1st term – Lect. (Audiologigal System 1)

Audiometer: Diagnostic

Purpose الغرض

Diagnostic audiometer is an instrument used for evaluating hearing impairment and the probable anatomic site/sites of dysfunction within the auditory system. Audiometers are basic equipment in audiology centres because evaluation of hearing ability of a person is an essential first step in the management of such patient. With the audiology equipment, it is possible to assess the functions of the peripheral and central auditory

(مقياس السمع التشخيصي هو أداة تستخدم لتقييم ضعف السمع والموقع التشريحي المحتمل/المواقع التي قد يحدث فيها خلل داخل الجهاز السمعي. تعتبر أجهزة قياس السمع من المعدات الأساسية في مراكز السمع لأن تقييم قدرة الشخص على السمع)

Principle مبداء العمل

Mechanism of Hearing Sound waves are longitudinal waves in which the motion of each particle of the medium, in which the wave is travelling, moves backward and forward along a line in the direction in which the wave is propagated. The human aural system responds to these oscillating pressure changes and transmits them to the brain through a series of steps. Figure 21.1 shows the anatomy of the human ear. The function of the external or outer ear is to funnel sound into the auditory canal or external auditory meatus to the ear drum. The sound vibrations then go through the middle ear by means of the ossicles (the malleus (المطرقة), the incus (السندان) , and the stapes (الركاب)) to the inner ear. The external auditory meatus is a convoluted tube, about 1 cm^3 in volume, and has at its inner end in the tympanic membrane (**غشاء الطبلة**) . The distance the tympanic membrane moves during a wave of compression is a function of the force and velocity with which the air molecules strike it and is, therefore, related to the loudness of sound. The tympanic membrane stretches across the ear canal and separates it from the middle ear cavity. The middle ear is exposed to atmospheric pressure, contains air, and is connected to the nose through a valved tube called the Eustachian tub قناة (استاكيوس) , which is responsible for keeping the pressure equal on the two sides of the ear drum. The sound energy from the tympanic membrane is transmitted to the labyrinth, which is filled with fluid. The fluid conducts the sound to the cochlea where the receptor cells are located, which convert the acoustic signal to nerve impulses, are located. The nerve impulses thus generated are propagated along the acoustic nerve fibres to the brain with a speed of **100 m/s.** The pattern of nerve impulses arriving in the brain is associated with the subjectively experienced sound, which has attributes of loudness, pitch, and timbre (quality**).** **(تنتقل طاقة الصوت من طبلة الأذن إلى المتاهة المملوءة بالسائل، وينقل السائل الصوت إلى القوقعة حيث توجد الخلايا المستقبلة التي تحول الإشارة الصوتية إلى نبضات عصبية، وتنتشر النبضات العصبية الناتجة على طول الألياف العصبية الصوتية إلى المخ بسرعة 100 متر/ثانية)**.

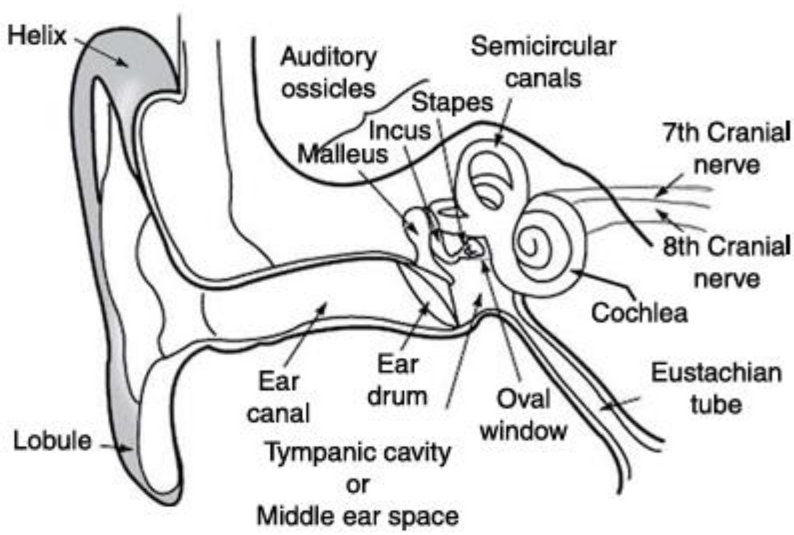

Figure 21.1 Anatomy of the ear.

The cochlea is a fluid-filled coiled tube about 1 cm long, which is a wound, snaillike, and round cone of bone (called modiolus**) (القوقعة عبارة عن أنبوب ملتف مملوء بالسوائل يبلغ طوله حوالي 1 سم، وهو عبارة عن مخروط عظمي مستدير يشبه الحلزون (يسمى modiolus),** which run the nerve fibres that form the auditory nerve. The cochlea is a very complex structure but essentially it consists of a fluid-filled tube with a sensitive (basilar) membrane dividing it. The

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membrane has different resonating properties along its length, responding to high frequencies at the stapes' end and to low frequencies at its upper end. The actual sensitive elements are hairlike structures, which respond to vibrations at different frequencies by setting up patterns of nerve impulses that travel along the auditory nerve to the brain. The sounds reaching the ear are characterized by loudness (intensity), which depends upon the amplitude of the waves; by pitch, which depends upon their frequency; and by quality, which results from the combination and interaction of the waves. **The human ear responds to vibrations ranging from 20 to 20 000 Hz.**

Hearing capability gets affected by anything that interferes with the conduction of sound waves to the cochlea, such as a perforated tympanic membrane (ear drum), disease of the middle ear or disease of the cochlea itself, or its connection in the central nervous system. **Normally, the disorders of hearing can be classified as follows**:

External ear: The hearing capacity of the ear is reduced whenever the acoustic pathway is blocked due to scrolling or deposit of foreign bodies.

Middle ear: Middle ear hearing problems are due to perforation of ear drum or diseased cochlea.

Inner ear: Hearing ability may be affected in case the sound signal is not transmitted properly to the brain due to injury or prolonged exposure to excessive noise.

Air and Bone Conduction

- Air conduction, by definition, is the transmission of sound through the external and middle ear to the internal ear (cochlea).
- Bone conduction, on the other hand, refers to transmission of sound directly to the internal ear by mechanical vibration of the cranial bones and soft tissues. **Hearing loss** is usually classified into two types: **conductive and sensorineural.**

1- Conductive (**موصلة**) hearing loss is due to a condition of the outer or middle ear that prevents sound from being conducted to the cochlea in the inner ear.
2- Sensorineural (حسية عصبية) hearing loss is due to a problem with either the sensory transducer cells in the cochlea or, sometimes, the neural pathway to the

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brain. In some cases, conductive and sensori neural hearing loss can occur simultaneously, resulting in so-called mixed hearing loss. Air and bone conduction hearing loss **(فقدان السمع)** can be determined by measuring hearing sensitivity using two different types of earphones. **For air conduction testing**, a pure tone is presented via an earphone or a loudspeaker to the outer ear, whereas in bone conduction testing, an electromechanical earphone is placed on the skull. This causes direct stimulation of the cochlea via mechanical vibration of the skull with almost no stimula- tion of the outer and middle ear.

Threshold of Hearing (عتبة السمع)

The human ear has an extremely wide dynamic range as regards its hearing capabil- ity. The **lower limit** of hearing, where sound is just detectable, is referred to as the **threshold of hearing (عتبة السمع)** . In other words, it is minimal stimulus intensity that is just barely adequate to elicit a response. The **upper limit** of hearing, where sound begins to become uncomfortable for hearing, is referred to as the **threshold of discomfor(عتبة عدم الراحة)** .

The objective of conducting audiological examination is the determination of the hearing threshold. Studies involving measurement of the minimum audible level of hearing have been made with stimuli presented to each ear separately or both ears together. A complete audiogram thus obtained shows both air and **bone conduction thresholds** bilaterally. It is a graphic representation of the dB loss at different frequency levels for **both air and bone conduction** and also indicates the type and location of the hearing impairment. Thus, on the basis of the audiograms, the conduction and sensorineural hearing deficiencies can be easily separated from each other. The results from the two methods show human hearing to be generally most sensitive between **500 and 10 000 Hz.** In audiometers, the hearing loss is measured in terms of decibels usually from **10 to 100 dB** for the audible range of frequencies.

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Diagnostic Audiogram

The diagnostic audiogram employs sounds of specific frequencies and intensity levels for determining what the person can hear in each ear. The sounds are delivered to the person through headphones and he/she is asked to identify each time a sound is heard in which ear. The intensity of sound is progressively reduced to determine the level at which a patient can barely hear, which defines the hearing threshold. The hearing threshold levels are determined by both air conduction and bone conduction audiometry. In air conduction audiometry, the test signal is delivered to the patient by earphones. In bone conduction audiometry, the test signal is provided by a bone vibrator placed on the mastoid of the patient. The purpose of masking is to apply a signal (noise) to the non-test ear to keep it from responding instead of the ear being tested. A narrow band noise centred on the pure tone test frequency or a wide band white noise is used for this purpose. White noise is a noise containing all frequencies in the audible spectrum at approximately equal intensities.

Instrumentation

An audiometer is used to identify hearing loss in individuals for quantitative determination of the degree and nature of such a loss. It is essentially an oscillator driving a pair of headphones and is calibrated in terms of frequency and acoustic intensity. Both frequency and intensity are adjustable over the audio range. The instrument is also provided with a calibrated noise source and bone conductor vibrator. Audiometers may be divided into different types on the basis of the type of stimulus they provide to elicit auditory response. A pure tone audiometer is primarily a diagnostic instrument to obtain air conduction and bone conduction thresholds of hearing.

Speech audiometers are normally used to determine speech reception thresholds for diagnostic purposes and to assess and evaluate the performance of hearing aids. Screening audiometers are used to separate two groups of people:

1- one that can hear equal to or better than a particular standard
2- and the other that cannot hear so well.

Diagnostic audiometers include all routine tests for tone and speech audiometry as well as different special tests. It offers pure tone audiometry via earphones or bone

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conduction, masking and speech audiometry with Speech Recognition Threshold (SRT) (**عتبة التعرف على الكلام**) and Speech Discrimination (SD) (**تمييز الكلام**) . Additional features include Hearing Loss Simulator (HLS) and Master Hearing Aid (MHA). These dual channel instruments support speech audiometry from live or recorded sources.

Most audiometers are microcontroller-based instruments. Such equipment offers greater convenience in calibration, test signal presentation, and versatility. Automated data collection and storage are essential features included in such equipment. They generate signals in a frequency range from approximately **100 to 10000 Hz**. The frequency in this range is adjustable in discrete octave or semi-octave steps, while others provide for continuously variable frequency over their designed range. The frequency must remain accurate at a value within **1-3%** of the indicated value. The test frequencies should be of sufficient purity of sine wave signal with the total harmonic distortion not more than 3%.

The **intensity range** of most audiometers starts from approximately 15 dB above normal to 95 dB below normal over a frequency range from approximately 500 to 4000 Hz. The intensity range is somewhat less for frequencies below 500 Hz and above 4000 Hz. This is partly because of certain instrumental limitations imposed by the earphone or vibrator and partly due to the desire to avoid the threshold of feeling from stimulation at the lower frequency levels. The threshold of feeling is the sensation of pain or tickle in the ear, which results from sound pressures and limits the maximal sound intensity that can be tolerated by the ear. The intensity level at which the threshold of feeling is stimulated varies with frequency.

Figure 21.2 shows a block diagram of a diagnostic audiometer. It consists of

1- Two generators, namely, pure tone generator and noise generator, and each channel having an attenuator,
2- equalization circuit,
3- power amplifier. The pure tone generator is a single frequency sound wave. It has an oscillator that generates signal with controllable frequency in the range from **250 Hz to 8kHz.**
4- The signal intensity can be varied from **10 to100 dB** using an attenuator.

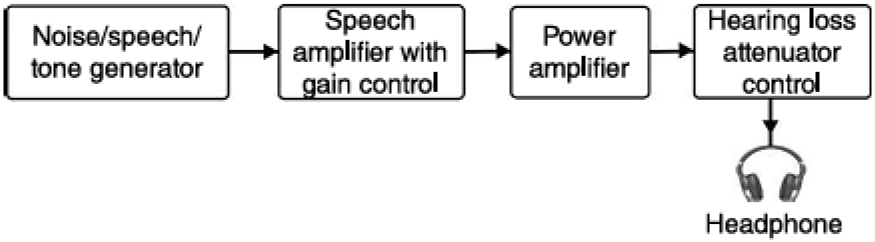

Figure 21.2 Block diagram of a diagnostic audiometer.

An 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 amount 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 of5 dB. The output sound level should be within 3dB of the indicated value. A power amplifier is required to amplify the signal. The signals are given to the ear through an earphone or headphone.

For the masking purpose, the noise generator provides 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. The output power available from the power amplifier determines the maximum sound pressure level available from the headphones and the bone vibrator. The amplifier must have low distortion and a good S/N ratio to meet the standard requirements. The audiometer can be connected to a PC for data processing. For conducting the speech test, spoken voices are used. A CD player is used when the test is to be conducted with the recorded speech. Live voice facility is incorporated in the microphone amplifiers for the purpose of communication.

Audiometric Booth كابينة قياس السمع

Although by using the noise protected headphones, audiometric tests can be conducted in a low level of environmental noise, it is preferable that the tests are essentially con- ducted in especially designed small cabins that provide the noise-free environment. Since most of the time the environmental noise is difficult to control, the noise-free conditions are achieved by using a sound isolating enclosure that is capable of attenuating all frequencies within the sensory range below the threshold of hearing of normal ears. By using double-wall construction and appropriate sound absorbing material, it is common to achieve 25 dB attenuation at 125 Hz and 60dB attenuation at frequencies between 1000 and 8000 Hz. Standard features of such booths or enclosures include lighting, carpeting, vibration isolators, universal jack panel, forced air ventilation, and an audiometer shelf.

Specifications

Tests: Pure tone audiometry, speech audiometry Frequency range: 125-8000 Hz Masking: Narrow band/wide band noise, speech-masking nois

Transducer: Earphones, bone vibrator, insert free-field loudspeaker via extension amplifier

Test modes: Air conduction, bone conduction, free-field

Speech test input: Microphone or CD player

Applications

Diagnostic audiometer is intended to be used by an audiologist or hearing healthcare professional to detect hearing loss in a patient.

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