Unit - 2 ❑ Assessment and Identification of Needs

Structure

2.1 Introduction

The hearing mechanism in humans is an interesting and intricate process. An intact hearing system helps to acquire adequate speech, language and communication skills. This further helps in educational, psychological and social development of an individual. Any deficit in the hearing mechanism causes varied amount of effect on an individual depending on the extent of deficit. The most important of these are hearing impairment that is inability to hear. The deficit can be by birth or can be acquired due to any ailment, accident etc. The deficit can take place in the external ear, middle ear or inner ear. For e.g, there can be wax accumulation in the external ear, there can be infection in the middle ear or there can be a permanent damage of hair cells in the inner ear. Moreover there can be a combination of these conditions. The resulting hearing impairment can range from minimal loss to total loss of hearing.

An individual with hearing impairment needs early identification, accurate diagnosis and timely rehabilitation in order to lead a healthy life. For this purpose, correct identification and assessment of hearing loss is necessary. There are a number of tests in the field of audiology, which help to assess the hearing capacity of an individual.

Correct selection and administration of these test(S) helps to find the degree of hearing loss and also the site of deficit/damage. Audiology is very closely related to education. The role of special educators in assessment and rehabilitation of hearing disorders is well established. Moreover the results of audiological assessment have important implications for educational assessment and planning the educational management of a hearing impaired child.

In this chapter we will discuss about the various tests, their procedures, their importance, the instruments used, the interpretation of resultsand their implication on educational assessment and management.

2.2 Objectives

At the end of this chapter students will learn about

- Concept of sound, its parameters and units.
- Auditory development in humans
- Various audiological tests- Subjective and Objective used for children
- The audiometer
- Interpretation of results from the tests
- Implications of results and application in educational management of the hearing impaired child

2.3 Audiological Assessment Orientation

Audiology refers to the study of hearing and hearing disorders. Audiology is concerned with the human's response to auditory stimuli which is basically "sound". In order to gain knowledge about the various assessment procedures used in audiology, the basic understanding of "sound" and its properties is essential. As measurement of hearing loss requires accurate and dependable instrumentation, so the knowledge of instrumentation, tests performed with the help of these instruments and the various response patterns is crucial.

2.3.1 Sound

Sound is a form of energy which is generated in the form of vibrationsand is perceived by the hearing mechanism. It can propagate in any medium like air or water.

Sound has two aspects namely physical and psychological. Because hearing disorders represent an inability to respond normally to acoustic stimulation or "sound", it is very important to learn briefly about the physical and psychological aspects of sound.

2.3.2 Physical Correlates of Sound

Sound is produced when a force sets an object into vibration that in turn disturbs the molecular movement of the medium surrounding the object. The disturbance is propagated as a sound wave is heard by the human ear. So the chain is Source ◗ Medium ◗ Object that will vibrate ◗ Hearing mechanism.

2.3.3 Psychological Correlates of Sound

The act of hearing something that is sound is an auditory experience. There are certain psychological attributes attached to the physical properties of sound namely pitch,loudness and timbre. Pitch corresponds to frequency, loudness corresponds to intensity and timbre corresponds to quality of sound.

2.3.4. Basic Attributes of Sound

Physical attributes of sound are frequency, amplitude and phase which are psychologically correlated with pitch, intensity and time. Sound can be a simple single frequency puretone or a combination of many frequencies called a complex tone.

Frequency

The frequency of a sound refers to the number of vibrations that occur in one second and is expressed in Hertz(Hz).Each vibration consists of one cycle of compression and rarefaction. So a pure tone of 1000 Hz means 1000 cycles per second. The period of a sound T,is the reciprocal of frequency.

$T = 1/f$

The range of human hearing is 20 Hz-20 000 Hz. However in basic Puretone Audiometry we test from 250 Hz to 8000 Hz. The length of one cycle called the wavelength decide the frequency of a sound wave. Low frequency sounds have longer wavelengths and high frequencies have shorter wavelength.All the sounds heard by human ear including speech can be categorised as low,mid or high frequency sound. E.ga sound from a Drum is a low frequency sound whereas a bird's chirp or a whistle are categorised as high frequency sounds.

Amplitude

The amplitude of a sound refers to how far an object moves back and forth and the amount of maximum and minimum air pressure created. The larger the movement or

pressure variation the greater the amplitude for any given frequency. The sounds in human environment are categorised as soft, moderate and loud. E.g Rustling of leaves is a soft sound and sound of a cracker is a loud sound.However a term called intensity is used to express amplitude whether to describe sound energy per area or sound pressure. Logarithmic units are used to express amplitude.

Phase

Phase refers to amplitude of a sound at a particular time during the cycle. Phase can be expressed in units of time such as seconds or can be expressed as an angle. Phase can also be used to describe the time relationship between two or more tones occurring simultaneously.

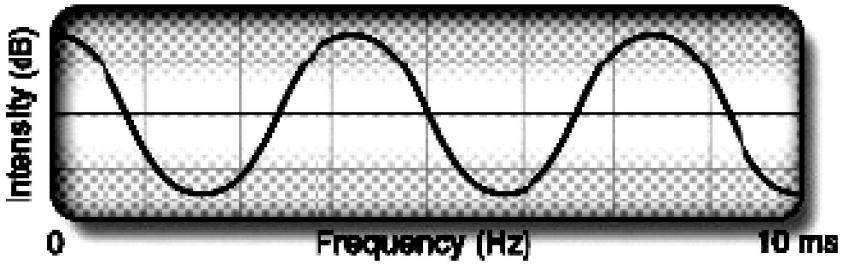


Fig 1. A simple pure tone waveform showing intensity, frequency and time

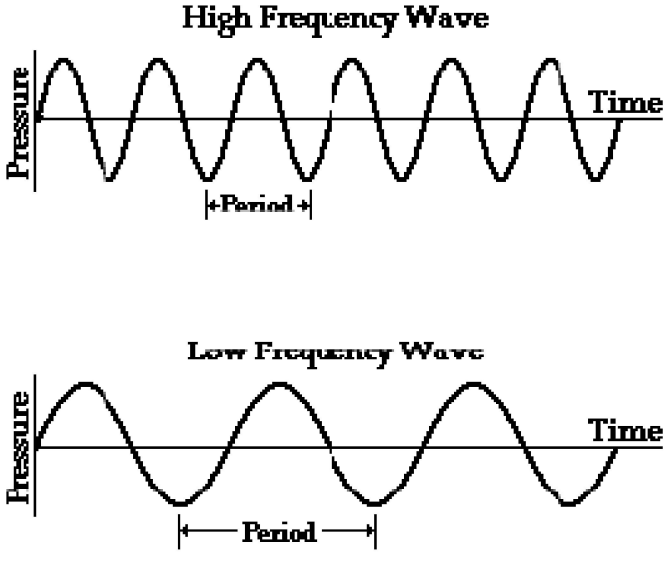


Fig 2: frequency, intensity and phase

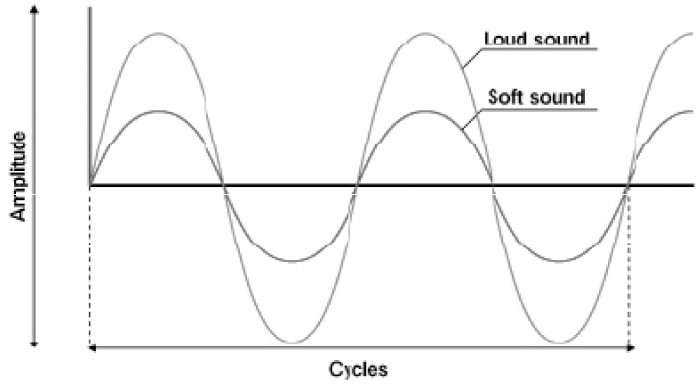


Fig 3: Loud and soft sound

2.3.5 Decibels

Decibel is one-tenth of Bel, which is a relative unit in logarithm. It is the unit of measurement of intensity used in audiology.

Linear scales of intensity or pressure ranges require working with large numbers or scientific notations. To simplify our work, a decibel scale is used. The decibel scale is a logarithmic ratio scale where any measured value is relative to some specified reference value. It can also be stated as a unit for expressing the ratio between two sound pressures or two sound powers.

dB= 10 log(Xmeas/Xref),

WhereXmeas is the sound that is being measured and Xref is the reference sound to which Xmeas is to be compared.

Sound can be measured in sound pressure or sound intensity where Intensity(I) and pressure(P) are related as

$I = P^2$

dBIL=10log(Imeas/Iref)

dBSPL = 20 log (Pmeas/Pref)

CONCEPT OF dBHL VS dBSPL

dBHL

The conventional audiometers used today are set to a standard that the lowest sound intensity that stimulates normal hearing has been variously called 0 hearing loss and 0 hearing level (HL).This was also called audiometric zero. The minimum amount of Sound Pressure Level needed to generate 0 HL is variable across frequencies, due to

sensitivity of ears. E.g 7 dBSPL produces a sensation of 0dBHL at 1 KHz, whereas 13dBSPLis needed to produce 0dBHL at 8KHz.Therefore the hearing dial or the intensity dial of all audiometers was calibrated with reference to normal hearing (audiometric zero)

dBSPL

Sound Pressure Level is an expression of the pressure of a sound. When in the measurement of decibel the reference value (Xref)is the lowest pressure needed to hear (20μPa), it is called dBSound Pressure Level. This value is universally accepted standard reference value (20 μPa).

2.3.6 Auditory Milestones in Typical Children (0-2 Years)

Prenatal Hearing

The human hearing organ that is the cochlea has normal adult function after the 20th week of gestation. There is ample research which shows prenatal hearing. The developmental response to sound in the foetus is primarily reflexive in nature, including startle, generalised body movement, possible cessation of activity and the involuntary eye blink.

NEONATAL HEARING

At birth or soon after birth the infant is able to discriminate his/her's mother's voice. They are also able to discriminate the various segmental and suprasegmental aspects of speech.

The Auditory development can be understood in the following stages

Birth to 4 weeks: Startle response: the infant may startle or jump to loud sounds.Eyes may widen or blink, arms and legs may fling out.Infants may awaken from sleep.

3 to 6 months: Searching Response:Baby will turn head and eyes to look for an interesting sound e.g name call. He or she enjoys sound making toys and music.Begins to coo and gurgle,repeats sounds like bababa

6-10 months:Localisation; baby will start to turn towards the source. He or she can move head towards the side and indirectly below. Responds to familiar voices and familiar sounds e.g mobile ring, name call, doorbell. Makes many different babbling sounds, even when alone. Understands common words such a "no" and "bye bye".

10- 15 months: Response to speech; the infant directly locates the sound source to the side and below. Also starts to localise indirectly above.They start to understand simple speech,play with own voice,imitate simple words and start using meaningful words.

15-18 months: Direct Localisation; can identify the source of all sounds,localises on

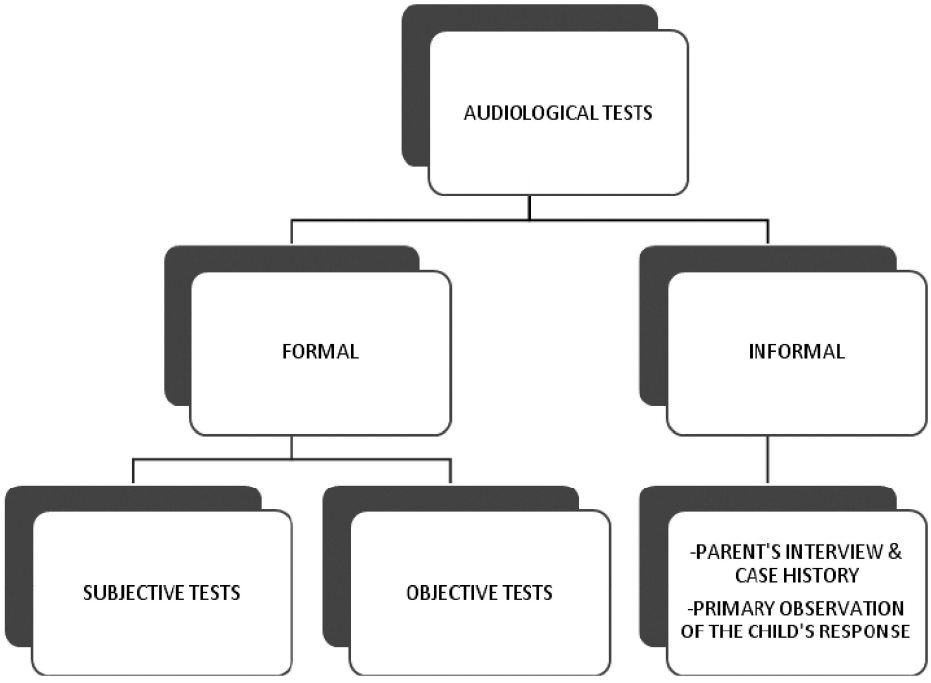
the sides,below and above.By 18 months the infant correctly responds to simple speech,follows simple commands, uses more words in expression, may initiate to join two words.

24 months: the child locates directly a sound at all angles, starts to use phrases and simple sentences. Understands more of adult speech and talking.

2.4 Assessment and Methods of Assessment

2.4.1 Test Battery Approach

Children with hearing loss,acquired or congenital will not demonstrate the typical auditory skills described earlier. Audiological assessment is necessary to correctly identify, diagnose and remediate hearing loss in children. Audiological assessment in children should be characterised by TEST BATTERY APPROACH that is more than one test should be carried out to confirm the detection and diagnosis of hearing loss. The test results should be cross-checked and validated .Parents may need to be advised that the paediatric hearing examination is an ongoing, age-specific activity, so that as the child grows older, more accurate hearing results may be obtained. The various tests used for audiological assessment in children can be classified as



FORMAL HEARING TESTS

All the formal tests make use of instruments which can vary from simple to most sophisticated ones. The tests are characterised by presentation of a sound stimulus such as puretones, speech, warble tones, noise and elicitation of a time locked response from the child to be tested. The tests are performed by an audiologist (Tester) on subjects with or without hearing loss .The tests give a result, which is again interpreted by the tester.The ultimate goal of each test is to establish the auditory/hearing threshold, which is the minimum stimulus level that elicits a response consistently. It is always advocated to use the cross-check principle in paediatric audiometry. According to this principle the results of subjective tests such as BOA (Behavioural Observation Audiometry) should be cross-checked with objective tests such as ABR. All these tests are carried out in sound treated rooms(usually double room set up) which prevent external noise to enter that may interfere with the testing procedure. The instrument used for basic tests are audiometer, immittance audiometer, instrument for electrophysiological tests such as ABR (with software and other accessories), and OAE instrument. The sound stimulus is presented in sound field condition that is via loudspeakers or under closed field condition that is via headphones.These tests can be used for both screening and diagnostic purposes. These tests can be used for school screening programs also. The tests are carried out by an audiologist and an assistant tester is employed if needed.

Prerequisites for Formal Test

1. Case History/Parental Interview
2. Otoscopic examination of ears- to ensure clean ears,no infection/discharge, no ear anomaly

Fig 4: Otoscopic Examination

3.Tuning Fork Test – can be performed by using tuning forks in older and cooperative children to get an idea about probable site of pathology(middle ear or inner ear)

Fig 5: Tuning fork test

4. Selecting and deciding on the tests to be administered- Usually it is important to use a test battery approach in case of infants and children. This is because, it is often difficult to obtain reliable and complete results from any one particular test. So more than one test should be administered depending on the child's age, hearing status, cognitive status and economic status.

e.g For a child aged one year, BOA, IMMITTANCE AUDIOMETRY AND ABR/ASSR can be administered for correct threshold estimation.

2.4.2 Subjective Tests

As the name suggests these tests need participation of the subject.The participation can be active or passive. In these tests the response is recorded after the presentation of a stimulus. The response can be a predefined active one,e.g. raising hand in response to a sound stimulus,or it can be a change in behaviour of the child, e.g. searching for the sound stimulus or startle response which can be noted by the tester.

2.4.3 Orientation to Subjective Tests

These tests can be classified into two major divisions;

1) Techniques used without reinforcement
2) Procedures based on reinforcement of the infant or child's responses

The techniques utilized that do not incorporate reinforcement principles are known as Behavioural Observation Audiometry(BOA).Procedures that use reinforcement to develop repeatable responses are known as conditioned audiometry,such as Visual

Reinforcement Audiometry(VRA)

The first type of techniques are carried out for younger children (upto 12 months), however can be used till 24 months. Conditioning techniques are carried out for older infants and children,between 12-48 months.However the use of behavioural and conditioning procedures with infants and young childrenmay lack sufficient precision to establish valid auditory sensitivity thresholds. An improvement in response behaviour should always be anticipated as the child matures.Auditory evaluation of hearing in children should be considered as completed when earphone thresholds can be obtained for frequencies 250 Hz to 8000 Hz in a test called puretone audiometry.

Let us briefly learn about these tests

2.4.4 Behavioural Observation Audiometry

It is an important clinical test in day to day clinical use. This is mostly used for children upto 6months, but can be used for older children as well, especially those who cannot be conditioned. The use of noisemakers and sound field signals from an audiometer as acoustic stimuli is done in BOA.The major advantages of BOA are efficiency in time required and the lack of need for specialised equipment. The disadvantages of BOA include the fact that it is difficult to eliminate tester bias, the responses of infants quickly reach saturation and a wide variance of responses are noted in infants.Moreover the test does not yields ear specific responses and only gives an idea about degree of hearing loss.This test should ideally be carried out in a quiet background, and sound field condition. The stimulus should be presented in an ascending manner (soft to loud). During the test one audiologist makes a sound, making sure that the child cannot see them, while a second audiologist watches for any change in the child's behaviour (e.g., a "startle" or sudden reflexive movement, eye blinks or cessation of activities). The type of sound is recorded together with its intensity and the nature of the behaviour change. The infant or child can exhibit reflexive response such as startle (younger children/infants below 3 months)or attentive behaviour (above 3 months)such as quieting responses.Children quickly grow accustomed to sounds and may stop showing a response if they hear the same sound often enough. For this reason, it is recommended that repeated "testing" at home is avoided prior to formal BOA testing with the audiologist.

The intensity and frequency of noisemakers can be premeasured for estimation of hearing levels. Puretones,warble tones,speech andnarrow band noise can be used for sound field testing via an audiometer.Handheld paediatric audiometers with intensity and frequency dials/interrupters can also be used.This test can be used for both screening and diagnostic purposes.

Fig 6: BOA

Importance of BOA

1. This test is a true test of hearing unlike electrophysiological tests or objective tests,

   which are not actual tests of hearing. Moreover there are very less chances of the response being affected by instrumental errors or recording artifacts.This test gives information about degree of hearing loss across frequencies.

2. This test can be carried out with passive participation of the child. The child/ infant is the best person to inform about his/her hearing status,that is,it is always very helpful when we can observe the child's actual response to sound stimuli instead of relying on parents' reporting.

3. This test can be carried out in a state of light sleep,as passive participation of the infant/child is needed.

4. This test can also be carried out for difficult to test(for conditioned audiometry)population. E.g children with multiple disability or non-co-operative child.

5. This test is cost effective as not much sophisticated instruments are needed,it is very important to save expenses of the parents.

6. This test can also be performed with the help of noisemakers, if proper instruments are not available.

7. It is an important screening tool.

2.4.5 Reinforcement Audiometry

These tests involve the use of conditioning techniques.The response of the infant or child is conditioned with use of reinforcers.This procedure has been called as operant conditioning. Reinforcer is any entity-verbal praise, an object, food, that increases the likelihood that response will occur again. If a stimulus is given, then a response is obtained and then reinforced, it is likely that the response will occur for many more stimuluspresentations. With more responses available it is possible to obtain thresholds.

Visual Reinforcement Audiometry

It is the use of visual reinforcer in the process of obtaining auditory thresholds. A variety of visual reinforcers can be used. It can be used for children aged 6 months to 2 years. The reinforces can be video-based or made up of animated toys placed in dark Plexiglas boxes located at an angle to each side of the child. The reinforcers should be located approximately level with the child's head at a distance of 1-2 m. Close proximity between speaker and reinforcer is preferred in order to help conditioning when using soundfield stimuli; so in practice adjacent positioning of loudspeaker and reinforcers is recommended. At first, the audiologist lights up the boxes in conjunction with the sound. This "trains" the child to respond by shifting her eyes or turning her head toward the sound source. Once a child understands what to do, the audiologist can "reward" the child by briefly delaying the visual stimuli. The boxes are lit to elicit a head turn associated with a sound source.During the testing phase the light is flashed immediately following the response of the child looking toward the light.

Fig 7: VRA

Importance of VRA

1. It is an important test for children between 6 months to 2 years and gives accurate findings as the child gets motivated for the reinforcement used
2. It is an important test for developmentally delayed children, who cannot cooperate for puretone audiometry.

2.4.6 Conditioned Play Audiometry

As the name suggests use of games or play techniques is done in this procedure to obtain hearing thresholds of the child. This procedure can be used for children from 2 years till 5 years. However for younger children, behavioural observation and parental interview should always guide the threshold estimation.The child is conditioned to a sound stimulus through some play activity such as to place a ring on a stand, put a block in a box upon hearing the sound (either in sound field or through headphones). Initially the tester might demonstrate the activity and the try to engage the child. If interesting toys are used the child can be kept interested for long enough to get lots of testing accomplished. Blocks, puzzles, chips, pebbles, all of which can be dropped into a bucket are good. It is important to have many toys available so when the child becomes tired of a toy,it can be changed quickly. It should be kept in mind that the child may not be cooperative through the total testing time,may need breaks or might need a follow up.However it is always wise to test the speech frequencies first,some testers might do the bone conduction testing first or might use speech signals to generate interest of the child. The child will begin by using both visual and auditory cues. When he can do the task by himself using both visual and auditory cues, visual cue can be removed and auditory alone can be tried. The parents can be instructed to teach conditioning to the child at home with use of noisemakers so that the child can give better responses in the next session.

Fig 8: Conditioned Play Audiometry

Importance of Conditioned Play Audiometry

1. This test prepares the child for puretone audiometry.
2. Frequency wise information on hearing can be obtained. This test gives information about both degree and type of hearing loss.
3. Hearing in both ears can be tested.

2.4.7 Pure Tone Audiometry

Pure tone audiometry is a routine audiometric test used to measure auditory threshold of an individual in a sound proof test room. The instrument used in this measurement is known as the audiometer. This is a subjective investigation, the accuracy of which is dependent on the response of the patient. It can be used for children 5 years and above.Pure tone audiometry provides information about the type of hearing loss and also helps in quantifying frequency specific threshold. This test is generally performed with headphones(FIG 9) for air conduction testing (AC) and bone conduction vibrator(Fig 10) for bone conduction testing (BC).Simple pure tones varying in frequency from 250 Hz to 8000 Hz;and varying in intensity from 0 dBHL to 120 dbHL are used for testing.However the frequency and intensity range depends on the test. For example,in case of BC testing,the measurement is done from 250 Hz to 4000 Hz. The intensity range is also maximum up to 85 dBHL. With the help of a particular pattern/sequence of presenting the puretones,the ear specific threshold across all the test frequencies is established and plotted on an audiogram.The tester should be aware of false responses made by the child and should know how to minimize them.Younger children might need reinforcements,breaks in between testing and often repeated sessions for establishment of reliable thresholds across all the frequencies. The better ear is always tested first, and also masked if required. The AC testing gives information about external, middle and inner ear, whereas the BC testing gives information about inner ear. In case of children, the ultimate goal of assessment should be to obtain puretone audiometry results. The response pattern of the child can be any conditioned response from simple hand raising to keeping blocks in a box.

Fig 9:A) Air conduction testing B) PTA in double room setup

Fig.10: Bone Conduction Testing

Importance of Puretone audiometry

1. The ultimate goal in paediatric evaluation is to obtain puretone thresholds because they give accurate information on type and degree of hearing loss.The information about type of hearing loss is very important for otologists to take decisions about medical treatment. Audiologists can use this information to plan the other tests to be administered.The information about degree of hearing loss is very important for selection of amplification devices, planning speech-language therapy goals and educational placement
2. It givesindependent information about hearing in both ears and the full audiometric frequency range.
3. Regular or periodic assessment of hearing sensitivity by puretone audiometry helps in identifying the changes in hearing sensitivity of subject at regular intervals. This helps in early detection of progressive hearing loss.
4. It helps in determining the amount of benefit from medical and surgical treatment.
5. The pure tone audiometry also helps the audiologist in selection of suitable amplification device and accurate adjustment of the same.The results of puretone audiometry also help to decide about ear to be fitted and also about monoaural vs binaural fitting.
6. The results of pure tone audiometry also help to decide in selection of assistive listening devices,e.g classroom amplification solutions and their adjustment.
7. It provides direction for further management and suggests direction for further investigations.
8. The results of this test help the child to get a handicap certificate,which further helps to get benefits from State and Central Government in job reservations,exemption in tax, travel reservations etc.
9. The results of this test are accepted by agencies to ascertain auditory fitnessfor certain jobs like pilots, policemen,corporate sector etc.

2.4.8 Speech Audiometry

As the name suggests,the stimulus or signal used for this test is speech. Speech audiometry is an additional test,which is done to confirm the results of pure tone audiometry. Moreover it gives an idea about difficulty in real life situation where the most important stimulus to be heard is human speech. A pure tone audiometer is used

for this testing,when the speech is presented live,the tester speaks in the microphone attached to the audiometer which can be heard by the child wearing headphones,or through loudspeakers in the test room. The speech signal can also be recorded and presented using a CD player which can be connected with the audiometer.The speech stimulus can be monosyllables or PB words like /pa/, /cha/, /sha/, word pairs called spondee like /ma-baap//aaj-kaal/the child has to repeat the stimulus upon hearing,or they can write it down. Younger children can also point out picture cards corresponding to the stimulus words or sentences.However the child's receptive vocabulary and cognitive level should be considered while selecting the speech material.There are basically some subtests done under speech audiometry

a) Speech recognition threshold (SRT)-gives us the threshold at which the child can just hear speech clearly and repeat. This is measured in dBHL. It can be correlated with the pure tone audiometric threshold. If there is any discrepancy between the two thresholds, then it can be suspected that either the testing procedure was faulty or the child's response is doubtful.

b) Speech discrimination score/word recognition score (SDS/WRS)-gives us idea about theamount of speech the child can understand or finds intelligible in percentage.eg. WRS is 60% that means out of 100 words, the child can correctly hear 60 words.

c) Ling Six-Sound Test-this test can be carried out without or with the audiometer. Six sounds /a/,/u/,/e/,/i/./m/,/s/.which represent most of the human speech frequencies are used for this test. Detection, identification and discrimination of these sounds is tested.

Importance of Speech Audiometry

1. It validates the result of puretone audiograms.
2. In case of difficult to test population, the child may respond to speech stimulus better than pure tones.
3. Speech discrimination test can be used to differentially diagnose pathologies beyond cochlea,e.g central deafness,where a discrepancy between PTA and SRT/ SDS

2.4.9 Objective Tests

These tests need no active participation from the child. The child's state of arousal,cognitive level or vocabulary do not affect the results of these tests. These tests are time effective and also provide an important tool in the test battery approach. They

also help to cross check the results obtained from subjective tests. The use of these tests give information about functioning of the hearing structures, beyond cochlea.These tests give information about type and degree of hearing loss and the probable site of lesion.However these tests are at an extra expense to the routine hearing tests,so the selection of these should be rightly justified.Many of these are also used for screening purposes in neonatal stage. Moreover these tests are very important for difficult to test population e.g.children with intellectual impairement, non-cooperative child.

2.4.10 Immitance Audiometry

Also known as impedance audiometry,it is an automatic and objective means of assessing the integrity and function of the peripheral hearing mechanism. The impedance audiometer helps to determine tympanic membrane mobility,middle ear pressure,Eustachian tube functioning,continuity and mobility of middle ear ossicles,acoustic reflex threshold(8^{th} and 7^{th} cranial nerve function) and non-organic hearing loss.This test is routinely performed along with puretone audiometry.This test can be carried out in neonates,in sleeping children. However this test cannot be performed if the child is moving,crying or speaking.As a prerequisite it needs clean ear canals and no active infections,pain or discharge from ears. In this test a small probe is inserted into the external auditory canal of the child.The probe has three small holes. One emits a probe tone,the second is an outlet of air pressure system,and the third leads to a pick up microphone that measures the SPL of probe tone in the ear canal cavity.

Fig 11: Impedance Audiometry

There are two subtests of Immitance audiometry

a) Tympanometry-the mobility of tympanic membrane as a function of mechanically varied air pressure in the external ear canal is measured. The introduction of air pressure in the ear canal leads to mobility of the tympanic membrane, this can be recorded as a tympanogram. The movement of the TM depends on the functional status of middle ear. Any abnormality in the middle ear,effects the normal movement of the tympanic membrane. Along with tympanic membrane mobility(compliance), middle ear pressure and ear canal volume are also measured in tympanometry.The tympanogram can be of following types
    1) Type A – normal middle ear function
    2) Type As – Restricted mobility of tympanic membrane(otosclerosis)
    3) Type B – No mobility of tympanic membrane(fluid in middle ear)
    4) Type Ad- Abnormal or excessive mobility of tympanic membrane(ossicular chain discontinuity)
    5) Type C- normal mobility of tympanic membrane with negative middle ear pressure.

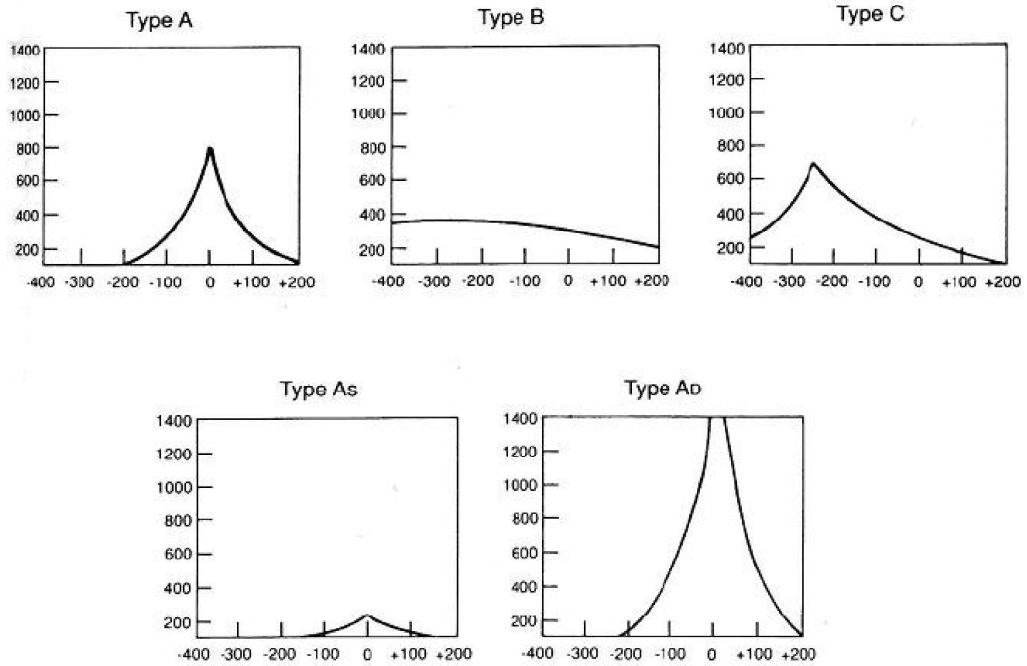


Fig 12: Types of tympanogram

b) Acoustic Reflex Threshold- the acoustic reflex test in the immittance battery is the determination of the signal threshold level at which the stapedial muscle contracts.The lowest signal intensity capable of eliciting the acoustic reflex is the acoustic reflex threshold for the stimulated ear.In normal hearing ears,it is usually between 70 and 100 dBHTL.This means an individual with a puretone threshold of 20 dB, is likely to have ART between 90 and 120 dB (20 +70)The measurement is made both ipsilateral(stimulated ear) and contralaterally(opposite ear) simultaneously.

Importance of Immittance Audiometry

1. It helps to determine the type of hearing loss. Also helps to detect the presence of middle ear pathology and probably the type and stage of disease. This further helps otologists to provide medical treatment.
2. It provides as a useful tool to assess pre-treatment and post treatment condition. E.g a child with Eustachian tube dysfunction will have C type tympanogram, after treatment it becomes A type.
3. It is a quick test and can be used for screening.
4. It is a very important test used to cross-check the results of puretone audiometry.
5. It can provide useful information about hearing in difficult to test population who do not cooperate for conditioned responses.
6. It can be carried out when the child is asleep, needs no active participation.

2.4.11 Brainstem Evoked Response Audiometry

Also known as Auditory Brainstem Evoked response measurements provide information about functioning of peripheral hearing system and hearing upto brainstem level.This objective test helps in hearing assessment and also helps to locate the site of a particular lesion along the auditory pathway. A stimulus called click or tone burst is given through headphones/insert earphones and the response is recorded from the electrodes placed on various positions on the scalp of the child. There is continuous ongoing activity in the brain, an introduction of sound in the auditory path, causes a change in this ongoing activity and this can be recorded in a form of waveform. This testing is best done when the child is calm or asleep. This can be done in new-borns, difficult to test children and also in children suspected with neurologic dysfunction (8th

nerve-tumour,dyssyncronyetc.). This test can also be used for hearing screening programs in NICU.The test is carried out using a BERA instrument. The test also aims to determine the threshold of hearing, however the results obtained are interpreted and deduced in order to get the actual threshold of hearing. The waveform obtained is denominated with certain peaks(I-VI).The lowest intensity upto which peak V can be identified is defined as the threshold obtained from BERA and is usually 15 dB above PTA threshold.

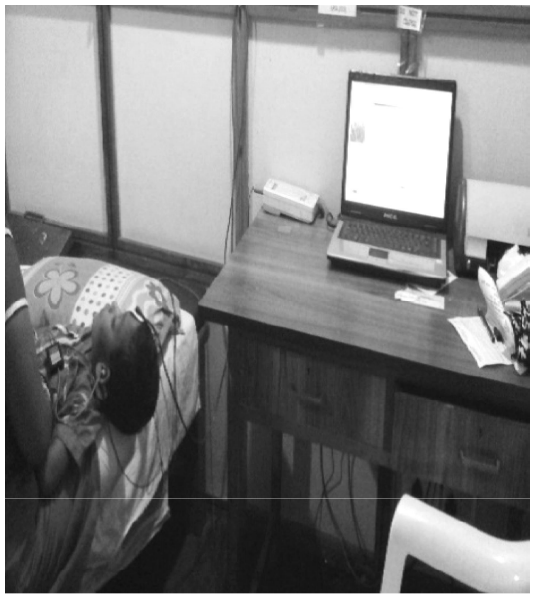


Fig 13: Set up for ABR/ASSR

Importance of BERA

1. It is a very important screening and diagnostic test. It can be used in neonates also.
2. It is an important component of the test battery used to assess young children and difficult to test population. This is because it gives ear specific information about degree of hearing loss.
3. It is also an important test for differentiating between cochlear and nerve pathologies, e.gtumor.
4. It is a very important test as it is not affected by state of arousal, cognition and vocabulary of the child.

2.4.12 Otoacoustic Emmisions

Otoacoustic emission are low level,inaudible sounds produced in the inner ear. Further these can be elicited and recorded from ear canal on introduction of external sound.This is a quick procedures. The instrument consists of a probe assembly, to deliver tone and record responses at the same time from the ear canal. The presence of response indicates intactness of some part of inner ear, however the response can get affected by middle ear pathologies, presence of wax in ear canal etc. Used both as screening and diagnostic purposes.Children who fail in this test are referred for further testing.This test is also used as a part of test battery.Diagnostic tests can be Transient Evoked OAE(TEOAE) or Distortion Product OAE(DPOAE).

Fig 14: OAE

Importance of OAE

1. It is an important test as it is quick, and reliable. It can be used for neonates.It can be used for screening as well as diagnosis of hearing loss.
2. It can detect early signs of sensorineural hearing loss.

Frequency wise responses can be obtained in a special OAE test called DPOAE.

2.4.13 Auditory Steady State Response

The auditory steady-state response (ASSR) can be thought of as an electrophysiologic

response to rapid auditory stimuli. The goal of ASSR is to create an estimated audiogram from which questions regarding hearing, hearing loss, and aural rehabilitation can be answered. Stimulus is modulated pure tone. Has potential to be a faster test than ABR when perfected.Some equipment can test multiple frequencies and both ears simultaneously.Uses same basic set-up and equipment as ABR.ASSR is similar to the Auditory Brainstem Response (ABR) in some respects. For example, ASSR and ABR record bioelectric activity from electrodes arranged in similar recording arrays. ASSR and ABR are both auditory evoked potentials. ASSR and ABR use acoustic stimuli delivered through insert earphones (preferably). ASSR is evoked using repeated sound stimuli presented at a high repetition rate, whereas ABR is evoked using brief sounds presented at a relatively low repetition rate.

Importance of Assr

1. ASSR allows the hearing care professional to create valid audiograms for those unable to participate in traditional behavioral tests.

2.5 Audiometer

The audiologist uses an instrument called AUDIOMETER for many hearing tests like puretone audiometry, BOA etc. There are different types of audiometers that are commercially available. These can be classified as diagnostic, screening, computer-based depending upon their function. Also there are different makes and models available commercially.

2.5.1 Block Diagram

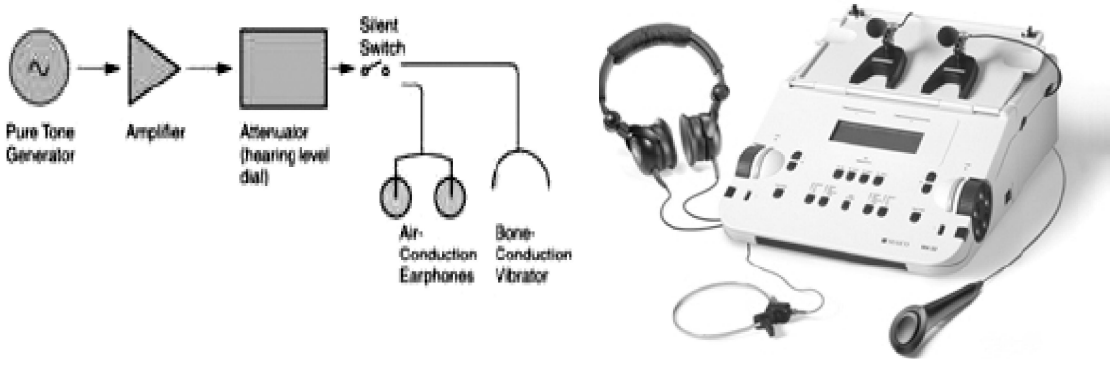


Fig 15: Audiometer

2.5.2 Parts And Their Use

The basic functions of an audiometer are to produce puretones at selected frequencies, change the intensity of the signal, select how the signal is delivered to the ear and direct the signal to a desired ear .For example a tester would select 1000 Hz as the frequency,40dB as the intensity, earphones as the transducer and right ear for the signal presentation.To achieve these functions following parts are required

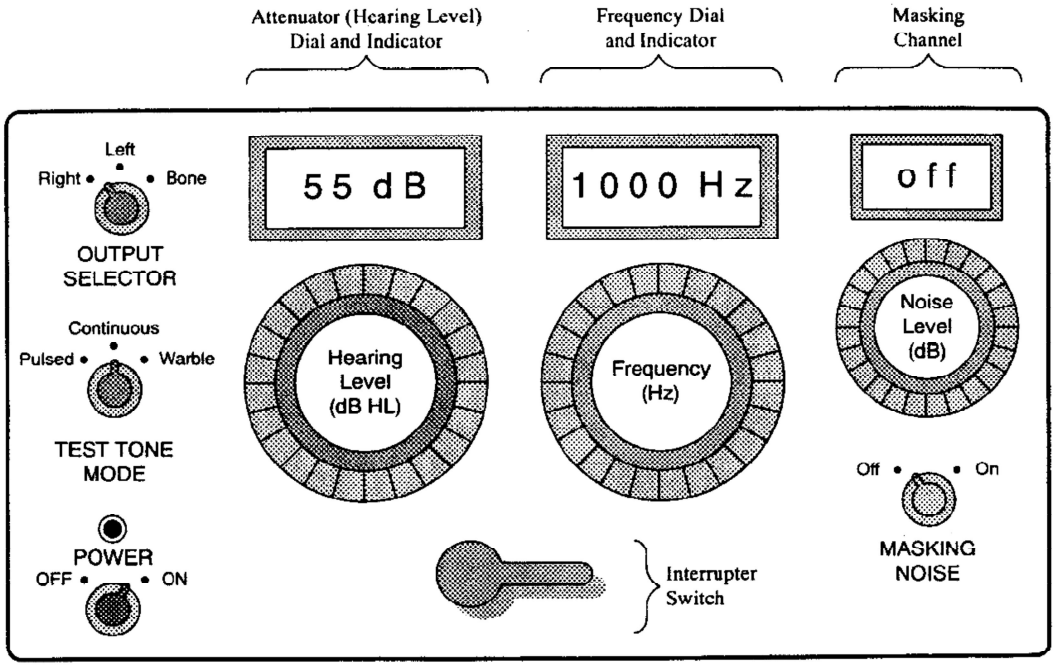


Fig 16: Parts of an Audiometer

1. Pure Tone Oscillator(Frequency dial)- it is the part of the electronic circuit located in the audiometer which generates pure tones at different frequencies like 250 Hz,500 Hz,1000 Hz,2000 Hz,4000 Hz,8000Hz. Some audiometers also provide option to test mid frequencies. It is represented as frequency dial/ switch with markings of various frequencies on the audiometer.
2. Attenuator/Attenuator Dial- This part of the circuit helps to control the sound pressure level or the intensity of the sound.The intensity can be changed in 5

dBsteps from -10dBHL to a maximum output level which varies with the test and frequency.

3. Interrupter Switch – this part of the circuit helps to present the signal to the patient. It is an on-off switch for puretone presentation. It also controls the duration of the signal presented to the patient.
4. Power Switch- This is used to switch the audiometer ON and OFF.A.C main supply of 220 volts or batteries can supply the power.
5. Transducer Selector - This part of the circuit helps to select the transducer through which the signal will be delivered. Transducers are the parts which convert electrical energy into sound energy or vibratory energy.For example Headphones are selected for air conduction testing.The BC vibrator is selected for bone conduction testing.
6. Router switch - this part of the circuit helps to direct the signal to desired location. For example right ear or left ear.
7. Signal Selector Switch-helps to decide the type of signal to be delivered. For example puretone, speech or noise.
8. Masking Dial/Switch: A part of this test makes use of noise to stop participation of a particular ear. The masking switch is used to present the masking noise in some audiometers.
9. V-U Meter- this helps to monitor the output level.
10. Microphone- is used to present speech through headphones or loudspeakers.
11. Patient Response Switch- Optional facility, given in patient's hand. He can press the switch to indicate his response upon hearing the sound, simultaneously a light glows on the audiometer for the tester to understand. Not recommended for young children as they can give false response.

2.5.3 Type of Audiometry

Sound Field Audiometry

Sound field audiometry is a test in which the test stimuli are delivered through a loudspeaker instead of earphones, is commonly used in the clinical evaluation of difficult

to test clients, such as infants, young children, and persons with developmental disabilities, as well as in the assessment of hearing aid benefit for adults and children. The loudspeakers are placed at anangle from the child in the test room,for example 45 °.The type of signal used can be pure tones, modulated tones (warble), noise or speech .The response of the child can be obtained by behavioural observation(BOA, VRA) or conditioned responses (free filed audiometry). An audiogram can be obtained across the audiometric test frequencies.

Fig 17: Sound Field Audiometry

Closed Field Audiometry

The audiometric results obtained in a sound treated room, under headphone condition. More accurate results (thresholds) can be obtained in this condition. Under headphones the thresholds can be obtained frequency wise and ear wise. The stimuli which can be used are pure tones, warble tones or speech. Moreover we can block the participation of either ear by using noise in a special procedure called masking. This yields the true thresholds of each ear.The stimulus can be presented using a variety of transducers names supraaural headphones,circumaural headphones, or insert earphones. Closed field audiometry is suitable for older children (more than 5 years) and adults, who can keep wearing the transducer during the test time.

Fig 18: Transducers for Closed Field Audiometry

Supra Aural HeadphoneCircum Aural Headphone

2.5.4 : Role of Special Educator in Conditioning for Pure Tone Audiometry

Special educators are one of the important team members in the identification and intervention of hearing loss. These professionals are included in the daily routine of a hearing impaired child. A child being conditioned for puretone audiometry, often takes days of practice before delivering the accurate response. Prior to that a regular conditioning practice needs to be carried out. The hearing impaired child spends most of his waking hours in school after being at home, therefore parents and special educators play an important role in conditioning the child for PTA. The concept of classical conditioning or operant conditioning can be implemented in the course of conditioning the child. The special educator can easily communicate with the child and make him/ her understand the whole process as the teacher shares a good rapport with the child. The teacher can make use of certain noisemakers, loud sound generating items to elicit the conditioned response in the child. He can plan to have a daily 15 minutes practice session during classroom hours. He can train the child to give conditioned responses, such as raising hand, keeping a peg etc upon hearing the sound. The teacher can initially

give the sounds with visual cues (in front), then without visual cues (from the back).This practice helps the audiologist to finally carry out the entire testing and get a reliable audiogram.

2.6 : Audiogram

The results of puretone audiometry, are plotted on a graph. This plotting is done at various frequencies and intensity level. The graph is called an audiogram.

2.6.1 Understanding of Audiogram

The figure shows a typical audiogram. The X-axis shows the frequencies and the Y-axis shows the intensity levels across which the testing is carried out. The thresholds are plotted at the junction of frequency and intensity. For example in the figure below, the threshold at 1K(1000 Hz) is 25 dBHL. Each vertical line represents frequency and each horizontal line represent the intensity level. The frequencies are expressed in Hz or KHz from 250 to 8000 Hz (left to right). The intensities are expressed in dBHL, from low to high (top to bottom),-10 dBHL to 120 dBHL. In a typical audiogram the air conduction threshold for both ears is plotted, the bone conduction threshold of better ear is plotted first followed by the other ear. If needed the masked AC and BC thresholds are plotted. A typical audiogram is plotted in figure 19.

Symbols: For plotting audiograms, specific symbols are used for air conduction and bone conduction threshold of each ear. These symbols are internationally standardised. Red colour is used for plotting of right ear and blue for left ear.The thresholds for air conduction are joined by a solid line, but the thresholds for bone conduction are joined by dotted lines. The symbols are shown in figure 20.

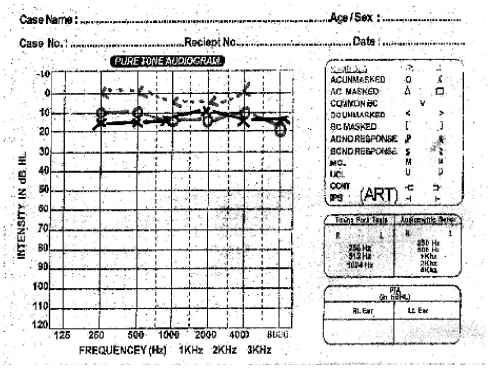


Fig 19: Typical Audiogram

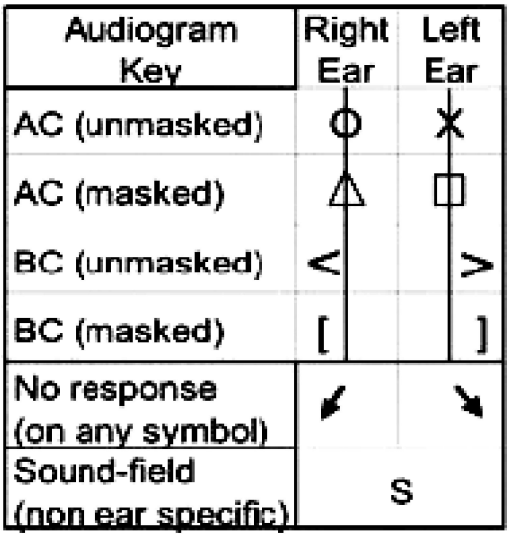


Fig 20: Symbols used on an audiogram

2.6.2 Audiogram Interpretation

Audiogram mainly provides information about type and degree of hearing loss. Also it provides separate information about each ear, which helps in diagnosis, as well as planning appropriate management.The PureTone Average (PTA) provides information about the degree of hearing loss and the difference between air conduction threshold and bone conduction threshold indicate the type of hearing loss.

Degree of hearing loss- for determining the degree of hearing loss (amount of impairment) the pure tone average is calculated. The pure tone threshold of each ear at three frequencies 500 Hz, 1000 Hz and 2000Hz, are summed and divided by three. For example the threshold at 500 Hz, 1000 Hz and 2000 Hz is 50, 60 and 40 dBHL. The PTA is calculated as follows:

$$\frac{50 + 60 + 40}{3} = \quad 150/3 = 50\text{dBHL}$$

The degree of hearing loss in the above example is moderate.

The degree of hearing loss in the above example is moderate.

Table 1 : PTA and Degree of hearing loss

PTA	Degree of Hearing Loss
-10 to 15 dB	Normal Hearing
16-25 dB	Minimal Hearing Loss
26-40 dB	Mild Hearing Loss
41-55 dB	Moderate Hearing Loss
56-70 dB	Moderately Servere Hearing Loss
71-90 dB	Severe Hearing Loss

Type of Hearing loss:

Hearing loss is categorized into different types, depending on what part of the auditory system is damaged. The three types of hearing loss are conductive, sensorineural and mixed hearing loss. For understanding the various types of hearing loss, we need to understand the normal hearing sensitivity.

Normal Hearing Sensitivity: When the thresholds for both AC and BC are within 15 dBHL, also the difference between AC and BC thresholds is less than or equal to 10 dBHL, we can interpret it as normal hearing sensitivity.

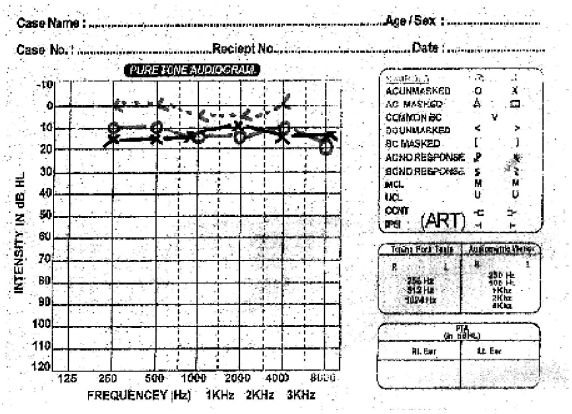


Fig 21: Audiogram showing normal Hearing

Conductive Hearing Loss- When the AC thresholds are abnormal (upto 70 dBHL), BC thresholds are within normal range creating an Air-bone gap (ABG), the audiogram gives an indication of conductive hearing loss. It can be seen for one ear or both ears. Both ears may show the same degree or different degrees. Any deficit or malfunction in external ear and/or middle ear causes a conductive hearing loss.

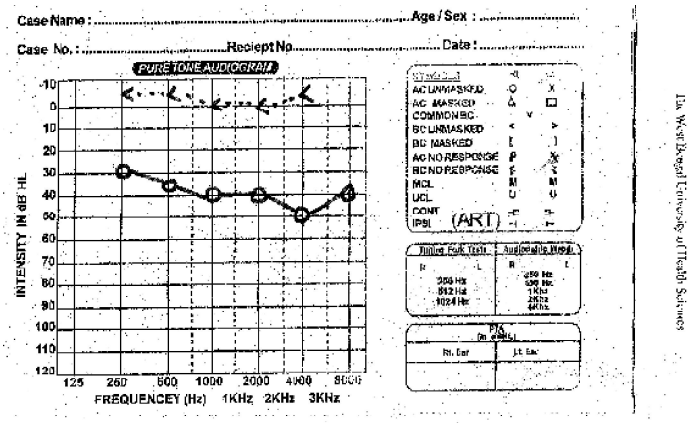


Fig 22: Audiogram showing conductive hearing loss in both ears.

Sensorineural Hearing loss- When both AC and BC thresholds are affected or abnormal, with ABG equal to or less than 10 dBHL, the audiogram indicates sensorineural hearing loss. The defects of inner ear or auditory nerve results in sensorineural hearing loss.

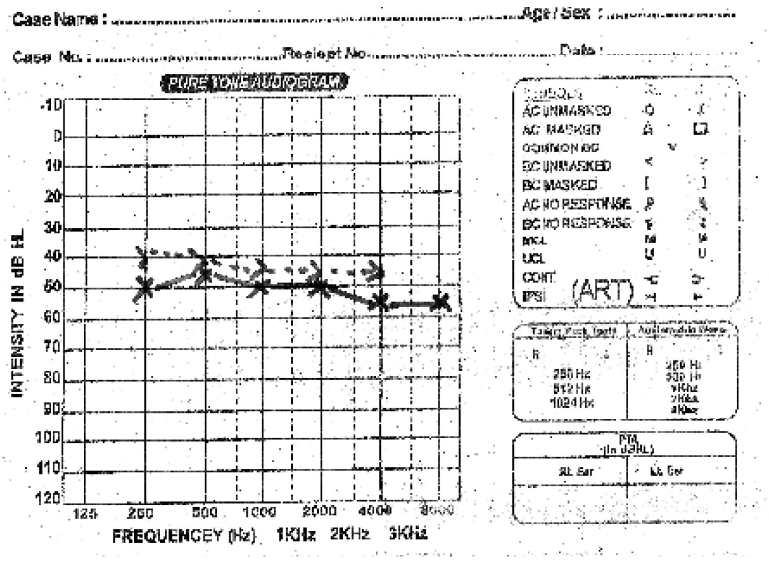


Fig 23: Audiogram showing sensorineural hearing loss

Mixed Hearing Loss – When both AC and BC thresholds are affected, the ABG is more than 10dBHL. The mixed hearing loss occurs when there is involvement of the outer ear and / or middle ear and the inner ear.

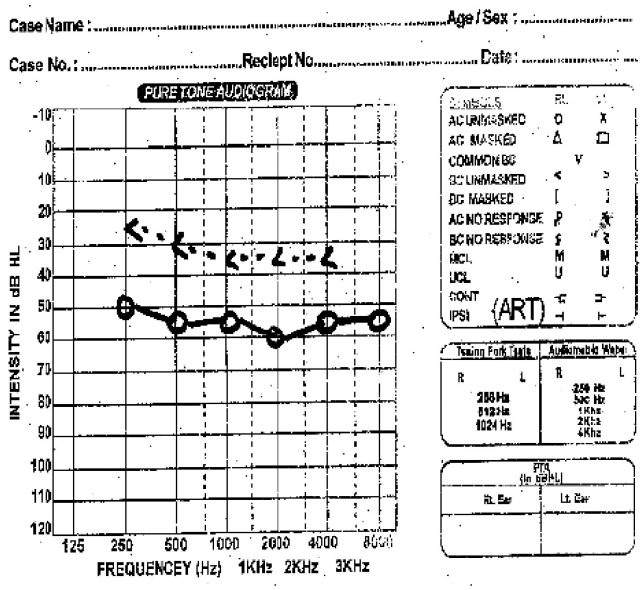


Fig 24:Audiogram Showing Mixed Hearing loss

Configuration of Audiogram

The shape or contour of the audiogram is called its configuration and can be understood from an audiogram. It suggest the underlying pathology. Depending upon the configuration, certain frequencies will be more affected than others. It helps to decide about amplification device and plan the rehabilitation work up. Also helps to predict benefit from amplification and various rehabilitation programs including educational management. Some configurations are as follows:

1. Flat Configuration; all frequencies are equally affected
2. Sloping Configuration: High frequencies are more affected than low frequencies
3. Rising Configuration: Low frequencies are more affected than high frequencies.

2.6. Audiogram Interpretation and Educational Implication

The degree, type and configuration of hearing loss helps to assess the educational needs of the hearing impaired child. The educational needs which can be assessed using

information from audiogram are as follows:

1. Deciding on the schooling option. Depending upon the degree and type of hearing loss selecting the type of school-
    a) Special School placement – this option is for children with more severe hearing loss(bilateral profound hearing loss).Moreover for children who had a late identification and hearing aid fitting with severe to profound hearing loss, special school placement is recommended.
    b) Mainstream school- Hearing impaired children with less severe hearing losses can be included in mainstream schools provided they had an early identification and intervention. It can be further decided depending on their degree and type of hearing loss about the type of mainstreaming to be done- regular school (minimal or mild hearing loss),integrated school, and inclusive school.
    c) Non-formal Education – national open school placement
    d) Some children need special school in early years and then they can move on to mainstream school.(mild to severe degree)
    e) Some children may need special school after primary education.
    f) Some children may need specialized individualized input along with enrolment in mainstream school.
    g) Some children may benefit from mainstream schools and yet require specialized academic support for social studies, science or languages or literacy.(moderate to profound sensorineural hearing loss)
    h) Some children may need some classroom amplification and some may need sign language interpretation in the class.(severe to profound sensorineural/ mixed hearing loss)
    i) Some may need certain concessions and exemptions and the others may not need them.
2. Deciding on the curriculum- Some children may follow the standard educational hierarchy, but some might need a flexible curriculum. For example children with more severe sensorineural hearing loss, might need a flexible curriculum, they often find language and literature subjects difficult as these need more proficiency in speech and language skills.

3. Deciding on the type of evaluation of performance to be administered. For example, conducting written exams over oral exams, using a grading system instead of any examination etc.
4. Deciding about classroom needs- The most important place where the child spends quality time for acquiring education is the classroom. Classrooms for hearing impaired children should be designed and equipped according to their hearing needs.
    a) Seating Arrangement- For instance children with severe to profound sensorineural hearing loss and limited benefit from hearing aids may need preferential seating in the classroom, front seat, close to teacher.Children with milder losses,conductive type may not need this seating arrangement.
    b) Classroom Acoustics- Children with more severe losses and sensorineural type are affected by noise and reverberation. The classroom must be designed to keep them noise and reverberation free.
    c) Installation of classroom amplification devices – All children with hearing impairment benefit from assistive listening devices installed in classrooms. However children with severe to profound hearing loss benefit the most from these devices.For example, FMsystems, loop induction systems.Children with unaidable hearing loss might need installation of alerting devices,such as flash lights to indicate end of period.
5. Deciding on teacher-student ratio – Children with more severe loss need more individualised support. So a lesser ratio is preferred for more severe hearing losses.
6. Deciding upon the communication strategy to be used – unisensory vs multisensory approach. Children with more severe loss will need multisensory approach for teaching, for example use of visual and tactile clues.
7. Deciding upon medium of instruction and communication to the child.
8. Help to design appropriate teaching aids that will excel the child's learning in classroom.
9. Assess the child's hearing every day, with or without hearing aid in the classroom. This can be done by using simple tools like conversation, using Ling Six sound Test.
10. Plan an educational management strategy depending upon the degree, type and configuration of hearing loss.

2.7 Concept of Unaided, Aided Audiograms, Speech Spectrum and its applications

2.7.1 Unaided Vs Aided Audiogram

Audiogram obtained in unaided condition (without amplification device) and in aided condition (with amplification device) is compared to know the actual benefit from amplification. This procedure helps to determine the functional gain. In both the conditions, conditioned (VRA OR PTA) or behavioural responses (BOA) are obtained in sound field environment. The stimulus can be modulated tones (warble), narrow band noise, pure tones.The stimuli are presented via loudspeakers in both unaided and aided conditions. The minimum response level of the child are noted on the same audiogram, to compare the difference in both conditions. The amplification device (e.g hearing aid) is adjusted according to child's hearing thresholds. More recently speech stimuli is used. (Speech perception tests) or real ear measurements are carried out to get more appropriate responses. However measurement of functional gain is still practiced as a routine clinical test. The functional gain can also be estimated by using the results of aided ASSR.

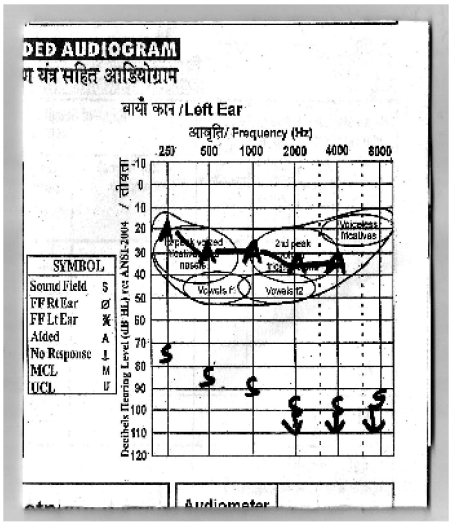


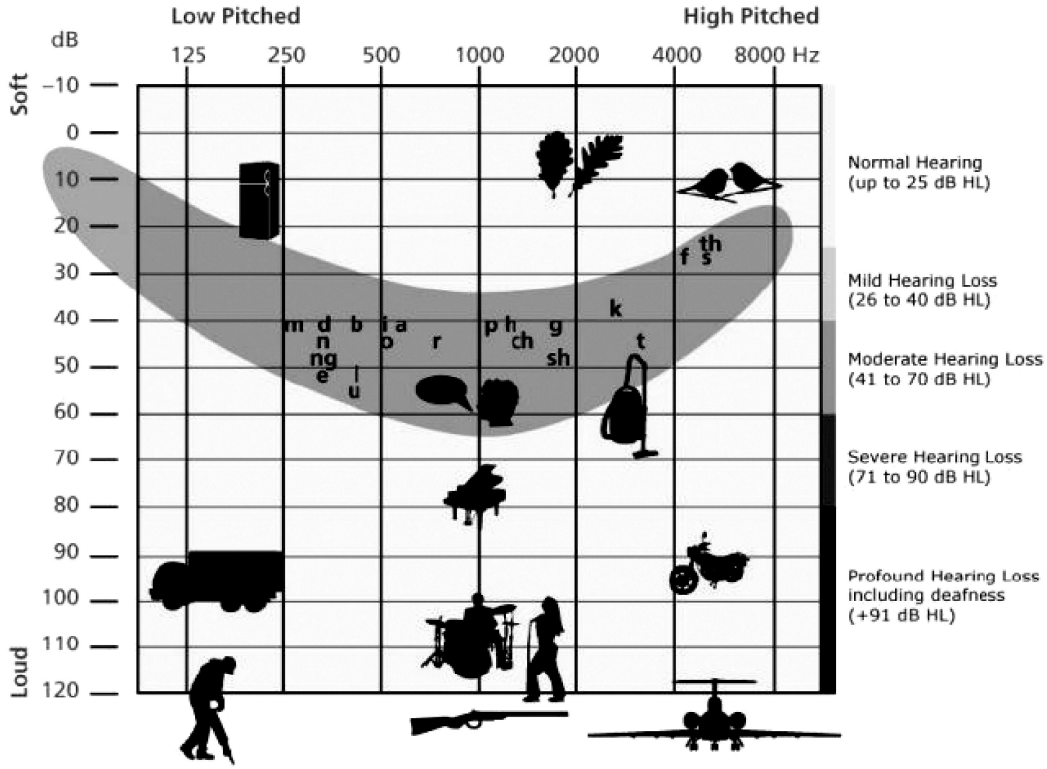
Fig 25: Aided(A) and Unaided (S) responses

Clinical Implication

1. Measurement of functional gain is a very useful tool for young children and infants.

2. Measurement of functional gain is very important and useful for children with associated problems.
3. It gives us an idea about the actual benefit from the amplification device.
4. It suggests about the modification to be made in the current aided hearing, or the device setting.
5. Depending upon the results of functional gain measurements comparison between two hearing aid settings or two different devices can be done. As a result the most appropriate device can be chosen for the child.
6. It is a very effective counselling tool, to explain the parents about hearing aid benefit.
7. Functional gain measurements can be used to select between communication strategies to be used with the child(verbal vs non verbal)
8. The results of functional gain measurement can be used to predict progress in speech language skills and educational skills.

2.7.2 Concept of Speech Spectrum



The speech spectrum also called the speech banana is a representation of different speech sounds on the audiogram depending on their frequency and intensity at typical conversation levels. Most speech sounds are within the 250 to 4000Hz range, with a few high frequency sounds between 4000Hz and 6000Hz.

A plotting of the child's thresholds at each frequency on the speech banana will show the speech sounds which the child is able to hear. Any sound which is below the level of the child's threshold will be heard, and anything above this threshold line will not be heard. A child with a mild loss may not hear f, v and z in the low frequencies and f, s and th in the high frequencies. Thus, children with mild losses develop speech and respond to sounds, and the hearing loss is identified at a later age. These children will often have difficulties with pronunciation of words, depending on the sounds they are unable to hear. Difficulty will be experienced in noisy environments such as the classroom.

A moderate loss will result in missing out on number of consonants in the speech banana, depending on the shape of the loss, while a severe (and greater) loss will result in all speech sounds being missed. However, environmental sounds (like the piano, dog barking, and heavy machinery) will be heard. These children will respond to sound but, without amplification, will not hear sounds clearly.

With amplification the threshold at which sounds are heard will be improved and thus speech sounds will be heard clearly.

2.7.3 Clinical Applications of Speech Spectrum

1. One use of the speech banana is to help visually understand what sounds are not audible. It is an excellent counselling tools for parents to understand why their child seems to hear certain sounds or words but not others. In some cases, audiologists will do aided testing to show what sounds within the speech banana can be heard when using a hearing aid or cochlear implant. When the child's unaided and aided audiogram are plotted on the speech spectrum, it helps us to understand the child's hearing status (environmental and speech sounds). This further helps us to select amplification device, and plan rehabilitation program.
2. For children who are already wearing amplification device, the aided response can be plotted on the speech spectrum, and depending upon the response, the hearing aid can be readjusted, if required.

2.8 Let us sum up

1. Sound is the basic acoustic unit perceived by human ear. It has certain parameters which can be expressed in different units.
2. The auditory development in humans starts before birth and attains almost adult like hearing by 2 years of age.
3. The hearing capacity can be assessed using a variety of tests. These tests can be either objective or subjective depending upon the participation of the child. Usually a test battery approach is used for correct diagnosis of hearing loss.
4. The basic instrument used for testing is an audiometer. The audiometer is capable of generating certain sound signals e.g pure tones, speech etc. The signal generated is presented to the child via transducers like headphone, loudspeaker etc. The selection of transducer depends upon the test to be done.
5. The ultimate goal of assessment is obtaining threshold of hearing with the help of puretone audiometry.
6. The results of pure tone audiometry are plotted on an audiogram. The results can be plotted ear wise. The interpretation of audiogram helps us to understand the probable site of deficit/damage. It also gives information about degree of hearing loss.It helps to plan the rehabilitation process including educational aspect.
7. According to standardised classification the hearing loss might range from minimal to profound degree in either ear or both ears. There can be asymmetric hearing loss in each ear.
8. The hearing loss can be conductive,sensorineural or mixed depending upon the site of deficit/damage.
9. Aided vs unaided audiogram gives us an idea about the child's hearing with and without hearing aid. Also helps to plan the rehabilitation process.
10. Aided and unaided audiogram are plotted on the speech spectrum, which is a representation of all the speech sounds used by humans, depicting their frequencies and intensities. Plotting the aided and unaided audiogram on the speech spectrum gives an idea about the sounds the child can hear with and without hearing aid.

2.9 ‘‘Check your Progress’’

1. What are the physical attributes of sound?

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2. By which age the child starts localising the sound source?

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3. What are the subjective tests of hearing? Briefly describe the procedure for conditioning a child with hearing loss.

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4. What is an audiometer? Name its parts.

   .....

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   .....

5. A child’s Air Conduction threshold are as follows. What is the degree of hearing loss?

   .....

   .....

   .....

250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
85 Db	90 dB	100 dB	120dB	120dB	85dBNR

6. What information you can get from a child's aided audiogram? What is a speech spectrum?

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2.10 References

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