the hearing or tone level control, should be capable of controlling the output sound level over a desired range in steps of 5 dB. The output sound level should be within 3 dB of the indicated value. Some audiometers have an automatic sequencing mode, in which a special audiometric test sequence is presented automatically by the audiometer. As with most clinical tests, calibration of the test



Block diagram of a pure tone audiometer.

environment, the audiometer, and the stimuli to ISO standards is needed before proceeding for the test.

Procedure

During the test, the person is asked to sit in a soundproof room to prevent any background noise interfering with the test results. For air conduction audiometry, the person is asked to wear a pair of headphones. Pure tones generated by an audiometer are presented to the patient via a transducer. The audiologist selects the frequency of the tones, the intensity of the tones, and the transducer through which the stimuli are presented to the patient. The person is asked to signal whenever the sound is heard by the person, usually by pressing a button or raising the hand. Different types of transducers that include supra-aural air conduction earphones, circumaural air conduction earphones, insert air conduction earphones, bone conduction headphone, and loudspeakers (sound field) are available.

For bone conduction test, a bone conductor vibrator is attached to the head at the centre forehead position to see whether the hearing threshold improves. If it does, then the disorder is most likely wholly or partly conductive in origin. To avoid stimulation of the ear not under test with the vibrator, it can be temporarily made deaf by introducing a suitable masking noise in the non-test ear via an earphone. A narrow band noise centred on the pure tone test frequency or a wide band white noise is used for this purpose.

Specifications

1- Frequency range: 250, 500, 1000, 2000, 3000, 4000, 6000, 8000 Hz
2- Frequency range accuracy: Better than +3%
3- Hearing threshold range: 0-90 dB, 5 dB steps
4- Hearing threshold range accuracy: Better than +2 dB
5- Harmonic distortion: < 3%

Applications

Pure tone audiometric test reflects a key indication of an individual's ability to hear and respond to sounds. The pure tone audiogram is widely accepted as the gold standard assessment of peripheral auditory function. Depending upon its sophistication level, it is used mostly in clinics and hospitals.