IMPEDANCE AUDIOMETRY IN CHILDREN

A- REVIEW

AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT FOR FIRST M.Sc., (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE-570006.

MAY 1988

To

My teacher

Dr.M.N.VYASAMURTHY

CERTIFICATE

This is to certify that independet project entitiled: "Impedence Audiometry in Children - A Review" is the bonafide work on part fulfillment for the Degree of Master of Science (Speech and Hearing) of the student with Register No.8707.

Dr.N. Rathna,
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CERTIFICATE

This is to certify that the Independent Project entitled: "Impedance Audiometry in Children - A Review" has been prepared under my superivison and guidance.

Dr. M. N. Vyasamurthy
GUIDE.

DECLARATION

I hearby declare that the Independent Project entitled: "impedance Audiometry in Children - A Review" is the result of my own Study under the guidance of Dr. M.N.vyasamurthy, Depatemnt of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degreee.

Mysore.

May 1988. Register.No.8707

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INTRODUCTION

The middle ear is imposed between the source of the signal and the cochlea. Therefore the conduction of the middle ear has a major influence on the flow of energy to the cochlea that is the input to the cochlea. Any pathology affecting the middle ear structures will impede the conduction of the sound to the inner ear and this might adversely affect the development of the child.

Many studies have reported of the affect of middle ear pathology on several aspect of child's development (Holm and Kunze, 1969; Libby 1974; and Rock, 1974; Schwartz and Redfield, 1975 and Ling, 1972).

The middle ear pathology resulting in minimal or fluctuating loss has been reported to impede speech and language (Holm and Kunze, 1969; Schwartz and Redfield, 1975).

As delay in the development of language skills requiring the reception or processing of auditory stimuli or the production of verbal responses has bean reported by (Holm and Kunze, 1969; Schwartz and Redfield, 1975) have reported of lower scores on vocabulary and reading teats in children with, mild conductive loss compared to the normal hearing

Children (Hemilton, 1973) has also reporting of findings similar to that of Schwartz and Redfirled, 1975).

Ling (1972) and Glase (1982) has reported of a causal relationship between otitis media and educational retardation. A mean loss of 25dB in children of age 9 to 10 years was observed to results in retardation in the areas of problem arithmetic, mechanical arithmetic and mechanical reading. Libby and Rock (1974) have also reported of educational handicap in Children with middle ear pathology.

The middle ear dysfunction has also been observed to deprive a child of proper sleep and thereby resulting in impairment in the ability to live and learn in one's environment (Sittor, Koze, Leskey (1976).

Medical complication following an unidentified and untrated middle ear pathology has been reported (Sitter, Koze, Leskey and Woodford, (l976); Dermody, Mackle (1983).

The types of complication which can result from a middle ear disease are permanent SN loss (English, Northern and Fria, 1973), mastoiditis, meningitis and other intracranial Complications (Sitter, Koza Leskey and woodford (1976); Bluestone (1977).

Thus all above studies, point to the importance of an early accurate identification and assessment of middle ear disease in children. The traditional method of identification of middle ear disease in children has been through 'otoscopy'. But the Otoscopic examination has certain limitations. In very young children one often faces difficulty in conducting adequate otoscopy examination. Another limitation is that all the pathologies are not revealed by otoscopic examination. So there is a necessity for a more refined method for accurate identification of middle ear pathology. This leds to the use of impedance audiometry for a diagnosis of middle ear pathology.

Hopkinson (1979) he compared the effectiveness of otoscopic and audiological screening in preschool children and found out that the impedance measurement are more efficient then other aspects of middle ear measurement or of pare tone screening. Renvall (1979), be says that pure tone has hitherto been employed as a sole means of identifying ear pathology. During the last decade it has been demon-started that even hearing which is normal according to pure-tone audiometry screening (20dB) can be associated with middle ear pathology. so if we use the combination of tympanometry and puretone, the number of false-positive is minimized.

Impedance admittance measurements aid in the assessment useful in evaluating the middle ear function in detecting middle ear diseases (Berry, Blustone and Cantekin, Brooks, 1977) and also in a rough estimation of a child's nearing sensitivity (Jerger et al l974a). Impedamee measurements have an advantage of being independent of the subject's willingness and ability to give voluntary response.

Keith (1973 and 1974) reported that impedance measures are adequate to test neonates individually, though they may not serve the purpose of mass screening programmes. Jerger et al (1974) also reported that impedance measurement could be used to validate the air-bone gap observed in pure tone audiogram. Measurement of impedance also aid in detecting those cases with fluctuating hearing loss who might show normal hearing on pure tone audiometry (Jerger, et al 1974).

In addition to their diagnostic utility, impedance are also useful in preschool screening programmes. (Fiellau-Nikolajzen et al (1977) (1979) and in school screening (Brooks, 1971, 1973, 1974, 19707, 1978; Cooper et al. 1975; Orchik and Heardman, 1974; Orchik, Morff and Dunn 1978). Evaluation of eustachian tube function in children could also be done with ease by making impedance admittance measurements (Bluestone, Berry and Cantekin, 1973; Berry, Bluestone and Cantein, 1973).

Ichimura (1980), in young children if only one method is available, impedance testing should be preferred for the following reasons.

1. It requires less time to complete measurement.

2. It is not greatly influenced by either environmental or motivational factors.

3. It is quiet effective in accurate identification of middle ear problem.

4. It is less affected by test techniques. Since, the impedance audiometry has many advantages when compare to other otological and audiological measurements. This impedance measurement should be an essential part of audiological evaluation, of children.

Another important application of impedance test battery with children is in testing the 'difficult-to test' population (Burns, Cram and Rogus 1973; Fulton and Lamb, 1972; Lamb and Norris,1970; Muller and Geier, 1976) like mentally retarded, developmentally delayed, deaf-blind, children with cerebral palsy and also impedance audiometry is useful in testing high incidence groups like children with cleft lip and palate, with Down's syndrome, with cranifacial/ skeletal disorders, profoundly deaf children.

It is thus clear that impedance measures are useful in different ways in identifying and testing hearing disorders in children.

CLINICAL MEASUREMENT PROCEDURES IN IMPEDANCE AUDIOMETRY

1. Preparing the patient.
2. Tympanometry
3. Static compliance.
4. Acoustic reflex threshold.

CLINICAL MEASUREMENTS PROCEDURES IN IMPEDANCE AUDIOMETRY

Impedance simply is a measure of the acceptance or rajection of energy per unit time. A mechanical system with high impedance accepts energy readily than a mechanical system with low impedance.

The operational principles underlying the electro-acoustic impedance audiometer are relatively simple and the technical manipualtions of the test procdures are also not particularly complex.

The impedance test battery consists of tympanometry, static compalince, acoustic relfex tests and the physical volume test. Although each of these tests provides some information about the function and integrity of the auditory mechanism (Alberti and Kristensen, 1970), the technique becomes much more meaningful when relationship among the four procedures are considered, when they are considered in combination, the battery yields patterns of great diagnostic vlaue. Diagnositc judgment and patient referral are made with great authority anad assurance when the overalll pattern in considered. Jerger (1970) indicates that tympano-metry alone is useful to only a limited degree, static compliance norms are too variable for accurate diagnosis, and the absence of the acoustuic reflex may occur from serveral factors. When considered together, however, the limitations of each test are reduced while their combined implications are enchanced.

1. Preparing the patient:

The main limitations of impedance measurements in young children is that the test battery cannot be completed while the young child is vocalizing, speaking, crying, yelling or any combinations. Stapedial muscle reflex contraction and eustachian tube changes during vocalization cause the complaince of the tympanic membrane to change rapidly, thereby making impedance measurements impossible. The clinician's most challenging task is to make the youngster stop vocalizing for just the necessary few moments to obtain impedance data.

Each clinican must divise his or her on techniques for momentarily districting the screaming child. Impedance skill with children requireds the highest competency in main-pulating both the equipment and the child.0

For children less than 3 years of ago it is also helpful and essential that a second or even third person be utilized for impedance measures. One person operate the impedance instrument while a second stabilizes the child's head and inserts the probe tip. This second person must be appraised at all times as to whether or not a seal has been obtained so the pressure manometer must be in a position to be observed directly by him.

The age range between two months and twelve months presents one of the most difficult periods in which to obtain impedance tests. The children are not old engouh to understand the test or to respond to verbal enticements. So it is more effective to employ a distractic technique to redirect the youngster's attention from the test. The external stimuli can be visual, tactile, auditory or any Combination of the three. Before assuming a distractive procedure to be essetnial in impedance testing, one should first try to place the probe tip quickly, but gently in the ear. Frequently, this takes the child by surprise, and further games are not necessary. Often the entire impedance battery can be completed before the child really has time to react or respond.

For most children older than 3 years of age no special distraction is required when applying impedance measures, most 3 year olds can be tested with a single examiner. Allow-ing the child to observe other children or adults being tested help to remove any fears that a pain will occur.

When necessary, one can reduce anxiety by saying simply "we are going to test your hearing, please hold still" or toher uncomplicated statemnts of reassurance. Di-stractive techniques are viewed with suspicion, so treat this age category essentially as you would adults except for mild and occational words of instruction or envourage-ment. On occasion it may be necessary to consider the use of sedation to quiet a noncooperative youngster for acoustic impedance evaluations. Clinician must be aware, however, that a child's reaction to such medication is not always as expected, Children vary considerably in thier response sensitivity to sedatives, and the recommended dosages may not be sufficient to induce the desired effect. Especially, in difficult-to-test children, it may be necessary to consider the use of sedation to queit a non-cooperative youngster for acustic impedance evaulation.

It is routinely necessary to fit a protective cuff onto the tipe of the probe tip. This cuff is used to provide an airtight seal of the probe tip in the patients ear canal. Because ear canal come in different of shapes and sizes. cuffs of different sizes and shapes must be avilable.
Obtaining the airtight seal of the probe tip in the patient's ear canal often poses the most serious problem

to the novice in the performance of impedance audiometry.

It is usually quicker to select the largest size cuff and work towards small sizes than to begin with the small cuffs. The pinna is raised and pulled posteriorly. This will expose and straighten the ear canal slight rotation of the probe and cuff helps to slip the tip into the canal comfortably. When the probe and cuff are settled securely in the ear canal, the pinna is released and the canal is allowed to collapse around the probe cuff. To check the airtight seal, can be done by increasing the air pressure in the external canal to plus 200mm H_2o, While the clinician observes the air pressure meter to see if the positive air pressure can be maintained.

The impedance audiometry test battery includes tympanometry, static compliance, and acoustic reflex threshold measurements. Their diagnostic capabilities are strengthened when the results from all three procedures are considered together.

Impedance audiometry applications:

1. Tympanometry - (1) Tympanic membrane mobility

   (2) Hiddle ear pressure measurement

   (3) Perforation of the tympanic membrane cam be identified.

   (4) Estimation of static compliance.

   (5) Eustachian tube function.

2. Static compliance - Differentiates middle ear fixation from disarticulation.
3. Acoustic reflex thresholds –
   (1) Measures of loudness recruitment.
   (2) Validates nonorganic hearing loss.
   (3) Validates conductive hearing loss.
   (4) Differential diagnosis of conductive hearing loss.
   (5) Inference of hearing sensitivity.

2. Tymanometry:

Tympanometry is the measurement of eardrum compliance change as air pressure is varied in the external canal. Middle ear pressure and eustachian tube function ca be found out by using impedance bridge.

When the sound wave strike the tympanic membrane, some energy is reflected back, identical in frequency to the probe tone frequency but differing in phase and amplitude. The amount of difference in phase and amplitude between the probe frequency and the reflected wave depends upon the impedance characteristics of the tympanic membrane and the middle ear system.

The point of maximum compliance occurs when the pressure in the middle ear is balanced by the introduced pressure in the closed external ear cavity. Thus tympanometry provides an indirect measure of existing middle ear pressure by identifying the air pressure in the external canal at which ear drum shows a peak of maximum compliance.

The mechanical aspect of tympanometry begins by pushing or 'clampling' the tympanic membrane into position of poor compliance with and pressure equal to plus 200mm H_2o. At this point the stiffened ear drum reflects most of the probe tone energy, creating a high SPL measurement at the probe pick-up microphone. Air pressure is then reduced in the ear canal cavity. Permitting the compliance of the tympanic membrane to increase; the impedance meter mow measures a decrease in reflecting SPL. The lowest SPL is achieved at the maximum compliance of the tympanic membrane, and as negative air pressure are created in the external auditory canal, compliance decreases and is noted by am increase in the SPL meter, Actually tympanograms is a graphic record-ing of changes in SPL in the external ear as air pressure is varied by the clinician.

By displaying the tympanograms in terms of the relative change in compliance from a standard arbitrary reference compliance at plus 200 mm H_2o the amplitude of the tympanograms is independent of the size of the ear canal. In this way a 'standard range' of normal tympanograms is available for most impedance meters independent of patients age and individual vaiance in anatomy. Utilization of that tympanogram 'norms' pattern is an important guide for clinical interpretation.

3. Static Compliance (CS):

Static compliance is also a measure of middle ear mobility. The factors of compliance include mass, friction, and stiffness, which work together in a complex manner to facilitate or impede motion of the middle ear system.

Static compliance is measured in terms of equivalent volume based on two volume measurement.

The firs volume measure (C_1) is made with the tympanic membrane clamped in a position of poor compliance with + 200 mm H_2o air pressure in the external ear canal. The second volume measurement (c_2) is made with the tympanic membrane at the maximum compliance pressure. Since sound is more easily trans-mitted by the tympanic membrane during the second volume measurement (c_2). The probe sound pressure in the enclosed cavity of the external canal is lower than noted in the first volume measurement (c_1) and a larger 'equivalent volume'.

The static compliance measure is contaminated by the compliance of the air in the external canal itself.

Static compliance is calculated by subtracting C_1 from c_2, which cancels out the compliance due to the volume of air in the external ear canal. The reminder is the compliance due to the middle ear mechanism. Thus C_2-C_1 equals the static compliance of the middle ear in units of equivalent air volume in cubi centimeter.

Middle ear compliance is influenced by many variables including patients age, sex and pathological state.

Physical volume test:

The electroacoustic impedance meters rely on the physical principle that the intensity of a sound trapped in a closed cavity is a direct function of the cavity size. Thus, a signal of fixed intensity of a sound introduced into a large cavity and into a small cavity will produce two different sound pressure levels in the cavities. The large cavity will have a lower sound pressure level while a higher sound pressure levels in the two cavities. The large cavity will have a lower sound pressure level while a higher sound pressure level will be measured in the smaller cavity. In the presence of an intact eardrum, the typical enclosed ear canal cavity between the probe top and the tympanic membrane should be 1.0 to 1.4 cc in an adult or 0.8 to 1.0cc in a child. In infants the PVT value may be as small a 0.5 cc value may very depending on how far the probe tipe cuff is inserted into the ear canal or low large or small the diameter of the external canal might be

When the physical volume size is considerably grater than these norms. The clinician can assume that the cavity includes the external canal, middle ear space, and possibly even the mastoid air cells and entrance to the eustachian tube orifice. PVT is used to rule out the non-observable perforation. Knowledge of the physical volume helps to clarify the itiology responsible for B-type tympanogram, Non-mobile tympanic membranes with volumes larger than 2.0cc in children are usually indicative of a perforation or patent ventilation tube; B-type tympanograms with normal volume measurement are indicative of a non-mobile intact tympanic membrane; abnormally small physical volume may be related to cerumen occluding the external canal or probe tip or perhaps the probe tip is pressed against the canl wall.

4. Acoustic reflex threshold:

The stapedial muscle contracts reflexively when the ear is stimulated with an efficiently loud sound. This contraction occurs bilaterally, even when only one ear is stimulated. The electroacoustic impedance technique measures the sudden change in sound pressure caused by decrease in compliance of the middle ear system as the muscle contract. The acoustic signal is introduced through an earphone attached to the impedance audiometer headset. If the signal to the earphone ear is sufficiently loud to elicit the bilateral acoustic reflex, the contraction of the stapedius muscle in the ear containing the probe tip will suddenly decrease the compliance of that eardrum (creating a sudden increase in the cavity sound pressure levels synchronously with the presentation of the stimulating earphone signal. The contralateral technique of eliciting the acoustic reflex is recorded as the acoustic reflex threshold for the stimulated ear.

Measurement:

1) Insert the probe in subjects ear with suitable ear tip.

2) Get the air pressure at middle ear pressure.

3) Get the sensitivity knob to ‘3’ position.

4) Adjust the compliance control knob until BM needle shows zero.

5) Present the audiometer stimulus through ear phones and find out the minimal intensity of the stimulus which produces a noticeable deflection of the BM needle. This intensity of stimulus is the acoustic reflex threshold.

PRACTICAL PEDIATRIC IMPEDANCE CONSIDERATION

1) Meaning of impedance while testing children

2) Sedation.

PRACTICAL PEDIATRIC IMPEDANCE CONSIDERATIONS

Many clinician have little difficulty testing a cooperative adults. But the real problem occurs when the clinician is fact-to face with screaming, uncooperative children. The main requisite for impedance clinicians faced with a screening child is confidence. Persistence has its reward when working children and impedance. So we should not give up easily if difficulty is encountered.

On occasion, the clinician must be willing to compromise the entire test battery for less than optimal information. While it is desirable to complete the impedance test battery whenever possible, with some difficult to manage children the clinician may have to settle for a quick tympanogram and a single acoustic reflex measurement in each ear. Clinician must be prepared to work rapidly and efficiently.

1. Managing of impedance while testing children:

The main limitations of impedance measurement in young children is that the test battery cannot be completed while the young child is vocalizing, speaking, crying, yelling. Stapedial muscle reflex contraction and eastachian tube changes during vocalizations, causes the compliance of the tympanic membrane to alter widely, thereby making impedance measurements impossible. The most difficulty and challenging task is to make the youngster stop vocalizing to obtain impedance data. Every clinician can devise his own techniques to momentarily distract the screaming child. The impedance audiometry with children requires the competency in both manipulating the equipment and the child.

Northern (1977) had given number of practical suggestions pertinent to impedance measurements in children. Though these techniques are useful in children under 2 years of age, they have also found it useful with difficult to test children.

For children less than 3 years, a second or a third person be utilized for obtained impedance measures. It is difficult for one person to manipulate the ear insert while at the same time operate the pressure pump and other dials of the impedance devices.

It is preferable to have one person to operate the instrument at the same time the second stabilizes the child’s head and inserts the probe tip. The second person must whether or not a seal has been obtained or the pressure manometer must be in a position to be observed directly by him. Sometime it works well to hold the probe tip in place by hand after insertion and the head stabilized by the assistant during the entirely of the test to prevent a loss of pressure seal due to head movement. In young children it is helpful to have a parent cradle the child with their arm passively immobilizing him, then place the head band over the parent’s shoulder and insert the ear phone into the child’s ear while holding the head phone on the contralateral ear.

The age range between 2 month and 12 months presents one of the most difficult period in which to obtain impedance tests. It is very important to employ a distractive technique to redirect the youngster’s attention from the test. The districting stimuli can be visual, tactile, auditory or in combination. the form of distracting is relatively unimportant so long as it as sufficiently novel to compel the infant to disregard the insertion of the probe tip. The distractive tactics are most effective if the headset is not used. Instead, rely on as assistant to insert the probe tip while holding the headpiece over the wrist or over the mother’s shoulder with the child in the parent’s lap. When using visual distraction keep the diversionary object well within the child’s field of vision to prevent undue head movement which produces artifacts.

Here are examples of many possible distractive techniques which can be used while testing the children under the age of 3 years. Give by McCandless (1973).

Pendulums:

Make a pendulum with about 18 inches staring. The examiner will swing the pendulum in various motions within various areas of the infants vision. Frequently stiping or altering the swinging motion can provide novelty to the pendular action.

Watch:

Simply remove one’s wrist watch, manipulated or with it well out of reach of the child or point to it.

Mirror:

Infant less than one year who is capable of reacting and attending to faces a large mirror is sometime irresistible, at least for a period sufficiently long to place a probe tip and to perform the impedance test battery.

Show:

Lacing and unlacing a child’s shoe either on or off his foot. This should be carefully timed to coincide with the insertion of the test tip into the ear.

Action toys:

These are not best distractive technique because children 1 year and older often wish to handle or manipulated this type of toys.

Toys which produce sounds:

Toys or other device which elicit intense sounds should be avoided if at all possible, since they may evoked an acoustic or other reflective responses from the child. Toys which produced softer sounds in no way interfere with the test and therefore be used.

Food:

Children seem to enjoy sweets and although swallowing and sucking movements are notorious for producing artifacts in the tympanogram and reflex measures food can still be used as distractive technique.

Miscellaneous devices:

Tongue blades, cotton swabs, colored yarn or similar devices are all effective as distractive devices. They are best utilized when manipulated or ‘played with’ by the examiner. If the child insists he can be allowed to manipulate tape or string etc. But care must be taken to permit only passive action so as to reduce movement artifacts while the test is proceeding.

In many instances the children between 1 and 3 years of age, they are most concerned whether or not the procedure will be painful. For these reason, there are some general rules, firstly, never ask a child for permission to perform impedance tests, secondly, avoid undue explanation regarding the test procedures. Instructions do not contribute nothing to the test results, even if you give child may not understand. Unless it is to reduce the physical movement, it should be given. It is very sufficient to say something like ‘listen to this radio’, ‘hold still’. Then proceed with the test. For most children older than 3 years of age, no special distraction is required and most of them can be tested by a single examiner. Allowing the child to observe other children or adults being tested helps to allay the fear.

2. Sedation:

Any drug that alters central nervous system responses may have a dilatory or inhibitive effect on the acoustic reflex. Infants and small children are not always able to cooperate in impedance audiometry measurements. So sometimes it may be necessary to consider the use of sedation to quiet a non-cooperative youngster for impedance evaluation. The first report on stapedial reflex and general anesthesia was published by Minketal (1981) under the effect of Tiobutabarbital, Propanidid and Diazepam. There is no reflex response. Acoustic reflex can be elicited with ketanin hydrochlorid and alphaxalone – alpha dolone acetate narcosis. The reflex threshold remains unchanged and the amplitude of the muscle contraction is somewhat increased.

Chloral hydrate and secobarbital are often used because of ease of administration and general effectiveness. Drousiness, quieting and sometimes deep sleep are achieved with in an hour. The main disadvantage of these drugs are long-acting sedations. Acoustic reflexes can be observed in patients sedated with these drugs but researches have shown the acoustic reflex thresholds to be elevated.

The clinician should be aware that children vary considerably in their response sensitivity to sedatives and the recommended dosage may not be sufficient to induce the desired effect.

Impedance evaluation under condition of general anesthesia is not always successful. Many a time results are influenced by the drug agents. Thomsen et al (1965); and Drake (1981) middle ear pressure is increased under inhalation of gases like nitrous oxide. Theory decreasing the compliance of the tympanic membrane and observing the acoustic reflex.

Richards and colleagues (1975) the absence of acoustic reflex may be drug related. He evaluated impedance findings under general anesthesia in ten functionally retarded, normal hearing children on phenobaribital. They reported that low level amounts of Phenobarbital have no effect on the acoustic reflex threshold.

Mitchell and Richards (1976) reported about the effect of various anesthetic agents on normals and decreased middle ears. Thirty patents were intubated with one of six anesthetics while undergoing various surgical procedures. Results indicate that pre-anesthetic medications had no effect on middle ear muscle threshold. The acoustic reflexes, however, followed the same pattern demonstrated by other observable reflexes, such as deep tendon and papillary reflexes, though the various anesthesia states. Acoustic reflex thresholds were elevated 20 to 25 dB at 1000Hz during plane I by the plane III anesthesia maintenance was reached. The middle ear reflexes were completely abolished.

TYMPNOMETRY IN CHILDREN

1. Tympanometry in neonates and infants.
2. Tympanometry in children.
3. Interpretation of the tympanograms.
   - (i) Amplitude
   - (ii) pressure peak
   - (iii) Shape.
4. Classification of tympanograms.
5. Factors affecting tympanometric results.
6. Tympanometry in diagnosis of auditory pathology.
   - (i) Otitis media
   - (ii) Perforation of Tympanic membrane
   - (iii) Tests for eustachian tube function.

TYMPANOMETRY IN CHILDREN

Tympanometry is an objective technique for measuring the compliance or mobility of the tympanic membrane as a function of mechanically varied air pressures I the external auditory canal (Northern and Downs, 1974). The compliance of the tympanic membrane at specific air pressures in plotted on a graph is known as tympanogram. A tympanograms provides information about the pressure status of the middle ear, the integrity and mobility of the ear drum, the integrity of the ossicular chain and the resonant point of the middle ear.

This an interpretation of the tympanograms includes the analysis of (a) pressure peak (b) amplitude and (c) the shape, with this framework it is possible to differentially diagnose the various pathological conditions affecting the middle ear. In the analysis of tympanogram one can use either a coding system approach (Liden et al 1974 and Jerger, 1970) or a descriptive analysis approach (Feldman 1976).

Tympanic membrane mobility is of particular interest since almost any pathology located on or medial to the ear drum will influence its movement. By using the pneumatic otoscope, usually the otolaryngologist makes subjective judgment regarding the mobility of the tympanic membrane. But the tympanometry is more objective when compare to pneumatic otoscopic examination. Often, ear drum noted to have abnormal mobility with tympanometry.

The ear drum achieves its best mobility when the aid pressure in the external auditory canal is exactly same as the existing air pressure in the middle ear. The compliance of the tympanic membrane is at its maximum when air pressure on both sides of the eardrum are equal.

The electroacoustic impedance meter permits the compliance of the ear drum to be evaluated under systematic variance of air pressure which is controlled by the clinician. Thus when the clinician finds the air pressure value where the ear drum reaches its maximum compliance, he can then infer that the middle ear pressure is the same as the ear canal air pressure.

The knowledge of middle ear pressure is important clinical information. Whenever there is tubal obstruction, due to pathological condition. The static aid in the middle ear space is absorbed by the blood vessels in the musical lining. (Ballenger, 1969). This produces negative middle ear pressure causing transudation of fluid and retraction of the tympanic membrane. If the infection continues for a period of time, fluid may totally fill the middle ear space. Thus the early identification of negative middle ear pressure may permit the physician to practice medicine and avoid the condition of otitis media.

Jerger(1970)and Liden et al(1974) have described types of tympanograms and have associated each type to a group of specific middle ear pathological conditions.

But the classification mentioned above were obtained from the adult population. Whether this would hold good to children is the question,that is to be answered. Many investigators have reported of a similarity in the basic types of tympanograms between neonates, other children and adults (Fulton and Lamb, 1972, Jerger, 1970, Keith, 1973, Norther and Down, 1978).

1. Tympanometry in neonates and infants:

A child's tympano-ossicular system is observed to be flaccid at birth. This gradually shifts towards normal. However, as age advances, the incidence of negative pressure increases, once again making the tympanogram abnormal. The following reports reveal these changes clearly.

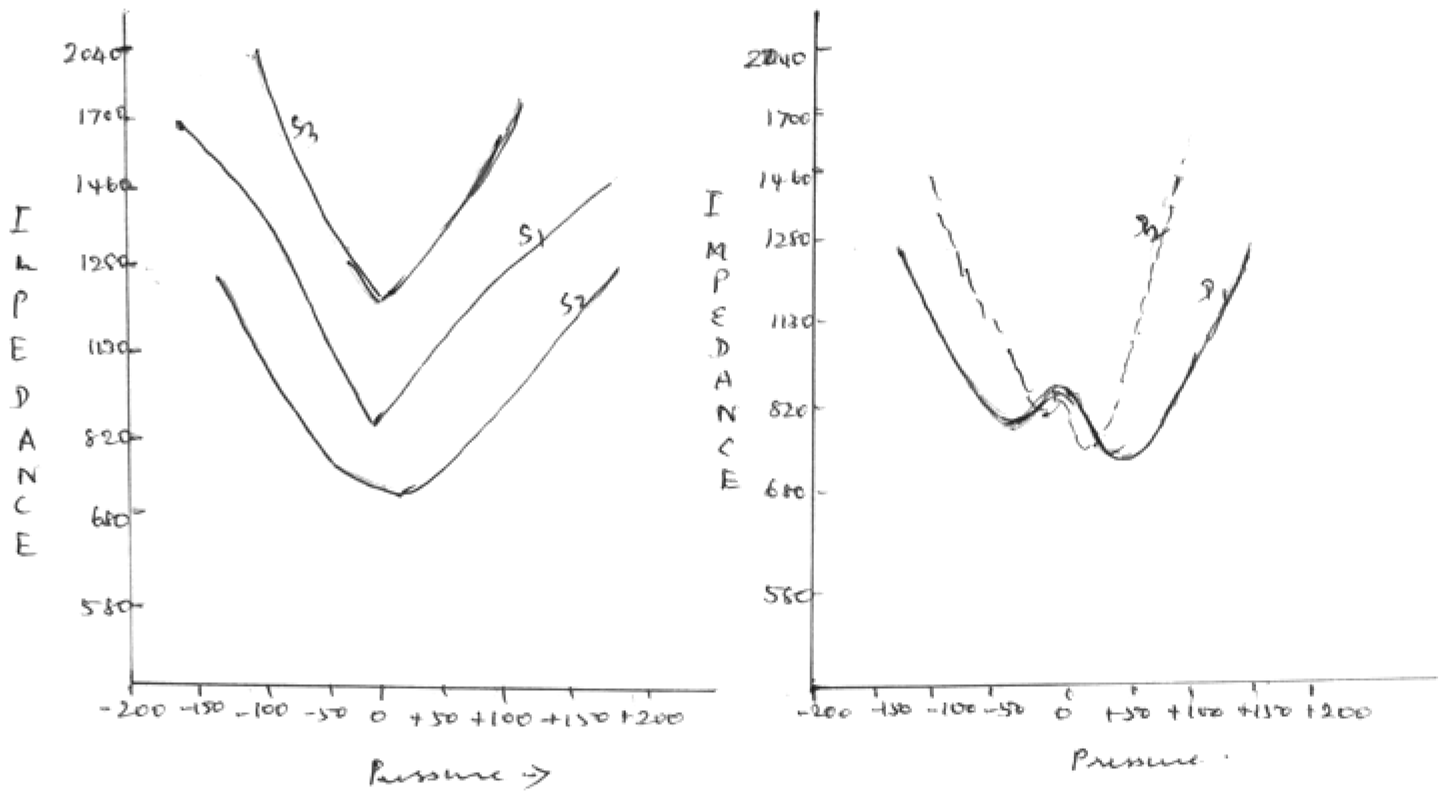
Keith (1973) obtained tympanometric data from forty neonates 36 to 151 hours old. A majority of them, 55 out of 80 ears gave rise to ‘AD’ type of tympanograms. Only 4 ears gave “As” type tympanogram. The rest (21 ears) exhibited normal tympanograms. Similar to the results obtained by Keith, were that of Bennett (1975), who also noted that there was a tendency for a neonates ear to be flaccid.

Many investigators have reported of a similarity in the basic types of tympanograms between neonates, other children and adults (Fulton and Lamb (1972), Jerger (1970) keith(1973); Northern and Downs (1975). One difference in the type of tympanogram which has been reported is the presence of a ‘W’ shaped tympanogram, obtained using 200Hz probe tone. But this configuration was observed to approximate the adult pattern with the advancement of age (Cannon, Smith and Keith, 1976). Cone and Gerber have also reported of changes in the type of tympanograms which maturation.

Pollazzon (1982) he also reported of changes in the type of tympanograms with maturation. He had taken 80 subjects aged between 2 hours and 6 months and 28 subjects aged between 6 months and 18 months. He reported that in neonates and flat type B curve is recorded in the first 12 hours, which later evolved into a type A curve. After the first week the majority of subjects present a peculiar double peak curve, if the probe tone is 220Hz, or a flat curve (curve of mass) if the probe tone is 660Hz. After the first month the tympanogram becomes similar to that observed in adults though disagreements persist between 220Hz and 660 Hz.

Bennett (1973) has observed a double notch tympanogram, in some neonates of 5-218 hours of age, which returned to a single notch tympanogram with increase in age. He denoted single notch tympanogram as ‘S’ and double notch tympanogram as ‘D’. He made a further subdivision in these two categories.

The subject was further subdivided into S1, S2, and S3. The S1 which was similar to the tympanogram obtained in normal adults (Jerger, 1970; Liden et al. 1974), that is the position of the notch was at 0 mm middle ear pressure. The s2 referred to the tympanogram with a broad notch, with a mean width of 300 mm H_2o. Type S3 exhibited a steep increase in acoustic impedance, when either positive or negative pressure was applied in the ear canal (Bennett, 1975).



(From Bennett (1975).

Double notch tympanograms were subdivided into two types, viz. ‘D1’ and ‘D2’. ‘D1’ was similar to ‘S1’. The difference between the two was in the number of notches. ‘D1’ had tow notches while ‘S1’ had a single notch. Similarly ‘D2’ and ‘S3’ were alike except for the presence of two notches in the former and a single notch in the latter. The positive notch of the ‘D’ type tympanograms occurred when the pressure was round +12.9 mm H_2o. The negative pressure peak occurred at approximately -30mm H_2o. The separation between the positive and negative notching varied from 15 to 85 mm H_2o (Bennett, 1975). As type ‘S2’ was closure to ‘D’ type rather to any of the other ‘S’ categories. It was therefore hypothesized that ‘S2’ could an extreme case of ‘D’ type.

From 5 to 11 years after birth, only ‘D’ types of tympanograms were observed. The number of single noted tympanograms gradually increased with increasing age. The high incidence of notchings in tympanograms of children was attributed to a possible flaccidity of tympanic membrane (Bennett, 1975) seen most often in neonates. This flaccidity of ear drum improved the transmission characteristics of the middle ear on application of position or negative pressure, resulting in a double notched tympanogram.

As otitis media was found to be very common in neonates and young children; more importance was given to the middle ear pressure measurement (Lamb and Dunkel 1975).

The first indication of the serous otitis media is a negative pressure peak in the tympanogram. But what constitutes normal pressure in children in still being departed.

A lot of controversies existing regarding the cut off point that is to be employed to demarcate normal and abnormal pressure in children.

McCandless and Allerd (1978) observed a mean middle ear pressure of +26 mm H_2o, with a range of +60 to -40 mm H_2o from birth to 48 hours after birth. It was also observed that a tympanogram obtained with a 660Hz. Probetone showed higher impedance than that obtained with a 220 Hz probe tone.

Keith (1973) found normal pressure in neonates of 26 – 151 hours of age.

The average pressure was found to be 4.5mm Bennett (1975) also found normal pressure with a range of -45 to +45 mm in neonate of 5-218 hours after birth. Allerd et al (1975) reported a positive pressure in neonates 20 to 50 hours following birth, but which was found to become slightly negative at the age of 6 weeks.

Paulson and Jos(1978) obtained tympanograms in children at birth, at three months and at six months of age.

At birth, a pressure of -100mm H_2o was observed in 10.5% of the ears and a pressure of -12mm H_2o was recorded in 0.3% of the ears. However, in most ears pressure normalized a little later. At three months of age, 17.9% of ears had a negative pressure of -100mm H_2o or less. The incidence of negative pressure increased to 39.2% at the six months. In addition, 9.6% of ears gave raise to flat tympanograms. Catarrhalia was observed in 23% at three months an in 60% in three to six months period. It is possible that eustachian tube catarrhalia, is one of the important, though not the only causative factor for the increase in the incidence of negative pressure with age. Paulson and Jos, recommended the differentiation of ‘C’ type to types ‘C1’ and ‘C2’, ‘C1’ corresponds to negative pressure of -200 to -300 mm H_2o, it was observed that the incidence of type ‘C1’ was higher in newborn delivered by section rather than those delivered normally (Paulson and Jos, 1978).

After an investigation of tympanometric measurements in neonates intensive care unit zarnoch and Balkary (1978) concluded that the incidence of middle ear effusion in these babies is higher than that observed in normal babies. The authors reported that tympanometry was not very useful in detecting middle ear effusion in very young children, as six out of seven ears gave normal tymapnogram despite the pressure of fluid. This was attributed to the highly compliant ear canal walls present in the newborns.

Pestalozza (1974), HE compared tympanometric findings in normal newborns and 34 ears of infants aged 5 to 120 days with middle ear pathology. In most cases a large smooth notched was found, both in cases of serves otitis or purulent otitis. The W shaped curve was present, only in case of normal middle ear conditions. The large smooth-notched curve may be representative of a normal or a pathological condition. For this reason tympanometry is not always a useful clinical tool to differentiate normal from pathological conditions of the middle ear upto fourth month of life.

Jos, Poulson and Hancke (1979) observed the tympanometric patterns in 151 children (82 males and 69 females) at birth, at six months, at nine months and at twelve months of age. They found out the middle ear pressure becomes increasingly negative as age increased.

At birth all children had normal middle ear pressure. At six months, 62% of the tympanograms had a pressure peak of 0 to 99 mm H2o and 1% showed absence of pressure peaks. At nine months, it has worsened. At twelve months, 40% had a pressure of 0 to -99 mm H_2o, 28% had a middle ear pressure of -100 to -199 mm H_2o, and 13% showed an absence of pressure peak. The increase in the incidence of negative pressure was attributed to the increased frequency of occurrence of Eustachian tube catarrahalia in older age group.

It may be concluded from the above report that, at the time of birth and a little after, tympanograms are indicative of a flaccid systems. However, the system gradually moves towards normality. There some to be some evidence to say that the incidence of negative pressure in the middle ears increases with increasing age. However there is not report regarding the age at which it stops becoming more negative and returns towards normal.

2. Tympanometry in children:

Tympanometry is very useful in finding out the middle ear pathology in children. Since the common cause of hearing loss in school going children in otitis media. Tympanometry will be a useful tool in detecting the hearing loss early.

Fabritius (1968) reporting on more than fifty thousand hearing tests carried out on school children over a nine year period attributed no less than 70% of the detected losses to otitis media. Among children seen in hospitals with conductive hearing loss the percentage with secretary otitis media is even higher. Robertson (1966) suggested 80 percent Carter (1963) 90% Wehrs and Pround (1958)at vertically 100 percent.

The conclusion to be drawn from these figures is that otitis media with effusion in responsible for the majority of conductive impairments in school children. And this conductive hearing loss has several consequences if it is not detected and treated earlier. They are ossicular fixation through fibrosis, severe conductive hearing loss, retraction pocket formation tympanic membrane perforation, appearance of cholesteatoma, sensorineural hearing loss secondary to this effusion, and the equally real possibility of vertigo (Stell, 1978).

Hence it can be concluded that, the hearing loss among school going children should be identified early and treated to arrest the effusion in the early stage. So, to detect, there is a great need of more efficient means of testing for those children who have middle ear effusion that may lead to serious consequences. Since tympanometry has becomes a popular technique for the differential diagnosis of middle ear disorders, It should be routinely used in conjunction with the other impedance measures. And also tympanogram is more objective. In addition to its objectivity it is an easy test to administer it is not time consuming and the results are usually easy to interpret. So this method should be used indifferential diagnosis of middle ear disorders in children.

Jerger (1970) and Liden et al (1970) have described basic types of tympanogram patterns and related them to conditions of the middle ear. To make it more simple, he has assigned an alphabetical letter to each type of curve. This classification is more convenient, but it may be more explicit.

2. Interpretation of the tympanograms:

In the previous chapter we have seen about the accurate way of finding the tympanogram. Now, in this chapter we are going to discuss about interpretation of obtained tympanogram in order to find out (1) the presence of absence of middle ear pathology (2) the kind of middle ear pathology.

To interprete tympanograms three factors are generally considered, which varies depending on the kind of pathology present. They are (a) amplitude (b) pressure peak (c) Shape, (Feldman, 1974, 1976a and 1976c, Liden, et al 1977).

(i) Amplitude:

It represents the compliance, admittance or impedance in relation to pressure. In interpreting the tympanogram we should see whether the amplitude increased or decreased or it is normal (Feldman, 1977).

In pathologies that increases the stiffness of the ossicular chain and tympanic membrane, amplitude of the tympanic membrane is decreased.

Eg. Otosclerosis, tympanosclerosis.

Decreased middle ear volume is also said to give rise to a reduction in the amplitude of tympanograms (Renvall, Liden and Bjorkman, 1975).

In pathologies where the system is highly mobile and thereby reduce the stiffness, the amplitude is exaggerated eg. Osicular chain discontinuity and tympanic membrane abnormality (Feldman 1976a and 1976b). If the condition are accompanied by alternations in the middle ear space, the amplitude and also there will be alteration in pressure peak but if, only the mobility of the tympano ossicular system is affected without affecting the middle ear space, then there will be change is amplitude not in the pressure peak.

ii) Pressure Peak:-

The normal middle ear pressure is approximately equal to the ambient pressure. Omm H_2o. Thus when the ear canal pressure is at or near the ambient pressure, the impedance offered to sound flow is minimum (and therefore flow is maximum). Therefore, in case a normal ear, the tympanogram shows a peak at or near Omm H_2o. In other words, the pressure at which the maximum amplitude occurs is at the middle ear pressure.

When the peak is shifted towards negative pressure, it indicates that the middle ear pressure is negative. Such a condition is observed in cases of eustachian tube malfunction (Jerger, 1970; Feldman 1976a and 1976c). When the peak is shifted to the positive side, it indicates of positive pressure in the middle ear. This is observed in early stage of middle ear effusion, sneezing prior to testing (Feldman, 1976c).

In addition, complete absence of pressure peak is also observed. Flat tympanograms imply the absence of and aid space in the middle ear. This is observed in cases of fluid filled middle ears and in cases of space occupying lesions.

eg. Cholesteatoma (Feldman, 1976a).

iii) Shape:

Normally tympanograms are smooth. Alterations in the smoothness appear as alteration in the shape of the tympanogram. Eg. notching, perturbations, etc.

Alterations in the shape are less common than alterations in the amplitude or pressure peak. Alternations in the shape is said to be indicative of altered resonance (Feldman, 1977). Shape of the tympanogram is more important while interpreting tympanograms obtained with high frequency probe tones (Feldman, 1974a).

Shape alterations in the form of undulation and notchings are observed in cases of ossicular chair discontinuity and tympanic membrane abnormalities respectively (Feldman, 1976a, Lidan, Harford and Hallen, 1974a, Liden et al, 1977a).

Though the common trend is to make use of these three parameters – amplitude pressure peak and shape. Brooks (1969) recommends a similar but slightly modified method for the interpretation of tympanogram. To determine the shape of the curve, a measure of steepness near the peaks is considered. The change in the compliance for a pressure difference of 50 mm H_2O from the peak value is computed. This represents what he calls the “gradient”.

4. Classification of tympanograms:

Based on the parameters discussed above tympanograms may be classified into different types. Liden (1969) made the initial attempts at the description tympanograms from normal and pathological ears. Jerger (1970) made the initial attempts at classification of tympanograms into different types. Since then some additions have been made to the classifications. The different types of tympanograms are:

Type-A: Type ‘A’ tympanograms are characterized by a minimum compliance at or near 0mm H_2o. They are smooth (Jerger, 1970). They are ‘V’ shaped with a notch depth of 5.3 ± 2.0 (Liden, 1969).

Type-As: ‘S’ in ‘AS’ represents the word ‘shallow’. ‘AS’ type tympanograms have normal pressure peak, they are smooth and their characteristic feature is the reduction in amplitude.

Type-Ad: ‘d’ in ‘Ad’ stand for ‘deep’, In ‘Ad’ type tympanograms amplitude is exaggerated and maximum compliance may be beyond zero (on the scale) from +40mm H_2o to -40 mm H_2o.

Type Add: ‘dd’ in ‘Add’ represents ‘double peak’. This is similar to ‘Ad’ type. The difference is that compliance remains beyond zero from +100 to -100 mm H_2o.

Type-B: It shows almost an equal compliance over pressure, i.e. compliance remains unchanged with alteration in the pressure introduced in the ear canal (Jerger, 1970).

Type-C: It is characterized by a negative pressure peak. The point of maximum compliance is towards negative middle ear pressure and the curve is smooth (Jerger, 1970).

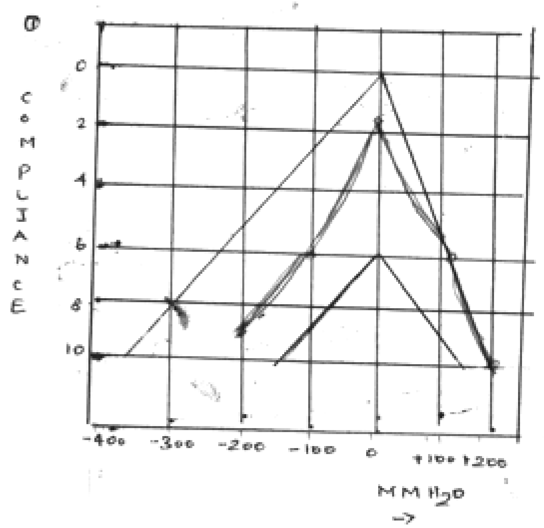
Type-D: The amplitude of a Type 'D' tympanogram is exaggerated. A sharp notch is observed in the tympanogram (Liden, Harford and Mallen, 1974a).

Type-E: It is characterized by the presence of double pressure peaks. The amplitude is exaggerated and the tympanogram exhibits undulation (Liden, Harford and Hallen, 1974a).

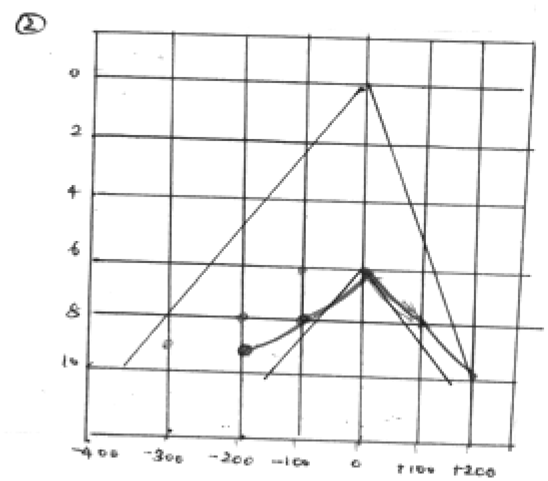
Type of tympanograms	**Conditions or pathologies associated with it**
A1	Normal
AS	Otosclerosis, tympanosclerosis
Ad	Ossicular chain discontinuity
Add	Necrosis of ossicular chain
B	Serous otitis media wax
C	Eustachian tube dysfunction
D	Tympanic membrane abnormality
E	Ossicular chain discontinuity

It is often observed that some tympanograms are better described than classified into types. Classification of tympanogram may sometimes restrict the amount of information

TYPES OF TYMPANOGRAMS

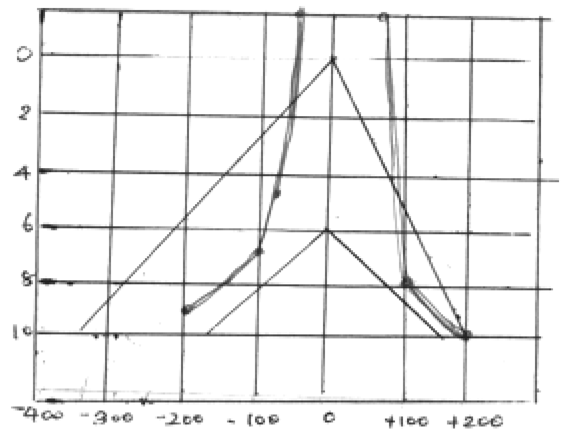


'A' TYPE



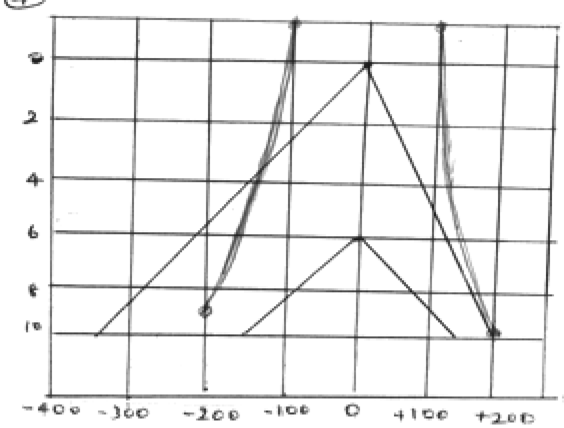
'As' TYPE

(3)

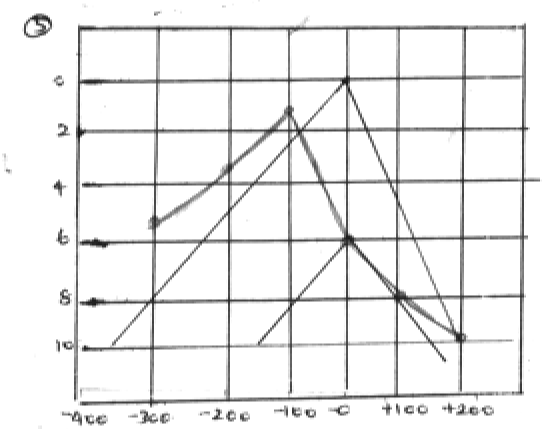


'A_d' TYPE

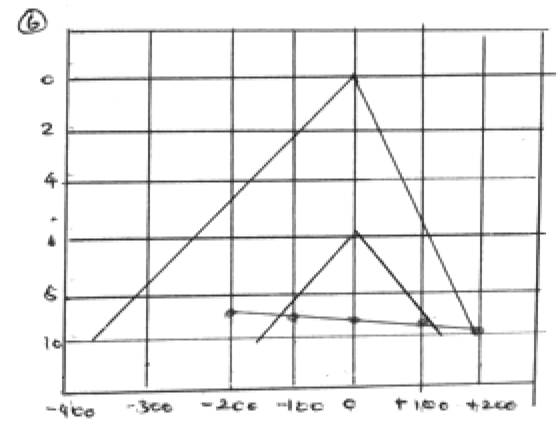
(4)



'A_{dd}' TYPE.


5
0
2
4
6
8
10
-400
-300
-200
-100
0
+100
+200

TYPE 'C'


6
0
2
4
6
8
10
-400
-300
-200
-100
0
+100
+200

TYPE 'B'

conveyed. Eg. In cases of positive middle ear pressure once cannot classify the tympanogram into any of the above listed types.

5. Factors affecting tympanometric results:

The pathology or the condition of the middle ear is the prime determiner of the type and configuration of the tympanogram obtained. However certain factors also appear to affect the tympanogram.

A. Rate of pressure change.
B. Direction of pressure change.
C. Air tight sealing in the ear canal
D. Eartip
E. Manual vs. automatic recording
F. Component analysis vs. complex admittance measurement
G. Probe tone frequency.

6. Tympanometry in Diagnosis of auditory pathology:

Tympanometry is done with the chief purpose of detecting and diagnosing middle ear pathologies. Different middle ear lesions such as, Otitis media, cholesteotoma, otosclerosis, ossicular discontinuity, etc. are found to yield different tympanic pattern.

(i) Otitis media: Otitis media is a condition which decreases the mobility of the ossicular chain and which reduces the middle ear space. As we have seen earlier, such a pathology would reduce the amplitude and flatten the tympanogram. Generally, otitis media is preceded by Eustachian tube dysfunction, which because of inadequate aeration brings about a negative middle ear pressure. Thus, in case of otitis media, the tympanometric pattern changes from a negative pressure to a gradual blunting of the peak to a complete flattening of the tympanogram (Jerger, 1975b). Tympanometry according to Feldman (1976c) is far superior compared to audoimetry in monitoring the middle ear effusion.

Flat tympanogram are the most commonly reported pattern in cases of middle ear effusion. Liden, Peterson and Bjorkman (1970) report of flat tympanograms both in the presence of a middle ear fluid or a perforation of tympanic membrane, which is a consequence of middle ear effusion. A rare possibility is to obtain a tympanogram with positive peak in case of early otitis media (Feldman 1976c).

Even in case of adhesive otitis media, a flat tympanogram is observed (Liden, 1969; Jerger, 1970).

Feldman (1976c) reports the adhesive ossicular chain fixation would give rise to reduction in amplitude alone (eg. as in otosclerosis). This, however is rare, because middle ear effusion is quiet common prior to this condition. Scars on the tympanic membrane would also affect the tympanogram.

A similar report from Dieroff (1978) showed that, 48% of adhesive otitis media cases gave a normal tympanogram because of fine scars in the tympanic membrane.

Brooks (1969) has shown that in cases of otitis media the gradient is reduced to less than 10%.

One should remember that, all the above listed points, viz. flattening of tympanorgram and absence of pressure peak and reduced amplitude point to a type ‘B’ tympanogram. Thus, to say that otitis media gives rise to a ‘B’ type tympanogram is the same as saying it gives rise to ‘flat’ tympanogram.

Orchik, Dunn and McNutt (1978) reports that type ‘B’ tympanogram is a very strong indicator of the presence of middle ear fluid. However, there is no clear relationship between the magnitude of the negative pressure and the presence or absence of middle ear effusion. Similarly, Berry et al. (1975) in a study with the children, found that a high negative pressure is not necessarily a reliable indicator of middle ear effusion.

Renvall, Liden and Bjorkman (1975) introduced water into the human temporal bone and obtained tympanograms using 800Hz probe tone. They found that, when the water level was very low, there was no change in the shape of tympanogram. However, as water level increased, the tympanogram gradually shifted towards type 'B'. This demonstrated that the change in the tympanogram depended on the fluid level.

The type of tympanogram said to change gradually from 'B' to 'C' to 'A' as the system shifts from a pathological condition to the normal state (Jerger, 1975b). It may be concluded that tympanogram gradually flattens with the development of otitis media and gradually returns to normal as recovery process ensues.

ii) Perforation of tympanic membrane:

1) BM needle cannot be brought to '10' in lower scale or +5 in upper scale.

2) And when we adjust middle ear pressure to 200mm H_2o. Suddenly the needle falls to zero i.e. pressure cannot be maintained at +200 mm H_2o. But we should make sure that the air has not escaped through the sides of the tip (In latter case needle falls gradually.

3) Tympanogram will be flat.

In some cases of perforation we may be able to get + 200 mm H_2O because of blocked Eustachian tube. So we should be cautions in diagnosing.

iii) Eustachian tube function:

1) Valsalva monovure –Keep the pressure at +200 mm H_2O. Then ask the patient to swallow. Then the pressure should fall to zero because of pressure in the middle ear is released by opening of Eustachian tube if pressure does not fall then we can suspect Eustachian tube blockage.

2) ‘C’ type of tympanogram shows Eustachian tube clock age.

3) Williams test (pressure Sallow test).

a) Obtain tympanogram with usual procedure.

b) Set the pressure at +400 mm H_2O and ask him to sip water from a glass 4 to 5 times, the Eustachian tube opens and the air is driven out.

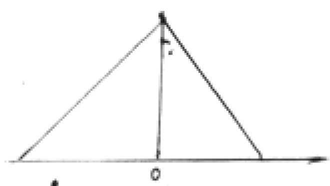
c) Obtain tympanogram with usual procedure

d) Set the pressure to subjects original middle ear pressure and ask him to drink water 4 to 5 times.

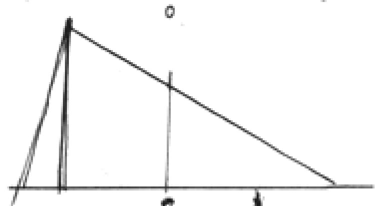
e) Set the pressure to -400 mm H_2O and ask him to drink water.

f) Obtain tympanogram using usual procedure.

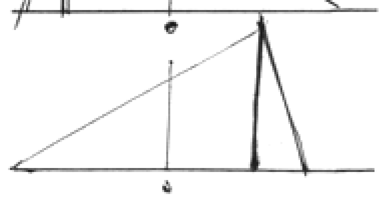
Step (a)



Step (e)



Step(f)



All these shows normal eustachian tube functioning, if this is absent, eustachian tube can be suspected.

7. Analysis of tympanometric configuration of some common middle ear pathologies

Middle ear disorders	**Pressure peak**	**Amplitude**	**Shape**	
			High frequency probe tone.	**Low frequency probe tone**
Serous otitis acute	Non-severe negative.	None-shallow.	Flat-slight rising	Flat falling -------- Converging
Serous otitis resolving	Moderate negative	Shallow normal	Normal	Normal
“Glue” ear	Moderate severe Negative	None-Shallow	Flat	Flat-falling -------- Converging
Cholesteotoma	Normal-negative to absent	None-shallow	Flattened	Lower at negative pressure
Acute otitis media	Positive	Normal	Normal	Normal
Block Eustachian tube	Mild-moderate negative	Normal	Normal	Normal
Glomus tumour	Non-normal	Extremely shallow	Vascular perturbation	Vascular perturbation
Otosclerosis	Normal	Shallow	Normal	Normal
Melleolar fixation	Normal	Shallow	Normal	Normal
Perforated tympanic membrane.	None	Elevated base line	Flat	Flat

STATIC COMPLANCE

1. Neonates and Infants
2. Children

STATIC COMPLAINCE IN CHILDREN

The term compliance refers to the mobility, or springiness, of a system (Northern and Aorous, 1975). As the compliance measurements are made during resting conditions of the system, the term ‘static compliance’ was suggested (Jerger).

In the discussion of compliance measures, there are three main factors of middle ear mechanism should be considered. These are the mass, friction and stiffness of the system. The mass is provided by the bulk of the ossicles, the friction is contributed by the suspensory ligaments and the muscles supporting the ossicular chain. The stiffness has been attributed to the resistance components of the stapes footplate, the last factor is considered to have the major influence on the unit of static compliance.

Static compliance is measured in terms of equivalent volume in cubic centimeters based on two volume measurements. The first volume measurement (C_1)is made with the tympanic membrane clamped in a position of poor compliance with plus 200 mm H_2O air pressure in the external canal. The second volume measurement (C_2)is made with the tympanic membrane at the maximum compliance pressure. Since sound is more easily transmitted by the tympanic membrane during the second volume measurement (C_2), the probe-sound pressure in the enclosed cavity of the external canal is lower than noted in the first volume measurement (C_1)and a large “equivalent volume”. The static compliance is calculated by subtracting C_1 from C_2, which cancels out the compliance due to the volume of air in the external canal. The remainder is the compliance due to the middle ear mechanism. Thus C_2-C_1 equals the static compliance of the middle ear units of equivalent air volume in cubin centimeters.

The major clinical contribution of the static compliance measurement is to differentiate between the fixated middle ear and the middle ear with an ossicular discontinuity.

The static compliance measure is corroborative information following tympanometry, since both these tests measure “compliance”. The static compliance measure is considered by many to be the least valuable test in the impedance battery. Indeed, Feldman (1974)indicates that the static compliance measure is appropriate only when the patient tympanic membrane is devoid of any abnormalities.

One of the major weakness of static compliance is its wide variance in values related to specific pathologies of the auditory mechanism. The central tendencies of small sample populations may reflect significant difference among various ear pathologies which makes the measure look quiet valuable. However, in clinical patient populations, the variations in static compliance values create considerable overlap among normal middle ears, otosclerotics, and ears with ossicular discontinuity shown clearly by Alberti and Kristensen (1970). And they also say that considerable overlap may be noted especially in 2 to 5 and 6 to 13 age group. Jerger (1970) has told that differential diagnosis based only on static compliance measures may be difficult.

Jerger (1972)has also found that normal static compliance to vary as a function of age and sex. Men show higher acoustic compliance than female at all ages. But in case of children there is no significant difference in compliance value in terms of sex while both men and women show a general overall decrease in compliance as they grow older. These facts caution against attempts to construct norms for static compliance. However, as a guideline, particular values have been given to identify abnormally flaccid and stiff middle ear.

The static compliance is the inverse of acoustic impedance. A measure of acoustic impedance can be used to measure the same entity as the static compliance. But the measure of acoustic impedance will be inverse of static compliance. Here the resistance of a system to movement is measured and the expression is in acoustic ohms. Thus the mobility of the system can be determined either by measuring static compliance or acoustic impedance.

As we have noted already and also many literature in this area, reveals that static compliance values in normal children varies from that of adults. The difference in norms for the two groups have been attributed to two reasons. One is that, the neonates manifest high static compliance because of the hyper mobility of the tympanic membrane and or due to the relatively soft walls of the ear canals, the other reason was that, the norms for the children, may b probably influenced by a rather high incidence of middle ear diseases which occurs in this age group and there by decreasing the compliance.

1. Neonates and Infants:

Keith (1973) found a median compliance of 1.2 cc with a range of 0.25 to 1.65cc in a group of neonates of 2 ½ to 20 hours of age. In an earlier study of neonates of

27 to 150 hours old observed a median compliance of 1.10cc with a range of 0.54 to 1.75 cc.

Keith (1973) obtained a range of static compliance of 0.54 to 1.75 cc with a median compliance of 1.1 cc in neonates of 36 to 151 hours old. Cone and Gerber (1975) (cited in Cone and Gerber 1976) measured the static compliance in infants ranging from 5 days to 13 months of age. For the youngest group a median compliance value of 6.79cc was obtained and in the oldest group it was 0.39cc. The difference between the two oldest groups was not significant. Thus compliance values in neonates seem to be significantly high.

Correlating with increasing compliance is the observation of lower impedance value in neonates.

Bennett (1975) found an impedance of f1840 acoustic ohms in neonates with 'S_1' and 'S_3' type tympanograms. Neonates in whom S_2, D_1 and D_2 tympanograms showed lower impedance values than did those with S_1 and S_3 tympanograms. Contradictory to he above reports high compliance – and low-compliance values, were the result obtained by McCandless and Allerd (1978). They reported a mean impedance of 3100 acoustic ohms and 4500 acoustic ohms with a 220 ohms with a 220Hz and 660Hz probe tone respectively, in a group of children aged 25 to 50 hours.

At 6 weeks of age, an impedance value of 3002 acoustic ohms and 4205 acoustic ohms were recorded at 220Hz and 660Hz respectively. Thus it appears that probe tone may have significant effect on the impedance value recorded however, it is not clear why impedance value obtained at 220 Hz in their study is higher than that reported in previous studies.

2) Children:

The impedance value in children has been given by some investigators (Jerger, 1970; Brooks, 1971; Keith, 1973).

Keith (1973) has given values of 935 ohms as normal in neonates. Jerger (1970) and Brooks (1971) has given values as 2250 and 7500 ohms in children of 2 to 5 years of age. Thus it is clear that the compliance varies a as function of age, but overlap with the adult values is also encountered. As a guideline, Jerger (1972) has given the following cut-off points to judge the compliance as normal and abnormal. The range is given to be 0.25 cc to 2.5 cc. As a guideline, the middle ear can be considered abnormally stiff when the static compliance is less than 0.28 cc of equivalent volume and abnormally flaccid when the static compliance is greater than 2.5 cc of equivalent volume. Serous otitis media often creates poor compliance of 0.1cc of equivalent volume or less. But, Jerger et al (1974a) he has found static compliance to be the least informative test of the impedance battery in children under 6 years of age.

Jerger et al (1974) has reported of the compliance values in different pathological conditions in subjects, age ranging between 3 to 79 years. The pathologies and the associated mean values for each of the condition is a follow:

Otosclerosis - 0.35cc

Otitis media – 0.29cc

Cholesteotoms – 0.16cc

Scarred or thickened tympanic membrane 0.37 and ossicular discontinuity 1.9cc.

It appears that in the first few months of life children show high compliance of the tympano-ossicualr system. As age increases, the impedance value gradually decreases and corresponds to the adult value within a few months after birth.

It may be concluded that compliance is high and impedance is low at birth. Compliance decreases and impedance increases with increase in age; till they reach adult values. In children, there is no significant difference in compliance value, in terms of sex.

To summarize, compliance is high and impedance is low at birth. Gradually compliance decreases and impedance increases with age. Males and females children to not differ significantly in terms of compliance value.

ACOUSTIC REFLEX MEASUREMENTS

1. Pathways of acoustic reflexes
2. Acoustic reflex measurements in neonates
3. Acoustic reflex in older infants
4. Acoustic reflex in older children
5. Clinical applications of acoustic reflexes
    (i) Difference ratio quotient.
    (ii) Reflex decay test.
    (iii) Sensitivity prediction by acoustic reflex.
    (iv) Jerger’s box pattern.

ACOUSTIC REFLEX MEASUREMENT

This test is the third test in the impedance audiometry battery. It is the determination of the signal threshold level at which the stapedial muscle contracts (Northern and Downs (1974), Hemelfarb et al (1978) he says that acoustic reflex threshold is the sound pressure level of the activating stimulus which results in the smallest detectable stimulus locked changes in conductance, derived from the recorded tracings. Metz (1952) and Jepsen (1963) reported that in normal hearing individuals, a bilateral stapedial muscle reflex can be elicited by stimulating the subjects test ear with purstone signal between 70 and 100 dBHTL and approximately 65 dBHTL for white noise. The lowest signal intensity capable of eliciting the acoustic reflex threshold for the stimulated ear.

The function of the stapedial muscle still open to question, but the classical interpretation offered by Wever and Lawrence (1954)is the stapedial muscle reflex is responsible for protection of the inner ear from loud sounds when the stapedial muscle contracts, it pulls posteriorly on the ossicular chain, thereby decreasing the compliance of the middle ear system and attenuating the intensity of the sound which actually reaches the cochlea.

The acoustic reflex has been claimed to have a potential value in the evaluations of peripheral and central auditory system. (Himelfarb, Popelka and Mangolis (1976).

Much emphasis has been placed on the clinical value of the acoustic reflex measurement. Since the acoustic reflex is mediated by loudness, it is a sensitive indicator of cochlear pathology. The acoustic reflex threshold level in patients with cochlear pathology may often occur at sensation levels less than 60dB above the auditory puretone threshold. The patient with cochlear pathology hears the test signal as though it were much louder due to abnormal appreciation of loudness. Thus, the acoustic reflex threshold provides an objective simple technique for the measurement of loudness recruitment. The ability to find the presence of the loudness recommitment phenomenon permits the clinician to localize the site of auditory lesion to the cochlea. Klocknoff (1961) states that a recordable stapedial reflex is proof of the absence of a conductive or middle ear component to a hearing disorder.

Initially hearing loss identification, and estimation form the acoustic reflex were studied primarily in adult populations. More recently, however, hearing loss prediction from the acoustic reflex has been reported in children (Margolis and Popelka, 1975; Abahazi and Greenberg, 1977;

Fox, 1977). Objective prediction of hearing loss in children has obvious clinical value. Recent reports of acoustic reflex measurements in children, including traditionally “difficult-to-test” children, are, therefore, highly encouraging (Jerger, and Hayes, 1976).

1) Pathways of the acoustic reflex:

Experimental studies on animals have shown that the pathways of acoustic stapdieal reflex are located in the lower part of the brain stem (Hammerschlag, 1899; Borg, 1973) Monoaural acoustic stimulation of high intensity is followed by bilateral reflex contraction of the stapedius muscle. The ipsi-and contralateral stapedius reflex are not identical.

Ispilateral stapedius reflex: The ipsilateral stapedius reflex are thus consist of mainly three but to some extend four neurons. The electrical impulses from the sensory cells in the cochlea are transmitted through the primary acoustic neuron to the ventral cochlear nucleus. The majority of axons from the ventral cochlear nucleus pass through the trapezoid body to the medial part of the facial motor nucleus, and from this nucleus the electric impulses are transmitted trough the facial nerve to the ipsilateral stapedius reflex. In addition, some nerve fibres pass from the ventral cochlear nucleus through the trapezoid body to the ipsilateal medial superior olive. From this nucleus the electrical impulses are transmitted to the medial part of the ipsilateral facial motor nucleus.

Pathways of the contralateral stapedius reflex: The impulses from the sensory cells in the cochlea pass via the primary acoustic neuron to the ventral cochlear nucleus as in the ipsilateral stapedius reflex. From the ventral cochlear nucleus the impulses are transmitted through a second neuron to the region of the medial superior olive. A third neuron connects the medial superior olive to the medial part of the contralateral facial motor nucleus. A fourth neuron transmits the electrical impulses from the facial motor nucleus to the contralateral stapedius muscle.

2) The acoustic reflex measurement in neonates:

Acoustic reflex may not be elicited in very young children. The response becomes more evident with increasing age.

Keith (1973) observed that about 30% of neonates (aged 36 – 151 hours) he tested gave clear acoustic reflex response. In 44% of the neonates he examined, the reflex response cannot be clearly detected because of the generalized behavior response. The remaining twenty six percent babies gave no acoustic reflex response.

Allerd et al (1974) have reported of measurable reflexes in 33%. Neonates of 25 to 50 hours (cited in Lamb and Dunekel (1975). In this study the possible contaminating factors of generalized body movements were not considered (Keith and Bench, 1978).

Bennett (1975) reported that about 16% of children aged 5 to 218 hours gave clear spapedial reflex response to noise from Earanay’s box. The strength of the response was, however weaker than that observed in adults.

Stream et al (1977, cited in Keith and Bench, 1978) could record reflex response in only 4.2 % of neonates and in about 11.9% of children aged 49-72 hours. No reflex was recorded from 73 to 136 hours.

Keith and Bench (1978) made similar observations. They observed reflex response in less than 5% of 20 clinically normal neonates.

Contradictory to the above reports, McCandless and Allerd (1978) reported that almost all children including neonates as old as 4 hours gave reflex response. They found higher number of reflex response for low frequency tones. These measurements were done with a 660Hz probe tone. About 89% of 48 hours old children showed clear reflex response at 500Hz when a 660Hz probe tone was used. On the other hand, with a 220Hz, Probe tone, this study differs from that of Keith (1973) and Keith and Bench (1978) in the criteria used for the determination of reflex response. While the latter two have considered only those children in whom acoustic reflex response were not contaminated by behavior response. Although McCandles and Allerd (1978) note that, ”Behavioral activity was a significant factor in test duration and also had a probable effect on the reading of the reflexes especially at ages beyond about four weeks”. It is not clear whether the data contaminated by behavior response were also in the analysis.

Himmelfarb et al (1978) evaluated neonates between 8 to 96 hours after birth. Tympanometric result through not entirely normal, was found to be adequate to make reflex measurements feasible, 88% of the children showed reflex response at atleast one frequency. Frequency of occurrence of reflex response was the greatest at 500 Hz. Frequency of occurrence decreased with increase in frequency. Median reflex threshold were higher than that found in case of adults. Jerger (1981) have identified systematic age effect in the acoustic reflex threshold noting that reflex hearing threshold levels decreases at al test frequencies with increasing age.

Acoustic reflex thresholds in “presumably normal“ infants 55-132 days old (means 98.3% days) in normal, for white noise as well as puretones of frequency 500, 1000, 2000 and 4000Hz (Margolis and Popelka, 1975). Sleep was not found to affect the reflex threshold. The authors recommend that hearing thresholds by predicted in these children by obtaining reflex thresholds during sleep. Anasthetic agents that do not alter the reflex thresholds may be used if necessary (Morgolis and Popelka, 1975).

The low incidence of acoustic reflex response in the neonates has been attributed to one or more of the followings:

1) Depth of sleep might have affected the response.

2) Presence of meschchyme in the middle ear which could inhibit ossicular movement.

3) Neurological development might have not been complete in order to give a stapedial reflex response (Keith and Bench, 178).

3. Acoustic reflex in older infants:

Acoustic reflex thresholds in ‘Presumably normal’ infants, 55 to 135 days (mean of 98.3 days) in normal for white noise as well as pure tones of frequency 500, 1000, 2000 and 4000 Hz (Margoris and Popelka, 1975a). Sleep was not found to affect the reflex thresholds. The authors recommended that thresholds be predicted in children by obtaining reflexes threshold in sleep. Although anesthetic agents did not alter the response it was recommended that its use should be restricted only to those cases where it is essential (Margolis and Popelka, 1975a).

Gerber and Cone (1975, cited in Cone and Gerber, 1977) observed that an intensity of 106 dB SPL was required to elicit reflex response in children less than 5 months of age. In the other age groups of 5 months – 8 months and in the oldest group 8 to 13 months, reflex was elicited at 97 and 98dB SPL. Thus a significantly higher intensity was required at an younger age than at an older age.

Abahazi and Greenberg (1977) examined 108 infants aged one month to one year. Children with normal tympanograms alone were included. It was found that reflex threshold for noise occurred at lower intensities than that for pure tones. Lower intensities were required to elicit response as age increased. The mean threshold predicted using reflex threshold was 21dB as against 17dB in adults.

	A	B	C	D	E	F
Parameters	500Hz	1000Hz	2000Hz	L.P.n	L.P.n.	W.n.
dBSPL	105.3	97.9	98.9	90.7	88.3	84.2
Range	91.5-116.5	87-112	84-114	70-105	75-105	65-100
N	54	51	47	48	51	

Mena infant acoustic reflex threshold in dB SPL averaged across age for pure tone and noise stimuli. Ranges and samples sizes are also included. Any two treatment means not under scored by the same line are significantly different t 0.01 level. Any tow treatment means underscored by the same line are not significantly different. (From Abshazi and Greamberg, 1977).

Ino et al (1977) found that in a group of 56 infants, reflex response to white noise was the lowest, some children despite hearing, failed to demonstrate reflex at 4000Hz. The age group of the children is not specified.

Frequency of occurrence of reflex response was found to increase with age, in a study of children of age from birth to 15 weeks (Stream et al. 1978). Bearbar K Skinner et al 1981).

Acoustic reflex thresholds were determined on 211 preschool children ranging in age from 36 to 72 months. Puretone stimuli were used to elicit the reflex by the contralateral and ipsilateral presenting mode. Broad band noise (BBN) and filtered noise were used contralaterally to determine reflex thresholds. Contralateral reflex thresholds to puretones (500, 1000, 2000Hz) were elevated by approximately 10 dB when compared with reflex thresholds to the same pure tone stimuli in adults. The mean contralateral reflex thresholds to pure tone stimuli when averaged over the frequencies of 500, 1000, 2000Hz was elevated by approximately 4 dB when compared with the same reflex threshold average obtained ipsilaterally. Noise proved to be a more effective stimulus in eliciting the acoustic reflex.

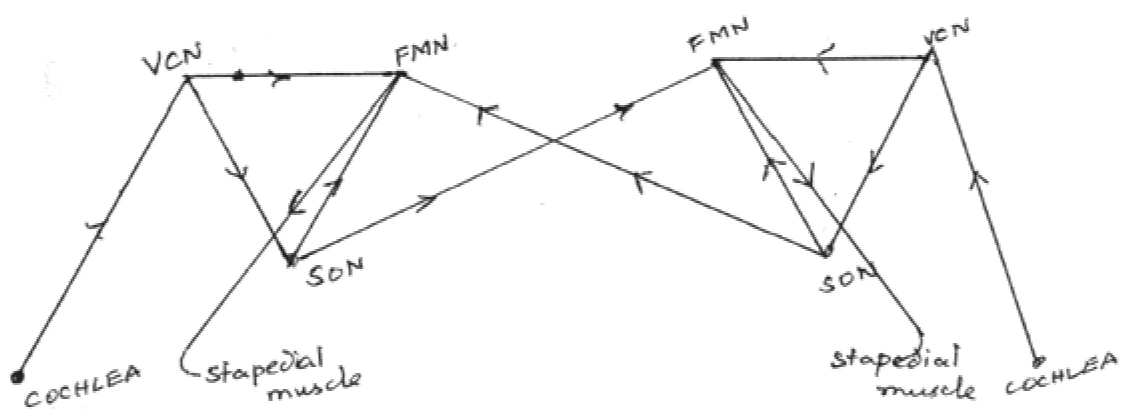
A BEN contralateral stimulus reduced the threshold by approximately 20 dB, high pass filtered noise (greater than 3200Hz) by approximately 15 dB and low pas filtered noise (lesser than 3500Hz) by approximately 10 dB.

4. Older Children:

Robertson, Peterson and Lamb (1968) investigated the acoustic reflex activity in children aged 12, 18, 24 and 30 months. There were 10 subjects in each group. The test frequencies were 500, 1000 and 2000 Hz. A Madsen ZO 61 impedance bridge was used. Reflexes were presented at all frequencies, in all subjects. It was observed that as age decreased, the intensity required to elicit reflex had to be increased. However, no major differences were observed that as age decreased, the intensity required to elicit reflex had to be increased. However, no major differences were observed between reflex threshold data for children and adults. Reflex thresholds were lowest at 500 Hz, and highest at 2000Hz. Inters subject variability was high in 24 months and 36 months old children than in children 18 months old and in adults. In an investigation with older children (Brooks, 1971) would elicit normal reflex response in 1063 children, aged 4 to 11 years.

5. Clinical application of acoustic reflex:

Acoustic reflex pathways (Ipsilateral and contralateral)



The presence of the acoustic reflex establishes two facts regarding the peripheral hearing mechanism: it verifies the integrity of the middle ear system, and it confirmed a cochlear residual in the stimulated ear. Aside from acknowledging the existence of a cochlear residual, investigators have used the reflex threshold to estimate hearing levels.

In conductive loss cases (middle ear pathology reflex will be absent)

Condition-1

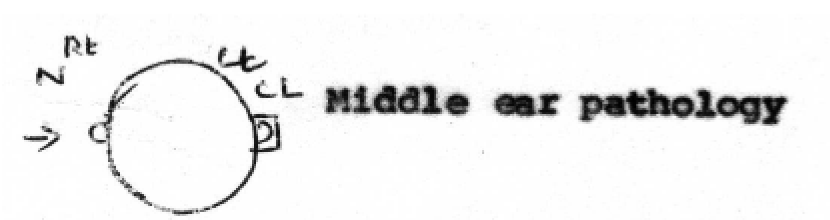
but there are three exceptions.

1. Stapes crura fracture which affects thresholds but not the reflex.
2. If middle ear pathology is conductive high tone loss.
3. Collapse of ear canal.

In the above said, three conditions reflex will be present. But sometimes audiogram shows normal hearing, but reflex is absent. That shows congenital absence of stapedial tendon.

If above said condition-1 is revered.

Condition-2:



Reflex will be present provided energy reaching cochlea is 80dBHL. It conductive loss ear is phone ear, reflex will be present but al elevated level.

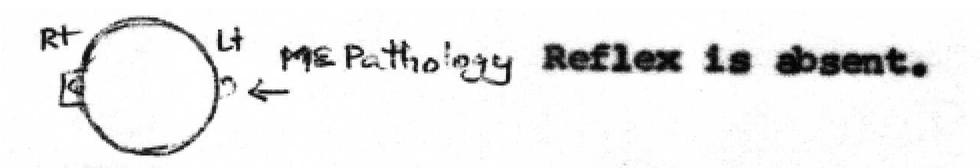
So 80 + 40 = 120 dB. At 120dB reflex will be present (Maximum energy in impedance bridge = 125 dB).

Middle ear pathology ear = probe ear, integrity of ossicular chain decides the presence of reflex.

Middle ear pathology ear = phone ear, presence of reflex will be decided by AB gap.

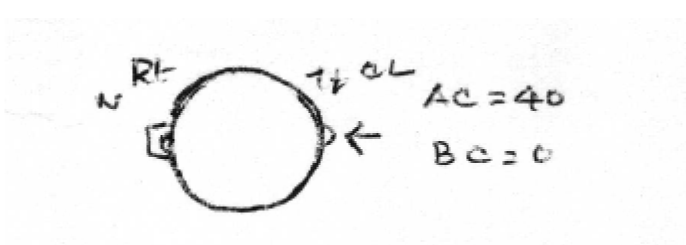
Condition – 3:

If probe ear is middle ear pathology and normal ear is phone ear, reflex is absent.

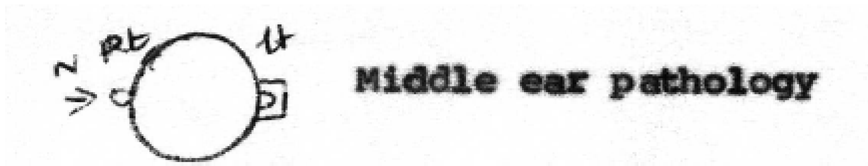


For the presence of reflex in probe ear, the ossicular chain should be intact. Middle ear fluid causes no change in stiffness, so no reflex, for otosclerosis – no reflex. Reflex measurement is very useful in knowing middle ear pathology.

Condition-4:

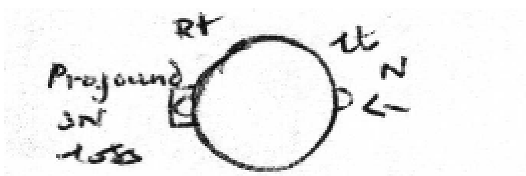


Tone is right ear, left ear is probe ear, if reflex is absent then middle ear pathology is in left ear. Further confirmation is reverse condition.



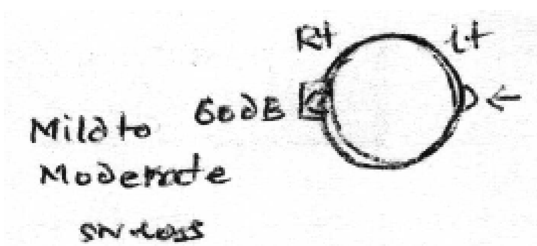
Then the thresholds will be elevated. Thresholds always refer to stimulus ear. During reflex measurements phone ear and probe ear are better terms than non-test-ear and test ear.

Condition-5:



In S.N.loss, if it is profound loss reflex will beadsent.

Condition-6:



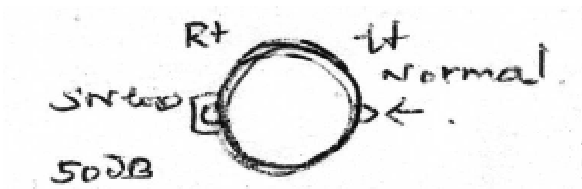
In mild and moderate SN losses reflex will be present at 90dBHL, since tone decay is absent. So reflex occurs at almost equal levels.

In cases of unilateral moderate SN loss cases by comparing the reflex thresholds we see cochlea or retrocochlea case. If both ear reflex thresholds are same it is cochlear pathology. If the thresholds are different then retrocochlear pathology.

Identification of presence of recruitment:

If difference but acoustic reflex threshold and absolute threshold is lower than 60 dB. Then recruitment is said to be present.

Condition-1:



1) ART=90db, then 95-50 = 45

lower than 60 dB, so recruitment is said to be present.

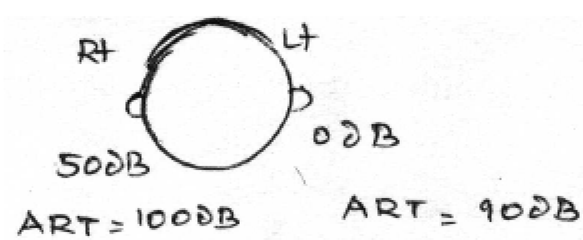
Condition-2:

ART=120dB. Then 120-50 = 790, it is more than 60dB, so recruitment is absent. By using reflex measurements we can find out the presence of recruitment.

DRO: Difference ratio quotient:

$$\frac{(\text{ART Normal ear.} - \text{Abs. th Normal ear.} - (\text{ART Poorer ear} - \text{Abs. Th Poorer ear}}{\text{Absolute threshold of poorer ear} - \text{Absolute threshold of normal ear.}} = 1$$

Condition-3:



$$DRQ = \frac{???? ??? \ ????? ???}{???? ?} = \frac{?? ? ??}{??} = 0.8$$

If DRQ = 1 then complete recruitment

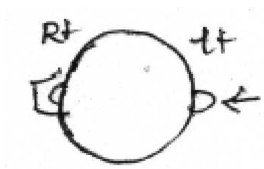
DRQ = more than 1. hyporecruitment

DRQ = 0 no recruitment.

Reflex decay test:

This test is used to detect retrocochlear pathology. LDT (50% decay time).

Administered at 500Hz and 1000Hz.



ART_{500} = 95 dB

Presentation should be at 10 + ART. So it will be 105dB. Presenting it for 10 seconds continuously. The deflection of BM needle is positive side (not at zero). If the magnitude of reflex reduces by 50% within 5 seconds. The presence of reflex decay indicates retrocochlear pathology, In cochlear pathology no decay. This test is not done at high frequency because high frequency reflex decay is present is normal subjects also. It is an objective test of tone decay to identify retrocochlear pathology.

SPAR: Sensitivity prediction by Acoustic Reflex:

Degree of loss can be identified by using acoustic reflex.

More recent publications continue to hold promise for the SPAR technique. Sappis (1977) evaluated 50 clinical subjects and reported that the SPAR was 100% accurate in identifying patients with sensorineural hearing loss. He confirm that a SPAR prediction of normal hearing is highly accurate although some of his patients who indeed had normal hearing obtained SPAR predictions of hearing loss.

Jerger et al (1978) he found that accurate prediction of sensorineural hearing loss by SPAR is a function of the patient’s chronological age. Prediction accuracy is most successful in children (age 0 to 10 years) and least accurate in older adults. And also he concluded that the best approach to predicting the presence of hearing loss of any degree seems to be reliance on the broadband noise and pure tone reflex difference, while reliance on the absolute acoustic reflex threshold level, especially for broad band noise stimuli, to predict degree of hearing loss.

First you find out the acoustic reflex threshold for 500, 1000Hz, 2000Hz, Broad band noise, HPFN (high pass filter noise) and LPFN (low pass filter noise).

Then you find out the difference in the thresholds for pure tone and noise = NTD (Noise tone difference).

LTD = ―――

L = ART Average of (500, 1000, 2000 Hz) – ART noise

M = ART $_{500}$ - ART noise

n = ART lowest of 3 frequencies) - ART noise

If

NTD = 20 normal hearing

NTD = 10 tp 20 mild to moderate

NTD = below 10 severe SN loss.

If

ART - ART

HPFN - LPFN = 0dB then flat hearing loss

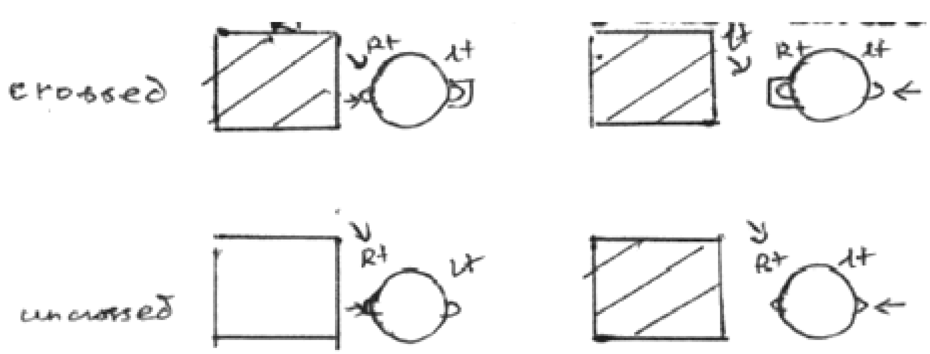
5dB gradual loss

5dB steep loss

Jerger’s box pattern:

Jerger suggested box patterns for clinical application of crossed and uncrossed reflex measurement. These boxes shows the position of the probe in ear. The filled box indicates abnormality.

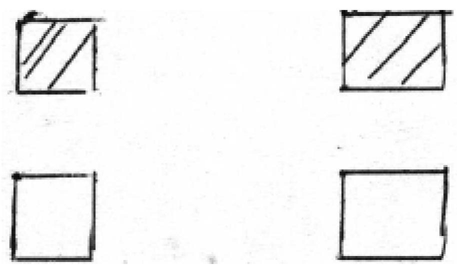
1. Left conductive hearing loss – inverted L pattern.



2. Right retrocochlear pathology.

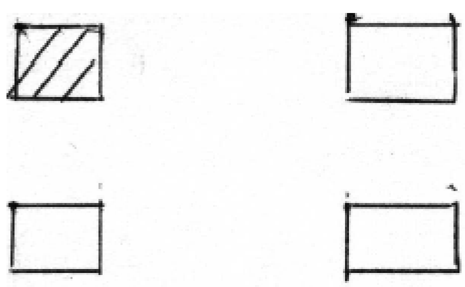
Diagonal pattern.

3. Brain stem lesion



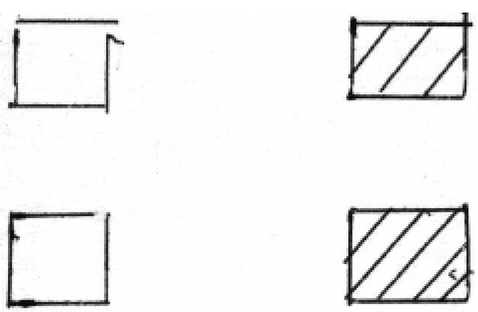
Horizontal pattern.

4. Extraxial lesion



Uni box pattern.

5. Left facial paralysis



Vertical pattern.

IMPEDANCE MEASUREMENT IN THE HANDICAPPED AND "DIFFICULT TO TEST" POPULATION

I. Difficult to test children:

1) Impedance measurements in deaf children
2) Impedance measurements in mentally retarded.
3) Deaf-blind children
4) Children with cerebral palsy.

II. High Incidence group:

1) Children with cleft palate
2) Allergic children
3) Children with Down syndrome
4) Children with craniofacial /Skeletal disorders
   (i) Mobius syndrome
   (ii) Klippel-feil syndrome.

IMPEDANCE MEASUREMENT IN THE HANDICAPPED AND "DIFFICULT TO TEST" POPULATION

Impedance measures aid in the detection and diagnosis of hearing defects in otherwise normal children. They also aid in testing hearing function and in the detection of ear disease in the 'difficult-to-test' population.

The special populations are divided into two major categories.

(1) Difficult-to-test children such as retarded, developmentally delayed, the deaf-blind, and multiply handicapped children.

(2) Groups in whom a high incidence of middle ear disease may be expected such as patients with cleft lip and cleft palate, Down's syndrome, allergy, and children with craniofacial or skeleteal disorders.

I. Difficult to test children:

Impedance measurement in deaf children:

Impedance measurement in deaf children are helpful in the early detection of otitis media and in the assessment or recruitment. According to Wilber et al (1970, cited in Dempsey, 1975), children of mothers with history or rubella showed higher impedance than in normals. Dempsey (1975) reported that in deaf compliance does not increase with age.

Gersdorff (1977) reported that in deaf, otitis media may be detected using impedance measures. According to Morgenstern and Jones-Crymes (1979) it is difficult to detect conductive pathology in the severe to profoundly deaf, using pure tone audiometry. This is because, their threshold of hearing is usually above the maximum BC out put of the audiometer. Thus, it is not possible to detect any AB gap characteristic of conductive loss. It can be detected only if associated with discomfort or pain. Such undetected conductive pathologies may add to the damage already present.

To investigate the incidence of middle ear pathology among the deaf, Morgentern and Jones-Crymes (1979) tested 104 children aged 4-17 years. They found that about 62% of children aged 4-6 years demonstrated abnormal tympanograms. The number of abnormal tympanograms decreased with increasing in age. The authors concluded that impedance screening helps in the early detection of middle, ear pathology in deaf children with server to profound loss. Jerkildson (1960) tested 127 children with hard of hearing for the presence of recruitment. Reflex measurements were done at 500, 1000 and 2000 Hz. Hearing losses of parental origin were found to affect the cochlea more. The incidence of recruitment was higher in this group. On the other hand, hearing loss of post-natal origin affect the retro-cochlear

cochlear part of the auditory pathway more. In this group recruitment was absent. Children attending schools for the deaf are not routinely evaluated. Bone conduction measurements are of limited usefulness in this special population with server to profound sensorineural hearing impairment.

Brooks (1975) studied impedance in 306 children who were residents of two deaf school. He pointed out two important conclusions.

(1) The incidence of middle ear effusion is the same in deaf and normal hearing children at 5 years of age, but the rate of which the disease diminishes in subsequent years is considerably slower in the deaf group.

(2) The residual level of middle ear disorders at age 11 and older is markedly higher in deaf children. Brooks reported 7% of the deaf students older than 11 years had middle ear disease. Keating et al (197) also found a high incidence of abnormal tympanogram (25%) of deaf students aged 12 to 13 years. Brooks concluded that although the incidence of middle ear problems in deaf children is at least equal to that noted in normal hearing children, the likelihood of detection of the middle ear problem is considerably less.

These studies show that impedance audiometry provides a useful means of evaluating the conductive mechanism in patients with profound deafness. In deaf children this additional hearing loss may have significantly effect on hearing aid performance. So the impedance audiometry should, by all means, be routine procure for children attending schools for the deaf.

2. Impedance audiometry with the mentally retarded:

Mentally retarded subjects are a part of the difficult to test population. It is often difficult to use behavioral techniques with them, because of their inability to understand instructions or because of the examiners difficulty in distinguishing their behavior response from the on-going activity, which may be high enough to predominate over the behavior response. In such cases impedance measurements may prove useful.

Burns (1979), he screened 79 physically handicapped and mentally retarded school children with impedance audiometry. Results indicated that the presence of middle ear abnormalities increased as the degree of retardation increased and age deceased.

Lamb and Norris (1970) measured the acoustic reflex in 15 mentally retarded and 15 children, of comparable age. A Madsen ZO-61 bridge was used for the measurement of reflex. Reflex thresholds were obtained for pure tones of 250, 1000 and 4000 Hz. The results obtained in the two groups were in good agreement with each other and with the norms for normal adults. Reflex thresholds were slightly lower than in the mentally retarded children than in the normals. Descending approach gave rise to lower reflex thresholds, in both normals and in the retarded children. The author contended that impedance measurements could be used incases where behavioral audiometry proves to be difficult.

Fulton and Lamb (1972) tested 100 mentally retarded subjects with the mean age of 14 years and 11 months and with an IQ range of 21 to 87, 68 male and 32 female subjects participated in the study. Impedance value was similar to that obtained with normals. Inter subject variability was high. It was hypothesized that this might have been due to middle ear pathologies that were undetected on pure tone audiometry or otoscopy. The authors concluded that impedance measurements would be useful in cases were mild conductive pathologies may go unnoticed on pure tone audiometry.

Wooten, Sheely and Hannah (1975) recommended the use of impedance measurement in all mentally retardates. They differentiate between “hard signs” and “soft signs”. The former includes a type ‘B’ tympanogram or a type ‘C’ tympanogram with negative pressure of -101 to -400 mm H_2O and an impedance of 0 to 734 acoustic ohms or 4000 acoustic ohms.

The incidence of defective hearing in mentally retarded is several times grater than in normal population (Lloyd and Reid 1966; Jordan (1977) points out that even a mild degree of hearing loss may have a disproportionate impact on the mentally retarded because he is less capable of compensating cerebrally with the aid of his other sense. So the early identification of hearing loss in M.R. and for the further treatment procedures, impedance audiometry is very helpful.

3. Deaf-Blind-Child:

The deaf blind children come under the groups of “Difficult-to-test population”. Impedance measurements are useful in the evaluation of auditory function in these subjects (Northern, 1978).

Evaluating of hearing in deaf-blind children is one of the most difficult tasks faced by the audiologist. The task is even more difficult when mental retardation accompanies the deaf-blind handicap. Audiometrically we are limited to observation of basic behavioural auditory orientation responses. The acoustic startle reflex, and quieting behavior to brief introduction of various interesting sound stimuli, if server visual, motor or other neurologic deficits are present. The Primitive reflexive auditory behavior responses may be inhibited or absent.

The tympanogram information helps in identifying those who are in need of medical evaluation. The presence of acoustic reflexes confirms the child’s ability to hear.

It is the audiologists responsibility to make the decision about the blind child’s hearing ability. It is often useful to the audiologist to discuss the hearing potential of deaf-blind children with the parents who are with the child for a long period of time. Sometime the peripheral reflexive hearing mechanism seems with in normal limits, but the child is “functionally deaf” since sounds are seldom imitated, little vocalization occurs, and response to verbal cues is inconsistent.

Impedance measurements in children with cerebral palsy:

Snow and McCandless (1975), cited in Northern 1978) found that children with spasticity and hypertonia exhibited alterations in latency and reflex release times.

II. High-Incidence groups:

1. Children with Cleft palate:

Incidence of hearing loss is higher in children with cleft palate than in normal children. The loss might be mild to moderate. It is usually bilateral and of conductive type. Excessive contamination of nasopharynx is common in these cases. This results in eustachian tube inflammation. Consequent to this the middle ear effusion which results in a conductive hearing loss (Bess, Lewis and Cieliczka, 1975). Children with cleft palate exhibit a severe functional obstruction of eustachian tube while swallowing. In an animal experiment (using Rhesus monkeys) Cantekin et al (1980) found that severing the tensor veli palatine muscle lead to the development of otitis media with effusion. This seems to be the prime determiner of pathogenesis of otitis media with effusion in cleft palate population (Boyle, Cantekin and Bluestone, 1980).

Billings and Lowry (1974) found impedance measurements to be more useful for diagnosis than for screening in a cleft palate population. Arora et al (1982) secretary otitis media being the most common lesion. Impedance audiometry give more valid information about conditions in the middle ear.

so impedance audiometry should be done as a routine whenever facilities exist, in conjunction with the clinical examination.

Gopalakrishna (1983) he analyzed middle ear pressure, static compliance, and acoustic reflex in the normal and cleft palate children and found out that poor eustachian tube function, evidence by persistent negative middle ear pressure continues to be commonly seen in the older subjects with on cooperated clefts. The static compliance that reflects the elasticity of conducting mechanism of the middle ear is poorer in cleft-palate patients.

According to Bess, Lawis and Cieliczka (1975) only about 40% of cleft palate cases demonstrated type ‘A’ tympanogram, where as about 80% of the normal subjects give type ‘A’ tympanogram. In about 45% of the cases, compliance was less than 0.2cc. In the rest 55%, it ranged from 0.3to 0.8cc. Just as the tympanometric and compliance measures, even the reflex measurements showed abnormalities. About 80% of the ears failed to show reflexes in two or more frequencies. In the rest 20% where reflex could be elicited, the reflex threshold was slightly higher than in normals (median of acoustic reflex threshold of 100dBSPL, as against 90dB SPL in normals).

It was also observed in the above study that, about 47% of the subjects who showed normal hearing on pure tone audiometry showed abnormal results in impedance audiometry 9cases of perforation)gave normal thresholds but showed abnormal impedance findings). Impedance measurement were also found to be useful in evaluating Eustachian tube function (Bess, Lewis and Cielizka, 1975). Pure tone audiometry was found to be least useful among the three measures, viz. puretone audiometry impedance measurements and otoscopy, when used with a cleft palate population (Bess Schwarta and Redfield, 1976). About 57% of the cases showed abnormal tympanograms, of these 12% of A type, 5% belonged to type ‘B’ and 20% showed ‘C’ type.

2. Impedance measurement in Allergic children

The role of allergy in recurrent middle ear effusions continues to be a controversial topic. Allergy affects the ear by obstructing the eustachian tube and by increasing the secretion of mucoid material from the middle ear mucosa.

Fernades et al (1977) compared results of otoscopy and tympanometry in 102 children with allergic rhinitis or asthma. This author concluded that tympanometry is an important adjunct to the emulation of allergic children supplying objective evidence of middle ear disease when none is evident to physical examination.

Dorsett et al (1975) reported that 51 percent in 488 had yield of abnormal ear findings. This investigators reported tympanometry to be a practical, useful addition to pediatric allergy, and recommended its routine use in every child referred for respiratory allergy recurrent otitis or delayed speech development.

3. Children with Down’s syndrome:

Down’s syndrome or mongolism, is the result of chromosomal abnormality either as a twenty one trisomy a tralscolation trisomy or as mosaicism. Mental retardation is almost universal is Down’s syndrome children who have a characteristic personality that is warm, friendly and affectionate.

Ear symptoms commonly associated with Down’s syndrome include small pinnae, narrow esternal auditory canals, abnormal external ear configuration, and strong tendency for otitis media. The child with Down’s syndrome may be more susceptible to upper respiratory tract infection than the normal child because of abnormal skull development which can adversely affect proper drainage of sinuses and middle ear cavities.

Down’s syndrome have a higher than normal incidence of hearing loss, but little unanimity exists regarding the incidence or nature of the hearing problem. Figure for incidence of hearing loss in this special population range from 8 to 85 percent. (Northern and Downs, 1978). Glovsky (1966) reported that only two out of thirty-eight children with Down’s syndrome had normal hearing “an incidence of hearing impairment of 95 percent. Fulton and Lloyd (1968) reported the incidence of hearing loss in Down’s syndrome to be the same in the retarded population in general. The Glovsky study found the prevalent type of hearing loss in Down’s syndrome to be sensorineural, while Fulton and Lloys reported conductive type hearing impairment to be dominant. Confusion regarding the incidence and type of Down’s syndrome hearing loss is due to the difficulty of evaluating hearing in this population.

Schwartz and Schwartz (1978) reported impedance data obtained from subjects with Down’s syndrome having stenotic ear canals. They found that out of 15 subjects with stenotic ear canals, 12 showed otoscopic and tympanometric evidence of otitis media with effusion. They conducted ipsilateral reflex measurements in order to rule out the interference of the pathology of the other ear in the reflex measurement of the test ear. About 38% of the normal ears showed absence of reflex even on ipsilateral measurements.

The results of the above study may be explained by considering the generalized hypotonia present in cases of Down’s syndrome. Hypotonia of the tensor veli palatine could result in Eustachian tube. Dysfunction which could be the predisposing factor for the high incidence of middle ear effusion.

Brooks (1972) reported impedance findings in a population of 100 children with Down’s syndrome. He evaluated these children with audiometry and tympanometry and compared results with a matched control group of 100 retarded children. His results indicated that middle ear conductive loss problem existed in to percent of those with Down’s syndrome and in only 17 percent of the control group, that 36 percent of the Down’s syndrome group showed some element of sensorineural hearing loss compared with 11 percent in control group; and finally, that only 23 percent of the children with Down’s syndrome had normal auditory function as compared with 74 percent in the control group. Brooks reported the conductive loss in Down’s syndrome to be due primarily to otitis media. Schwartz and Schwartz (1977) examined 39 non institutionalized children with Down’s syndrome.

Using impedance audiometry and otoscopy. Nearly 70 percent of their sample population demonstrated evidence of ear disorders.

An extensive research effort ongoing at the university of Colorado medical centre, to evaluate the incidence and type of hearing problem in 100 Down’s syndrome children. Only 15% of the group have bilaterally normal hearing, 50% have significant bilateral conductive loss. 15% have sensorineural hearing loss, and 9% show mixed type hearing impairment. A number of the conductive hearing impairments are of such a degree to not be commensurate with otitis media. Approximately one half of the group has normal type ‘A’ tympanograms, while one fourth has type ‘B’ tympanogram and one fourth has type ‘c’ tymapnograms. Acoustic reflexes were also evaluated in these children.

All the Down’s syndrome children in their study have had through otoscopic evaluation and some have been treated with ventilation tubes. A number of children persist with conductive type hearing impairment despite placement of tubes and improvement in the condition of their middle ears. At the time four selected children from study undergone exploratory tympanotomy. An additional middle ear was viewed by microscopy through a 90 percent tympanic membrane perforation. All five of these ears showed congenital abnormalities of the middle ear ossicles. Two cases were observed to have abnormally shaped include and three cases had a congenitally fixed stapedial footplate. As above study says 80% of incidence of hearing impairment in Down’s syndrome and suggested that middle ear anomalies may be a relatively common clinical feature.

Schwartz (1978) pneumo-otoscopy and acoustic impedance measures were performed in 36 young children with down syndrome. Results indicated that more than 60% of children demonstrated otoscopic and acoustic impedance evidence of middle ear effusion. In particular large number of normal ears that displayed absent crossed and uncrossed acoustic reflex which suggested that measurement of the acoustic reflex only may be an unreliable parameter for confirming the presence of middle ear effusion in children with Down’s syndrome. A careful examination to detect middle ear effusion must be performed on periodic intervals in conjunction with impedance measurement.

4. Children with craniofacial/skeletal disorders:

There is a tendency for middle ear anomalies to occur together such as bronchial arch abnormalities which involve the external ear and ear canal is cases of microtia and ateesia.

Since the mandible shares common embryonic origin with the middle ear ossicles malformation of the lower jaw may be accompanied by congenital conductive hearing impairment. Multiple congenital malformations frequently “run together in syndromes”. Children with craniofacial and/or skeletal disorders may also have congenital conductive or sensorinueral hearing loss. Although audiometry in older children can be used to describe the nature of the hearing impairment, impedance audiometry has an important contribution to make in the overall diagnosis of the auditory defect.

i) Mobius syndrome:

The child will have bilateral facial weakness (nearly complete paralysis) submucous cleft palate with bifid uvula, obvious malformations of the external ears, macrostomia or greatly exaggerated width of the mouth resulting from failure to proper union of the maxillary and mandibular processes. In addition to no measurable hearing, radiographic tomographic studies reveal symmetrical middle ear anomalies involving malleous and incus deformities and absence of the oval window bilaterally. The cochlea and vestibular system appears normal by x-ray, but the internal auditory canals are hypoplastic measuring only 1.5 mm in diameter instead of the normal diameter of approximately 8.0mm. The external canals and tympanic membranes are normal bilaterally to otoscopic examination.

The impedance study indicated type ‘B’ tympanograms low static compliance and absent acoustic reflexes.

ii) Klippel-feil syndrome:

The characteristic features of children with Klippel feil syndrome are profound sensorineural hearing loss and middle ear anomalies has congenital absence of several cervical vertebrae with obvious shortening of the overall length of her cervical spine. Neck appears short with slight webbing. The child may have befid uvula and submucous cleft palate. Radiographic tomography revealed bilateral fused ossicular masses.

The impedance study is sensitive to the ossicular deformity producing type ‘B’ tympanograms, low static compliance and absent acoustic reflexes.

The craniofacial/skeletal disorder also includes Apert’s syndrome and Treacher Collins syndrome. Early identification of children with congenital deafness is, of course, essential for successful habilitation. Many researchers found impedance to be invaluable in the diagnostic evaluation of children with craniofacial problems. Decisions regarding educational placement and referral, possible exploratory tympanotomy or even selection of appropriate amplification devices may be made earlier, and with increased authority, when specific condition of the middle ear is known.

IMPEDANCE MEASUREMENTS IN SCREENING

(1) Impedance measurement in preschool children.

(2) Impedance measurement in school children.

(3) Recommendations for impedance screening.

(4) Open ended tympanometric screening.

IMPEDANCE MEASUREMENTS IN SCREENING

A screening programme aims at early detection of problem under concern. Conductive hearing disturbances are common in the school going children. A mild conductive disturbance in a young child may go unnoticed until it develops into a serious problem. The use of impedance screening is gaining popularity for its high sensitivity in the detection of middle ear pathology. It may also detect the presence of sensorineural loss. It could point to the need, if any, for detailed testing in any given case. Its usefulness is enhanced by its quickness and low cost. Another factor which makes it successful as a screening device with children is that, it needs very little cooperation of the child. It does not need a high intellectual functioning. This section reviews the different studies on impedance screening.

1. Impedance measurements in preschool screening:

According to Marion (1971) (cited in Weaver et al 1976), impedance screening is the most reliable technique in the detection of conductive pathology in preschool children.

Fiellau-Nikolajsen et al (1977) reported the use of impedance measurements in preschool children. They reported the user of impedance measurements in preschool children. They reported that girls and boys did not differ significantly interms of incidence of middle ear pathology. This was in agreement with Brooks (1969) and contradicted Davidson’s (1966, cited in Filleua-Nikolajsen, et al 1977)report that males show a higher incidence of middle ear pathology than do females and that of Reisman and Benstein (1975) who found a higher incidence in girls (cited in Fieleau-Nikolajsen, et al (1977).

These authors agree with Brooks reasoning that “.... boys and girls are equally likely to suffer from auditory tube abstraction, but that girls are more likely to recover without formation of fluid in the middle ear”.

Filleau-Nikolajsen (1979) reported that incidence of middle ear pathology in a large population of 3 years old children (1868 ears) was higher in winter.

Fielleau-Nikolajsen and Lous (1979) followed up children with ‘B’ or ‘C’ type tympanograms for 6 months. They found that spontaneous recovery occurred in over 70% of the cases. Spontaneous recovery was more in females in cases of ‘B’ type tympanogram.

In a group of preschool children aged 36 to 72 months skinner, Norris and Tirsa (1978), found that mean contralateral reflex thresholds for pure tones 500, 1000 and 2000Hz was elevated by about 10dB when compared to that in adults. The mean ipsilateral reflex threshold was higher by about 4dB. Reflex thresholds for white noise was 20dB lower than that of pure tones. Reflex thresholds for high pass filtered noise (greater than 3200Hz) was lower by 15 dB and for low pass noise was about 10dB when compared to reflex thresholds for pure tones).

2. Impedance measurements for screening:

It was pointed out by Jordon and Eagles (1961, cited in Harker van Wagoner, 1974) that audiometric screening, however complete, cannot identify all children with ear disease. They reported that about one half of their subjects, had normal hearing sensitivity despite otological abnormality.

Brooks (1971) opined that pure tone screening is insufficient and unsatisfactory. Some children with normal hearing sensitivity may fail to respond on pure tone audiometry, while some children with aural pathology may pass a puretone screening test. In such cases impedance screening has been proved to be better than pure tone screening.

Mills (1972, cited in Weaver et al 1976) also found impedance screening to be more effective than pure tone screening. Similarly otoscopy may also fail to detect certain abnormalities. This is because, otoscopy is sensitive only to lesions near the tympanic membrane and often fail to detect lesions at or near the eustachian tube. These could be detected through impedance screening. The number of errors is identification is lesser and reliability is higher in impedance screening is sued, than when pure tone screening is employed (Brooks, 1973; McCandless and Thomas, 1974).

Referring to the case of a child who passed on a pure tone screening with a 20 dB criterion, but who had a serous otitis media, that was identified and confirmed with impedance testing, Libby (1974) emphasized on importance of impedance measurement in screening.

Secretory otitis media is a common cause of hearing loss. Screening with impedance helps in early detection of secretory otitis media. Its efficacy improved when used with pure tone audiometry. The latter is inefficient if used alone (Brooks, 1974).

Fox-Buckley et al (1974) compared impedance measurements, pure tone audiometry and otoscopy, in a group of 341 elementary school children. They found that impedance measurements had the highest accuracy of identification of auditory disorders.

Orchik and Herdman (1974) screened 205 preschool children using two method (a) pure tone audiometry alone and (b) pure tone audiometry with impedance measurements. In the first method, hearing sensitivity for pure tones was tested from 250 to 8000Hz at 20 dBHL. In the second, tympanometry reflex measurements at 500Hzx, and 2000 Hz at 100dBHL and pure tone screening at 3000Hz at a level of 25 dHHL were included. It was observed that pure tone screening may fail to detect a number of cases 2ith middle ear pathology. Criteria (i) proved to be better, when impedance screening, as the use of the second criterion gave rise to a high rate of false positives.

Impedance measurements were found to be preferable to pure tone audiometry in a study conducted by Harker and Van Wagoner (1974). They found that about 10% of children who were found normal on pure tone audiometry were found to be abnormal on impedance measurements.

Ferrer (1974), cited in Renvall et al (1975) reported that about 55 to 58% subjects with middle ear pressure of less than or equal to -150mm H_2o gave normal hearing with a 25 dB pure tone screening.

Renvell et al (1975) found that, about 65% of the subjects with middle ear pressure of -100 to -400 mm H_2O and about H_2O show normal hearing on pure screening. They therefore reported that pure tone alone cannot be used for screening.

Cooper et al (1975) were of the opinion that pure tone audiometry may miss certain cases with hearing loss. This is because (1) an intensity level of 20 to 25 dB is inefficient in detecting mild conductive hearing loss (2) in condition were ambient noise is high, level of the signal used for screening is also high and this results in a higher false negative and (3) reliability of response may be poor.

In a group of 539 children (91 from preschool, 82 from Kindergarten, 63 from First grade and 303 from fifth grade, impedance screening detected hearing disorders in 90% as against the 24% detection of pure tone screening. Impedance screening with a high frequency screening was found to be ideal for school screening (cooper et al 1975).

Cumming, Sterrett and McCulloch 91977) reported that 50% of their subjects were missed with the 25 dB criterian pure tone screening. They opined that impedance measurements do not need much cooperation from the subject and the procedure is simple and reliable. They, however, emphasized that impedance testing should not replace pure tone audiometry but should only supplement it.

Roser et al (1977) recommended the use of impedance screening for reasons that it was not much influenced by environmental or motivational factors and because it is cost effective. They suggested that tympanometry, reflex testing at 100dBHL and a puretone screening at 2000 or 4000Hz at a level of 20-30 dBHL, would be sufficient for screening purposes.

Brooks (1978) opined that absolute compliance measurement of middle ear pressure alone may not be adequate. He recommended the use of gradient of tympanogram as a criterion. According to him impedance screening is useful and is cost-effective. He opined that it is not a very expensive but is in fact less expensive than pure tone screening.

Urban (1978) also reported that impedance screening has a high sensitivity and works at quite a low cost.

Impedance, screening comprises either tympanometry or measurement of the acoustic reflex or both, carried out by means of electroacoustic impedance instruments, and is intended to detect the presence of middle ear effusion or of certain other less common otologic disorders. These deseases have a high degree of association with conductive hearing loss, the most common type of hearing impairment in children.

Impedance screening fulfills the principal criteria for an effective screening test-acceptability, reliability, validity and reasonable cost. Impedance testing is acceptable to both the child and the provider of health care because it is safe, non-invasive, and simply executed.

3. Recommendations for impedance screening:

Preschool and School age children

i) Tympanometry and acoustic reflex measurement should be used.

ii) For eliciting the acoustic reflex, a signal of 105 dBHTL should be used in the contralateral mode, or a signal of 105 dB SPL in the ipsilateral mode, or both.

iii) Whether broad-band noise or pure tone is preferable as an eliciting stimulus for the acoustic reflex remains to be established. A pure tone between 1000HZ and 3000HZ would be acceptable for this. The stimulus should be specified or described or both.

iv) Acoustic reflex measurements can be obtained either with the ear canal air pressure that results in minimum acoustic impedance or with ear canal air pressure equal to ambient pressure. The condition used should be specified.

v) For tympanometry, a 220Hz probe tone is preferred. However, other two frequency probe tones upto 300Hz are acceptable.

vi) For tympanometry, an air pressure range of -400 +100mm (H_2O) is preferred. However, a range of -300 to +100 mm (H_2O)is acceptable. Automatic recording should be used whenever possible and the rate of air pressure change should be specified.

vii) Failure of the initial screening test is denoted by either an absent acoustic reflex or an abnormal tympangoram. An abnormal tympanogram is defied as one that either (a) is flat or rounded (without definite peak) or (b) has a peak at, or more negative than -200 mm (H_2O). Flat or rounded tympanograms appear to be more highly correlated with middle ear effusions than do tympanogrms with peak at negative pressure readings.

viii) Any child failing the initial screening should be retested in four to six weeks. Parents or guardian should be advised accordingly. Any child who has an acoustic reflex and a normal tympanogram on the initial screening passes and is 'cleared'.

ix) The following scheme is recommended for various screening findings.

Classif-ication	Initial Screening	Retest	Subject Out come
I	Acoustic reflex present and tympanogram normal	Not required	Cleared.
II	Acoustic reflex absent and/or tympanogram abnormal	Acoustic reflex absent and/or tympanogram abnormal	Referred
III	Acosutic reflex absent and/or tympanogram abnormal	Acoustic Reflex present and tympanogram normal	At risk rechecked at later date.

The classification I and II should constitute the majority of children in a given population. Referral, when indicated after confirmatory retest. Classification III constitute a group of children "at risk should be retested periodically to determine the possible need for future medical referral.

x) Headbands, if used should be designed and manufactured to fit infants and small children. Probe tip should be soft and remain soft after use and cleaning. The entire probe assembly, including the tubing, should be durable.

xi) Calibration of instruments should be performed routinely. This calibration should involve the intensity and frequency of the probe tone, the manometer for pressure variation, and the reflex activating stimulus.

4. Open ended tympanometric screening:

Tympanograms obtained from children do not remain the same from day to day (Lewis et al 1975; Schwartz et al 1978. However there seems to be some consistency in the change. An ‘A’ type tympanogram obtained in the first trial may change to a type ‘C’ and less likely to a type ‘B’. There is a high probability of type ‘C’ changing to type ‘A’ or type ‘B’. While a type ‘B’ is a clear indication of middle ear pathology, type ‘C’ or ‘A’ do not give unequivocal results. Children with type ‘c’ or type ‘A’ tympanograms should be retested before referral (Lewis et al 1975). These recommended that the screening be done on successive days. Although the procedure appears to be not so economical but it is more economical than needless follow up due to over referral. Similarly, the loss due to under referral is irreversible. Therefore it is worth employing repeated testing for screening purpose (Lewis et al 1975).

Schwartz et al (1978) performed successive day tympanometric measurements for 5 days in children under 5 years of age. This was done with the aim of assessing the variability in the tympanometric data with time. They found that the middle ear pressure is of a fluctuating nature. It was observed that use of -100 mm H_2O criterion for referral in a single day screening program might work out costly and might result in unnecessary referrals. As successive day screening could also work out costly, Schwartz et al (1978) recommended that tympanometry be done on two non-consecutive days. If there is a negative pressure beyond or equal to -200 mm H_2O or if there is a flat tympanogram on either of these days, then, referral is essential. If there is a middle ear pressure of -100 to -200 mm H_2O or if the tympanogram pattern changes, a retesting after 6 weeks is recommended. It any spontaneous recovery were to occur, it would be complete by 6 weeks (Schwartz et al 1978). Konkle et al (1978) also recommended a re-screening after some time lapse in ears with negative pressure of -101 and -200 mm H_2O.

Liden and Renvall (1978) also found two repeat tests to be useful in reducing the number of false-positives. They recommended the use of a time gap of 4 weeks between the initial and the soon second test.

Brooks (1978c)recommended the use of tympanometry in conjunction with reflex measurements. he suggested that re-test after a time lapse would indicate if the abnroamlity noted in the first screening is transient or not.

Hardford, Fox, and Clemis (1978) pointed out that impedance measurements should not be used in isolation, for screening purposes. Children with pure sensori-nerual hearing loss may be missed if such a screening method is employed. They recommended that impedance screening should be used in conjunction with pure tone screening and otoscopy.

In conclusion, it may be said that impedance screening is of great use of clinicians and educational audiologists. Appropriate environment and ‘pass-fail’ criterion employed are factors which contribute to an influence the efficacy of impedance measurements in screening. Thympanometry in conjunction with reflex testing and a high frequency pure tone is preferable, because of lower rate of false negatives, than the use of the these methods in isolation.

CONCLUSION

As we have seen many studies have reported the effect of middle ear pathology on several aspect of the child's development like Speech and Language development, educational retardation, ability to live and learn in ones environment and also medical complications like permanents SM loss, mastoiditis, meningitis and other intracranial complications. So there is a great need of early, accurate identification and assessment of middle ear disease in children. The traditional method of identification of middle ear desease in children has been through otoscopy and also the puretone audiometry. But this has certain limitations.

(1) Impedance measurements have an advantage of being independent of the subject's willingness and ability to give voluntary responses; (2)It requires less time to complete (3) It is not greatly influenced by either environmental or motivational factors (4) It is less affected by test technique and (5) also it is useful in testing 'difficult-to-test' population. Since, the impedance audiometry has many advantages when compare to other ontological and audiological measurements. The impedance measurements should be an essential part of audiological evaluation of children.

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