TUTORIAL
ACOUSTIC IMMITTANCE MEASURMENTS

Reg.No.M9822

Independent Project as a part fulfillment of first year M.Sc,
(Speech and Hearing), submitted to the University of Mysore,
Mysore

ALL INDIA INSTITUTE OF SPEECH *AND* HEARING MYSORE 570 006
MAY 1999

CERTIFICATE

This is to certify that this Independent Project entitled : A TUTORIAL ON ACOUSTIC IMMITTANCE MEASURMENTS is the bonafide work in part fulfilment for the degree of Master of science (Speech and Hearing) of the student with Register No. **M9822.**

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This is to certify that this Independent Project entitled **:A TUTORIAL ON ACOUSTIC** IMMITTANCE MEASURMENTS has been prepared under my supervision and guidance.

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DECLARATION

This Independent Project entitled : **A TUTORIAL ON ACOUSTIC IMMITTANCE** MEASURMENTS is the result of my own study under the guidance of *Mr.Animesh Barman* Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

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INTRODUCTION

The word 'tutorial' as defined by scientific and English dictionaries refers to an 'instruction book' or 'intensive instruction in some area'. It aims at providing supplementary instruction in order to present better opportunities to students and concerned professionals to actively participate in the learning process and receive immediate feedback. The information is carefully selected and delivered in an organized and structured manner. It also evaluates the user's knowledge through different kinds of questions which gives him/her an immediate feedback of the performance. It thus acts as an efficient guide for students and experts linked with the particular field.

The present tutorial aims at providing intensive instruction in the area of 'ACOUSTIC IMMITTANCE MEASUREMENTS'.

Among the great number of tools employed in the field of Audiology, acoustic immittance measurement is one which helps mainly in understanding the middle ear, its functions and its pathologies. Its reach extends beyond middle ear and it can even help in identifying inner ear and also higher level pathologies.

Though the concept of acoustic immittance very old, it has been applied to clinical use only recently. Earlier, it was used to measure the capacity of telephones and for other such purposes. Later, experts like Fowler, Troger, Keibs etc. used this procedure to study the middle ear. Following their footsteps, various authors conducted such studies leading to the rapid progress of acoustic immittance techniques, procedures and instruments.

A landmark in this area was made by Metz (1946) when he published his classic monograph on impedance. A number of experiments were conducted in 1950s and 1960s which had led to such a vast growth of this technique.

Acoustic immittance measurement includes two major procedures -'TYMPANOMETRY' and 'ACOUSTIC REFLEX'. Tympanometry is used to study the compliance changes of the tympanogram with respect to pressure variations in the external ear canal. The measurements are represented in graphical form called 'tympanograms'. Depending on the type of tympanogram obtained, one can predict the possible middle ear pathology.'

Acoustic reflex measures the impedance changes occurring in the middle ear on the presentation of a loud stimulus. This procedure also gives us an insight into the middle ear functioning and even provides information about the hearing sensitivity of the individual.

The applications of acoustic immittance measurments is not limited to these alone. These procedures have been applied to all age group people in both screening as well as diagnostic tests. As mentioned earlier, peripheral as well as central disorders of the auditory system can be detected using this. In cases for whom behavioural audiometry is difficult, these objective measures can be employed. It is also used in hearing aid selection and management. Acoustic immittance measurement has made its impact on the field of speech pathology also. Various speech disorders like stuttering and spastic dysphonia have been studied using this technique. Certain disorders like myesthenia gravis which are caused by lesions in the nervous system have also been investigated using acoustic immittance measurements

This procedure is now common not only in Audiology clinics, but also in ENT centres and other diagnostic units. In the present century when great importance is being given to early identification and intervention, it is obvious, how great an importance this technique has in school screening programs conducted to identify middle ear and other otological abnormalities at an early stage. This would prevent many of the harmful consequences which may hamper the child's development. Thus, acoustic immittance measurements have a wide range of applications./

From the above discussion, it is clear how important it is for students and professionals in this field to know about these measurement procedures in depth. The present tutorial has been developed keeping this aim in mind. It deals with tympanometry and acoustic reflex in separate sections under which a great amount of information has been presented on each sub-topic in a comprised form. This information has been collected from books, journals and other sources. This is followed by a set of questions. These questions are of the following types :

- Fill in the blanks
- Multiple choice
- True/False
- Puzzles

- Short answers
- Block diagrams
- Matching
- Answering with the help of cues, etc.

The questions are neither too complex nor too simple. These provide the user with an opportunity to test the knowledge that he/she has gained through this tutorial. In order to cross check the results, there are answers provided to all the questions at the end of each section. This would give an immediate feedback of one's performance.

Thus, this particular independent project has been eveloped to serve the following purposes :

1. Give intensive information about acoustic immittance measurements and its applications.
2. To test one's knowledge of the topic.
3. To serve as a guide for students and other concerned professionals.
4. To train and evaluate trainees during a training program.

HISTORICAL ASPECTS

The history of clinical acoustic immittance is well over 100 years old. According to Feldmann (1970), first attempts at objective assessment of middle ear function using acoustic immittance measures were performed by Lucae (1867). The substantial literature on the measurement of acoustic immittance characteristics of human ears dates back to early 1900's.

The concept of acoustic impedance was introduced in 1914 (Webster, 1919). West (1928) was the first to do impedance measuring on the ear using electroacoustic devices. This was done in order to get necessary data for the construction of an artificial ear, required to measure the capacity of telephone (i.e. the energy radiation) under normal conditions.

Fowler (1923) studied hearing threshold changes resulting from positive and negative pressures in the external ear canal. The static pressure was seen to decrease the hearing sensitivity. Middle ear pressure was also estimated by observing the tympanic membrane through the otoscope during pressure application.

Troger (193 0), he first determined the impedance in a tube introduced into the meatus and thus determined the impedance at the drum.

Keibs (1936) using a tubes, he measured the impedance on a subject with normal hearing.

Waetzman (1936) and Kurtz (1938) measured impedance using Keibs tube in connection with determination of the sensitivity of the ear.

Geffcken (1934) reported that voluntary contraction of middle ear muscle changes the acoustic impedance of the ear drum in humans.

Schuster (1934) developed a mechanical acoustic impedance bridge to determine the acoustic impedance of various materials. Prior to this only electroacoustic methods were used for impedance measurement.

Waetzman (1938) and Menzel (1940) were the first authors to adapt Schuster's bridge to human ear impedance measurement. They report only the absorption values obtainedsince phase measurement was difficult.

Application of acoustic impedance in clinical audiology is evident from the work of Metz. He published his classic monograph on impedance in (1946).

The origins of tympanometry as used in today's clinical practice were reported in 1959 by Terkildsen and Thomson. Thomsen demonstrated the principle that middle ear pressure could be determined by changing the air pressure into the auditory meatus until minimal impedance was obtained. Terkildsen was the first to use the word 'tympanometry' to describe the pressure compliance function of tympanic membrane. By late 50's and early 60's, electroacoustic instruments started becoming commercially available and following this acoustic immittance measures started gaining popularity.

In 1968, Denzil Brooks advocated the use of impedance meter in identifying children with fluid in the middle ear. Liden, Peterson and Bjorkman (1970) described four distinctive tympanometric patterns associated with normal and pathological ears.

The first 'tympanograms' as presently known were reported by Terkildsen and Thomson (1980) using Madsen ZO61. This marked the beginning of a new development of admittance and impedance measurements. Following this Terkildsen (1983) developed a sensitive monometric device for measuring tympanic membrane movements.

Over a span of 30-35 years acoustic immittance measurements have progressed from an experimental procedure in isolated clinics and laboratories to a routine clinical tool in most of the audiological set-ups.

Questions

I Fill in the blanks

1) The concept of acoustic impedance was introduced in......
2) The first person to do impedance measuring on the ear using electroacoustic devices was.... in .....
3)..... in.... was the first to determine the impedance at the ear drum using a tube.
4) The first person to develop a mechanical acoustic impedance bridge was ....

II **Choose the correct answers**

1) The author who first used the word 'tympanometry' to describe the pressure compliance function of tympanic membrane was.
   (a) Peterson
   (b) Thomson
   (c) Terkildsen

2) The first 'tympanograms' as presently known were reported by
   (a) Bjorkman and Liden
   (b) Terkildsen and Thomson-
   (c) Terkildsen and Metz.

3) One of the first attempts at detecting fluid in the middle ear of children using impedance meter was made by
   (a) Keib
   (b) Kurtz
   (c) Denzil Brooks

4) He published his classic monograph on immittance in 1946 and this marked the beginning of application of acoustic impedance in clinical audiology. Who is he?
   (a) Kurtz
   (b) Waetzrnan
   (c) Metz

5) These authors described four distinctive tympanograms associated with normal and pathological ears. Who are they?
(a) Liden, Peterson and Bjorkman
(b) Terkildsen, Thomson and Kurtz
(c) Waetzman, Liden and Peterson.

HI **Answer the following questions**

1) When was the first attempts at objective assessment **of** middle ear function using acoustic immittance measures made, and by whom?

2) What was the purpose of impedance measurements earlier?

3) Who was the first author to report that voluntary contraction of middle ear muscles change the acoustic impedance of the ear drum in humans?

4) Name the author who has made substantial contributions to the application of acoustic impedance in clinical audiology.

5) Who were the authors who first included tympanometry as a clinical tool in audiological evaluation?

Answers

I Fill in the blanks

(1) 1914 (2) West, 1928 (3) Troger, 1930 (4)Schuster.

II Choose the correct answers

(1) c>Terkildsen (2) b>Terkildsen & Thomson (3) c>Brooks
(4) c>Metz (5) a>Liden,Peterson & Bjorkman

HI Answer the following questions.

1. First attempts at objective assessment of middle ear function using acoustic immittance measures were performed by Lucae, 1867.

2. Impedance measurements were done mainly to obtain data for the construction of artificial ears which were used to measure the capacity of telephones, in olden times.

3. Geffcken (1934) was the first to report that voluntary contraction of middle ear muscles changes the acoustic impedance of the ear drum in humans.

4. Metz was the person who has made substantial contributions to this field.

5. Terkildsen and Thomsen (1959) were the first to include tympanometry as a clinical tool in audiological evaluations.

CONCEPT OF IMMITTANCE

A. Impedance

1. Mechanical Impedance Let us first discuss the concept of mechanical impedance before going to acoustic impedance.

a. Constant Force -

When a constant force (F) is applied to an object, the object moves over a smooth surface, with a velocity (V). By constant force we mean a force having an amplitude which does not change overtime. Since a certain degree of force is required to move the object of a certain weight by a certain distance, the object has an opposition to the force or in other words it has a MECHANICAL IMPEDANCE Z.

$$z = \frac{\text{Force applied to the object}}{\text{Velocity of the object}}$$

$$Z = \frac{F}{V}$$

b. **Alternating Force -** An alternating force is one whose amplitude changes over time. Consider an alternating force being applied on.a spring. This force is alternately pushing and pulling the spring.

In Fig. 1(A), the mechanical force has just been applied to push a spring. As we know, spring is a highly stiff object i.e. it is stiffness dominated. Initially, the force is at a minimum and the velocity is at a maximum since the spring has not yet been compressed. In Fig. 1(B), though the force is acting maximally on the spring, the velocity is minimum since the spring is completely compressed. In Fig.lC mechanical force decreases until it reaches a minimum and the velocity of the spring increases until it reaches a maximum a point at which the spring is completely uncompressed. If we have to pull the spring further, force has to be applied maximally and velocity will be minimum at this point.

If we plot this graphically, with time on X-axis and force or velocity on Y axis, we can see that at t=0 ms. the force is minimum and velocity is maximum (in the +ve direction). At t=l ms. The force is maximum and the velocity of the spring is minimum, it is clear that velocity of the spring reaches a maximum (90 degree) before the force applied to the spring reaches a maximum. Thus velocity leads force by 90 degree. This is in the case of a stiffness dominated system.

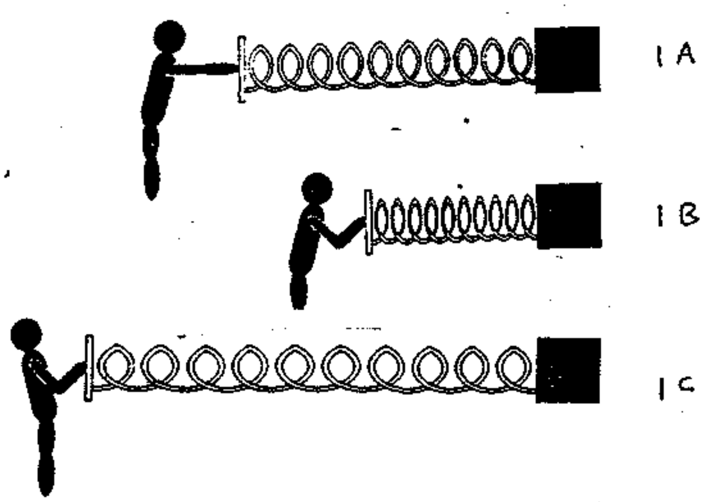


Fig. 1. Force being applied to a spring

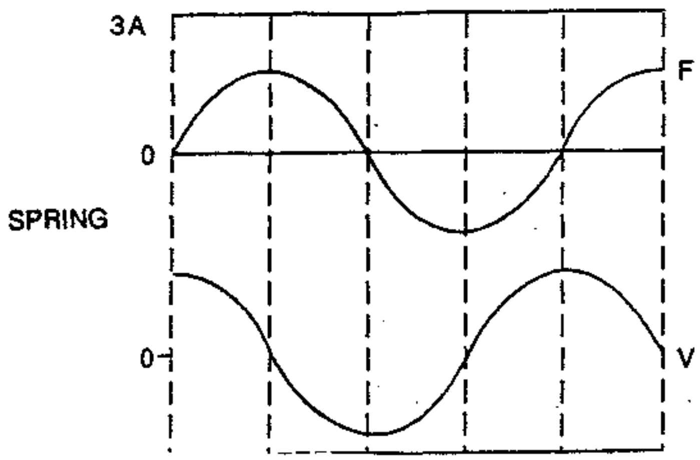


Fig.2 : Showing the relationship between force, velocity and time in a stiffness dominated system.

If we consider an object having mass, when a maximum force is applied to push the block, the velocity is minimum as the block initially rejects the push as a result of its inertia (a tendency for a mass to oppose a change in position). Once, the block starts moving, the force applied is less and velocity is more. If one has to pull the mass in the opposite direction, the force is more, but velocity is minimal. This is graphically represented below in fig. 3

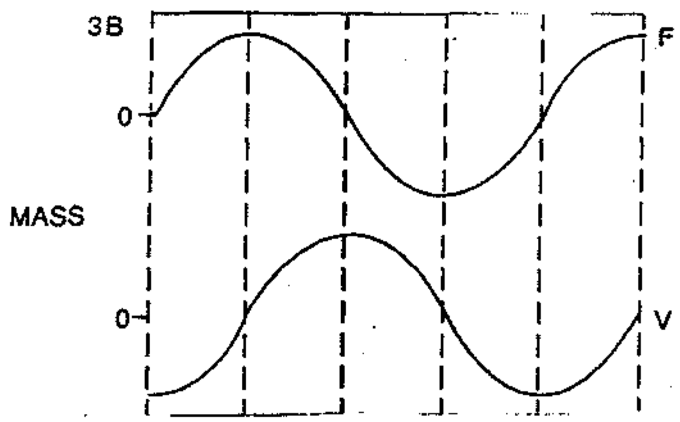


Fig. 3 : Showing the relationship between force, velocity and time in a mass dominated system.

It is clear from this illustration that, velocity of the mass reaches a maximum 90 degree after the force applied to the mass reaches a maximum. Thus force leads velocity by 90 degree in a mass dominated system.

If we consider an object in a frictional system with negligible mass or stiffness, we can see that on applying an alternating force, the velocity and force attain maximum and minimum values at the same time. Thus velocity and force are in phase.

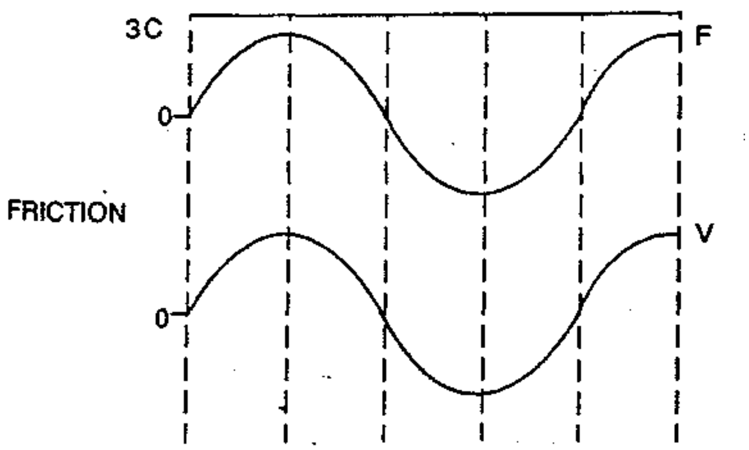


Fig.4 : Showing the relationship between force, velocity and time in a frictional system.

Thus impedance (Z) = force/velocity. Impedance consists of 3 components.

Mas reactance (+Xm) = Impedance offered by mass. The + sign indicates that force leads velocity by 90 degree.

Stiffness reactance (-Xs) = Impedances offered by spring. The- sign indicates that force lags velocity by 90 degree.

Resistance (R) = Impedance resulting from friction. For each impedance component, +Xm, -Xs or R, the impedance is equal to the force divided by the velocity.

When an alternating force is applied to several masses in a series, then the total impedance of the system is simply the sum of the mass reactances offered by each mass component. It is similar for a system having several springs in series on several frictional surfaces in series.

But if there is a system having the three types of impedance components, then the total impedance is not just the sum of the impedance components, since the relation between force and velocity is different for each of the-impedance components.

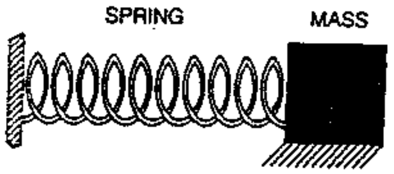


Fig. 5 : System having three types of impedance components

Therefore, a vector system is required to obtain the sum of impedance components. The resistance component of impedance is placed along the abscissa since velocity is in phase with the force.

Stiffness reactance component -Xs is placed along the negative ordinate as velocity leads force by 90 degree and mass reactance component +Xm is placed along the positive ordinate as velocity lags force by 90 degree. Xm and -Xs are out of phase by 180 degree. To obtain the net reactance, the stiffness reactance is added to the mass reactance i.e. Xt = Xm + (-Xs) = Xm-Xs. If the system has more stiffness than mass reactance. Xt will be negative and vice versa.

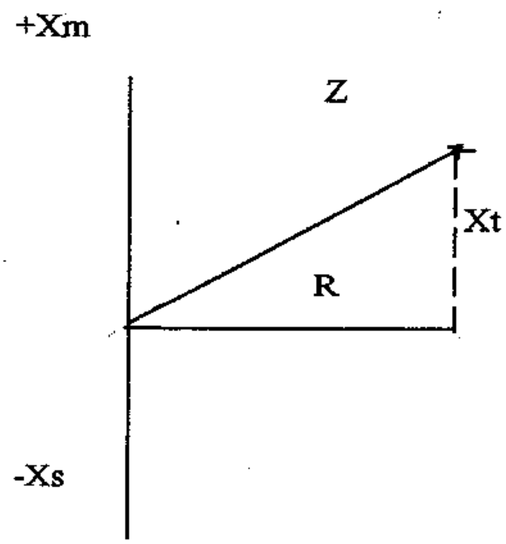


Fig. 6 Vector System illustrating the total impedance.

Applying Pythagoras Theorem, Z2 = R2 + (Xt)2
i.e. Z2 =R2+(XM-Xs)2

The mechanical impedance of a system also varies with the frequency of the applied force. The relation between mechanical stiffness reactance (-Xs), stiffness (s) and frequency (f) is illustrated by the formula (-Xs = S/2πf. According to this, staffer the spring, larger the stiffness reactance and higher the frequency, the smaller the stiffness reactance.

Similarly, $Xm = 2\pi fM$

Thus, mass reactance increases or decreases with respective increase or decrease in frequency or mass. Since, mechanical mass reactance decreases whereas mechanical stiffness reactance increases as frequency decreases and vice versa, there is a frequency at which, the stiffness and mass reactances are equal. At this frequency there is no mass or stiffiiess reactance. This frequency is called as the resonance frequency, which is given by the formula.

$fo = (1/2\pi (S/M)$

Fo = resonant frequency M= mass

S = stiffness.

M = mass

Resistance, unlike mass or stiffness reactance, does not change with frequency.

Since $-Xs = S/2\pi f$, the total impedance of a system which has a net reactance, that is stiffness reactance can be written as

$Z2 = R2 + (S/2\pi f)2$

Since $+Xm = 2\pi fm$, the total impedance of a system which has a net reactance, that is mass reactance can be written as

$Z2 = R2 + (2\pi fM)2$

Acoustic Impedance

In acoustics, the analog of a mechanical mass is the air volume in a tube open at both ends. Similarly, the analog of a spring is the air volume in a tube closed at both ends. When the air volume in a tube is compressed, it will behave like a spring. The analog of friction is the collision of the air molecules.

According to Van Camp, Margolis, Wilson, Gaten and Shanks (1986), the ear is an acoustico mechanical system that contains acoustical as well as mechanical impedance components. The tympanic membrane can be considered as a mechanical spring. The air volume enclosed in the middle ear can be considered an acoustic spring. The ossicular chain can be considered a mechanical mass and air molecules in the mastoid air cells can be considered an acoustic mass. The friction in the tympanic membrane, middle ear tendons and ligaments can be considered the mechanical friction and the air viscosity, the acoustic friction. As the ear also has certain impedance components, similar to mechanical impedance there is acoustic impedance which is represented by Za and +Xa represents the acoustic mass reactance and -Xa represents the acoustic stiffness reactance and Ra represents acoustic resistance.

Acoustic impedance is given by the formula Za=P/U where P represents the pressure and in dynes/cm2 and U represents the volume velocity in cm3. Volume velocity is the volume (cm3) of the sound - conducting medium which flows in a given area in a given amount of time (in sec). Za is the acoustic impedance in acoustic ohms = 105Pa x S/m3.

Acoustic impedance of a system having a net acoustic stiffness reactance is

$Za2 = (-Xa)2 + Ra2$

$Za2 = (S/2\pi f)2 + Ra2$

Acoustic impedance of a system having a not acoustic mass reactance is

$Za2 = (+Xa)2+ Ra2$

$= (27\pi fM)2 + Ra2$

Admittance

Mechanical Admittance

It is defined as the ease with which energy flows through a system. It is the reciprocal of mechanical impedance. It is given by the formula Y=V/F

Y = mechanical admittance, V = velocity, F = force

The unit of admittance is mh. The ease with which energy flows into a spring or an object having stiffness is called stiffness susceptance (+Bs) and the ease with which energy flows into a mass is called mass susceptance (-Bm) The signs of stiffness susceptance and mass susceptance are opposite to that of stiffness reactance and mass reactance respectively showing that they are reciprocal to each other. The ease with which energy flows into friction is called conductance (G).

-Bm is on the negative ordinate and Bs is on the positive ordinate and G is on the abscissa.

The admittance is given by the formula :

Y2 = bt2 + G2

Y2 = (B2 - Bm)2 + G2

Net susceptance

Bt =Bs + (-Bm)

= Bs-Bm

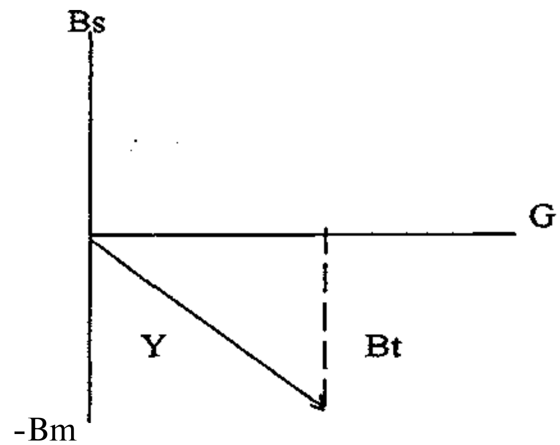


Fig. 7 Vector system illustrating the total admittance

If the system has more stiffness susceptance than mass susceptance Bt will be positive and vice versa.

Mass susceptance, stiffness susceptance etc. also varies with frequency.

+Bs = 2π f/s

-BM=1/2π fM

+Bs increases with frequency and decreases as stiffness increases. -BM increases with increase is frequency and mass and vice versa.

Acoustic Admittance

It is the ease with which acoustic energy passes through a system. It is represented by the formula :

Ya = U/P where Ya represents acoustic admittance in mho. One mho = m3 (10^8 Paxs). Acoustic stiffness susceptance is (+Ba) and acoustic mass susceptance = (-Ba) and acoustic conductance is (Ga).

Ya2 = Bta2 + Ga2

As we discussed earlier, the human ear contains various acoustical and mechanical impedance components. Our ear can be represented by the following diagram in which each block forms a particular component.

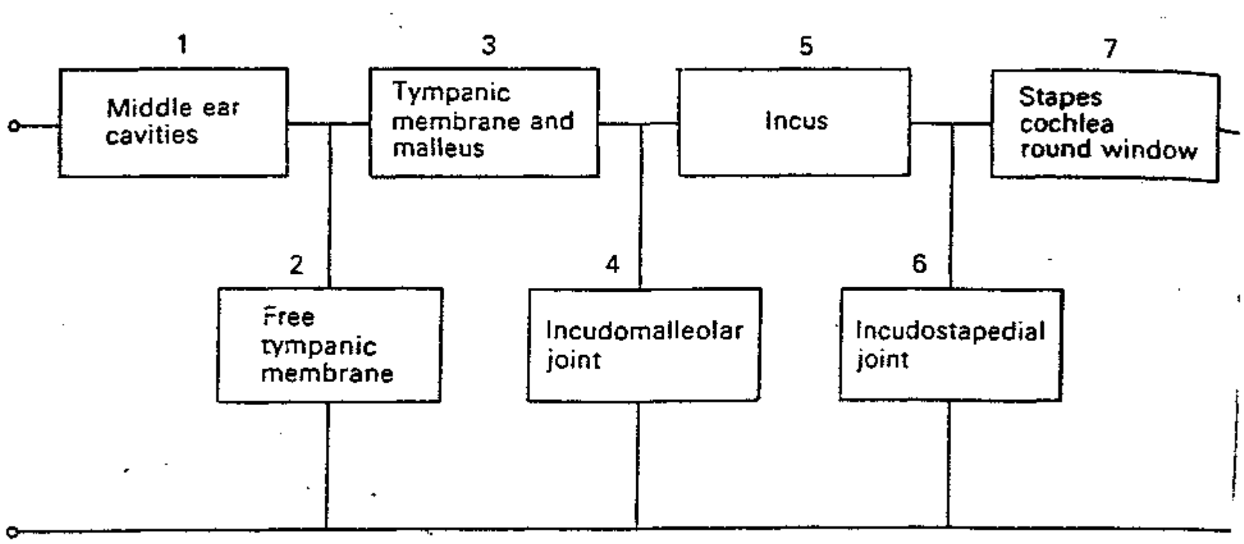


Fig.8 Functional block diagram of the middle ear.

All the blocks connected in series are associated with acoustic energy flow from the tympanic membrane to the cochlea. The shunt blocks (2,4, 6) indicate where the energy is diverted from the cochlea and provide varying amount of decoupling between the tympanic membrane and the middle ear parts located medially to the shunt.

These shunts suggest that pathological changes in the vicinity of the tympanic membrane have a stronger effect on the acoustic impedance measured at the membrane than do medial changes.

Eg. Perforation of the tympanic membrane makes it impossible to detect the additional pathology of the middle ear.

These blocks may be substituted by electrical capacitances. We know that capacitances sum when they are in parallel. Thus C6 and C 7 can be added.

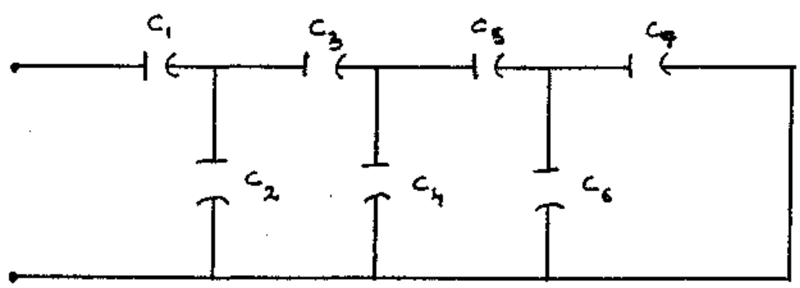


Fig. 9 Schematic representation of middle ear components in terms of capacitances.

Thus by knowing the abnormality in one component we can predict the impedance or admittance of the entire system.

Eg. C7 is the total capacitance of stapes and round window. By ankylosis of the stapes, there will be reduction in total capacitance. Thus one can expect a decrease in compliance in this case.

The current diagnostic interpretation of acoustic measurements in the ear canal are based on the above principle. It is to be noted that the term immittance refers to impedance or admittance.

It is tobe noted that the term immittance refers toimpedance or admittance.

The acoustic admittance or impedance is expressed using reactangular or polar notation. In reactangular notation, one value is given to the acoustic conductance or resistance component and one value to the net acoustic susceptance. Eg.Za =1500 - J3000, where j is the square root of-1. It is an imaginary number. In polar notation, one number is given to the magnitude of the acoustic impedance or admittance and one number represents the phase angle of the acoustic impedance or admittance Eg. Ya=0.6<+30.

(cited in Silman and Silverman, 1991).

Questions

I Fill in the blanks

1) The opposition exhibited by an obj ect to an applied force is called

2) In a stiffness dominated system. . . . leads. . . . by 90 degree.
3) The symbol for acoustic impedance is. . . .
4) Stiffness reactance. . . . with. . . . . in frequency.
5) Unit of acoustic impedance is. . . .

II Choose the correct answer

1) The formula for acoustic impedance is
a)Za=U/P
(b)Za=P2/U
(c) Za=P/U

2) The ease with which energy flows through a system is called. . . .
(a) impedance
(b) admittance
(c) force

3) When the stiffness reactance of a system increases, the resonance frequency
(a) decreases
(b) increases
(c) remains the same.

4) In a mass dominated system
(a) force lags velocity by 90 degree
(b) force leads velocity by 90 degree
(c) force and velocity are in phase

5) The symbol for acoustic admittance is
(a) +Ba
(b) -Ba
(c) Ya

6) In cases with ossicular chain discontinuity, the resonance frequency of middle ear is

(a) reduced
(b) increased
(c) unaltered

7) If there is a perforation of the tympanic membrane and also a fixation of one of the ossicles, the stiffness of the middle ear system is. . . . .

(a) decreased
(b) increased
(c) neither of these

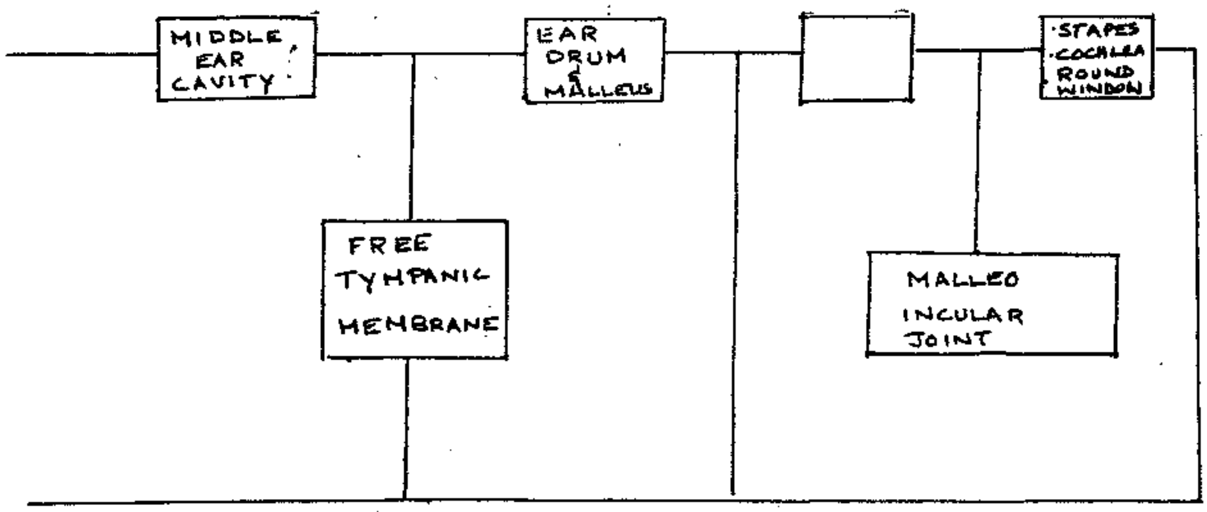
HI Match the following

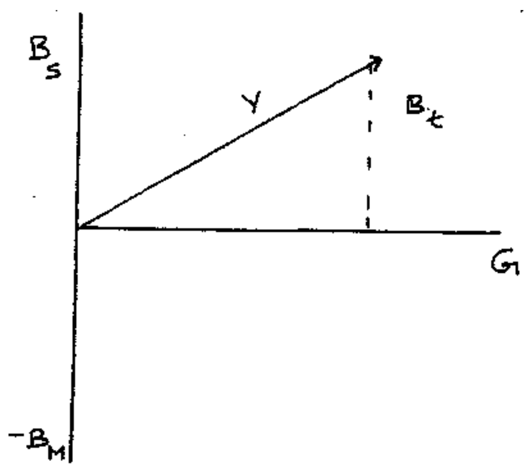
a) Alternating force	a) -Za
b) Acoustical stiffness reactance	b) mho
c) Acoustic impedance	c) R
d) Resistance	d) Amplitude changes over time
e) Acoustic admittance	e) Za
f) Acoustical mass reactance	f) Ga
g) Acoustic conductance	g) +Xa
h) Conductance	h) B
i) Susceptance	i) G

IV State whether the following statements are true or false

1) Constant force is one which changes its amplitude over time.
2) In a friction dominated system velocity and force are in phase.
3) Impedance resulting from friction is called conductance.
4) Resonance frequency is the frequency at which stiffness and mass reactances are equal.
5) The term immittance refers to only impedance and not admittance.
6) Mass reactance and stiffness reactance increase with increase in frequency.
7) In the case of fixation at the incudo stapedial joint, the compliance increases.
8) In cases with absence of incus, the stiffness is decreased.

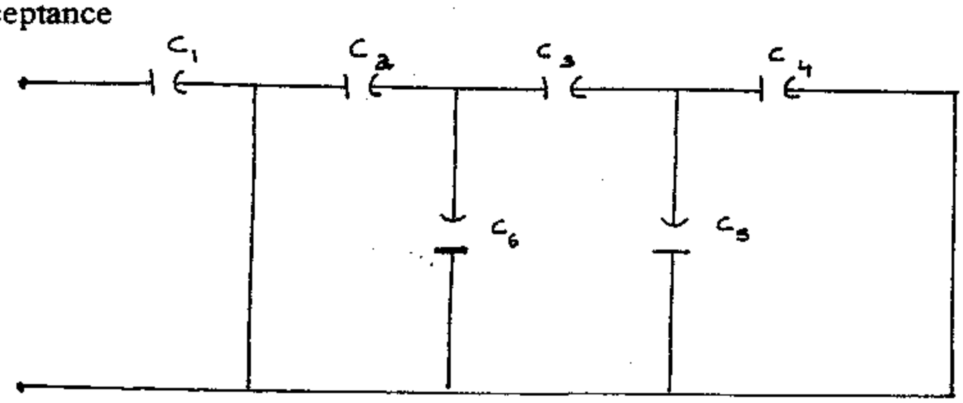
V Figure out the errors in the following figures and rectify them.



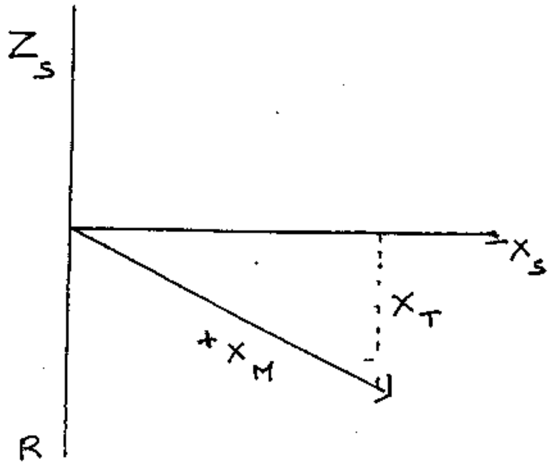


Acousti ear

susceptance



Acoustical and mechanical components of human ear substituted by capacitances.



Net reactance in the case of a system, with more stiffness reactance.

VI Complete or correct the formulae given below :

1. Z=F/-
2. . . . . . = R2 + (Xt)2
3. Xm = 2 f/M
4. Za2 = (2 fM)2 + ...
5. Ya2 = R2 + Ga2
6. V = Y/F

Answers

I Fill in the blanks

1) Mechanical impedance
2) Velocity, force
3)Za
4) decreases, increase/increases/decrease
5) acoustic ohm

II Choose the correct answer

l)c)Za-P/U
2) b) admittance
3) b) increases
4) b) force leads velocity by 90 degree
5) c) Ya
6) a) reduced
7) a) decreased

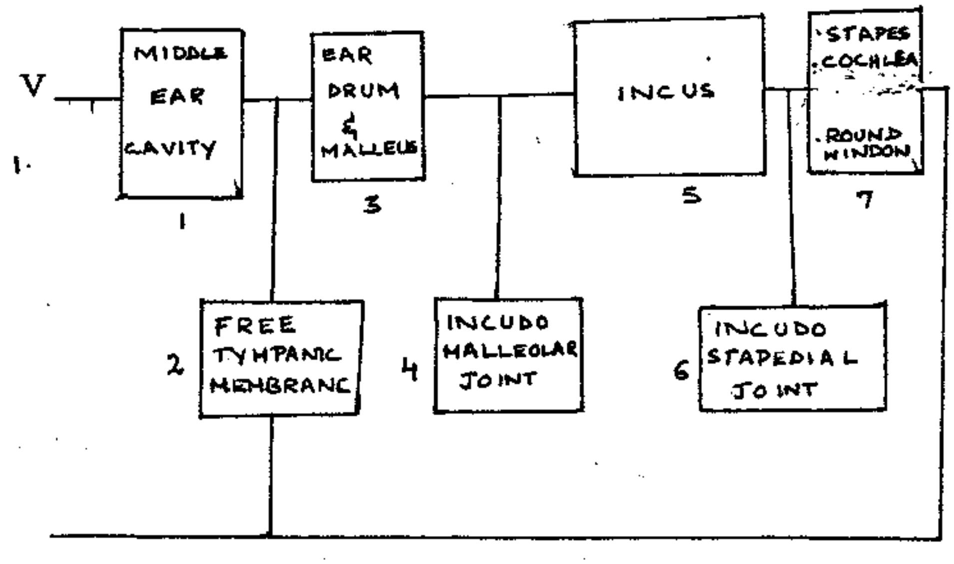
HI Match the following

a) d)
b) a)
c) e)
d) c)
e) b)
f) g)
g) f)
h) i)
i) h)

IV True or false

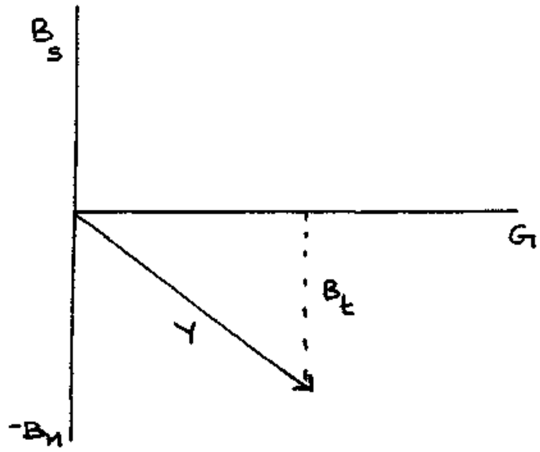
1) False (2) True (3) False (4) True (5) False (6) False
7) False 8) True

1.

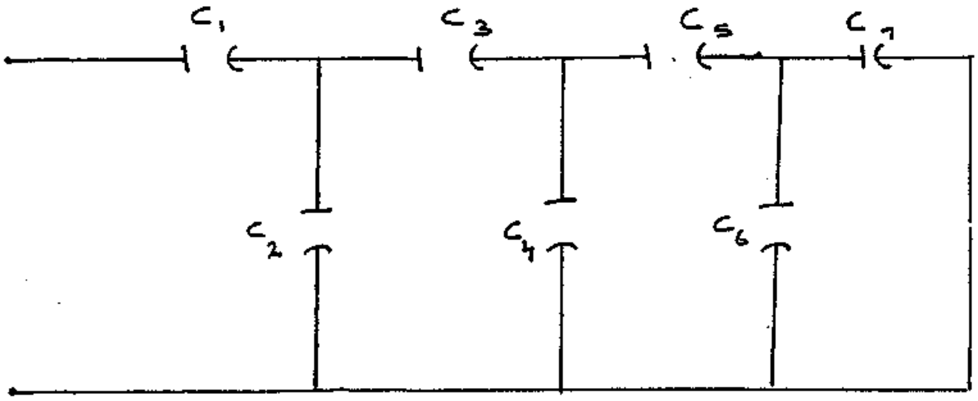


Acoustical and mechanical components of human ear.

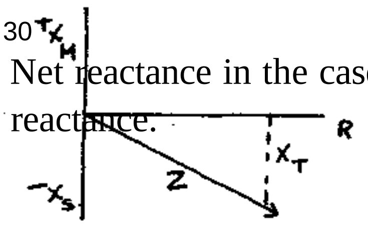
2.



The net susceptance in the case of s system with more mass susceptance.



Acoustical and mechanical components of human ear substituted by capacitances.



Net reactance in the case of a system with more stiffness reactance.

VI.

1. Z = F/V
2. Z2 = R2 + (Xt)2
3. Xm = 2 fM
4. Za2 = (2 fM)2 + Ra2
5. Ya2 = Bta2 + Ga2
6. V = YF or Y = V/F

INSTRUMENTATION

Currently, there are several manufacturers who manufacture acoustic immittance devices. All these, measure immittance according to the same theories and concepts. Any instrument used for the immittance evaluation, will posses the following systems.

Sound Source - This consists of a pure tone generator and a speaker that is used to deliver a probe tone into the external auditory canal. The frequency of this tone is relatively low usually about 220 Hz, or may be of a higher frequency i.e., 660 Hz or 1000 Hz.

The use 220 Hz probe tone has become widely accepted for the following reasons :

a) The wave length of the probe tone should be greater than the probe physical length plus the ear canal length and low frequency tones have longer wave length.

b) 220 Hz is not a multiple of the common main frequencies (50 and 60 Hz).

c) A low frequency probe tone allows a wider choice of ipsilateral stimulus frequencies as these must be at least one octave away from that of the probe tone.

d) Low frequency probe tones are more sensitive to pathologies which alter the stiffness of the ear and such pathologies are the ones most commonly seen.

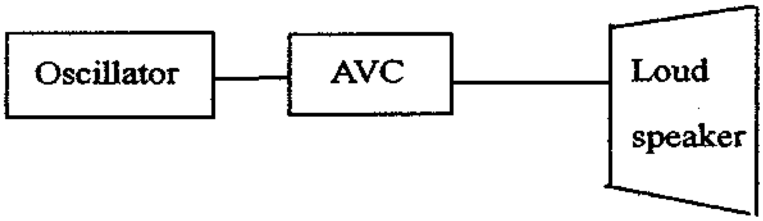
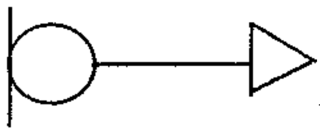


Fig.9 Sound Source

Measuring Apparatus - This consists of a microphone and an amplifier that is used to measure the intensity and/or phase of the sound pressure in the external ear canal.

Mic

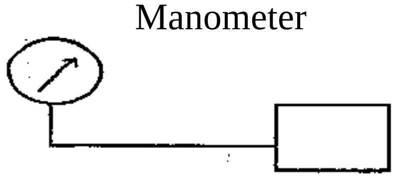


Amplifier

Fig. 10 Measuring apparatus

Air Pressure System - The air pressure system consists of a device capable of creating positive or negative pressures within a small sealed cavity. The range of pressures is generally from a positive 200 mm H2o to a negative 400 mm H2o. This range may vary from one instrument to another. The purpose of this system is to apply pressure of sufficient force to displace the tympanic membrane from its normal position in both the inward and outward directions, while at the same time of insufficient force which can cause damage to the hearing mechanism.

Manometer



Air pump

Fig. 11 Air pressure system

Probe Tip Assembly - This is a unit small enough to fit into the external ear canal with the capacity to accommodate some type of cuff that will allow an air-tight seal to be accomplished. This accommodates three lumina through which pass the access for the probe tone microphone pickup and the air pressure source.

Fig. 12 : Probe tip assembly

Comparator or Analysis System - This consists of an electronic network that compares what is being delivered into the sealed ear canal with what remains in the ear canal. It has a series of adjustment controls. These controls can be automatic or manual. Manual ones should be manipulated by the operator so that the energy matches the output energy. In an automatic one, this is done automatically by the deviceitself. There are read out devices also which can be digital, metered or adjustable scales. These controls help in maintaining a constant sound pressure level. These controls enables the examines with the proper manipulation of electroacoustic impedance device to gain useful information regarding the status of some aspect of the hearing mechanism.

Fig. 13 : Comparator

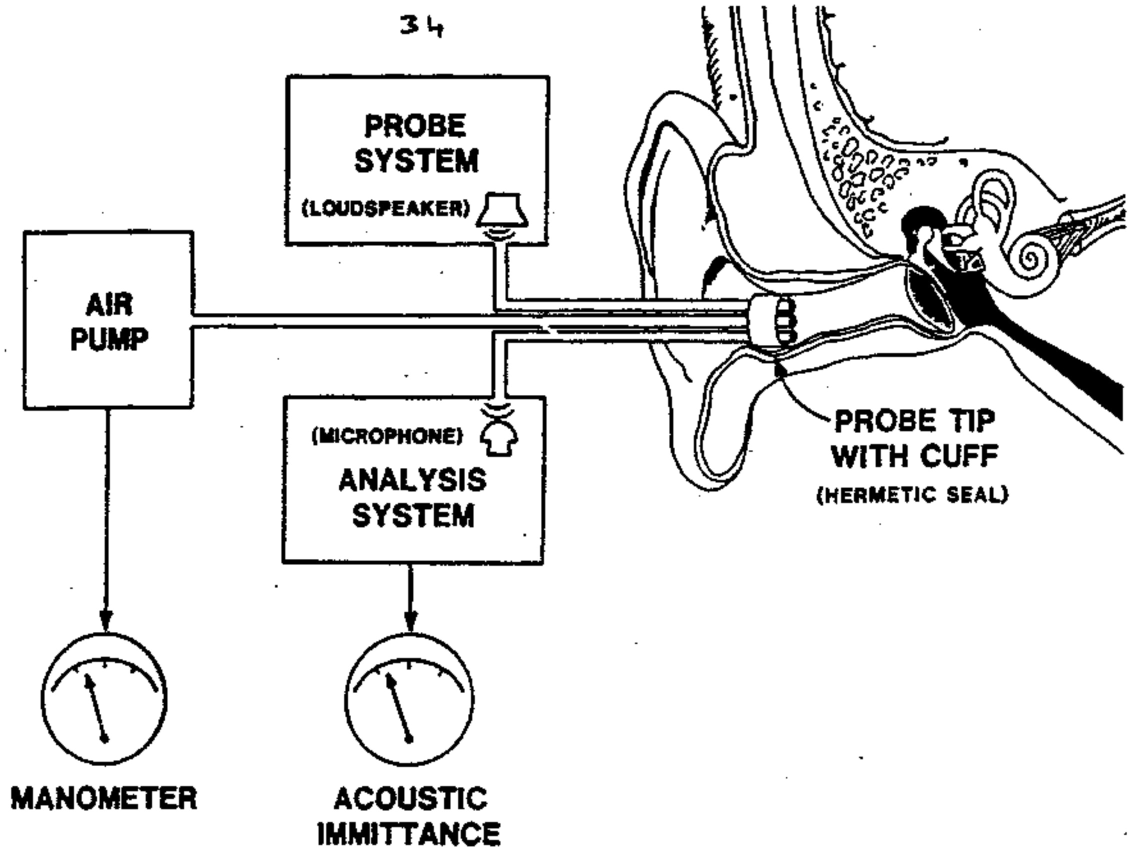


Fig. 14: Block diagram of acoustic immittance instrument.

The oscillator generates a puretone which is otherwise called as a probetone. This is altered by the automatic volume control (AVC) and it is then sent to the loudspeaker from where it goes to probe inserted into the ear canal of the subject. The reflected energy is picked up by the microphone and amplified. The comparator then compares the original signal and the reflected signal and if the energy is not at a constant level i.e. 85 dB SPL at 226 Hz, it is send to the automatic volume control. Otherwise it is send to thecompliance meter which displays the sound energy in terms of volume. If an instrument uses a variable control which can be manipulated in order to maintain the constant SPL, it is called an impedance bridge. If an AVC circuit is used for this purpose, it is called an immittance meter.

- (Cited in Block and Wiley, (1994); Crilson (1979); Keating and Olsen (1978) and Silman and Silverman (1991).

Questions

I Fill in the blanks

1. The most commonly used probe tone frequency in immittance measurement is .... Hz.

2. For immittance measurement, a.... is inserted into the ear canal of the subject.

3. The. . . . . . .compares the i/p and o/p energy.

4. The sound pressure level that should be maintained in the ear canal during immittance measurement is. . . . .dB SPL at...... Hz.

II Choose the correct answer

1. Which of the following is not used for immittance measurement?
   (a) earphone
   (b) probe
   (c) electrode

2. The device which picks up the reflected energy from the ear canal is
   (a) manometer
   (b) microphone
   (c) oscillator

3. Which device is used to introduce pressure changes in the ear canal in immittance measurement ?
   (a) microphone
   (b) amplifier
   (c) air pressure system.

4. Which of the following frequencies is not used in measuring immittance?
   (a) 1000 Hz
   (b)66QHz
   (c) 100 Hz.

III Match the following

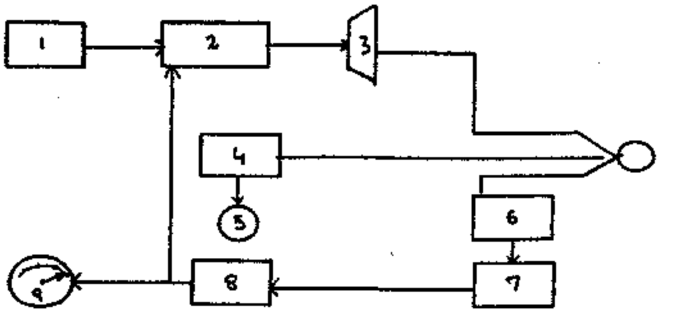
A	B
a) Sound source	a) 220 Hz
b) Sound pressure	b) Air pump
c) Probe tone	c) Oscillator
d) Manometer	d) 85^dB SPL

IV Answer the following questions

1. What are the different systems that are involved in immittance evaluation?
2. How is the immittance measurement carried out?
3. What are the three tubes that pass through the probe tip assembly?
4. Why is a low frequency probe tone most commonly used in immittance measurement?
5. There are four terms related to immittance measurement, hidden in this puzzle. Find out those terms.

OAO¥E
M A V B P
L I O T M
Q R C P Q
P P U M P

6. Fill in the blocks by choosing the correct answer from the list given in the next page.



1. Electrode
2. Loudspeaker
3. Insert receiver
4. Oscillator
5. Comparator
6. Audiometer
7. Headphone
8. Air pump
9. Barometer
10. Microphone
11. Manometer
12. AVC
13. Ammeter
14. Amplifier
15. Potentiometer
16. Compliance meters

Answers

I Fill in the blanks

1. 220
2. probe
3. comparator
4. 85 dB SPL at 226 Hz

II Choose the correct answer

1. c) electrode
2. b) microphone
3. c) air pressure system
4 c) 100 Hz

III Match the following

A	B
a)	c)
b)	d)
c)	a)
d)	b)

IV Answer the following questions

1. Immittance evaluation involves 5 main systems. They are the source, the measuring apparatus, air pressure system, probe tip assembly and the comparator system.

2. The oscillator generates a probe tone which is altered by the AVC and send to the loudspeaker. From there it goes to the probe which is fitted into the ear canal of the subject. The energy that is reflected back is picked up by the microphone and amplified by the amplifier.

The comparator compares the input and output signal and if the energy is not at a constant level i.e. 85 dB, it is send to the automatic volume control. If it is at a constant level, it is displayed in terms of volume on the compliance meter.

3. The probe tip assembly incorporates three tubes within it These three tubes are for the probe tone, microphone pick up and the air pressure sources.

4. The wave length of the probe tone should be greater than the probe physical length plus the ear canal length and low frequency tones have longer wave length. 220 Hz is not a multiple of the main frequencies (50 and 60 Hz). It also allows a wideer choice of ipsilateral stimulus frequencies. Low frequency probe tones are more sensitive to pathologies which alter the stiffness of the ear and such pathologies are the ones most commonly seen.

5.

1.MIC
2. AIR PUMP
3. AVC (AUTOMATIC VOLUME CONTROL)
4. PROBE

6. An immittance meter is one where an AVC circuit is used to maintain the constant SPL. In an impedance bridge, a variable control which can be manipulated is made use of to maintain the constant SPL.

7. 1 - (4)
2 - (12)
.3 - (2)
4 - (8)
5 - (11)
6 - (10)
7 - (14)
8 - (5)
9 - (16)

TYMPANOMETRY

The term tympanometry means 'to designate impedance measurements which require systematic pressure variations in the external acoustic meatus'. Tympanometry, is the measurement of eardrum compliance change, as air pressure is altered in the external auditory canal. These measurements are recorded on a graph which represents the compliance - air pressure function, known as a tympanogram.

Procedures in Tympanometry

Tympanometric measurement involves certain procedures. One of the important things to be remembered, is that, though it is an objective procedure, it does require at least passive cooperation of the patient.

The patient should be seated in a moderately quiet room (ambient noise level should preferably be less than 50 dB [A]) (British Society of Audiology, 1992). The patient should be instructed to sit still without speaking and the moving head and mouth. Swallowing should also be avoided. Since this procedure involves some discomfort, with young children, the testing should be done rapidly.

Inspection of the Ear Canal

Inspection of the ear canal with an otoscope is necessary prior to the actual measurement. This is done, in order to make sure that there is no obstruction in the ear canal, which can cause damage to the instrument. If there is presence of cerumen, it should be removed before starting the test. Visual inspection of the ear also helps in determining the size and shape of the ear canal, which will in turn help in choosing an appropriate probe tip.

Insertion of the Probe

Achieving an air tight seal is perhaps the greatest problem encountered while doing middle ear measurements. The clinician should lift the pinna back and up with one hand while the probe is inserted with the other hand, at the same time rotating it about 90 degree as it is pushed into the lumen of the ear canal in order to obtain an air tight seal.

Validating a seal

This is best accomplished by adjusting the pressure in the ear canal and observing the pressure meter. If the air pressure cannot be maintained, then this suggests a leak, either in the seal or in the test system. A leak which occurs only when a positive pressure is introduced implies an open tympanic membrane with the increased pressure being evacuated through the eustachian tube. Very small leaks can sometimes be tolerated.

After obtaining an airtight seal, a positive pressure (+200 mm/H2o) is introduced into the ear canal. At this point, the eardrum has least mobility. The air pressure in the external auditory canal is systematically reduced while changes in the complaince are recorded. As the air pressure is reduced, the eardrum becomes more complaint and when the air pressure in the external auditory canal is exactly the same as the air pressure in the middle ear cavity, the compliance of the tympanic membrane is maximum. As the air pressure is further reduced, the eardrum begins to show reduced compliance. This procedure can be done manually or automatically. (Cited in Feldman (1976) and Harford (1975).

The pressure sweep rate i.e., the rate at which the pressure is changed can be varied. Feldman et al. (1984) found that at a rapid pressure sweep rate the compliance is higher in both normals as well as in middle ear pathology cases. In normals, it was found that when the pressure change was faster, there was a shift in amplitude to the negative side and reverse was applicalbe for middle ear pathology cases. Hergils, Magnuson and Falk (1990) found that by using a decreasing pressure sweep followed by an increasing pressure sweep (forward-backward tracing tympanometry), the accuracy of tympanometric measures can be increased and this gives a better estimate of the true middle ear pressure than conventional decreasing pressure sweep tympanometry. The accuracy is maintained even at high sweep rates and therefore a forward-backward tracing tympanometry at a high sweep rate is recommended, but this may require limited modifications of the measuring instrument.

Questions

I Fill in the blanks

1. The compliance - air pressure function of the tympanic membrane is called as a.....

2. The ambient noise level during tympanometry should be within

3. The rate at which the pressure is changed during tympanometry is called as.....

4. The rate at which the pressure is varied in tympanometry ranges from.... to....

II State whether the following statements are true or false

1. Tympanometry is a purely objective procedure and requires no cooperation at all from the subject.
2. Tympanometry can be carried out in a highly noisy environment also.
3. One of the preliminary procedures in tympanometry is, to obtain an airtight seal.
4. Tympanometry can be carried out even if there is wax or discharge in the external ear canal.
5. The compliance of the tympanic membrane is maximum when the air pressure in the middle ear cavity equals the atmospheric pressure.

HI Match the following

A	B
a) Ear canal	a) Higher compliance
b) Rapid pressure sweep rate	b) 50 daPa/s
c) Pressure sweep rate	c) probe

IV The following are the steps involved in tympanometry. Rearrange them in the correct order in which they should be carried out.

1. Varition of air pressure in the ear canal.
2. Inspection of the ear canal.
3. Insertion of the probe.
4. Insruction of the subject.
5. Interpretation of the tympanograrn.

Answers

I Fill in the blanks

1. Tympanogram
2. 50 dB (A)
3. Pressure sweep rate
4. 50 daPa/s to400 daPa/s

II True or False

(1) False (2) False (3) True (4) False (5) True.

HI Match the following

A B
(a) - (c)
(b) - (a)
(c) - (b)

IV Rearrangement of the sentences in the correct order

4. Instruction of the subject.
2. Inspection of the ear canal.
3. Insertion of the probe.
1. Variation of air pressure in the ear canal.
5. Interpretation of the tympanogram.

Interpretation and Classification of Tympanograms

Liden, Peterson and Bjorkman (1970) proposed a method for the quantification of tympanograms. Their suggestion did not receive much popularity, as the shape of the tympanograms changed dramatically from one type of conductive abnormality to another and therefore, it has not been adapted by clinicians. Following this, Jerger (1970), Bluestone et al. (1973), Feldman (1976), Cooper et al. (1982) etc. reported on low probe-tone frequency tympanograms. Jerger's (1970) system is simple and clinically popular.

In this system, tympanograms have been classified as type A, B or C. Since then, same additions have been made to this classification. There are mainly three parameters which are considered for the classification of tympanograms. These are :

a) the maximum compliance of the eardrum (amplitude).
b) the peak pressure (the air pressure point of greatest compliance of the eardrum)
c) shape of the tympanogram.

The different types of tympanograms are :

Type A - This is the normal tympanogram which is characterized by a smooth notch and the point of greatest compliance which occurs between 0 and -100 daPa (the peak may slightly be shifted to the positive side e.g. +25 daPa) or even +50 dapa. Different authors have proposed different values for this, but -100 mm H2o is generally accepted as the point between normal and abnormal middle ear pressure). The static compliance ranges between 0.5 cc -1.75

This is usually seen in normal middle ears and sometimes in otosclerotic ears also. It can also be seen in cholesteatoma cases where the cholesteatoma produces only a slight pressure against the ossicular chain.

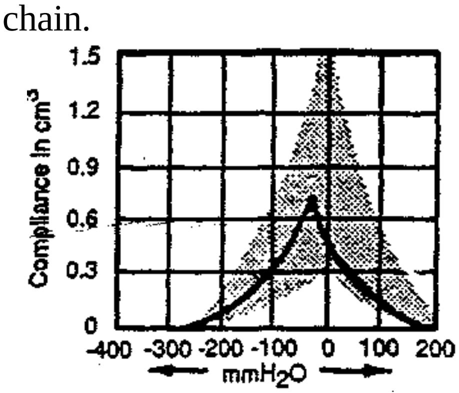


Fig. 1.5 Type ' A' Tympanogram

Type As - 'S' in As represents the word 'shallow'. These tympanograms usually have static compliance below 0.5 cc. The peak pressure is normal and they are smooth.

This is seen in cases of otosclerosis, tympanosclerosis etc.

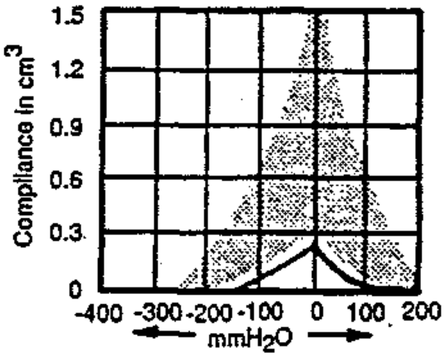


Fig. 16 : Type As tympanogram.

Type Ad - 'd' here stands for deep. The amplitude is above the normal value i.e. above 1.75 cc. The peak pressure is normal.

This is seen in ossicular chain disruption, scarred or flaccid TM (Jerger, 1970).

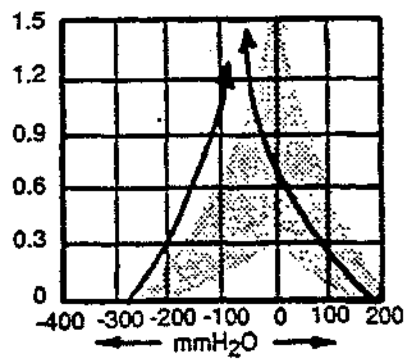


Fig. 17 Type Ad tympanogram.

Type B - There is no distinct point of maximum compliance in this type. There are relatively little changes in admittance, as the pressure in the ear canal is varied, it may be virtually flat. Sometimes, there might be a gradual increase in admittance with pressure change throughout the range of+200 --400 daPa without a peak.

This is found in cases with fluid in the middle ear space (e.g. serous otitis media) and also in cases with perforated tympanic membrane.

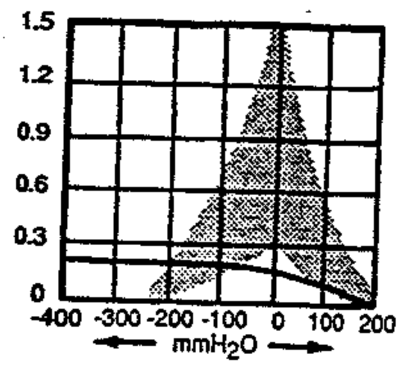


Fig. 18 Type B tympanogram

Type C - This tympanogram is characterized by a negative peak pressure i.e. it exceeds - 100 mm/H2o. There is a smooth peak.

This is seen in eustachian tube dysfunction and may be a precursor of serous otitis media.

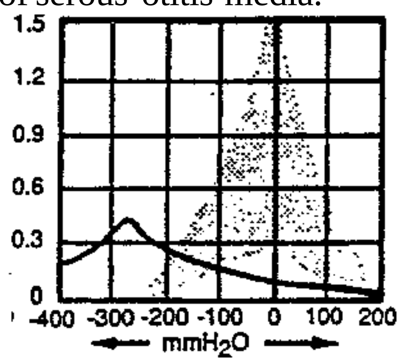


Fig. 19 Type C Tympanogram

Type D - This is a double peaked ' W shaped tympanogram (Liden et al. 1974). This is seen even in normals when a high frequency probe tone such as (600 or 800 Hz) is used. In pathological cases, this is found in simple scarred ear drums and in cases with atrophic or flaccid drum.

Fig.20 Type D tympanogram.

Type E - This has an undulating pattern (Liden et al. 1974). This also is seen in normal hearing subjects when a high frequency probe tone is used. It is found in ossicular chain discontinuity also.

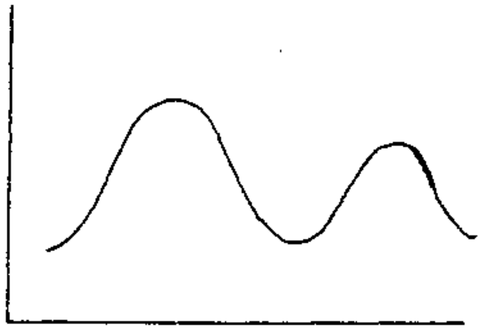


Fig. 21 Type E tympanogram

Type	Amplitude	Peak Pressure	Shape	Conditions where it is seen
A	Normal	Normal	Smooth	Normal ears, otosclerosis, cholesteatoma.
As	Reduced	Normal	Smooth	Otosclerosis, tympanosclerosis
Ad	Increased	Normal	Smooth	Ossicular chain disruption, scarred/flaccid tympanic membrane.
B	Reduced	No peak	Flat	Fluid, perforation.
C	Normal	Negative	Smooth	Eustachian tube dysfunction, serous otitis media.
D	Normal	Normal	W	Scarred ear drum flaccid ear drum.
E	Normal	Normal	Undulating	Ossicular chain discontinuity.

Questions

I Fill in the blanks

1. The_classification is the most popular and widely used system of classification of tympanograms.

2. The three parameters used for the classification of tympanograms are ...,.... and ....

3. In type A tympanogram, the peak pressure ranges from .... to....

4. Type As tympanogram is most commonly seen in cases of.... and....

5. In a case with perforated eardrum,.... tympanogram is obtained.

II Solve the following :

1. On using an 800 Hz probe tone, a double peaked 'W shaped tympanogram was obtained in a particular case. Is this a definite indication of a middle ear pathology? Justify your statement.

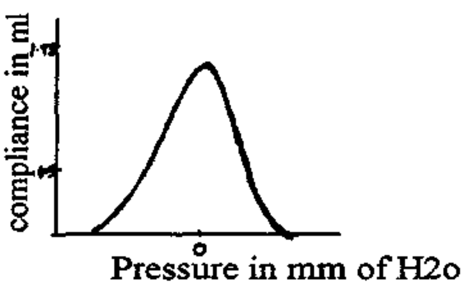
2. An adult case comes with the complaint of fullness and severe pains in his right ear. The pain is reported to be more at night. The problem is reported to have started following a severe attack of cold. The patient also complaints of slight difficulty in hearing in the right ear and also echoing of speech in the same ear. What type of tympanogram do you expect in this. Give justifications for your answer.

3. A case comes with a complaint of decreased hearing in his left ear. The medical report presented by the case shows that he had otitis media in his left ear before *6* months for which treatment was given Following this, the condition has resolved as per the report. What kind of tympanogram would you expect in this case and why

4. An adult female, while travelling by air suddenly developed fullness in her ears, following which she complaints of decreased sensitivity in both ears. The case has history of chronic sinusitis. The case reports to an Audiologist, one day, after the incident. Comment on the possible tympanometric findings.

5. An adult female aged 25 years comes with a complaint of decreased sensitivity in the right ear following pregnancy. The problem is reported to be progressive in nature. The case reports that many of her female relatives had the same problem in the past. The case does not complain of any pain in the ear but occasional giddiness is present. What could be the diagnosis based on tympanometric results?

6. Give your comments about this tympanogram.



III State. whether the following statements are true or false

1. Shape of the tympanogram is not considered as a major factor during the classification of tympanograms.

2. Type A is a definite indication of a normal middle ear.

3. Many a times in cases with otosclerosis, we may get A type tympanogram.

4. The compliance value is increased in cases with thin tympanic membrane.

5. An undulating pattern of tympanogram can be seen in cases with ossicular chain discontinuity.

IV Match the following :

A	B
a) As	a) perforated ear
b) B	b) severe deviated nasal septum
c) C	c) tympanosclerosis
d) Ad	d) Ossicular chain discontinuity.

V. Predict the type of tympanogram which can be obtained in the following conditions and justify answer.

1. A 4 year old boy with wax in the ear canal and eustachian tube catarrh.
2. A 25 year old female with qtosclerosis and malleo-incudial joint discontinuity in the same ear.
3. A 15 year old boy with perforated right ear tympanic membrane and eustachian tube malfunctioning of the same ear.
4. An adult male with furunculosis in the left ear and fluid collection in that ear itself.
5. A female aged 30 years, with fracture of incudo-stapedial joint and otosclerosis, both in one ear.
6. A 50 year man with thin tympanic membrane and fixation of malleoincudial joint.

Answers

I . Fill in the blanks

1. Jerger's(1970)
2. Amplitude, peak pressure and shape
3. +25 daPa, -100 daPa
4. Otosclerosis, tympanosclerosis
5. Type B

II. Solve the questions

1. No. ' W ' shaped tympanograms can be obtained even in normal cases on using an 800 Hz probe tone. Therefore it need not necessarily be an indication of a middle ear pathology.

2. These symptoms indicate the condition of serous otitis media. Therefore a 'B' type tympanogram can be expected.

3. It is likely to get an Ad type tympanogram in this case. As the medical report says that the condition has resolved, one can expect a scarred tympanic membrane(healed after perforation). Since the mobility of the tympanic membrane is increased an Ad type tympanogram is likely to be obtained.

4. As the case is suffering from chronic sinusitis, he is likely to have eustachian tube dysfunction which hasindeed caused the barotrauma. Therefore a C type tympanogram can be expected in this case.

5. The case history presented is highly suggestive of otosclerosis. Thus, an As type or even A type tympanogram can be obtained in this case.

6. The amplitude of the tympanogram is between 0.6 ml. and 1.5 ml. The peak pressure is between -100 daPa and +25 daPa. The curve is smooth. From these findings, we can conclude that, it is a normal type A tympanogram.

III State whether true or false

(1) False (2) False (3) True (4) True (5) True

IV Match the following

A	B
a)	c)
b)	a)
c)	b)
d)	d)

V

1. A 'B' type tympanogram will be seen in this case due to the presence of wax. The eustachian tube problem will not be detected as it is. . . . .away from the tympanic membrane.

2. An 'Ad' type tympanogram can be expected in this case, as the tympanogram usually reveals a pathology that is closer to the tympanic membrane. Therefore, discontinuity if the ossicles will be detected rather than the fixation of the stapes.

3. Here the tympanogram type will be 'B'. The reason is the same as above i.e. the closer the pathology to the tympanic membrane, more is its chance of being detected.

4. Furunculosis is a condition which affects the ear canal and tympanometry is concerned only with middle ear pathologies. Therefore a 'B' type tympanogram will be obtained.

5. Here again, otosclerosis cannot be detected through tympanometry as an Ad type tympanogram is obtained revealing the discontinuity of ossicles.

6. The tympanogram type obtainined will be 'Ad'. The fixation of ossicles will not be detected here.

Check your knowledge of tympanograms

1. The classification system of tympanograms which is currently used was proposed by

   (a) Liden (1974); (go to 7)
   (b) Jerger (1970) (go to 9)
   (c) Bjorkman (1970) (go to 8)

2. The normal tympanogram is
   (a) Type C (go to 12)
   (b) Type B (go to/10)
   (c) Type A (go to 10)

3. One of the types of tympanograms given below has a low compliance value. Which is it?
   (a) As (go to 14)
   (b) Ad (go to 15)
   (c)C(go to l3)

4. This type of tympanogram is very commonly seen in ossicular chain discontinuity. Which type is it?
   a) D (go to 17)
   (b)B(go to 18)
   (c) AD (go to 16)

5. Type B tympanogram is very commonly seen in.
   (a) Eustachian tube dysfunction (go to 19)
   (b) Perforated tympanic membrane (go to 17)
   (c) Fluid in the middle ear space (go to 22).

6. These types tympanograms were not included in the Jerger's (1970) classification. It was later introduced by someone. Name these two types and also the person who introduced them and the year in which it was given.
   (a) As and Ad1, (Peterson (1970). (go to 21)
   (b) A and C, Liden (1964). (go to 20)
   (c) D and E, Liden (1974). (go to 23)

7. Wrong. Liden (1974) only made additions to the classification system. Go back to 1.

8. Sorry. Bjorkman's (1970) classification did not become popular. Try again.

9. Yes, you are right. Jerger's (1990) classification is the one most widely used.

10. Very good. Type A is definitely the normal tympanogram.

11. Oh ! No. Try again.

12. You are wrong. Go back to 2.

13. No. C type tympanogram has normal compliance value. Only the peak pressure is affected. Try again.

14. Excellent. As type tympanogram is the one with low static compliance value.

15. Sorry. This is not the correct answer. Ad type tympanogram has a higher compliance value, not lower. Back to 3.

16. Correct Ad type is the one commonly seen in ossicular chain discontinuity.

17. No, you are wrong. D type is seen more commonly in the case of flaccid ear drum. Go back to 4.

18. Incorrect. B type tympanogram is seen in fluid filled middle ears or perforated ear drum cases. Back to 4.

19. Of course not. Go back to 5.

20. Wrong. Type A and C tympanograms were given by Jerger (1970). Back to 6.

21. Sorry. You are wrong. Peterson (1970) is not the one who introduced these two types of tympanograms. Go back to 6.

22. Yes. You are right but check whether there are other possible answers and then proceed to 6.

23. Excellent. Liden (1974) was the person to add two new types of tympanograms to the original classification and those were D and E type tympanograms.

24. Yes. You are correct but there is one more possible answer to this question given among the choices. Look for it and then proceed to 6.

Tympanometry in the diagnosis of certain exceptional disorders

1. Auditory Disorders

a) ***Cholesteatoma*** - In most of these cases, a flat or 'B' type tympanogram is observed (Feldman, 1976 and Ichimura, 1978). Ichimura (1978), reported that type 'A' or type 'C tympanograms were found in a few cases of cholesteatoma either due to a mass in the attic alone or due to a partial obstruction of eustachian tube, respectively.

b) ***Glomus jugulare*** **-** Shallow or As type tympanograms are obtained in this. Vascular perturbations may be observed either on the tympanogram or it may be observed as rhythmic, pulsating movements of the balance meter needle (Feldman, 1976).

c) ***Middle ear polyp*** - *A* reduction of ear canal volume along with a flattened tympanogram was reported in this case (Arnold and Williams, 1977).

2. Non-auditory disorders:

a) *Myasthenia Gravis* - Morioka et al. (1976) reported that, these cases showed a negative middle ear pressure which may be due to the weakness of tensor veli palatini muscle that causes a decreased or poor Eustachian function.

b) *Lymphangioma and Von Recklinghausen 's disease* - The latter is a condition characterized by the presence of multiple neurofibramatosis of the skin. In both the conditions, unusual shapes of tympanograms.were obtained as reported by Fukaya (1979). This is attributed to the deformed canal skin, it is also possible to observe respiratory movement superimposed on tympanogram indicating a patulous eustachian tube.

c) *Rheumatoid Arthritis* - Moffat et al (1977) found a reduction in stiffness in the ears of such cases indicated by a notching in 600 Hz susceptance tympanograms.

d) *Post-neck surgery patients* - Woodford and Eames (1977) performed tympanometric measurements in subjects who underwent neck surgery. A high incidence of middle earpathology was seen in these patients. This could be attributed to the dysfunction of eustachian tube resulting from an oedematous swelling in the entire region.

e) *Divers* - Saponara et al. (1976) showed that 9.5% of their patients showed abnormal middle ear pressure on tympanometry. About 93.3% of them showed decreased elasticity of tympano ossicular system. This reduction in elasticity correlated highly with subject's age, number of years of sport activity and average depth of diving.

f) *Diabetes* - In cases with insulin dependent diabetes mellitus, a significantly lower amplitude was seen in both ears. This could be attributed to the long duration of the disease and the microvascular complications associated with it. (Virtaniemi et al.,1993).

Questions

I Choose the correct answer

1. In cases with cholesteatoma, one can mostly expect a tympanogram with.
   (a) low compliance
   (b) high compliance
   (c) no change in compliance with change in pressure

2. In cases, with a pedunculated mass in the middle ear, which type of tympanogram do you expect.
   (a) Peaked
   (b) Normal
   (c) Flattened

3. While performing tympanometry on a particular case, pulsating movements of the balance meter needle was noticed and a shallow type tympanogram was obtained. What could be the possible pathology?
   (a) Ossicular chain discontinuity
   (b) Glomus jugulare
   (c) Otosclerosis

4. In cases with rheumatoid arthritis, a decreased resonance frequency (660 Hz) is obtained. This indicates -
   (a) decreased stiffness
   (b) decreased mass
   (c) increased stiffness.

5. An Olympic'diving champian comes to an Audiologist for consultation. On performing tympanometry, the resonance frequency in this case could be expected to be
   (a) increased
   (b) decreased
   (c) normal

II State whether true or false

1. In case with diabetes - mellitus who are undergoing insulin treatment, one can expect a lower amplitude tympanogram.
2. In cases, who are suffering from lymphangiona, tympanograms do not show any abnormality.
3. A high incidence of middle ear pathology is usually found in cases who have undergone surgery of the neck.
4. Myasthenia gravis patients usually have a low amplitude tympanogram, due to the poor mobility of the tympanic membrane.
5. In cases with cholesteatoma, it is possible to get 'A' type tympanograms.

III. Match the following

A	B
a) Glomus jugulare	a) unusually shaped tympanogram
b) Von Recklinghausen's disease	b) flattened tympanogram
c) Middle ear polyp	c) As
d) Divers	d) Abnormal middle ear pressure

Answers

I

1 a) no change in compliance with change in pressure
2 c) flattened
3 b) Glomus Jugulare
4 a) decreased stiffness
5 b) decreased

II State whether true or false

1. True 2. False 3. True 4. False 5. True

HI Match the following

A	B
a)	c)
b)	a)
c)	b)
d)	d)

Tympanometry in **Children**

It is only recently, that tympanometry has been applied to children and the results are both promising and perplexing. Several investigators have successfully obtained tympanometric data from subjects below two years of age. With minor modifications of probe tips and of the methods of coupling the probe to the head, and with sufficient patience, the measurements can usually be accomplished in a reasonable amount of time. Some children, however, require sedation before adequate results can be obtained.

In young infants, between 36-151 hours of age, Ad type tympanogram has been very commonly seen which indicates the flaccidity of their ear (Keith, 1973 and Bennett, 1975).

There is also the presence of a 'W shaped tympanogram even for 220 Hz probe tone frequency in younger children. But this configuration approximates adult pattern with the advancement of age (Cannon, Smith and Keith, 1976). Some infants might also show a B type tympanogram soon after birth but attain adult pattern with maturation (Pollazzon, 1982).

In terms of peak pressure, Keith (1973) and Bennett (1975) etc. have reported normal middle ear pressure in neonates. But Allerd et al. (1975) reported a positive pressure in neonates 20 to 50 hours following birth. In older age children, several authors have detected a negative peak pressure which could be attributed to the dysfunctioning of the eustachian tube.

Zarnoch and Balkary (1978), Pestalozza (1974) obtained normal tympanograms from young subjects with middle ear pathology. In spite of the presence of fluid in the middle ear, normal tympanograms were obtained due to the highly compliant ear canal walls present in them. For this reason, tympanometry is not always a useful clinical tool to differentiate normal from pathological conditions of the middle ear in very young subjects.

(Cited in Murthy, 1988).

Tympanometry in Screening Programs

Tympanometry is largely being used in auditory screening protocols. Bonny (1989) reported that use of tympanometry in school screening programs significantly enhanced the effectiveness of the screening. The availability of hand-held tympanometric devices has added to its efficacy.

Wolthers (1990) suggested that a single rinding of abnormal tympanogram should not be the basis for the diagnosis of middle ear disorders. Zielhus (1989) found that more than one half of the cases of otitis media with efffusion may resolve later. Therefore on obtaining positive screening results, repeated, more frequent screening should be carried out before making a diagnosis. Tympanometric screening programs are widely used with the paediatric population. Davis et al. (1988) suggested that such screening programs may be helpful even with geriatric population for the diagnosis of middle ear disorders as there is evidence of quite a high incidence of middle ear disorders even in the elderly group.

Tympanometry, being an objective technique, is a very useful tool in finding out the middle ear pathology in children. Since middle ear pathology is very common in school going children, it should be identified early and treated to avoid further complications. Tympanometry would be a useful and in this as it is easy to administer, non-time consuming aid the results are also easy to interpret. Thus it can be concluded that tympanometry has a secure role in clinical audiology.

Questions

I Say whether the following statement are true/false :

1. Ever since the evolution of tymapnometric procedures, it has been applied to children also for clinical purposes.
2. Tympanometry in children and adults are carried out in exactly the same manner.
3. Neonates never show any tympanometric pattern that is not found in adults.
4. Children with abnormal tympanometric pattern continue to give these patterns even with advancement of age.
5. In children, the abnormality in tympanometric patterns is only with respect to shape and not the peak pressure or amplitude.

II Choose the correct answer :

1. Normal tympanograms are sometimes found in children with fluid filled ears because
   a) the amount of fluid is very less
   (b) of the errors in theprocedure used
   (c) of highly complaint ear canal walls.

2. 'W' shaped tympanograms are found in children even at . . . . . . frequency unlike that in adults.
   a) 660 Hz
   (b) 800 Hz
   (c) 220 Hz.

3. This pattern is very rare in infants. Which is this pattern?
   a) As
   (b)Ad
   (c)W

4. Due to frequent crying behaviour of infants, ... middle ear pressure may be expected in them.
   a) Negative
   (b) Positive
   (c) Normal

5. One of the important modifications that has to be made while doing tympanometry in children is the
   a) modification of pressure variation
   (b) modification of probe tips
   (c) modification of probe frequency.

III There are three terms hidden in the puzzle given below. Find them out and state what kind of tympanometric patterns you can expect due to these .

F	I	U	L	D	W	A
N	L	O	Q	Z	S	V
E	U	A	E	I	M	Z
G	T	R	C	F	P	R
A	P	Y	I	C	T	E
T	R	R	M	N	I	X
I	V	E	E	S	S	D

IV Answer the following questions

1. Tympanometry has became a major part of the screening program since the invention of. . . . .devices.

2. Why is repeated screening required in the paediatric population to detect the presence or absence of middle ear pathology?

3. Tympanometric screening is used only in school screening programs. Comment on this statement.

4. In young children, if tympanometry shows any abnormal finding, diagnosis and intervention should be done without any further delay. *Give* your opinion about this.

Answers

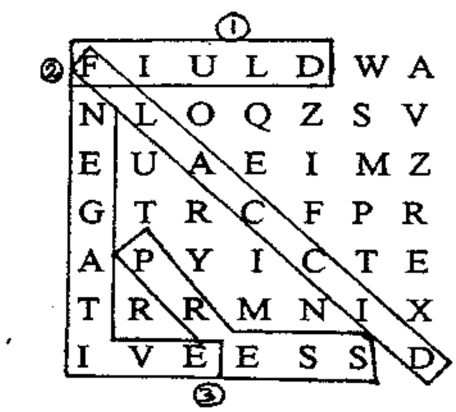
I Say whether the following statements are true or false.

(1) False (2) False (3) True (4) False (5) False

II Choose the correct answer

1. c) of highly complaint ear canal walls.
2. c) 220 Hz
3. a) As
4. b) Positive
5. b) Modification of probe tips.

III



1. FLUID - B TYPE
2. FLACCID - Ad TYPE
3. NEGATIVE PRESS - C TYPE

IV Answer the following questions

1. Hand-held tympanometric devices.

2. A single abnormal finding should not be taken as the basis for the diagnosis of middle ear disorders in children. In most of the cases, the pathology resolves after a short while and therefore repeated screening should be done before making a diagnosis in this population.

3. Tympanometric screening has been used for screening, infants, school going children and even geriatric population. Therefore, the above statement is not true.

4. As we saw earlier, the diagnosis cannot be based upon a single abnormal finding. Therefore, repeated screening over a period is necessary to make a correct diagnosis and then intervention can be done.

Physical Volume Test, Static compliance, Gradient

Physical Volume Test

In this, a pressure of +200 mm H20 is maintained in the outer canal to make the tympanic membrane maximally stiff. At such extreme pressures, as the tympanic membrane is maximally stiff its compliance is negligible.' The compliance reading at this point gives the actual volume in cc, between the probe and the TM i.e. the volume of the ear canal. This refers to the physical volume. In normal ears, it ranges between 0.6 cc to 1.8 cc with an average value of 1.1 cc. In rare cases it may range up to 2.8cc. In children, it may range between 0.7 to 1.0 cc.

In cases of perforation, it is more and may range from 1.3 cc to 5.0 cc. PVT may be helpful in delineating activity of a disease process behind a perforated TM, be it the middle ear or mastoid. For eg. in a space occupying condition like cholesteatoma, the physical volume will be reduced or in case of keratosis obturans, there is an increase in physical volume due to the destruction and enlargement of the total volume space. PVT also helps us in detecting any error in the measurement. For eg. if the physical volume is as low as 0.2 or 0.3 cc, it indicates an obstruction of the probe or the probe may be placed against the ear canal wall. Even a very high value such as 3.6 cc indicates erroneous measurement. It also helps in testing the reliability of the tympanogram. If an 'A* type tympanogram shows a physical volume of 3 cc, then the measurement is unreliable.

Thus, PVT is an important measurement which is helpful in differential diagnosis of various abnormalities of the ear.

Static Compliance/Static Immittance

Static compliance/static immittance is the acoustic immittance of the middle ear at rest, i.e. under normal atmospheric pressure. Though it is often calculated during tympanometry, static immittance is in contrast to the immittance - pressure function (tympanogram), which is a dynamic measure of middle ear physical properties.

Static compliance is measured in terms of equivalent volume in cubic centimeters. The recommended test method is to make two volume measurements with the impedance audiometer.

The first measurement Cl is made with the tympanic membrane in a position of poor compliance, clamped at +200 mm/ H20 air pressure. The second volume measurement (C2) is made with the tympanic membrane at maximum compliance. Since the sound is more easily transmitted by the tympanic membrane during the second volume measurement, (C2), the probe-sound pressure in the enclosed cavity of the external canal will be lower than noted for the first volume measure - but the equivalent volume in CC for the second measure will be larger than noted in the first volume measurement (C1). The static compliance of the ear is calculated by subtracting C1 from C2. This gives the compliance of the middle ear mechanism in cubic centimeters.

The compliance of the normal middle ear system is influenced by variables like patient age, sex, etc. (Jerger, et al. 1972). Brooks (1971) reported that increase in age caused increase in compliance. Jerger (1972) found lower average compliance in women when compared to men. The maximum compliance value in men was between 30-39 years of age and beyond this age, the compliance decreased with advancement in age. There are no interarual differences in static compliance. A stiff middle ear system demonstrates a compliance value less than 0.50 mAec. while a flaccid middle ear system should have compliance greater than 1.75 mho. However, the range of static compliance values for normal ears versus pathological ears overlap to some extent.

Though static immittance in isolation is of little value in the identification and differentiation of middle ear disorders, when interpreted in conjunction with other audiometric tests, it can be an important clinical measurement of middle ear status. The normal static compliance value ranges between 0.5 and 1.75 acoustic mhos for a 226 Hz probe frequency at a low pump speed. For a higher pump speed, it ranges from 0.57 - 2.00 acoustic mhos - Van Camp, et al. (1986).

Gradient

Gradient refers to the slope or width of the tympanogram at the peak. The gradient is given by the ratio of hp to ht, where hp is the distance from the tympanometric peak to the horizontal line intersecting the tympanogram such that the distance between the points of intersection (a and b) is 100 daPa and ht is the peak height of the tympanogram (Brooks (1969). The smaller the gradient the flatter the tympanogram. According to Brooks (1969) and Paradise, Smith and Bluestone (1976) a gradient is small if it is less than or equal to 0.15.

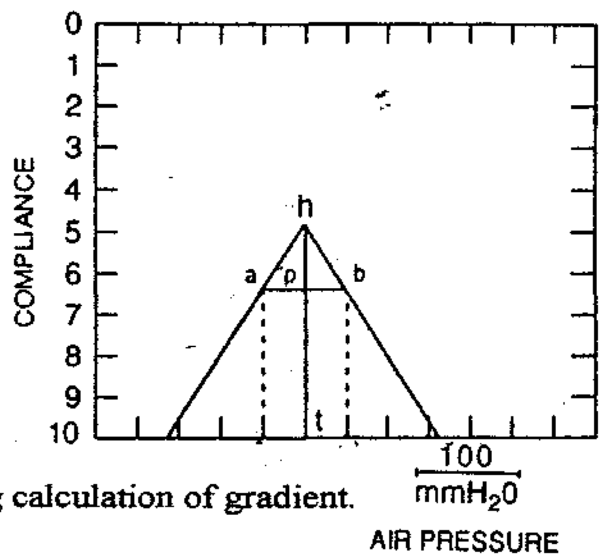


Fig.22 Showing calculation of gradient.

Another method of calculating the gradient, is the computa tion of tympanogram admittance relative to a pressure range. In this, a half-amplitude admittance (Y) point is determined and each side (positive pressure (Ya) and negative pressure (Yb) directions, by dividing the total amplitude of each side by 2.

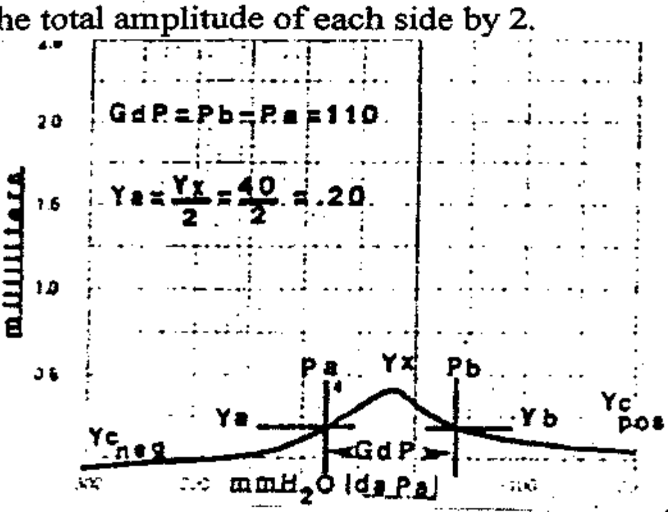


Fig.23

The difference in air pressure between each of these points on the slope of the tympanogram (Pressure for Ya, Pa; pressure for Yb, Pb) is referred to as delta (difference) pressure (dp) and is stated in daPa.

This method has been recommended by ASHA (1989) and is also incorporated into the Grason-Stadler 33 Middle Ear Analyzer. According to ASHA (1989), the 90% ranges for tympanometric width (gradient) of normal persons are 60-150 dapa in children and 50-110 daPa in adults (regardless of pumpspeed). A pressure interval wider than these values, suggest middle ear effusion.

Thus, it is a clinically useful tympanometric parameter. It can be used to supplement measurement of ear canal volume, pressure, peak admittance and static admittance.

Questions

I Choose the correct answer

1. The volume of the ear canal when the tympanic membrane is least compliant is known as the
   (a) static compliance
   (b) physical volume
   (c) gradient

2. The physical volume in normal adult ears ranges from
   (a) 1.2 -1.6 cc
   (b)0.6 cc- 1.8 cc
   (c)0.7- 1.0 cc

3. In cases of perforation of the ear drum, the physical volume.
   (a) decreases
   (b) remains the same
   (c) increases.

4. The physical volume decreases in cases with
   (a) mass occupying ear canal lesions
   (b) mass occupying middle ear lesions
   (c) none of these two.

5. Static compliance is synonymous to
   (a) compliance of the ear canal
   (b) static immittance
   (c) neither of these.

II Fill in the blanks, choosing the most appropriate answer from those given in brackets.

1. Gradient refers to the ..... of the tympanogram
   (shape/slope)

2. Static compliance is .... in the case of a .... middle ear system.
   (more/less; stifi/flaccid)

3. The method that is incorporated into GSI-33 middle ear analyzer to calculate the gradient, is the one recommended by.....
(ASHA, 1989; Brooks, 1969)

4. The compliance of the normal middle ear system is not influenced by the....
(Age of the subject / Ear which is tested)

5. Static compliance value does vary with.....

(Instrument used for measurement/pump speed)

III Match the following

A	B
a) Foreign body in the ear canal	a) 0.5-1.75 acoustic mho
b) Gradient as recommended by ASHA (1989)	b) Static immittance
	c) Decreased physical volume
c)C2-Cl	d)50-110daPa
d) Normal static compliance	e) Gradient
e) hp/ht	

IV Answer in brief

1. Describe the two procedures used to determine the gradient.
2. How is the physical volume test carried out?
3. Outline the procedure used in determining the static compliance.
4. The tympanometry results of a 4 year old boy shows 'B' type tympanogram in the left ear and the physical volume is 0.5 cc. What could be the possible pathology?
5. An adult male has a physical volume of 3 cc in right ear and 1.8 cc in the left ear. What could be the possible pathology and in which ear is it present?

Answers

I Choose the correct answer

1) b) Physical volume
2) b) 0.6-1.8 cc
3) c) increases
4) a) mass occupying ear canal lesions
5) b) Static immittance

II Fill in the blanks choosing the most appropriate answer from those given in brackets.

1. slope
2. more and flaccid/less and stiff
3. ASHA(1989)
4. Ear which is tested
5. Pump speed

III Match the following

A	B
a)	c)
b)	d)
c)	b)
d)	a)
e)	e)

IV Answer in brief

1. One method of determining the gradient is by drawing a line horizontal to the tympanogram, such that the distance between the two points of intersection is 100 daPa and then marking the midpoint of this line. The distance from the midpoint to the peak of the tympanogram is calculated. This value is divided by the total peak height of the tympanogram (vertical distance from peak to the X-axis) to get the gradient.

Another method, is to draw a line horizontal to the tympanogram at half its amplitude and find out the pressure difference, between the two points where the line insects the tympanogram.

2. In order to carryout the physical volume test, the tympanic membrane is made maximally stiff by applying a pressure of +200 H20. The compliance measured at this point will give the volume of the ear canal i.e. the physical volume.

3. To measure the static compliance, two volume measurements are made with the impedance audiometer. The first measurement C1, is made with the tympanic membrane minimally compliant i.e. at +200 mm H20 and the next with the tympanic membrane maximally compliant in (C2). Static compliance is calculated by subtracting Cl from C2 i.e. the ear canal volume is subtracted from the combined volume to give the static compliance of the tympanic membrane alone.

4. For a child, a physical volume of 0.5 cc is low. Therefore since it is occurring with a B tympanogram, there could be presence of wax in the ear.

5. As the difference in physical volume between the two ears is more than 1 cc, it indicates some abnormality. Since the physical volume in the right ear is more, there is possibly a perforation in that ear.

Multiple Frequency Tympanometry and Multicomponent Tympanometry

Multi Frequency Tympanometry

In tympanometric procedures a probe tone of 226 Hz is most commonly employed. We know that an abnormality is most obvious when a probe frequency close to the resonant frequency of the middle ear is used (i.e. 800 - 1200 Hz). Therefore, it is clear that by using such a low frequency as 226 Hz, it is difficult to detect middle ear abnormalities just based on the tympanometric shape. This is because almost all normal and pathological ears are stiffness - dominated at low frequencies and therefore a change in middle ear resonance need not produce a marked change in tympanometric shape. When multiple frequency probe tones are used in tympanometry a simple analysis of tympanometric shape may be sufficient to identify middle ear abnormalities. Liden (1969) was the first to report on multifrequency tympanograms.

Colletti(1975, 1976,1977) developed a multiple frequency impedance procedure. He used probe frequencies from 200 to 2000 Hz. Three distinct tympanometric patterns emerged at different frequencies A V-shaped pattern consistent with a stiffness - controlled middle ear, was identified for probe frequencies below 1000 Hz, a notched or W-shaped impedance pattern emerged between 650 and 1400 Hz near the resonant frequency of the middle ear, and an inverted V-shaped tympanogram was recorded above 1400 Hz, where the middle ear is mass controlled. The same three patterns were recorded in patients with middle ear pathologies, but the frequency range at which the patterns emerged was different from normal subjects.

It is seen that the resonance frequency is indicated by a notch in the tympanogram. In otosclerosis patients, using multifrequency tympanometry, the notch was found at higher frequencies (around 1300 Hz) indicating an increase in resonant frequency due to stifness reactance. Notching occurred at lower than normal frequencies in patients with ossicular chain discontinuity (500 - 850 Hz) indicating a decreases in stiffness reactance.

Bluestone et al. 1973; Holte, et al. 1991; Margolis and Heller, 1987; Margolis and Shanks, 1991; Van Camp et al. 1986; etc. have made valuable contribution to this area.

Presently, multiple frequency tympanometry is in the experimental phase. It is clear that high frequency probe tones are superior to low frequency tones in evaluating many middle ear pathologies especially those of the ossicular chain, but the optional frequency range and procedural variables have not yet been identified. The limited use of multifrequency tympanometry in clinical practice could be attributed to the lack of enough manufacturers marketing instruments with the capacity for more sophisticated measurements. Another major disadvantage of multifrequency tympanometry is that, the tympanograms generated for this tend to be more complex and difficult to categorize and interpret.

Multi-component Tympanometry

Till now, we have discussed only about single component tympanometry, where only admittance is measured. Multicomponent tympanometry is one, where all the three components i.e. susceptance, conductance and admittance are measured. These components can be measured at different probe tone frequencies (multifrequencies). The interpretation of these tympanograms demand lot of skill and expertise. Complexity of the tympanogram varies depending on the number of peaks and troughs (i.e. extrema) for each component at each frequency. An extrema may be referred to a maximum (increased admittance) or minimum (decreased admittance). It is seen that, as the frequency is increased, the susceptance notches first then the admittance and finally the conductance. The simplest normal pattern has one peak for susceptance (B), one for conductance (G), and one for admittance (Y), or a IBIGIY tympanogram.

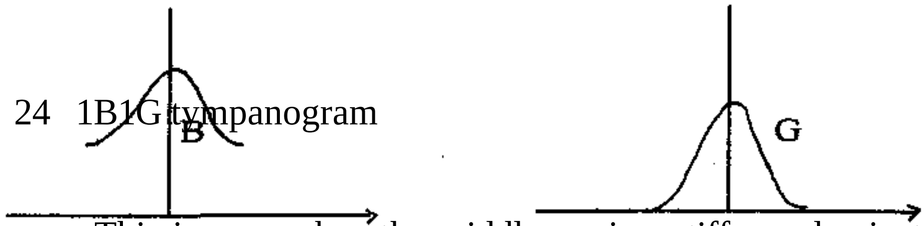


Fig. 24 1B1G tympanogram

This is seen when the middle ear is a stiffness dominated system and when the resistance of the middle ear is less than the absolute value of the stiffness reactance of the middle ear at all pressures (Vanhuyse et al. 1975; Margolis, 1978; and Shanks, 1984). The admittance component may not always be included in such classifications. Though a bell shaped tympanogram for each component is found for the majority of normal ears, there are other normal patterns also eg., 3BIG, 3B3G, 5B3G, etc.

The 3BIG tympanometric patterns one, where the maximum on the G tympanoagram falls between the two maxima on the B tympanogram.

This tympanometric pattern is obtained when the resistance of the middle ear is larger than the absolute value of the stiffness reactance around 0 dapa and when the resistance of the middle ear is smaller than the absolute value of the stiffness reactance at the pressure extremes (Vanhuyse et al. 1975; Margolis, 1978; and Shanks, 1984).

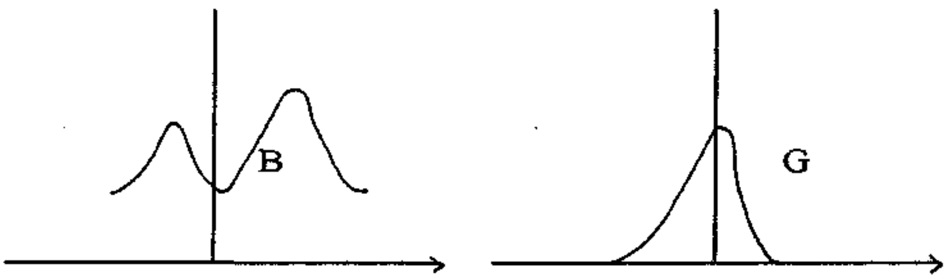
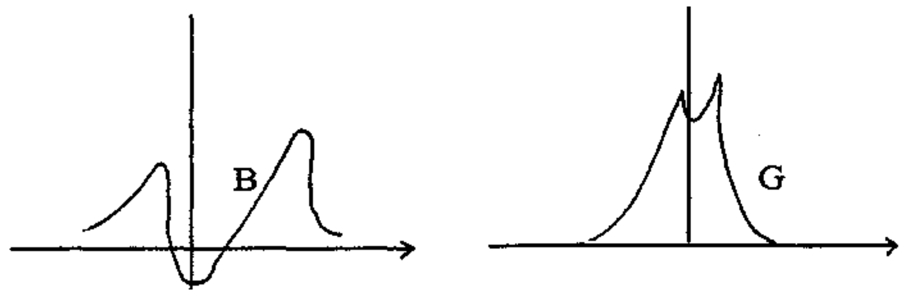


Fig.25 : 3B1G tympanogram

In the 3B-3G patten, there is a maximum on each side of the central minimum in both the conductance and susceptance tympanogram.

According to Vanhuyse et al. (1975), Margolis (1978) and Shanks (1984), the 3B-3G patterns occurs when the middle ear is mass controlled around 0 dapa but is stiffness controlled at the pressure extremes. At 0 dapa, the absolute value of the middle ear resonance is larger than the mass reactance. At the pressure extremes, the absolute value of the stiffness reactance is larger than that of the middle ear resistance.



Fig,26: 3B3G tympanogram

The 5B-3G pattern, according to Vanhuyse et al. (1975), Margolis (1978) and Shanks (1984), occurs when the middle ear is mass dominated around 0 dapa but stiffness controlled at the pressure extremes. The mass reactance is larger than the resistance at 0 dapa, the absolute value of the stiffness reactance is larger than that for the middle ear resistance at the pressure extremes.

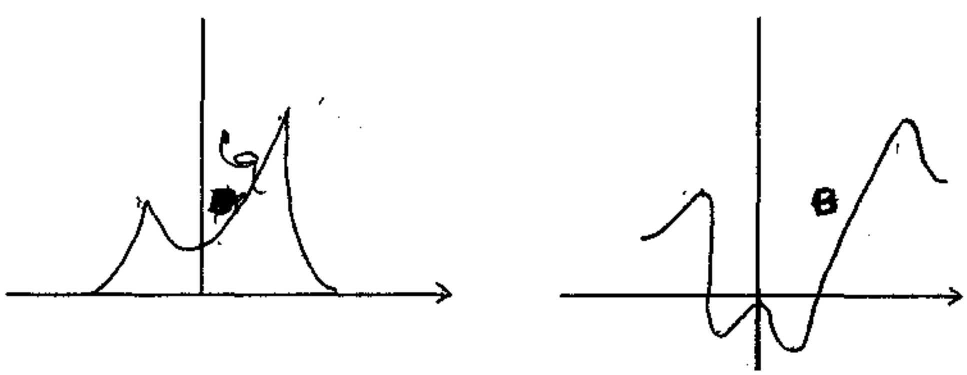


Fig:27 :5B5G tympanogram

In the figures given above, the horizontal line with an arrow shows the point at which susceptance tympanograms have been baseline corrected for each canal volume. Susceptance (B) values above this 0 line are +ve or stiffness controlled and those below the 0 line are -ve or mass controlled. Those which are on the 0 line indicates resonance.

Vanhuyse et al. (1975) gave a classification system according to which, a normally notched tympanogram must meet the following criteria (1) the number of extrema must not exceed five for the susceptance (B) and three for the conductance (G) tympanograms, (2) the distance (in decapascal) between the outermost conductance maxima must be smaller than the distance between the susceptance maxima and (3) the distance between the outermost maxima must not exceed 75 dapa for tympanograms with three extrema (eg. 3B3G) and must not exceed 100 dapa for tympanograms with five extrema (eg. 5B3G) (Shanks, 1984).

On the basis of this classification one can detect abnormal tympanograms. But, this can be applied only when the pressure change direction is from positive to negative as reported by Shanks (1984). This is because notching of tympanograms occurs very frequently in the cases of negative to positive direction pressure change when high frequency probe tones are used. This is the major disadvantage with this classification system.

Questions:

I Fill in the blanks by choosing the correct answer from those given in brackets :

1. The probe tone frequency that is most commonly used in tympanometry is. . . . .
(226 Hz/660 Hz).

2. In multifrequency tympanometry, one makes use of....
(high frequencies/frequencies ranging from low to high).

3. . . . . reported first about multifrequency tympanometry
(Jerger (1969)/Liden(1969).

4. Using multifrequency tympanometry, the resonance frequency is seen to .... in cases with otosclerosis
(decrease/increase)

5. The resonance frequency decreases in cases with .... using multifrequency tympanometry
(otosclerosis/ossicular chain discontinuity)

6. With increase in frequency.....component of the tympanogram notches first
(susceptance/conductance).

II Match the following

A	B
a) Simplest normal pattern	a) 3B1G.
b) 3 peaks/troughs on the susceptance graph and one on the conductance graph	b) 5B3G
c} 5 peaks/troughs on susceptance graph and 3 on the conductance graph	c) Criteria for normally notched tympanogram.
d) Vanhuyse et al (1975)	d} 1B1G1Y

III Answer the following :

1. With the use of a low frequency probe tone, it is very easy to detect middle ear pathologies, by observing the tympanometric shape alone. Justify this statement.

2. Explain what you mean by multifrequency and multicomponent tympanometry.

3. What could be the possible reasons for the limited use of multifrequency tympanometry in clinical practice?

4. What are the commonly seen patterns in multicomponent tympanometry?

5. Explain the classification system given by Vanhuyse for detecting abnormal tympanograms, and state its disadvantages.

Answers :

I Fill in the blanks choosing the correct answer from those given in brackets.

1.226 Hz.
2. frequencies ranging from low to high.
3. Liden(1969)
4.increase
5. ossicular chain discontinuity

II Match the following :

A	B
a)	d)
b)	a)
c)	b)
d)	c)

HI Answer the following :

1. Any pathology of the middle ear, can be most easily detected, when a probe tone frequency closer to the resonant frequency of the middle ear (i.e. 800-1200 Hz) is used. Moreover, at low frequencies, most of the normal and pathological ears are stiffness dominated and therefore a marked change in tympanometric shape may not occur with change in middle ear resonance. But if multiple frequency probe tones are used, it is possible to identify the middle ear abnormality just based on the shape of the tympanogram.

2. Multifrequency tympanometry, is a procedure where multiple frequencies ranging from low to high are employed. In multicomponent tympanometry, all the three components i.e., susceptance, conductance and admittance are measured and based on the number of peaks and troughs, they are named.

3. There could be several reasons for the limited use of multifrequency tympanometry in clinical practice. One major reason is that, there

are not enough manufactures, marking instruments with the capacity for more sophisticated measurements. Also, multifrequency tympanometry yields tympanograms, which are complex and difficult to be categorized and interpreted.

4. The most commonly seen patterns in multicomponent tympanometry are1B 1G - one peak for each of the components, 3B1G - 2 peaks and 1 trough for susceptance and one peak for conductance, 3B3G - 2 peaks and 1 trough for both susceptance and conductance and 5B3G pattern - 3 peaks and 2 troughs for susceptance and 2 peaks and 1 trough for conductance.

5. Vanhuyse's 1975 classification system, states the folio wing criteria for a normally notched tympanogram :

(1) the number of extrema must not exceed five for the susceptance and three for the conductance tympanograms.

(2) the distance between the outermost conductance (in decapascal) maxima must be smaller than the distance between the susceptance maxima.

(3) the distance between the outermost maxima must not exceed 75 dapa for tympanograms with three extrema and must not exceed 100 dapa for tympanograms with five extrema.

The disadvantage with this system is that, it can be applied only, when direction of pressure change is from positive to negative direction or else interpretations may be erroneous.

TESTS OF EUSTACHIAN TUBE FUNCTION

Adequate'eustachian tube function is a prerequisite for normal middle ear function. The immittance measuring instrument has been found to be a valuable tool for determining whether or not the eustachian tube is functioning normally.

The tests of eustachian tube ventilatory function that can be performed with the electroacoustic immittance measuring instrument are :

1) ***Inflation - deflation test****:* It was given by Bluestone (1972). The first step is to determine the resting middle ear pressure through tympanometric measures, following which a pressure of +200mm of H_2O is built in the ear canal and the subject is asked to swallow several times. This increses the middle ear pressure(inflation) and if the eustachian tube is functioning normally, the air goes down the tube into the nasopharynx during swallowing. If the test is successful, the middle ear pressure should be slightly shifted to the negative side. Following this a pressure of -200 mm H2o is built in the ear canal and the subject is asked to swallow several times. This decreases the middle ear pressure (deflation) and in normal functioning eustachian tubes, the air will pass into the middle ear from the nasopharynx causing the middle ear pressure to shift slightly to the positive side which can be tested by obtaining another tympanogram.

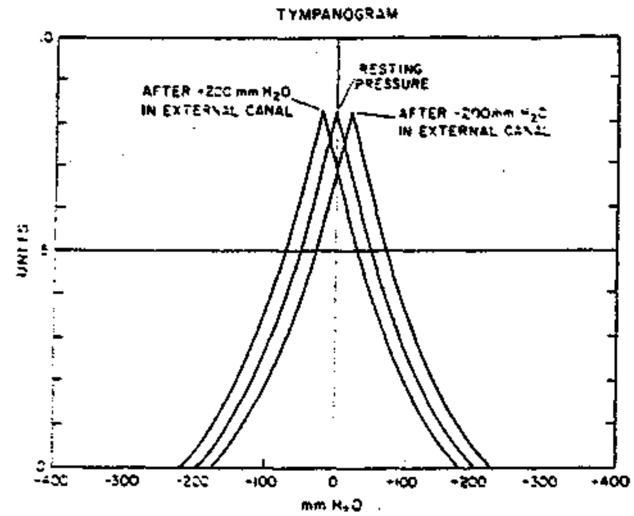


Fig. 28

. *Normal inflation-deflation Eustachian tube function test when the tympanic membrane is intact employing tympanometry.*

2) *Toynbee's and Valsalva 's Test* - In Toynbee maneuver, the resting middle ear pressure is initially determined. Following this, the patient is asked to manually compress the nose and swallow several times. This will create a negative pressure in the nasopharynx and therefore air will escape into the nasopharynx from the middle ear. The pressure remaining in the middle ear following this manuever can be determined by repeating the tympanogram while the patient refrains from swallowing. If a negative pressure is present in the middle ear, it indicates normal eustachian tube function. In Valsalva maneuver, the patient is asked to blow against the manually compressed nose and closed lips, creating a high nasopharyngeal positive pressure. Following this, air will escape into the middle ear creating a positive pressure there. Pressure remaining in the middle ear can then be evaluated by obtaining a tympanometric peak. If the test is successful, positive middle ear pressure results.

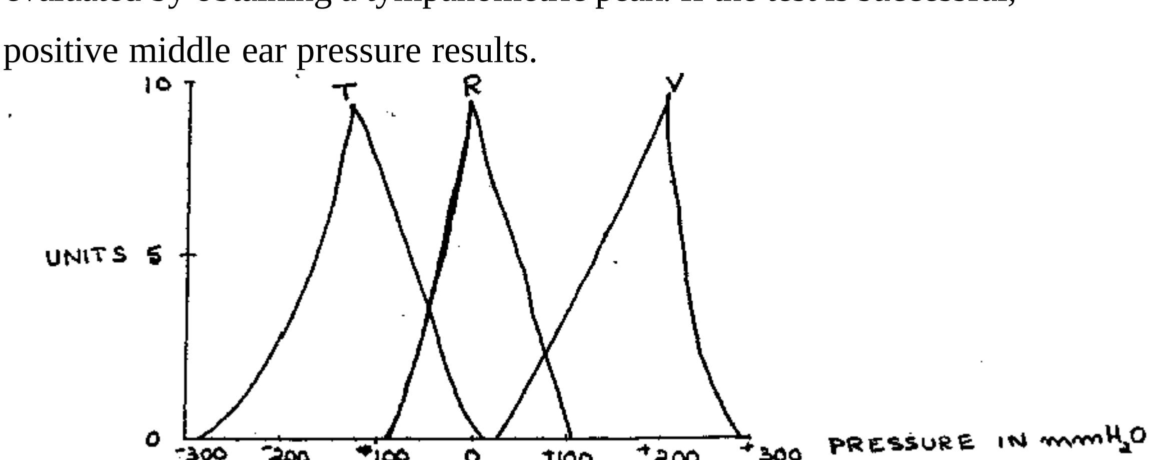


Fig. 29 Toynbee's and Valsalva's tests of eustachian tube function when tympanic membrane is intact tympanometry

3. Holmquist's method **-** Holmquist (1969 and 1972) recommends the use of "Air pressure equalization technique" for the evaluation of eustachian tube function. It involves 5 steps. First a baseline tympanogram is obtained. Then, a negative pressure is created in the nose and epipharynx by means of a pressure device connected to the nose. The subject is then asked to swallow in order to facilitate the transmission of negative pressure to the middle ear. By doing so, a negative pressure of -200 mm H2o develops in the middle ear. A second tympanogram is recorded and then the subject is asked to swallow repeatedly, when the tube opens and equalization of pressure occurs. A final recording of tympanogram is done to see if pressure equalization has occurred.

If despite repeated swallows, a residual negative pressure remains, it indicates inadequate equalization suggesting a tubal dysfunction.

4. The Pressure Swallow Test **-** This test is based on the same principle as that of Valsalva's and Toynbee's tests. However, it does not involve any active participation on the part of the subject. Changes are created tympanometrically and recorded (Williams, 1975).

1) First, an air-tight seal is obtained following which the subject is asked to swallow once or twice with the air pressure setting at 0 mmH2o.

(2) After this a baseline tympanogram is obtained.

(3) Then, the ear canal pressure is increased to +400 mm H20. The subject is again asked to swallow or drink some fluids. Obtain another tympanogram.

(4) Bring the middle ear pressure back to the initial one (0 mm H_2O).

(5) Reduce the ear canal pressure to -400 mm H_2O and ask the subject to swallow or drink some fluids. Obtain yet another tympanogram.

In the second tympanogram a slight negative pressure is seen usually because of the air expelled through the eustachian tube after the building of positive pressure in the ear canal.

The reverse of the above occurs when ear canal pressure is made negative.

If this pattern is not seen, it is suggestive of eustachian tube dysfunction.

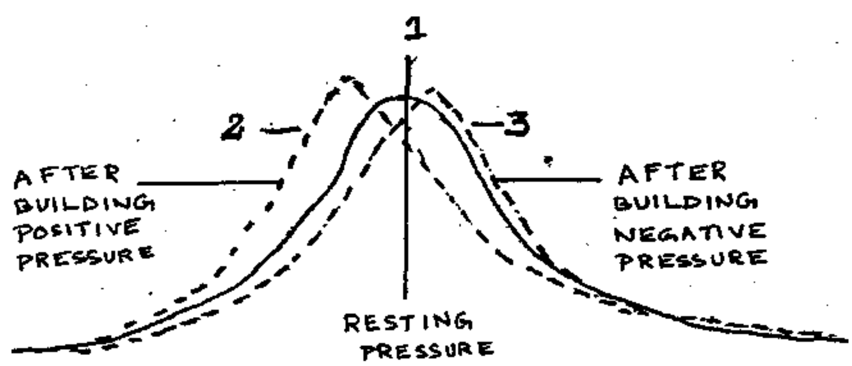


Fig.30 Pressure - swallow test

The above tests are used in the case of an intact tympanic membrane. In the case of a non-intact tympanic membrane, the diagnosis can frequently be made by using an immittance device. When tympanometry is attempted, either the needle cannot be balanced or a larger than expected volume is noted. Another indication would be the finding of a sudden loss of pressure during the attempt to pump +200 mm H_2O pressure in the external canal. For further confirmation, the pressure can be increased to +400 mm/H_2O in attempt to reach an opening pressure. In spite of this, if the eustachian tube does not open, the subject should be asked to swallow and if there is a drop in pressure, diagnosis is confirmed. This helps in the detection of even microscopic perforations of the ear drum.

Patulous Eustachian Tubes **-** This is a condition where the eustachian tube is abnormally open at rest. If it is suspected, the diagnosis can be confirmed by doing tympanometry in the case of an intact tympanic membrane. A tympanogram is first obtained while the patient is breathing normally and is repeated during breath-holding. The fluctuation in the tympanometric line which coincides with breathing is a clear sign of a patulous eustachian tube.

In the case of a non-intact tympanic membrane, this can be detected by applying a positive and negative pressure. If this pressure cannot be maintained in the middle ear or the presence of low opening pressure also indicates the presence of a patulous eustachian tube.

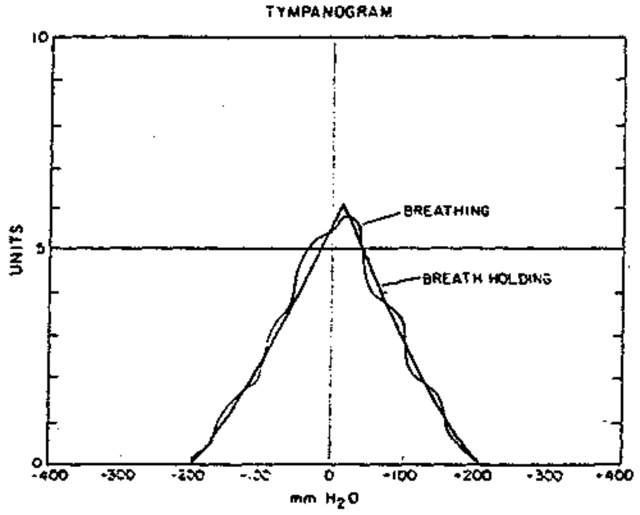


Fig.31

Tympanogram of a patient with a patulous Eustachian lube. Wavy line was obtained while subject was breathing. Steady line taken while breath-holding.

Questions

I State whether the following statements are true or false

1. After inflating the middle ear, one can expect the middle ear pressure to shift to the negative side in the case of a normally functioning eustachian tube.
2. The middle ear pressure usually shifts to positive side after administering Toynbee's maneuver, whereas it shifts to the negative side on administering Valsalva's maneuver.
3. The presence of a negative pressure after the administration of Holmquist's test is an indication of a normally functioning eustachian tube.
4. In pressure swallow test, there is a shift in tympanometric peak pressure to the positive and negative side on building a negative and positive pressure respectively in the ear canal.
5. In the case of a perforated tympanic membrane, one cannot maintain a high positive pressure in the ear canal during tympanometry.
6. In the case of eustachian tube dysfunction, Valsalva's maneuver would show a shift in middle ear pressure to the positive side.
7. The absence of pressur shfits during inflation - deflation test is a clear indication of a tubal dysfunction.

II Match the following

A	B
a) Patulous eustachian tube	a) Williams (1975)
b) Inflation-deflation test	b) Fluctuations in the tympanometric line
c) Pressure swallow test	c) Patulous eustachian tube with non-intact tympanic membrane
d) Low opening pressure	d) Bluestone (1980)

III Answer the following in two or three sentences

1. On performing an inflation-deflation test, what are the results you expect? If a particular case does not show these findings, what will your diagnosis be?

2. How is Valsalva's manuever different from that suggested by Toynbee?

3. Describe briefly, the procedure used in Holmquist method and how it helps in detecting tubal dysfunction.

4. What is the cause for the shift in middle ear pressure to positive and negative side during pressure swallow test?

5. How can one detect the presence of a patulous eustachian tube using rympanometric procedure?

IV Unscramble the puzzle given below to obtain four meaningful terms names related to the topic.

V M I L L W A I
E A N F L A T I
B P L M A C E O
E S P S R G I N
Y D X K A F G X
N O I J M L C P
T Q N K L Q V Z
O E S U W X K A

Answers

I State whether true or false

(1) True (2) False (3) False (4) True (5) True (6) False (7) True

II Match the following

A	B
a)	b)
b)	d)
c)	a)
d)	c)

HI Answer the following in two or three sentences

1. During inflation, i.e., on increasing the middle ear pressure, a negative pressure should be seen, as the air should go down the tube into the nasopharynx after the patient swallows, thus creating a negative middle ear pressure. The reverse should occur during deflation, as the air is transferred from the nasopharynx to the middle ear to equalise the negative pressure that was created here.

If these findings are not obtained in a particular case, that is indicative of a eustachian tube dysfunction.

2. In Toynbee's manuever, after determining the resting middle ear pressure, the patient is asked to compress the nose and swallow several times. One expects a shift in the middle ear pressure to the negative side following this. Whereas in Valsalva's manuever, the patient blows against the compressed nose and closed lips, creating a positive middle ear pressure.

3. The first step in Holmquist's method is to obtain the base line tympanogram. Following this, a negative pressure is created in the nose and epipharynx by means of a particular device connected to

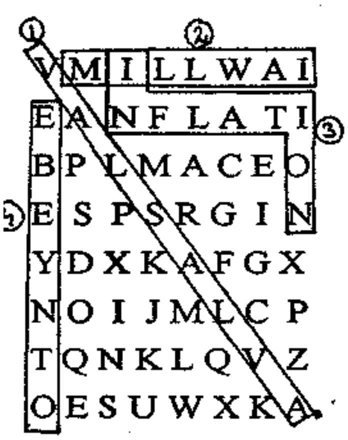
the nose, and then the subject is asked to swallow. This is supposed to transmit the negative pressure to the middle ear. After obtaining a second tympanogram, the subject is asked to swallow repeatedly in order to equalise the pressure and following this a final tympanogram is obtained.

If a negative pressure is seen in the final tympanogram even after repeated swallows, this confirms that there is dysfunctioning of the eustachian tube.

4. In pressure swallow test, initially, a high positive pressure is created in the ear canal, following which the subject is asked to swallow. During this the eustachian tube opens and the air gets expelled causing a shift in middle ear pressure to the negative side. Following this a high negative pressure is induced in the ear canal. On swallowing, air enters the middle ear through the eustachian tube causing the middle ear pressure to shift to the positive side.

5. In the case of an intact tympanic membrane, one can obtain the tympanogram while the patient is breathing normally and during breath holding. The fluctuations in the tympanometric line which coincides with breathing will indicate the presence of a patulous eustachian tube. If the tympanic membrane is not intact, one cannot maintain a positive or negative pressure in the ear canal. Thus, the presence of a patulous eustachian tube can be detected.

IV Unscramble the puzzle given below to obtain four meaningful terms names related to the topic.



1. VALSALVA
2. WILLIAM
3. INFLATION
4. TOYNBEE

ACOUSTIC REFLEX

Reflex is defined as the simplest form of involuntary response to a stimulus. Like in other organs, reflexes are observed in the middle ear also for loud sounds. It has been found that, on presenting loud sounds, the stapedius muscle contracts thereby stiffening the ossicular chain. This reflexive contaction of the stapedius muscle to loud sounds is termed as acoustic reflex. This results in an increase in middle ear impedance which can be measured by various impedance measuring instrument.

Thus, in order to determine whether or not an acoustic reflex has been obtained, the procedure requires that one measure the acoustic impedance at the eardrum and men, while continuing to monitor the impedance, one introduces an acoustic stimulus into either the contralateral or ipsilateral ear. If the stapedius muscle contracts following the acoustic stimulus, it should result in an increase in the monitored acoustic impedance.

Other direct approaches like opening the tympanic cavity and observing the muscle contractions or observing the changes in muscle activity with electromyography etc. have also been used. Clearly, these methods are not preferred for routine assessment of middle ear function.

The Neural Acoustic Reflex Pathways

The stapedius muscle is attached to the posterior side of the neck of the stapes and is the smallest muscle in the body. Our current understanding of the acoustic stapedius reflex pathway is based primarily on experimental study of the rabbit (Borg, 1973, 1976).

The neural network of the stapedius (acoustic) reflex is located in the lower brainstem and consists of both ipsilateral and contralateral routes. During loud acoustic stimulation, the ipsilateral pathway begins with impulses from the cochlear sensory cells from where it is transmitted to the ventral cochlear nucleus through the acoustic nerve. From here some fibres go to the facial motor neuron and from there to the stapedius muscle through the facial nerve. Some fibres from the ventral cochlear nucleus also go to the medial superior olivary complex and reach the facial motor neuron and then the stapedius muscle.

The contralateral acoustic reflex arc always contains four neurons. From the acoustic nerve and the neutral cochlear nucleus, impulses are transmitted to the medial superior olive and across to the contralateral facial motor nucleus. The fourth neuron transmits the impulse from the contralateral facial motor nucleus to the contralateral stapedius muscle. The other contralateral acoustic reflex are has (a) the first order neuron from hair cells of cochlea to ipsilateral ventral cochlear nuclei (b) second order nerurons from ipsilateral VCN to contralateral SOC and (c) third order neuron from contralateral SOC to contralateral FMN and (d) fourth from contralateral FMN contralateral stapedius muscle. The stapedius muscle is innervatd by the facial nerve (cranial nerve VII).

The acoustic reflex response depends on adequate physiologic function of the entire reflex are including cochlea, eighth nerve, brainstem seventh nerve and stapedial muscle. The specific site of lesion within the acoustic reflex are is determined by comparing stapedial reflexes between crossed and uncrossed stimulation (Jerger, 1980; Jerger and Jerger, 1983).

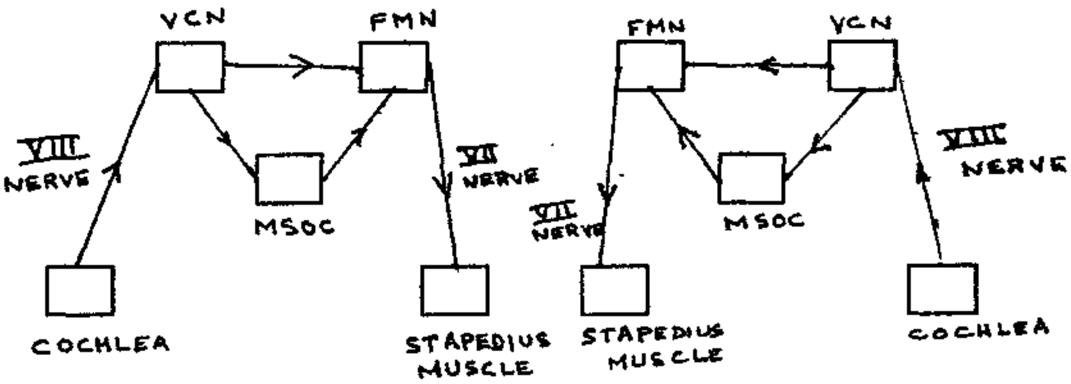


Fig. 32 Block diagram of ipilateral pathways
Fig. 32. Block diagram of ipsilateral pathways

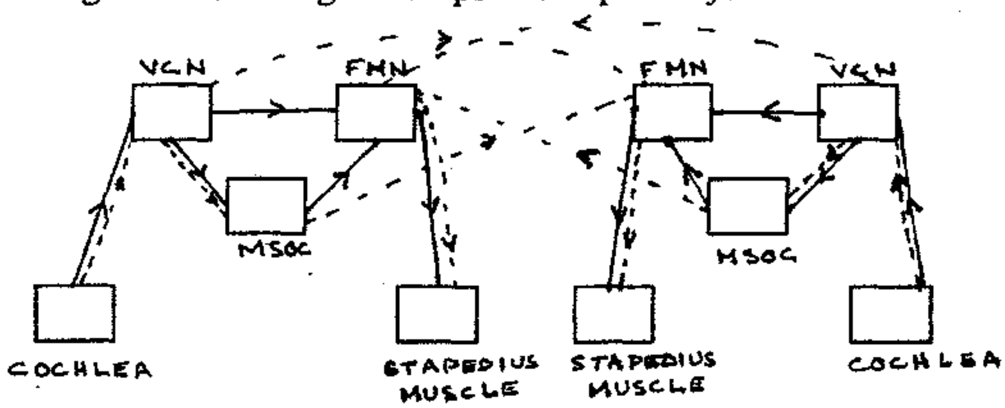


Fig.33 Block diagram of contralateral pathway (Dotted Lines)

Acoustic Reflex Threshold

As mentioned earlier acoustic reflex is indicated by an increase in acoustic impedance or decrease in compliance of the middle ear system. Acoustic reflex threshold (ART) is the lowest intensity of an acoustic stimulus at which a minimal change in the middle ear compliance can be measured. The ART for normal hearing subjects is 70-100 dB hearing level (HL) (Metz, 1946; Fria et al. 1975). For contralateral stapedial reflex, the threshold value is approximately 85 dB HL for puretones and 65 dB HL for broad band noise. Ipsilateral reflex thresholds are slightly lower (Moller, 1962).

Acoustic reflexes are usually elicited using puretones pulse tones or broad band noise clicks can also be used and at higher click rates, the amplitude of acoustic reflex is found to be more (Rawool 1996 and 1997).

Variables that affect the ART

1. ***Intensity-*** Reflex amplitude increases as stimulus intensity is increased above the reflex threshold for 10-15 dB. Beyond this increase little additional amplitude change can be noted at higher stimulus intensities. Wilson (1979) reported that reflex magnitude for puretone stimuli is similar across frequencies.

2. ***Duration*** - Silman and Gelfand (1982) suggested that activators lasting 1 to 2 sec. are ideal, because with brief activators (i.e. 300 msec or less) stimulus level must be increased in order to compensate for the reduction in stimulus on-time. Signals longer than 2 sec. seem to have little effect on the ART. .

3. ***Bandwidth*** - ART is found to be lower for broad-band noise than puretones. ART is reduced as bandwidth increases at each test frequency.

4. *Ipsilateral vs. contralateral reflexes* - Early studies report that ipsilateral acoustic reflex can be elicited at lower intensities than contralateral acoustic reflex (Moller, 1961; Fria et al. 1975). But Laukli and Meir (1980) did not find this difference. Jerger et al. (1978) used a special immittance measuring technique and reported that the differences between ipsilateral and contralateral reflex measurements were due to neuromuscular events. With the use of advanced instrumentation which uses signal averaging and the same stimulus origin for both sets of reflexes, such differences are not observed (Stach and Jerger, 1984, 1987).

Two other important points are to be noted here. One is that, artifacts are more in ipsilateral reflex measurements, as the probe tone and eliciting signals are presented through the same tube. Also intensity levels of ipsilateral reflex are reported in dB SPL rather than dB HL and therefore a correction factor has to be added before comparing it with contralateral reflexes.

5. *Drugs (including alcohol)* - Barbiturates and ethanol can elevate the ART, though the effect appears to be greater for alcohol (Bauch and Robinette (1978). Sedation is also seen to affect acoustic reflex thresholds. Borg and Moller (1968); Robinette et al. (1974) reported that acoustic reflex threshold may be elevated in sedated patients. Any drug that can alter central nervous system responses may have a dilatory or inhibitive effect on the acoustic reflex (Northern, 1980).

6. *Age :* Studies by Hall (1978), Jerger et al. (1978) and Hall and Weaver (1979) show that ART to puretone stimuli tend to improve slightly with increasing age from 0-59 years but there is no change observed for broad band noise stimuli. Contrary to this, Silman and Gelfand (1982) found no significant clinical change in ART measurements as a function of age. Wilson (1981) noted what the amplitude, or size of the acoustic reflex diminishes with age.

7. *Handedness* - Johnson (1979) reported that left handed children were significantly slower than the right handed in terms of development or maturation of acoustic reflex sensitivity. Right ears in general gave reflexes at about 3.8 dB lower than the left ear did.

Acoustic Reflex Adaptation - During sustained activation of the acoustic reflex, the stapedius muscle begins to relax and the acoustic immittance of the middle ear mechanism begins to return to the preactivator state. Relaxation of the stapedius muscle during presentation of a reflex - activator signal is called acoustic reflex adaptation or decay. In normal auditory system, the amount and rate of reflex adaptation is directly related to the frequency of the activator signal (Djupesland, et al. 1967; Johansson, etal. 1967) and is inversely related to the level of the activator signal, especially for levels near the acoustic - reflex threshold (Dallos, 1964).

Acoustic Reflex elicited by Bone-Conducted Puretones

Djupesland et al. (1973) measured acoustic reflex threshold for bone conductive pure tones. It was tested using a mini shaker (Bruel and Kjaer, Type 4810) at frequencies 250, 500, 1000, 2000, 3000, 4000 and 6000. A considerable difference between reflex thresholds for air and bone conducted pure tones was found, especially in the lower frequency range, where the difference amounted to 5-25 dB. At higher frequencies, in some cases, it was not possible to elicit the reflex, even when the maximum intensity was used. This difference in air and bone conducted thresholds could be due to a difference in the inner ear distortion for air and bone conducted pure tones.

Suprathreshold Measures of the Acoustic Reflex

1. ***Acoustic Reflex Latency*** - The latency of the acoustic reflex is the time difference between the onset of the reflex - activator signal and the onset of acoustic reflex. This is not a very reliable measure due to the following reasons. First the definition of the onset of the acoustic reflex is imprecise. Second, the commercially available electroacoustic immittance instruments have various time consonants (Jerger, Olives and Stach, 1986; Lilly, 1984; Margolis and Gilman, 1977; Shanks, et al. 1985). Third, investigators use different onset landmarks to define onset of the acoustic reflex. Some investigators use the initial detectable change in acoustic immittance whereas some others use a percentage of the maximum immittance change, which can be 10%, 50% or 90% (Borg, 1982; Bosatra, et al. 1984; Lilly, 1984). Fourth, the latency of the acoustic reflex is inversely related to the level of the reflex -activator signal (Dallos, 1964; Hung and Dallos, 1972;. Lilly, 1964;Moller, 1958; Ruth and Niswander, 1976; Terkildsen, 1960). Fifth, the latency of the acoustic reflex varies with the frequency and level of the activator signal. Ruth and Niswander reported that the latency was shorter for a 3000 Hz activator than for a 500 Hz activator at levels less than or equal to 104 dB SPL, whereas at activator levels greater than 104 dB SPL, the latencies for the two frequencies were the same.

Acoustic reflex latency measures have been used as a part of the differential diagnosis which will be discussed in detail in later chapters.

2. *Acoustic reflex amplitude* - The magnitude or amplitude of the acoustic reflex is the difference between the immittance of the middle ear during the resting or baseline state and the immittance of the middle ear during the reflexive stage.

Level of the activator signal is directly related to the amplitude of the acoustic reflex and so is the duration. As duration increases to about 500 ms, reflex amplitude increases. Other observations include steeper reflex growth functions for mid-frequency activator signals than for low-frequency activator (Moller, 1961). Also binaural activator signals produce largest reflex amplitude, followed by ipsilateral activator signals which produce the second largest amplitudes and finally the contralateral signals which produce the smallest amplitudes (Moller, 1962).

Questions

I Fill in the blanks :

1....is an indirect approach used in human to study the contraction of middle ear muscles.
2. The contraction of middle ear muscles results in an.... in acoustic impedance.
3. The lowest intensity of an acoustic stimulus at which a minimal change in the middle ear compliance can be measured is termed as......
4. When the intensity of the reflex eliciting stimulus is increased upto 10-15 dB above ART, the amplitude of acoustic reflex.....
5. The most suitable stimulus duration for eliciting acoustic reflex is.....
6. Increase in bandwidth.....ART.
7. Ipsilateral stimulus intensity level is indicated in.....
8. Acoustic reflex can be elicited through air-conduction as well as ....
9. The time difference between the onset of the reflex activator signal and the onset of acoustic reflex is termed as......
10. Acoustic reflex amplitude is.....related to intensity of the.....

II Choose the correct answer

1. When a loud stimulus is presented to one ear, the middle ear muscle of.....contract.
   (a) the same ear
   (b) both ears
   (c) one of the two ears

2. The cranial nerve which innervates the stapedius muscle is
   (a) Cranial nerve V
   (b) Cranial nerve VI
   (c) Cranial nerve VII

3. The acoustic reflex response depends on the physiologic functioning of the
   (a) entire reflex arc
   (b) middle ear
   (c) inner ear.

4. ART for normal hearing subjects ranges between
   (a) 70-100 dB SPL
   (b) 70-100 dBHL
   (c) 70-100 dB

5. Which of the following is not used as a reflex eliciting stimulus?
   (a) broad band noise
   (b) pink noise
   (c) clicks

6. ART is higher for
   (a) ipsilateral reflex
   (b) contralateral reflex
   (c) very long duration stimulus.

7. Drug intake .... the ART
   (a) elevate
   (b) lower
   (c) unalters

8. One of the following factors has no effect an acoustic reflex. Which is that factor?
   (a) Handedness
   (b) Sedation
   (c) Mental state of the subject

9. As temporal summation affects acoustic reflex, with increase in stimulus duration, the loudness ....
   (a) increases
   (b) decreases
   (c) remains unaltered

10. Latency of the acoustic reflex is .... related to the level of the activator stimulus.
    (a) directly
    (b) in no way
    (c) inversely

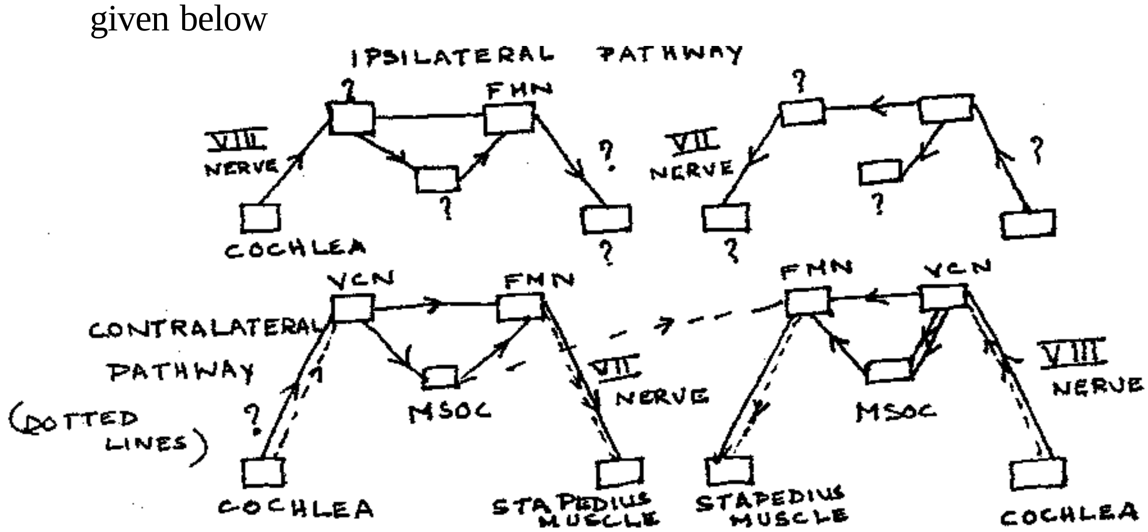
HI State whether the following statements are true or false

1. Acoustic reflex will definitely be present if the middle ear is functioning normally.
2. Acoustic reflex is usually elicited for all the frequencies at which puretone testing is done.
3. The amplitude and latency of acoustic reflex are directly related to the level of the activator stimulus.
4. The amplitude of the acoustic reflex and duration of the activator stimulus are directly related to each other.
5. Ipsilateral activator signals produce acoustic reflex with amplitude lesser than those produced by binaural signals but greater than those produced by contralateral signals.

IV Answer the following

1. Explain the procedure for testing the acoustic reflex.

2. Complete the diagram of the neural acoustic reflex pathways given below



3. Acoustic reflex does not depend on the functioning of the middle ear alone. Justify this statement.

Answers

I Fill in the blanks

(1) Acoustic reflex (2) Increase (3) Acoustic reflex threshold
(4) Increases (5) 1-2 sec. () Decreases (7) dB SPL (8) Bone conduction
(9) latency of acoustic reflex (10) directly, activator signal

II Choose the correct answer

1 (b) both ears
2 (c) cranial nerve VII
3 (a) Entire reflex arc
4 (b) 70-100 dB HL
5 (b) pink noise
6 (b) contralateral reflex
7 (a) elevate
8 (c) Mental state of the subject
9 (a) increases

10 (c) inversely

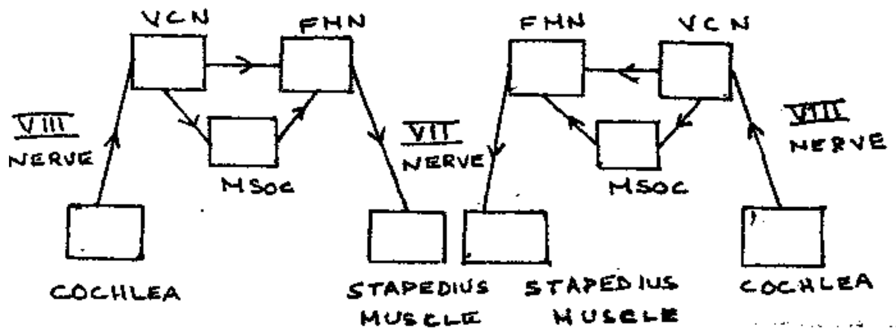
III State whether the following statements are true or false

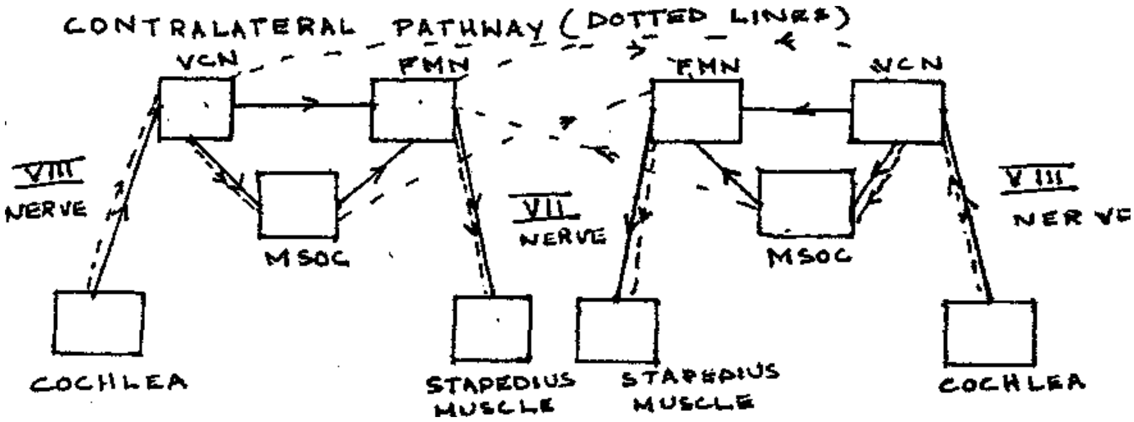
(1) False (2) false (3) false (4) True (5) True

IV Answer the following questions

1. The baseline acoustic impedance is determined first. While continuing to monitor the impedance, an acoustic stimulus (loud) is introduced either ipsilaterally or contralaterally. If there is an increase in impedance, it confirms the presence of acoustic reflex. The intensity of the activator stimulus can be decreased and the minimum intensity at which the acoustic reflex can be elicited can be found out to determine the acoustic reflex threshold.

2. Ipsilateral pathway





3. There is an entire neural pathway that is involved in the elicitation of the acoustic reflex. A pathology anywhere along this reflex arc can affect the acoustic reflex. Therefore acoustic reflex is not purely dependent on the middle ear.

Diagnostic Applications of the Acoustic Reflex Measurement

The diagnostic applications of the acoustic reflex considerably outweigh the contribution of tympanometry and static compliance in the acoustic immittance test battery (Jerger and Hayes, 1980; Northern, 1984). Since the publication of the classic monograph by Metz (1946), audiologists have realized the immense diagnostic value of this simple physiologic reflex. Acoustic reflex measurements, however should not be examined in isolation but must be considered as an integral part of the total immittance test battery.

Conductive Hearing Loss **-** It has been observed that when there is a middle ear disorder of even the slightest degree, reflexes are obscured in that condition. Since middle ear disorders prevent the tympanic membrane from showing a change in compliance when the stapedial muscles contract, both ipsilateral and contralateral reflexes are absent bilaterally in the presence of even a mild bilateral conductive hearing loss.

The presence or absence of the acoustic reflex also depends on the magnitude of the air bone gap. If the air bone gap is less than 30 dB contra lateral reflexes are usually present but if it exceeds 30 dB contra lateral reflexes are unlikely to be present. In the affected ear, the reflexes are absent (ipsilateral reflexes) even when the air-bone gap is very small, due to the mechanical problem of that ear. Thus, skillful interpretation of acoustic reflexes in unilateral hearing loss cases can suggest the degree and nature of hearing loss.

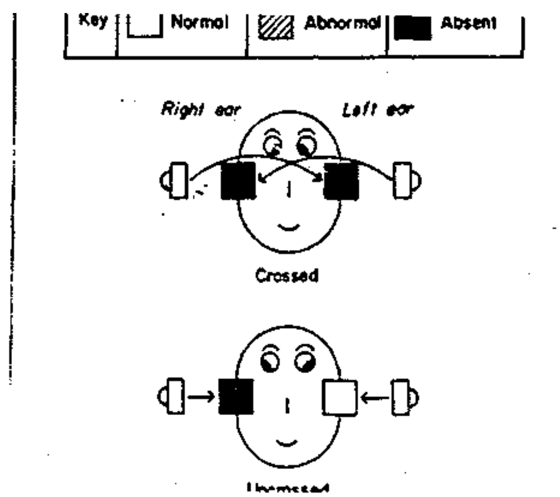


Fig.34 : Ipsilateral and contralateral reflexes in a unilateral right ear conductive hearing loss greater than 30 dB HL (inverted L pattern).

It has been observed that, patients with otosclerosis have a unique pattern of acoustic reflex. According to Terkildsen et al. (1973) and Jerger et al. (1973) the acoustic reflex is generally not observed in either ear. In early otosclerosis, there is a biphasic reflex pattern observed. This was first reported by Fottorp and Djupesland (1970). This is characterized by a momentary negative deflection at the start of the reflex and again at the end of the reflex as the stimulating signal is shut off (Bel et al. 1976). This is not seen in later stages of otosclerosis.

Biphasic reflexes are occasionally found in certain normal ears with loose coupling between the stapes and oval window. This is due to the decrease in the resistive component during acoustic reflex contraction. Another biphasic pattern in normal ears has been reported for high frequency probe tones. Another typical finding in conductive loss cases, is a combination of the following (a) presence of air bone gap with normal bone conduction threshold (b) 'A' type tympanogram (c) absence of reflexes. This combination is termed as impedance signature which is a definte indication of a conductive pathology.

Unfortunately, certain middle ear pathologies are exceptions to the normal rule and they do exhibit acoustic reflex. Northern (1977) reported that an exception occurs in cases of ossicular disruption when the connection is maintained between the insertion point of the stapedius muscle on the stapes and the eardrum. A middle ear cholesteatoma that does not impinge on the eardrum of ossicular chain, as well as some ears with serous otitis media and negative middle ear pressure, may also produce normal patterns.

Sensory-neural Hearing Loss -The differentiation of cochlear versus eight nerve disorders has been a primary challenge in audiometric evaluation.Acoustic reflex measurements have been very helpful in this purpose.

Cochlear Pathology - An early application of the acoustic reflex was in the evaluation of the cochlear phenomena of abnormal loudness growth. Mezt (1952) found that acoustic reflex is elicited at sensation levels of less than 60 dB SL in ears with cochlear lesions. The comparison between the acoustic reflex threshold hearing level (HL) to the degree of hearing loss is referred to as the *Metz test for loudness recruitment.* If the acoustic reflex is obtained below 60 dB SL, it is considered to be a positive Metz test result.

There are a few other tests which can be employed for testing the presence of cochlear pathology.

Differential Ratio Quotient (DRQ) - Fitz land and Balkany (1974) [cited in Malini, 1980] gave a formula for determining the amount of recruitment which was termed as DRQ.

DRQ = *(A-X)* - (B-Y) X-Y

Where A = ART of better ear
B = ART of poorer ear
X = Puretone threshold of better ear
Y = Puretone threshold of poorer ear

DRQ= 0-1 - Partial recruitment
= 1 - Complete recruitmen
t = > 1 - Hyper recruitment

Reflex Relaxation Index - Norris et al. (1974) compared the temporal characteristics of reflex in ears with sensori-neural hearing loss with that of normal ears, at 1000 Hz. He observed some difference between the normal and pathological ears in terms of latency.

To measure these alterations in reflex relaxation time, Norris, Stelmachowicz and Taylor (1974) described the procedure for obtaining reflex relaxation index. A pulse tone of 500, 1000 and 2000 Hz is presented at 10 dB above ART. The width of the pulsed component (b) is divided by the total reflex amplitude (a) to obtain RRI. An RRI of less than 30% was considered to be indicative of sensory hearing loss (Norris, et al. 1974). Letien and Bess (1975) suggested a cut off point of 40% instead of 30%.

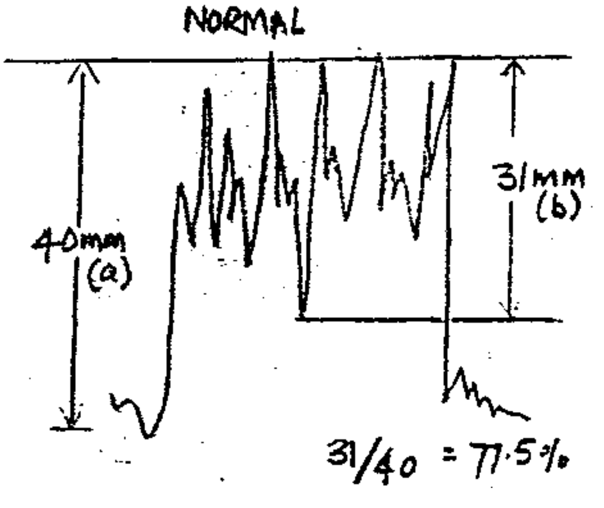


Fig.35

Thus cochlear pathology can be detected using any of these tests given above.

The acoustic reflex functions at 500, 1000 and 2000 Hz are quite similar and show a decrease in sensation level of ART as a function of increase in hearing loss. The acoustic reflex function at 4000 Hz does not follow the exact pattern of the other stimulus frequencies and it is often absent at this frequency for no clear reasons.

As long as the cochlear hearing loss is less than 60 dB, acoustic reflex is usually observed. If the loss increases above 60 dB, chances of observing the reflex decrease.

Silman and Gelfand (1982) point out that acoustic reflexes should be observed at 125 dB HL or lower for cochlear hearing loss of 75 dB or less.

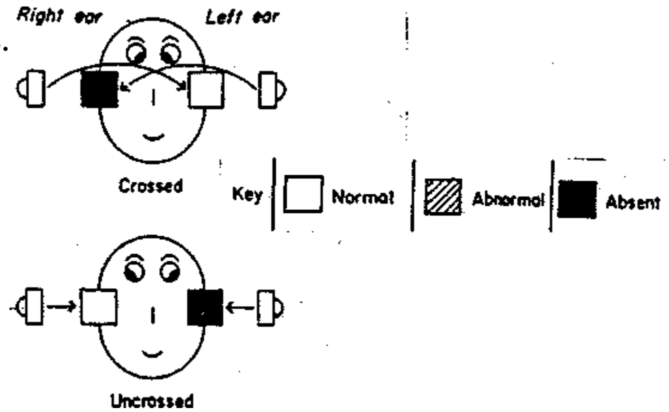


Fig. 3 6 Ipsilateral and contralateral reflexes in a unilateral right ear profound sensorineural hearing loss and normal hearing in the left ear (diagonal pattern).

Retrocochlear Pathology

Pathologic ears with eighth nerve involvement and normal hearing do not exhibit acoustic reflexes 30% of the time. The likelihood of absent reflexes quickly rises to 70% with a mild 30 dB loss. In most patients with acoustic tumors the acoustic reflexes are absent when the involved ear is stimulated even if the loss is very mild. If acoustic reflex is present in a patient who is suspected to have an eighth nerve lesion, the acoustic reflex decay test may be applied. Reflex decay is determined by presenting the stimulus test tone at 10 dB above the acoustic reflex HTL for 10 sec at 500 and 1000 Hz. Reflex decay may be measured for both contralateral and ipsilateral test conditions. Reflex decay occurs when the amplitude of the acoustic reflex declines by more than half its initial magnitude in less than 10 sec under continuous puretone stimulation (Anderson et al. 1969). Frequencies 2000, 3000 and 4000 Hz are not used as even normal ears sometimes show decay at these frequencies (Givens and Seidemann 1979).

Acoustic reflex latency has also been found to be altered in cases with retrocochlear pathology.

Hughes and Strasser (1973) [cited in Jerger, 1975] noted that subjects with retrocochlear lesions may show a longer reflex latency than do normal hearing subjects or than subjects with cochlear loss.

Acoustic reflex measures have been found to be very sensitive to eight nerve disorders. However acoustic reflex measures may sho false positive results also for eighth nerve pathologies (Chiveralls, 1977; Jerger, 1983). Therefore, it is important that the clinician keeps this in mind while using acoustic reflex measures as part of a test battery approach to identify retrocochlear pathologies.

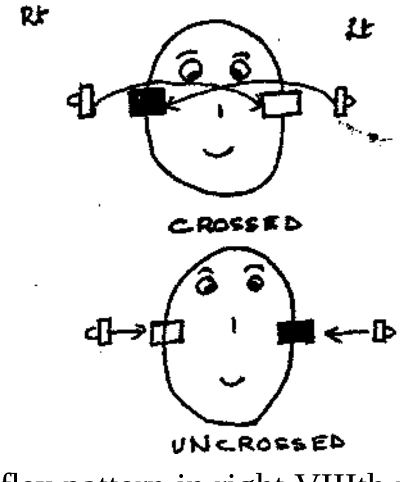
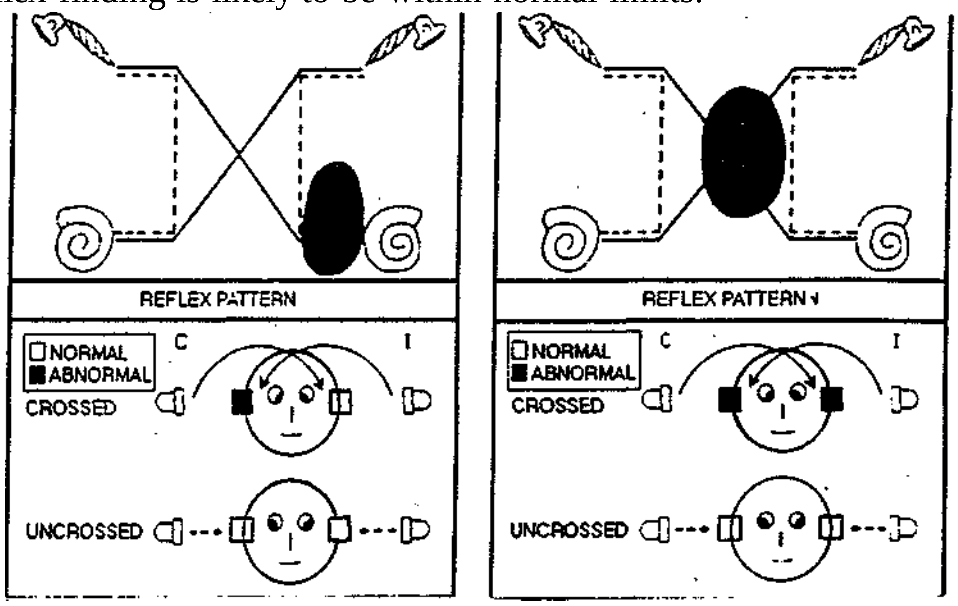


Fig.37 : Reflex pattern in right VIIIth nerve disorder.

Brainstem Pathology **-** The identification of brainstem pathology using acoustic reflex is done mainly by comparing the contralateral and ipsilateral reflex thresholds (Greisen and Rasmussen, 1970; Jerger and Jerger, 1975, 1983; Jerger, 1983). In the case of a lesion in the area of the crossed brainstem pathways with intact uncrossed brainstem pathways, the contralateral reflexes will be absent with ipsilateral reflexes intact.

If the lesion is higher in the auditory pathway, the acoustic reflex finding is likely to be within normal limits.



Reflex patterns in left extra axial brainstem disorder Unibox pattern

Reflex pattern in intra cranial brainstem disorder Horizontal pattern

Fig.38

Facial Nerve Disorder : Acoustic reflex measurement is helpful in determining the site of lesion of the facial nerve disorder as either distal (away from) or proximal (toward the point of origin) to the stapedial branch of the seventh nerve.

As the interpretation of facial motor disorder is a function of the efferent nerve pathway acoustic reflex results are interpreted for the immittance probe ear only. If the acoustic reflex is present at normal HL, the localization of pathology is likely to be distal to origin of the stapedius branch of the nerve, if the reflex is absent, the disorder is likely to be proximal to the nerve. If reflexes are present but elevated, the disorder is likely proximal to the nerve.

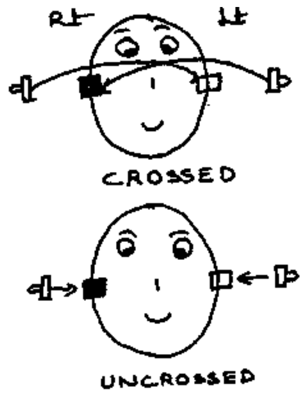


Fig. 3 9 - Reflex pattern in right VIIth nerve disorder (vertical pattern)

Nonorganic Hearing Loss - Acoustic reflex measurement also helps in detecting patients having a nonorganic hearing loss. As we have already seen, the greater the hearing loss, the less the likelihood there is of obtaining an acoustic reflex.

It is highly unlikely to observe an acoustic reflex at a level less than 15 dB above the patient's threshold and impossible to obtain a reflex measure at a lower hearing level than the true hearing threshold (Olsert, 1991). Thus from the ART we can determine whether the patient has an organic hearing loss or not.

Questions

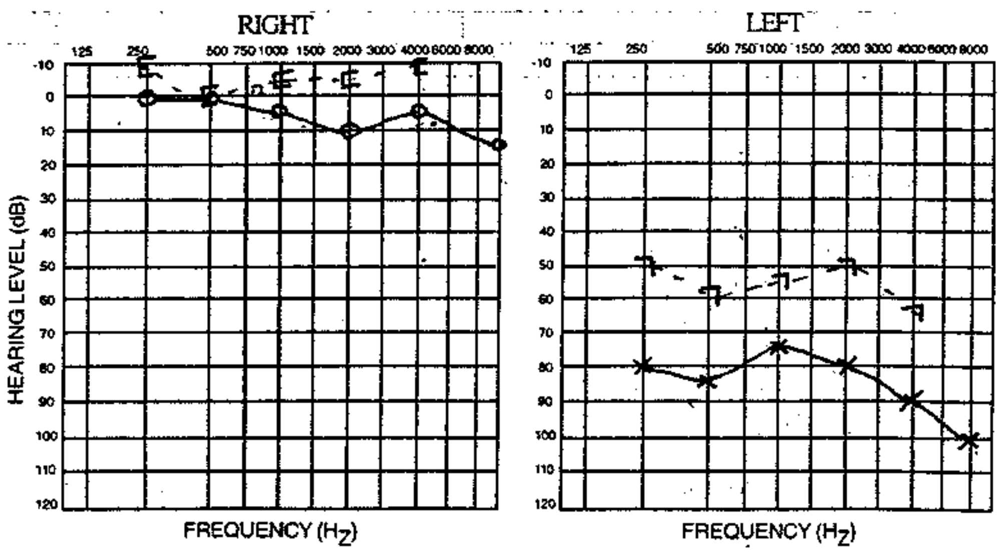
I Draw the Jerger box patterns for the following conditions :

1) A case has bilateral moderate degree conductive hearing loss. What could be the possible reflex patterns in this case?

2) A 49 year old female has severe sensory neural hearing loss in the left ear and mild conductive hearing loss in the right ear. •Outline the reflex patterns for this case.

3) Audiogram

PUNE-TONE AUDIOGRAM



4) A 65 year old male goes to a neurologist with the complaint of giddiness and occasional nausea. He also complains of reduced vision. The CT scan of this case showed an extraaxial lesion of the brainstem on the right side. If he consults an Audiologist, what kind of reflex pattern can one expect?

5) A 25 year old male after travelling overnight in an open jeep notices in the morning that his lips are deviated to the left side. What will be the reflex patterns in this case?

6) Given below are the air conduction and bone conduction thresholds of a particular case. Draw the Jerger box patterns for this case.

	Rt	Lt
AC	45	65
BC	35	30

7) With reference to the above case, if the BC threshold of the right ear was 10 dB, what changes would occur in the reflex patterns?

8) A3 year old boy is brought to an audiology clinic with the complaint of inability to hear even loud sounds. The audiological tests revealed that he had bilateral profound hearing loss. What is the reflex pattern you expect for this case?

9) A 30 year old female reported to a speech and hearing institute with complaint of hearing loss in the right ear following a bike accident. The main purpose of her visit was to procure a certificate. As the hearing loss was suspected to be functional, tests were carried which conformed the suspicion. What would be the acoustic reflex patterns for this case.

10) What kind of reflex pattern can you expect in a case of right auditory nerve lesion?

11. From the PTA rsults given below predict the Jerger box pattern

		Rt	Lt
a)	AC	30	50
	BC	-10	45.
b)	AC	60	15i
	BC	50	-10
c)	AC	120	110
	BC	70 NR	70 NR
d)	AC	30	10
	BC	-10	-10

e)	AC	70	55
	BC	60	50.
f)	AC	30	70
	BC	25	60

II Complete the diagnosis, using the acoustic reflex findings. Give justifications for your diagnosis.

		Rt	Lt	
1.	C	□	■	Right ear - normal hearing
	I	□	■	Left ear.... conductive hearing loss
		Rt	Lt	
2.	C	□	▨	Right ear - Moderately severe .... hearing loss
	I	▨	□	Left ear.... sensory neural hearing loss
		Rt	Lt	
3.	C	■	□	Right ear - Normal hearing
	I	□	■	Left ear - Profound .... hearing loss
		Rt	Lt	
4.	C	■	■	Right ear - Profound .... hearing loss
	I	■	□	Left ear - Normal hearing
		Rt	Lt	
5.	C	■	■	Bilateral.... hearing loss
	I	■	■	

III Answer the following

1. What is the peculiar pattern of acoustic reflex obtained in otosclerotic hearing cases? Why is it seen?

2. Acoustic reflex may not be absent in all cases with middle ear pathology. *Give* your comments.

3. *Give* the simplest test using acoustic reflex which can be used in detecting recruitment.

4. Name two tests to detect cochlear pathology using acoustic reflex.

5. Explain the reflex decay test. How can measurement of latency help in detecting retrocochlear pathology.

Answers

I Jerger box pattern

Rt Lt

1. C
I

re is a bilateral conductive hearing loss, reflexes will be absent in both the ears.

Rt Lt

2. C
I

there is a conductive loss in the right ear, both the reflexes are absent in that ear. The contralateral reflex of left ear are also elevated due to this. Due to the severe sensory loss in the left ear, ipsilateral reflexes are absent in that ear.

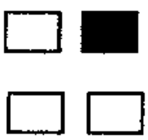
Rt Lt

3. C
I

Left ear audiogram shows severe mixed hearing loss. Therefore, we get an innervated L pattern. Both the reflexes of left ear and contralateral reflexes of right ear are absent.

Rt Lt

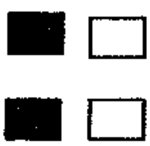
4. C
I



As the crossed fibres going from the right side to left side are affected, the crossed reflexes of left ear are absent. A unibox pattern is obtained.

Rt Lt

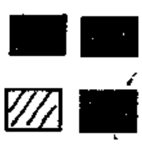
5. C
I



tion of lips to the left side is a typical sign of 7th nerve lesion of the right side. Due to this lesion, the reflexes of right ear will be absent. Left ear reflexes will be intact.

Rt Lt

6. C
I



As there is a moderate sensory neural loss in the right ear and moderately severe mixed loss in the left ear, the given pattern can be seen. Since the loss is only of moderate degree in the right ear, the ipsilateral reflexes of that ear may be elevated but in left ear due to the conductive component, all the reflexes will be absent. The right ear crossed a reflexes will also be affected due to the conductive component in the left ear.

Rt Lt

7. C I

I

threshold of right ear is 10 dB it would became a conductive loss of moderate degree in that ear. As both the ears have conductive loss, all the reflexes would be absent.

Rt Lt

8. C

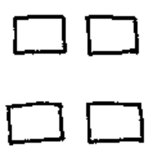
I

As there is a bilateral profound loss in this case, all the reflexes will be absent.

Rt Lt

9. C

I



Since the case was faking the problem, all the reflexes will be present in this case.

Rt Lt

10. C

I

is an VIII nerve lesion of the right side a diagonal pattern as represented here will be seen.

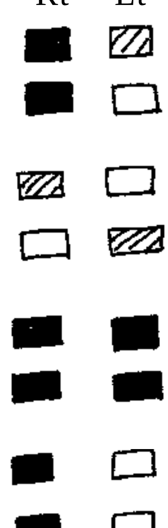
11. Rt Lt

a) C
I

b) C
I

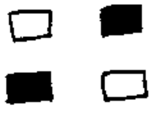
c) C
I

d) C
I



e) C
I

f) C
I



II Complete the diagnosis

1. Right ear - normal hearing
   Left ear - minimal/mild conductive hearing loss

Since all the reflexes are present in the right ear, the loss in the left ear has to be of minimal/mild degree (less than 30 dB). If the loss was of a higher degree, the contralateral reflexes would have been elevated or even absent in the right ear.

2. Right ear - moderately severe sensory neural hearing loss.
   Left ear - Mild sensorineural hearing loss

Since the contralateral reflexes are present and as the ipsilateral reflexes are only elevated in the right ear, it is confirmed that there is no conductive component, therefore, it has to be a sensorineural loss in the right ear. As the ipsilateral reflexes of left ear and contralateral reflexes of right ear are present, the loss in the left ear should be of a mild degree.

3. Right ear - normal hearing
   Left ear - Profound sensori neural hearing loss.

The diagonal pattern is suggestive of sensory neural hearing loss. If it was a mixed loss, a different pattern would have been seen.

4. Right ear - Profound mixed hearing loss
   Left ear - Normal hearing

The inverted L pattern shows that it is a mixed hearing loss.

5. Bilateral profound hearing loss

When all the reflexes are absent, it is difficult to predict the type and degree of loss. But since the degree is not mentioned here, there are more chances of it being a profound loss.

III Answer the following

1. In otosclerotic cases, one usually finds a biphasic reflex pattern. This pattern is obtained due to the decrease in resistive component during acoustic reflex contraction.

2. Though acoustic reflex is absent in majority of the cases with middle ear pathology, there are few exceptions. In cases with ossicular disruption, where the connection is maintained between the opertion point of the stapedius muscle on the stapes and the eardrum, in ears with middle ear cholesteatoma which does not affect the eardrum or ossicular chain and also in some cases with serous otitis media and negative middle ear pressure, reflexes may be seen. Therefore, middle ear pathology does not always result in absence of reflexes.

3. Acoustic reflex tests have been widely used in detecting recruitment. The most simple test is the Metz recruitment test. In this, the acoustic reflex threshold is found out. If it is less than 60 dB SL with respect to the puretone threshold, it suggests the presence of recruitment.

4. Differential ratio quotient and reflex relaxation index are two tests of acoustic reflex to detect cochlear pathology.

5. Reflex decay test is carried out at 500 Hz and 1000 Hz. Atest ton is presented 10 dB above the acoustic reflex threshold for 10 secs. If the amplitude of the reflex declines by more than half its magnitude in less than 10 secs, it indicates retrocochlear pathology. This is carried out both ipsilaterally and contralaterally. Retrocochlear pathology cases usually have a longer reflex latency. This feature would be helpful in diagnosis.

Special Applications of the Acoustic Reflex

1. *Use of Acoustic reflex in hearing screening programs*

Immittance screening for the detection of middle ear pathology when implemented in conjunction with puretone audiometric screening is a useful technique as it increases the accuracy of correct identification of the disordered group. The use of acoustic reflex in screening is based on the presumption that presence of reflex is a negative indication of conductive pathology. However, absence of an acoustic reflex does not necessarily indicate the existence of a medical problem as acoustic reflexes are absent in 5% of the normal hearing population (Jerger, 1970; Brooks, 1978).

Harford et al. (1978), Asha (1979) suggest acoustic reflex screening at 100 dB HL with a contralateral stimulus or 105 dB SPL with ipsilateral stimulation at 1000 Hz. Brooks (1976) states that acoustic reflex screening is a more sensitive test that tympanometry. Hoover et al. (1982) also reported of high sensitivity of the screening procedure using 1979 ASHA guidelines. But specificity rate was found to be very low. In recent ASHA (1990) guidelines, use of acoustic reflex was left out of the screening protocol on the basis of research reports that show a high false-positive, or low specificity rate.

There is also great deal of controversy regarding pass-fail and referral criteria for the screening procedure.

2. *Acoustic Reflex in Prediction of Sensitivity*

Different investigators have suggested different procedures for the purpose of predicting the sensitivity of hearing. All of them are based on the difference in reflex thresholds for noise and tone.

a) *Niemeyer and Sesterhenn 's Method* - Niemeyer and Sesterhenn (1974) measured the reflex thresholds for puretones, white noise and mixture of puretones which consisted of puretones representing one critical bandwidth each. Reflex threshold was found to be highest for puretones. They arrived at a particular formula for calculating the PTA.

$$PTA = ART_{\substack{PT(avg) \\ (500\ Hz\ -\ 4\ KHz)}} - 2.5\ (ART_{\substack{PT(avg) \\ (500\ Hz\ -\ 4\ KHz)}} - ART_{WN})$$

ART PT (avg) - This is the average acoustic reflex threshold for puretones within the frequency range of 500 Hz - 4 KHz.

ART WN - This is the acoustic reflex for white noise.

2.5 is a constant which was derived from certain calculations.

It was found that in majority of the subjects, accurate results could be obtained using this formula. In cases with flat loss the results obtained were less accurate.

b) *Baker and Lilly Method* - Baker and Lilly (1976) modified the previous formula. They have the following formula :
dB HTL =1.11 ART BBN (SPL) - 0.81 ART 500 HZ (HL)
+ 0.85 ART 1000 Hz (HL) - 0.43 ART 2000 Hz (HL) + 0.25
ART 4000 Hz (HL) - 64.7122122

The demerit of this method is that, in subjects with severe hearing loss, the predicted hearing level was grossly under estimated.

c) *Sesterhenn andBreuninger 's method-* Sesterhenn and Breuninger (1976) suggested a method of sensitivity prediction which involved a pre-activation of the acoustic reflex. A tone of 6 kHz or 8 kHz was presented at a level high enough to initiate a reflex response. The test tone was then presented along with the pre-activating stimulus. Keeping the intensity of the preactivating stimulus constant, the intensity of the reflex eliciting stimulus was reduced till reflex response just disappeared. This gives the reduced reflex threshold.

The ratio of distance between the hearing threshold and normal reflex threshold to the difference between the two reflex thresholds was called as K: The value of K differed for each frequency. The distance between normal and the reduced reflex thresholds was found to be 30 dB at 125 Hz and 20 dB at 4000 Hz in normally hearing subjects.

4. *Jerger 's method* - Jerger gave two formulae - unweighted and Weighted for the purpose of predicting hearing sensitivity. Out of these, weighted is more popular. This procedure given by Jerger (1974) is called as SPAR (sensitivity prediction with the acoustic reflex).

Unweighted formula

$D = AR_{PT}$ (500, IK, 2K) - $AR_{(WN)}$ +C

C = 26 dB (Keith, 1977)

AR_{PT} - Acoustic reflex for puretones

AR_{WN} - Acoustic reflex for white noise

Weighted formula - Jerger et al. (1974).

$$D = \frac{l + m + n}{3}$$

1 = ART 5OOHZ- ARTBBN (SPL)

m = ART(avg. of 500, IK, 2K) - ARTBBN (SPL)

n = ART(SPL) - ARTBBN (SPL)
(Lowest ART among that for 500 Hz, IK, 2K)

To predict the slope, Jerger et al. (1974) suggested that difference between reflex thresholds for low pass and high pass filtered noise be considered. When LPFN - HPFN was zero, a flat loss was predicted. A difference of-1 to -5 suggested a gradual slope whereas a slope of more than -5 suggested a steeply sloping hearing loss.

Jerger et al. also gave a table from which the degree of loss could be predicted by knowing the value of D. 'D' here represents the difference score i.e., the difference in reflex thresholds for 500, IK and 2K puretones and BBN.

5. *The Bivariate - Plot method* - This method was proposed by Popelka (1976). This divides the subjects into two groups based on presence or absence of hearing loss.

The acoustic reflex thresholds were determined for 500 Hz, 1 KHz and 2 KHz puretones and also for wide band noise. The ratio ART WBN is determined and it is plotted on a graph ART tones (avg. of 500, IK, 2K) which is separated into two regions by two lines.

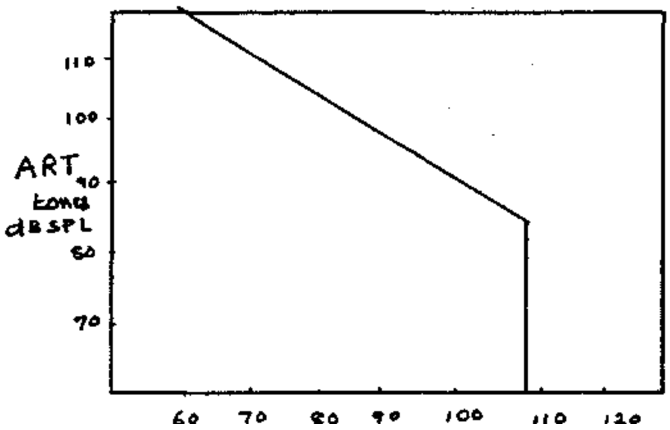


Fig. **40** ARTWBN x 100
ART tones

The region to the left of the two lines represents normal hearing and the region to the right represents hearing loss (Himmelfart etal. 1978). Depending on here the subject's score falls, the presence or absence of hearing loss can be detected.

3. ***Hearing Aid Selection, Fittings and Management***

Acoustic reflex measurement has been suggested in the selection and fitting of hearing aids, especially with young children and mentally retarded patients.

Acoustic reflex measurement is an objective technique through which the maximum power output and gain can be determined which is in turn used in hearing aid selection. The unaided gain is determined first and then the gain with the hearing aid is obtained (aided gain). This is compared to the target gain (actual gain required for the subject) and thus an appropiate hearing aid is chosen.

Various authors have suggested various criteria for selecting hearing aid on the basis of AR measurements. According to McCandless and Keith (1980), the output of the aid should be at or slightly above the ART for puretones of 500 Hz, 1 K, 2 K and 4 K. Dudich et al. (1975) suggest that output of the aid ideally should be set 5-8 dB lower than the ART, for ART for puretones is higher than that for verbal stimuli.

Keith (1979) also reported that ART procedure is highly successful in setting hearing aid gain for children.

Additional research is needed in this area which would be of greater help in selection and fitting of hearing aids.

4. *Utility of Acoustic reflex for monitoring ototoxity in paediatric population*

Kay Rabbitt Park (1996) took 21 children of age range 3.08 - 19.25 years. These children were subjected to cumulative dosages of (250-400 Mg/m2) of cisplatin. He noticed a shift in acoustic reflex thresholds withthe increase in dosage. Thus it can be concluded that ART measurements maybe of great help in the early detection of ototoxicity in paediatric population. However future research reports are required for confirming this finding.

5. *Acoustic reflex in difficult to test patients*

In the difficult to test population, where conventional methods of sensitivity testing are difficult to be administered, acoustic reflex measurements may prove to be a boon. In multiple handicapped children, autistics and retarded and other such groups, ART measurements have been widely used to identify the presence of hearing-impairment (Keith et al. 1976; Suria and Serra-Raventas, 1975; Lamb and Norris, 1970).

6. *Acoustic Reflex Measurements in Speech Pathology*

It is now well established that middle ear muscles contract in association with certain voluntary movements of head, neck and jaw and also during vocalisation. This is due to the reflexive interconnection between middle ear muscles and sensory nervous supply to larynx. On the basis of this it may be assumed that certain neuromuscular disorders affecting speech may show its effect on the middle ear muscles also.

Shearer (1966) reported of variations in the degree of contraction of middle ear muscles associated with stuttering. Thus impedance changes may afford a rather precise method of studying the initiation and course of stuttering.

McCall (1973) used acoustic measurements to study patients with spastic dysphonia. Tremor of one or both the middle ear muscles and problems in muscle relaxation were observed in these cases.

It has been observed that certain disorders of the central nervous system exhibit certain typical neuromuscular manifestations.

If these are exhibited in the middle ear functioning, acoustic reflex measurements may be helpful in the diagnosis, and differentiation of these disorders from one another.

Thus it may be assumed that the six different types of dysarthria- spastic, flaccid, hyperkinetic, hypokinetic, cerebellar and mixed and various other neuromuscular disorders can be diagnosed using ART measurements.

Blom and Zakrisson (1974) detected stapedial reflex decay of muscular origin in patients with myesthenia gravis.

Thus acoustic reflex measurements have its application not only in Audiology but also in Speech pathology.

Questions

I Given below are certain terms and four choice. One of these four choices will not have any connection to the term. Find out the odd one.

1. Acoustic reflex
   (a) Stuttering
   (b) dysarthria
   (c) Functional Delayed speech and Language
   (d) Myestheniagravis.

2. Hearing Aid Selection
   (a) Keith
   (b) Van Riper
   (c) McCandless
   (d) Dudich

3. Hearing Screening Program
   (a) Quick Neurological Screening Test
   (b) Acoustic Reflex
   (c) ASHA
   (d) Tympanometry

4. Prediction of Hearing Sensitivity
   (a) Jerger
   (b) Niemeyer and Sesterhenn
   (c) Popelka
   (d) Jack Katz

5. Acoustic reflex measurement
   (a) speech pathology
   (b) screening
   (c) sociology
   (d) audiology

II Match the following

A	B
a) Jerger	a) Pre-activation stimulus
b) Niemeyer and Sesterhenn	b) ARTWBN/ART tones
c) Sesterhenn and Breuninger	c) PTA=ART-2.5(ART-ARTWN)
d) Bivariate-plot method	(PTavg.5oo-4K) PTAvg.5oo-4K
	d) SPAR

III Fill in the missing parts and complete the following

1. Jerger's weighted formula is given as

$$D = \frac{1 + - + n}{3}$$

where 1 =__________

____= ART (avg.of 500, IK, 2K) - ART BBN (SPL)

n = ART (SPL) - ART (SPL)

(lowest ART among that for _____

500 Hz, IK, 2K)

2. In the procedure recommended by ASHA (1979), for hearing screening using acoustic reflex, contralateral stimulus should be presented at ....dB HL and ipsilateral at 105. . . . .at.... frequency.

3. Acoustic reflex is used in hearing aid selection, fitting and even management. It actually helps in determining the .... and ....

4. In Jerger's unweighted formula, what does C stand for?

5. Based on what parameter of acoustic reflex, has it been used to detect ototoxicity in children?

6. 'RASP' - The letters when rearranged will give the name of a particular procedure. Which procedure is it? Who gave it? What is it used for?

Answers

I Odd one out

1. c) Functional delayed speech and language
2. b) Van Riper
3. a) Quick neurological screening test
4. d) Jack Katz
5. c) Sociology

II Match the following

A	B
a)	d)
b)	c)
c)	a)
d)	b

HI Solve the following :

$$D = \frac{1+m+n}{3}$$

where 1 = ART (500 Hz - ART BBN (SPL)

m = ART (avg. of 500, IK, 2K) - ART BBN (SPL)

n = ART (SPL) - ART BBN (SPL)
(lowest ART among that for 500, IK, 2K)

2. 100, dB SPL, 1000 Hz

3. Maximum power output, gain

4. 26 dB - a constant

5. Acoustic reflex threshold. A shift in threshold is seen as a result of consumption of ototoxic drugs in children.

6. SPAR, Jerger (1974), Hearing sensitivity prediction

7. Stuttering, spastic dysphonia, dysarthria, myesthenia, gravis.

Acoustic Reflex in Children

Acoustic reflex measurements were initially used in adult population for the purpose of hearing loss identification and estimation. More recently, however, hearing loss prediction from the acoustic reflex has been reported in children. Recent reports of acoustic reflex measurments in children, have been highly encouraged because of its objectivity.

Keith (1973) observed that about 30% of neonates (aged 36-151 hours) he tested showed clear acoustic reflex responses whereas the rest 70% either had no response at all or gave unclear responses.

Most of the early reports also report that acoustic reflexes were not observable in most neonates (Barajas, et al. 1981, Bennett, 1975; Keith, 1975; Keith and Bench, 1978; & Stream, et al. 1978), Huneilfarb, et al. 1978, found elevated reflexes in neonates.

Using 220 Hz probe tone, Sprague, Wiley and Goldstein (1985) could elicit reflexes only in 50% of the cases.

Investigators who used a probe frequency higher than 226 Hz were in general, more successful in recoring acoustic reflexes from neonates (Kankkunen and Liden, 1984; Marchant et al. 1986;

McCandless and Allred, 1978; McMillian, Marchant and Shurin, 1985; Sprague, et al. 1985).

Weatherby and Bennet (1980) observed that as the probe frequency increased, the proportion of acoustic reflexes increased, and mean reflex threshold decreased. They also observed that the proportion of neonates with acoustic reflexes is higher for the broad band noise signal than for tonal activators.

McMillian etal. 1985; Sprague etal. 1985; found thatthere is higher percentage of acoustic reflexes with ipsilateral than contralateral stimulation in infants.

Bennet and Weatherby (1982) used a 1200 Hz probe tone to measure reflex thrsholds for tonal and noise activator signals in 4-8 day old infants and reported reflex thresholds that were similar to reflex thresholds reported for normal adults.

Cone and Gerber (1975) noted that reflex thresholds decreased at all test frequqncies with increasing age. Jerger (1981) also reported the same findings.

Margolis and Popelka (1975) found no affect of sleep on the reflex thresholds.

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

1) Depth of sleep might have affected the response
2) Presence of mesenchyme 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, 1978).

In older children, the reflexes are found in majority of the cases and at all frequencies. According to Robertson,Peterson and Lamb (1968) the ART were lowest at 500 Hz and highest at 2000 Hz in a group of 40 subjects that they tested between age range of 12-36 months.

In summary, the extent research on acoustic reflex thresholds in neonates suggests that the acoustic reflex is fully developed at birth and the reflex thresholds in neonates are similar to the reflex thresholds observed in adults.

The studies which reported of lower reflex thresholds in infants may have used the standard calibration couplers (eg. 2cm3 coupler) or it could be due to the higher sound pressure levels that are developed in the small external ear canal of the neonate (McMillian et al. 1985). The optimal probe frequency for reflex testing *in* neonates appers to be above 800 Hz. The differences between ipsilateral and contralateral reflexes are the same as that reported in adults (McMillian et al. 1985; Sprague, et al. 1985).

Questions

I State whether the following statements are true or false

1. Acoustic reflex is rarely used in children these days.
2. Childrn show the same pattern of acoustic reflexes as that of adults irrespctive of the probe tone frequency and other parameters.
3. Younger children show better reflex responses than older children.
4. Higher frequency probe tones are better than low frequency probe tones in infants for eliciting acoustic reflex.
5. Puretone is a better stimuli than noise for eliciting acoustic reflex in children.
6. Sleep has a great effect on acoustic reflex responses in children.

II Answer the folloiwng questions in brief:

1. In adults, some studies have shown higher incidence of reflexes for ipsilateral stimulation than contrlateral stimulation. Is it the same case in children? Support your answer by quoting studies.

2. Give explanation for the lower incidence of acoustic reflex in children.

3. Is it possible to obtain reflexes at a normal threshold in children? If yes, what are the factors which contribute to this?

Answers

I State whether the following statements are true or false

1. False (2) False (3) False (4) True (5) False (6) False

II Answer the folloiwng question in brief:

1. Yes, in children also higher percentge of acoustic reflex is obtained with ipsilaterl stimulation. The studies conducted by McMillan et al. (1985) and Sprague et al. (1985) are in support of this.

2. The lower incidence of acoustic reflexes in children could be attributed to one or more of the following reasons - the depth of sleep, presence of mesenchyme in the middle ear and the incomplete neurological development in infants.

3. Yes, in children, it is possible to obtain reflexes at a normal threshold, if the following factors are keep in mind (1) the probe tone frequency should be above 800 Hz and (2) the coupler should be of adequate size.

NON-ACOUSTIC REFLEX

It is now well established that the middle ear muscles arc activated not only by sound, but also by non-acoustic stimuli. This nonacoustic reflex was first described by Luscher (1929) who observed the contractions of stapedius muscle through a perforated tympanic membrane when a glass olive was introduced into the auditory canal.

Following this various authors like Potter (1936), Davis (1947), Metz (1946), Jepsen (1955), Klockhoff and Anderson (1959) etc. were able to successfully elicit reflexes using non-acoustic stimuli.

The reflex arc of the tactile stapedius reflex is still unknown. The presumed reflex arc of the tactile stapedius reflex is as shown in fig-

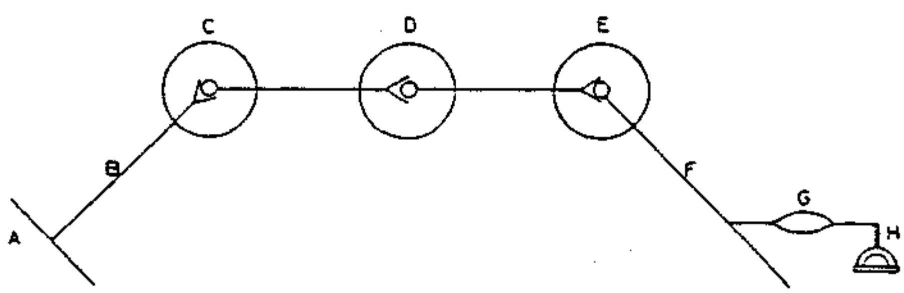


Diagram of presumed course of the tactile stapedius reflex in man, based on anatomical findings made in rats.

Fig.41

This is based on the findings in rates (A) the reflexogenic skin zone (B) sensory part of the trigeminal, facial (intermediate), glossopharyngeal and vagal nerves (C) nucleus of the solitary tract (D) dorsolateral part of the reticular formation (reflex center) (E) facial motor nucleus (F) motor part of the facial nerve (G) stapedial muscle (H) stapes.

Impedance changes can be elicited in two ways :

1) *Blowing towards the eyes or by lifting the upper eyelids.* This produces changes in the acoustic impedance of the ear if the stimuli used are forceful and/or surprising. Also the impedance change recorded in normal ears are caused by contraction of both middle ear muscles.

2) *Cutaneous stimulation* - This can be achieved through tactile stimulation, by slightly blowing against the outer ear or through electrical stimulation. The skin area most sensitive to nonacoustic stimulation (reflexogenic) was found to be largest on the homolateral side. The skin area closer to the homolateral external auditory meatus when stimulated elicited largest impedance changes. The size of the impedance changes and the frequency of reflex responses decreased with increasing distance from the external auditory meatus.

Fig. 42 - Reflexogenic area

Detection of and differentiation between various types of middle ear lesions

Nonacoustic reflexes are found to be very useful in detecting various types of middle ear lesions and also in differentiating them from one another.

1) *Ossicular chain discontinuity* - An abnormally large increase in impedance is found in cases with interruption of ossicular chain on non-acoustic stimulation. This is due to the abnormal mobility of the ossicles. These results may not be observed if the stimulus is not strong enough.

2) *Ossicular fixation* - lack of impedance change in response to lifting of the upper eyelids indicates fixation of the malleus or incus. Though, the muscles contract, as a result of lack of ossicular chain movement, no impedance change is recorded.

3) *Reduced mobility of the tympanic membrane and ossicular chain* - Abnormally small impedance increase or diphasic decrease in the acoustic impedance elicited by lifting the upper eyelids indicate slightly reduced mobility of the tympanic membrane and/or the ossicular chain.

4) *Otosclerosis* - The diphasic impedance decrease is very commonly seen in cases of otosclerosis. A decrease in impedance is noticed in these cases when the stimulus is presented and later withdrawn. It has been observed that as the disease progresses, the impedance changes became weaker and finally fail to occur.

Non-acoustic stimuli being independent of the hearing level can be made use of in testing the middle ear function even in profoundly hearing impaired individuals. This is not possible using traditional acoustic reflex procedure.

Thus, it can be concluded that observation of impedance changes elicited by acoustic and nonacoustic stimulation is a useful tool in testing the function of the middle ear.

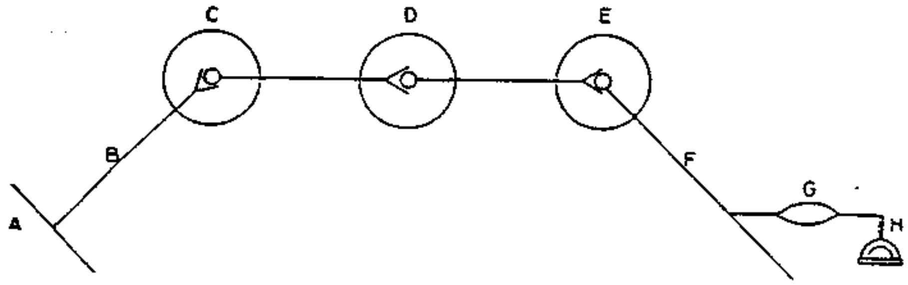
Jerger, et al. (1987) found that dynamic range in cochlear implant patients can be predicted using electrically elicited stapedius reflex. They varied the current level and found out the growth function. From this, the reflex threshold (RT) (the lowest current level at which reflex waveform could be visualized oscilloscopically) and the saturation threshold (SAT) (lowest current level at which the largest absolute amplitude of the reflex was observed were obtained. There was good agrement between RT and preferred listening levels obtained through behavioural methods and SAT was found to be below the UCL. Thus, it can be inferred that electrode mapping in cochlear implant cases can be done using this procedure, especially in young children in whom the dynamic range can be predicted using this.

Questions

I Solve the following questions

1. He was the first to describe nonacoustic reflex. Who is he? What procedure did he use to elicit reflexes.

2. Given below is the blockdiagram of a pathway
a) which pathway does it represent? (b) what does each alphabet stand for? Answers for part (b) may be chosen from the list given below. The alphabets are jumbled up. Rearrange them and solve the question.



1) SORYSEN RAPT OF V, X, VII, DC RACNIAL SERVEN
2) REXELFENICGO KINS OZNE
3) TERCEN FLEXER
4) LEVSCUN OF HET TARYOLIS RACTT
5)MNF
6) ROTOM TARP OF ACIALF EVREN
7) PESTAS
8) PEDASTTAL MUSCLE
9) CORTI OF GANOR

3. What are the two ways of eliciting non-acoustic stapedial reflex? Is tactile stimulation the only procedure used in cutaneous stimulation?

4. Which is the best site of stimulation for eliciting non-acoustic stapedial reflex?

5. Match the following :

A	B
a) Otosclerosis	a) No change in impedance
b) Fixation of ossicles	b) Diphasic decrease in acoustic impedance
c) Discontinuity of ossicles.	c) Increase in impedance
d) Middle ear pathology detection in profound hearing loss cases.	d) Acoustic reflex method
	e) Non-acoustic reflex method

6. How can non-acoustic reflex be used in cochlear implant cases.

Answers

I Solve the following questions

1. Luscher (1929). A glass olive was introduce into the auditory canal and contractions of the stapedius muscle were observed through a perforated tympanic membrane.

2. a) Tactile stapedius reflex arc/pathway

b) A - 2) REFLEXOGENIC SKIN ZONE
B - 1) SENSORY PART OF V, VII, DC, X CRANIAL NERVES
C - 4) NUCLEUS OF THE SOLITARY TRACT
D - 3) REFLEX CENTER
E - 5) FMN
F - 6) MOTOR PART OF FACIAL NERVE
G - 8) STAPEDIAL MUSCLE
H - 7) STAPES

3) The two ways of eliciting non-acoustic reflex are

1) Blowing towards the eye or by lifting the upper eyelids in a sudden or forceful manner.

2) Cutaneous stimulation - This can be through tactile stimulation or throughel electrical stimualtion of the outer ear.

4) The skin area closer to the homolateral external auditory meatus is the best site of stimulation for eliciting non-acoustic stapedial reflex, from a particular ear.

5)

A	B
a)	b)
b)	a)
c)	c)
d)	e)

6) The reflex thresholds and saturation thresholds measured using electrically elicited stapedius reflex are found to have good correlation with those measured using behavioural methods. Thus, electrically elicited stapedius reflex can be used in cochlear implant cases. It has valuable application in the paediatric population for predicting the dynamic range where behavioural audiometry is usually difficult.

CALIBRATION OF ACOUSTIC IMMITTANCE INSTRUMENTS

Acoustic in immittance instruments should be calibrated both biologically and instrumentally.

Biological calibration/Subjective Calibration : This refers to the calibration carried out without the help of any instrument but only with the help of normal hearing subjects. Here, subjects who have known normal values of the parameters that have to be calibrated are chosen and a listening check is carried out

The first step, is to check whether the stimulus is passing through the transducers. In case of any blockage of the probe or insert or any misconnection, it should be rectified before starting the actual testing.

The parameters that have to be checked are

1) Static compliance
2) Peak pressure
3) Physical volume
4) Acoustic reflex threshold.

A normal hearing subject whose static compliance, peak pressure, physical volume and threshold values are known, with no otological history can be chosen for these purposes. Tympanometry can be carried out first and the 1) static compliance and (2) peak pressure should be noted. The normal values are 0.5 to 1.75 cc for static compliance and +60 to -100 daPa for peak pressure for adults. If there is any deviation from the earlier findings **and** from the normalitive values, one can suspect that the instrument is out of calibration. To confirm the findings, the measurement can be repeated on the same subject or on another subject, satisfying the above mentioned criteria. If the same findings are obtained, then instrumental calibration should be carried out.

The third parameter to be checked is the physical volume. The normal physical volume for adults is 0.6 cc to 1.8 cc. If the physical volume falls below or above the normal range objective calibration is required after rechecking once.

Similarly, acoustic reflex measurements should also be done and if the reflex threshold does not correlate with the earlier values and if it is not within normal limits, calibration should be done instrumentally.

This type of a daily listening check is essential for the acoustic impedance instrument, to avoid any error in the diagnosis.

Instrumental/objective calibration

Instrumental calibration is very important as the biological calibration is not very reliable.

The parameters to be calibrated are -

a) Probe signal

b) Manometer/Air pressure system

c) Reflex activator system

d) Static volume

(a) *Probe signal calibration* - The probe signal should be accurate in frequency, at the specified level and free of unwanted distortion and noise. Measurements of the probe signal characteristics are performed in a standard 2cc coupler (HA-1).

Frequency check - Equipment required - Frequency counter

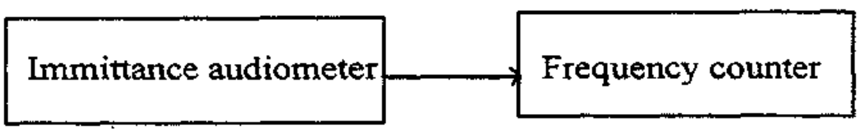


Fig. 43 Block diagram of instruments for calibration of frequency.

Connections are as shown in the figure. Select a particular frequency probe signal on the instrument. The probe signal frequency chosen on the instrument should correspond to the reading of the frequency counter. ANSI (1987) and EEC (1991) specify that the frequency of probe signal should remain within +/-3% of the nominal value.

Distortion measurement **- Equipment required - Distortion factor counter.**

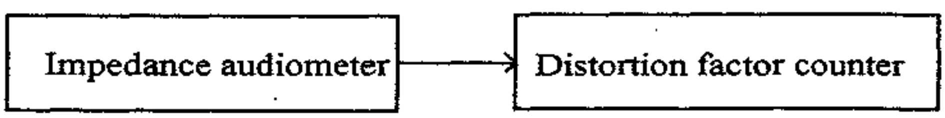


Fig. 44 Block diagram of instruments for distortion measurement. Connections are as shown in the figure.

The electrical output from the instrument is given to the distortion factor meter. The total harmonic distortion shall not exceed 5% of the fundamental when measured in a 2cc coupler (ANSI, 1987).

Output SPL - Equipments required

1) Probe with tip
2) HA1 coupler (2 cc)
3) Microphone (condenser microphone of pressure type)
4) SLM + OFS (calibrated)

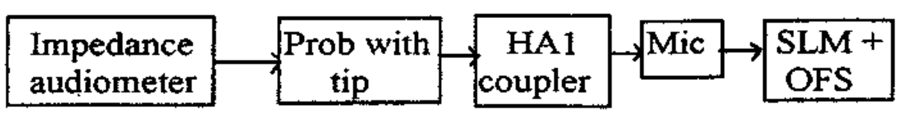


Fig.45 Block diagram of instruments for calibration of output SPL

Connections are as shown in the figure.

Set SLM into 'slow response' and 'external filter' mode.

Switch on the instrument and select a probe tone, eg.226 Hz.

Set attenuator of SLM to 80 dB.

The frequency chosen on octave filter set should correspond to the frequency of the probe tone selected.

The reading on SLM should correspond to the intensity specified by the manufacturer;(i.e.,85dbSPL) if not, internal calibration is required.

Continue the same procedure for all the probe signals.

(b) *Manometer/Air Pressure System* - The pneumatic system should be evaluated to determine the rate of the air pressure changes and the accuracy of the graduated steps on the air pressure indicator. The manometer accuracy can be determined using a U-tube manometer graduated in calibrated units. The probe is connected to the 'U' tube and water displacement is determined as the impedance device air pressure dial is rotated. The air pressure should not differ from that stated on the device by more than +/- 15% of the reading. [ANSI, (1987) & *JEC,* (1991)] ANSI (1987) states that the air pressure should be measured in units of 0.5 to 2 cm3. *JEC* (1986) stresses that the response of the measuring instrument should be at least three times faster than the rate of pressure change.

(c) ***Reflex activator system*** - The measures to be calibrated are :

- Frequency accuracy
- Output SPL levels
- Attenuator linearity
- Harmonic distortion

for both contralateral and ipsilateral acoustic reflex signal. According to ANSI (1987) & IEC (1991) the sound pressure level of the activators should be with +/- 3 dB of the stated value for frequencies

v

from 250 Hz - 4000 Hz.

Calibration of Ipsilateral Stimulus

Equipments required :

1) Probe with the tip
2) HA1 coupler (2cc)
3) Microphone (condenser microphone of pressure type)
4) SLM + OFS (calibrated)

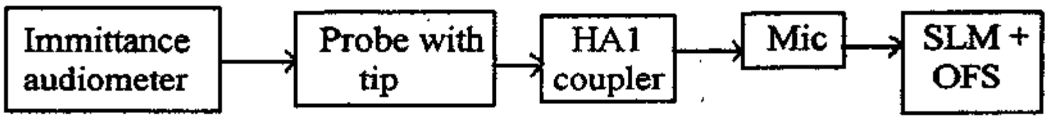


Fig. 46 Block diagram of instruments in calibration of ipsilateral stimulus

Connections are as shown in the figure.

Select a frequency of 500 Hz and an intensity of 70 dB on the immittance audiometer.

Set SLM to slow mode and external filter setting and attenuator to70dB.

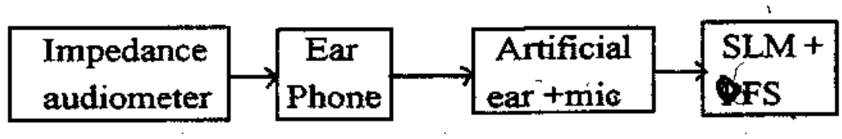
Choose a frequency an octave filter that corresponds to that on the immittance audiometer.

Present the stimulus continuously and check the SLM reading to see if the instrument is in calibration. If the instrument gives the value in SPL, it should be 70 dB SPL but if it is in HL, the reading should be 70 dB + RET SPL value.

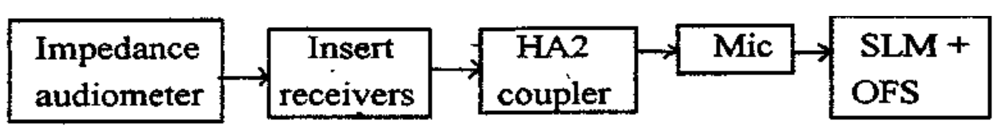
Continue the same procedure at all frequencies.

Calibration of Contralateral Stimulus Level

The transducers used for the contralateral stimulation is either a supraaural earphone or an inset or probe type receiver. The procedure is the same as that for ipsilateral calibration except for the instruments used. The block diagrams given below illustrate the instrumentation used for calibration of earphone, insert receiver and prototype receivers.



F



Fi

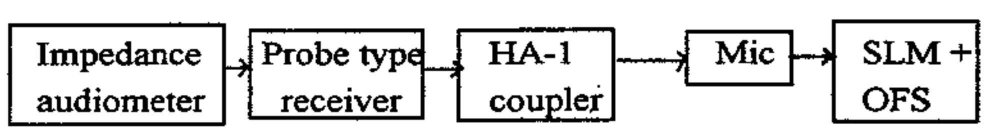


Fig. 49 Calibration of Probe type Receiver

If noise bands are used as activating stimulus, they should also be checked. The output can be sent through the transducer connected to a coupler, a microphone and then to a graphic level recorder. The BBN should be uniform within +/- 5 dB for the range between 250-6000 Hz for supraaural-earphones (ANSI, 1987). The spectrum pressure level should be uniform within +/- 5dB relative to the 1000 Hz level over the frequency range of 250 - 4000 Hz for the supraaural earphone and within +/- 10 dB over the frequency range of 400 - 4000 Hz for insert or probe type earphone. The frequency of the activator may be measured using a frequency counter. Frequency should be +/-3% of the stated value, harmonic distortion should be less than 3% at all specified frequencies for earphones and 5% or less for the probe tube transducer (ANSI, 1987).

According to IEC 1991 the harmonic distortion should not be greater than 5% for supraaural earphones and should be 10% or less for insert or probe type earphones.

(d) **Static Volume Calibration** - Equipment required - Hard walled Cavity (Volume range 0.1 - 3 cc)

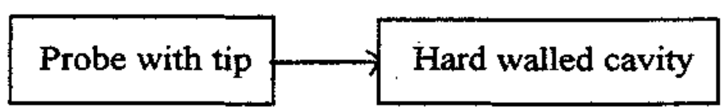


Fig. 50 Block diagram of instruments required for static volume calibration

Connections are as shown in the figure

After inserting the probe into the cavity of a particular volume and obtaining a good seal, the tone is directed into the cavity. The cubic centimeter scale should read the size of the cavity volume.

The measurement can be made for several cavity sizes over the measurement range of the impedance meter.

In summary, acoustic impedance devices should be calibrated carefully and regularly to avoid any error in the measurements made.

Questions

I Fill in the blanks

1. For calibrating the intensity of the probe tone, a. . . . .coupler is used.
2. The instrument used for calibrating the frequency of the probe tone is. . . . . .
3. A variable size hard-walled cavity is used for the calibration of
4. A …. coupler is used for the calibration of ipsilateral reflex eliciting stimulus.
5. A....coupler is used for the calibration of contralateral reflex eliciting stimulus when a probe-type receiver is used as the transducer.

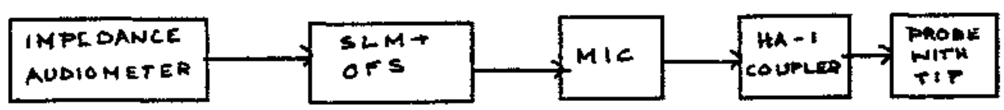
II State whether true or false

1. An SLM is usually employed for calibrating the frequency of the probe tone.
2. Noise, if used as a reflex eliciting stimulus, should be calibrated.
3. The % of distortion for probe tone should be within 5% according to ANSI, 1987 when measured in a 2cc coupler.

III Answer the following questions

1. What are the parameters that have to be calibrated before performing acoustic impedance measurments?
2. Describe the calibration of intensity of the probe tone.
3. How is the air pressure calibrated?
4. Describe the procedure employed in the calibration of static volume.
5. Draw the block diagram of the instrumentation used for calibrating the intensity of ipsilateral and contralateral reflex eliciting stimuli and explain the procedure.

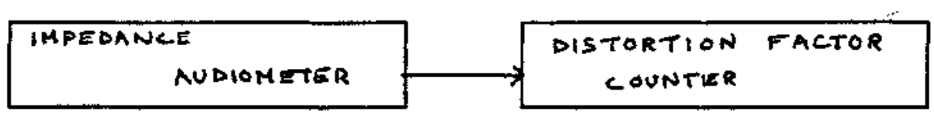
IV Given below are the block diagrams for the calibration of different parameters of acoustic impedance measurements. Spot the errors in them if any and correct them.



Instruments for calibrationof output SPL

Instruments for calibrationof earphone

Calibration of insert receiver



Instruments for Distortion Measurement

Answer

I Fill in the blanks

1. 2 cc
2. Frequency counter
3. Static compliance
4. Ipsilateral
5. 2cc or HA-l

II True/False

1. False 2. True 3. True

III Answer the following

1. Prior to performing the acoustic impedance measurements, a biological as well as electroacoustic calibration should be carried out. The parameters that should be calibrated biologically are :
   - Static compliance
   - Peak pressure
   - Physical volume
   - Acoustic reflex threshold

Those that should be calibrated electroacoustically are :

1) Probe signal
2) Manometer system
3) Reflex activator system
4) Static volume

2. The equipments required are

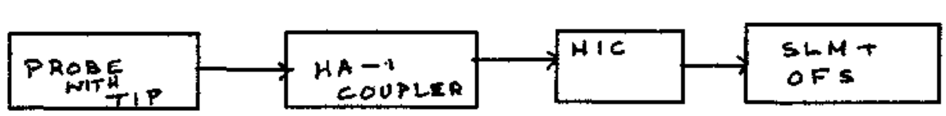
1) Probe with tip
2) HA1 coupler (2cc)
3) Microphone (condenser pressure type)
4) SLM + OFS (calibrated)

The SLM is set into 'slow response' and external filter mode.
The instrument is put on and 250 Hz tone is selected.
The attenuator is set to 80 dB.
Frequency of OFS and frequency of probe tone should match.
The reading on SLM should correspond to the intensity specified by the manufacturer; or else internal calibration is required. The same procedure is repeated for all probe signals.

3. The air pressure system is calibrated using a 'U' tube manometer. The probe is connected to this and the water displacement is calculated as the impedance device air pressure dial is rotated. The air pressure should not differ from the stated value by more than +/- 15% of the reading. IEC (1980) states than the response of the measuring instrument should be at least three times faster than the rate of pressure change.

4. For calibration of static volume, a variable size hard-walled cavity is used whose volume ranges from 0.1 to 3 cc. The probe is inserted into this cavity and a good seal is obtained. When the tone is directed into a cavity of a particular volume, the cubic centimeter scale should read the size of the cavity volume.

5.



The calibration of ipsilateral stimulus requires the following instruments

1) Probe with the tip
2) HA1 coupler (2 cc)
3) Microphone (condenser pressure type)
4) SLM + OFS (calibrated)

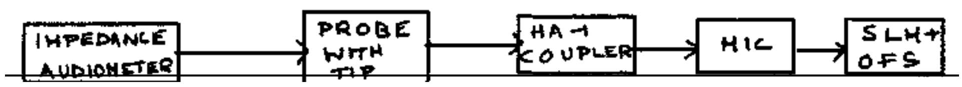
The frequency and intensity are set to 300 Hz and 70 dB respectively on the impedance audiometer.
The SLM is set to slow mode and external filter setting and attenuator to 70 dB.

The frequency of OFS and impedance audiometer should correlate.
The stimulus is presented continuously and the SLM reading is checked to see if the instrument is in calibration.
Same procedure is continued for all frequencies.

For calibration of contralateral reflex eliciting stimulus, the procedure is the same but the instrumentation differs. It is described below:

IV.Fig.

1.



Instruments for calibration of output SPL

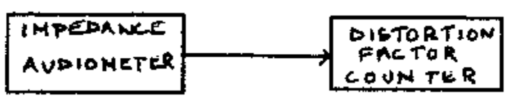
2.

Instruments for calibration of earphone

3.

Calibration of insert receiver

4



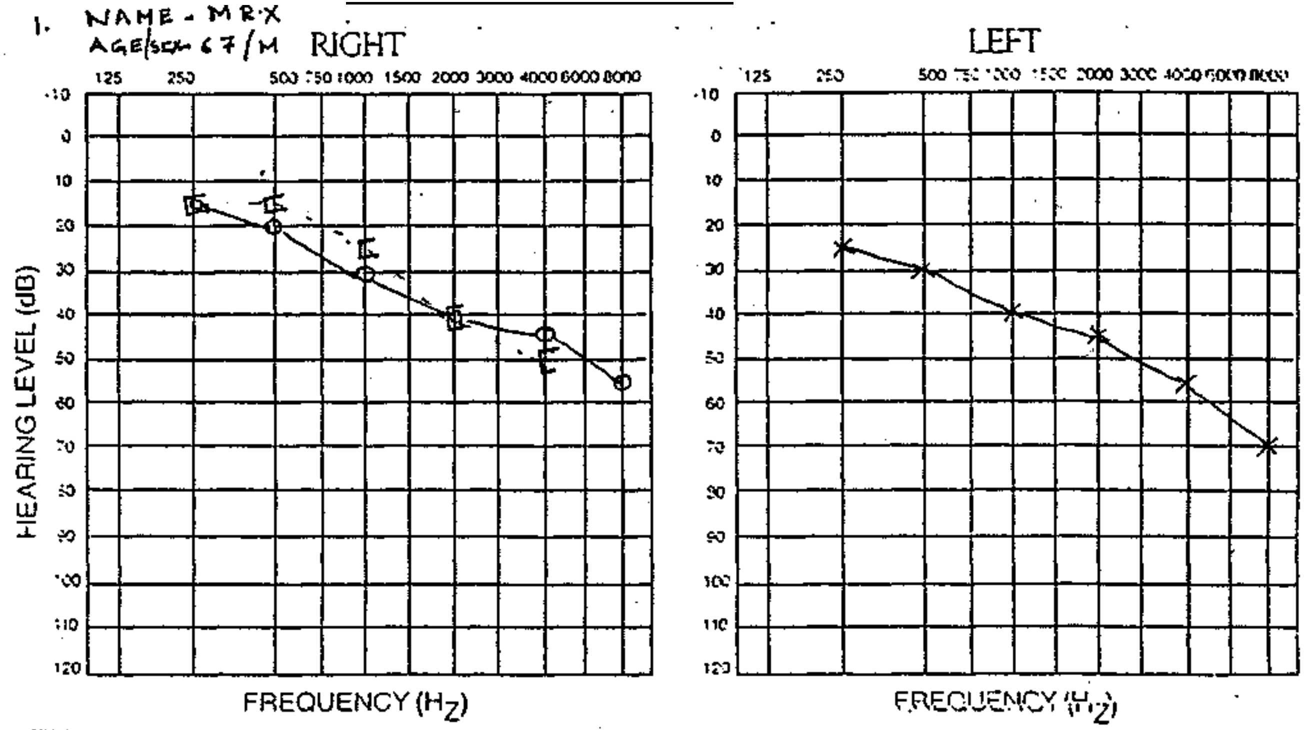
Instruments for distortion measurement.

LET'S CHECK YOUR KNOWLEDGE OF ACOUSTIC IMMITTANCE

I   From the puretone audiogram, predict the possible acoustic immittance findings.

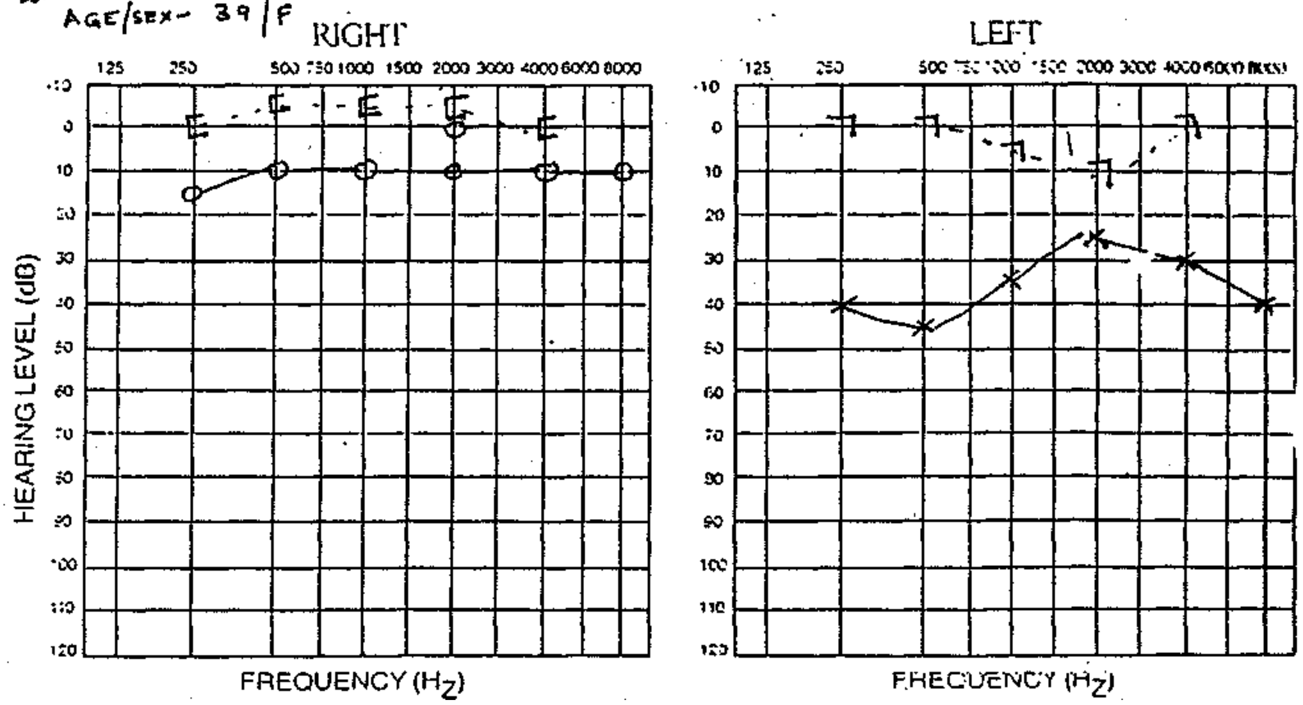
PUNE-TONE AUDIOGRAM

1. NAME - MR.X
AGE/SEX - 67/M



2. NAME - MRS.S
AGE/SEX - 39/F

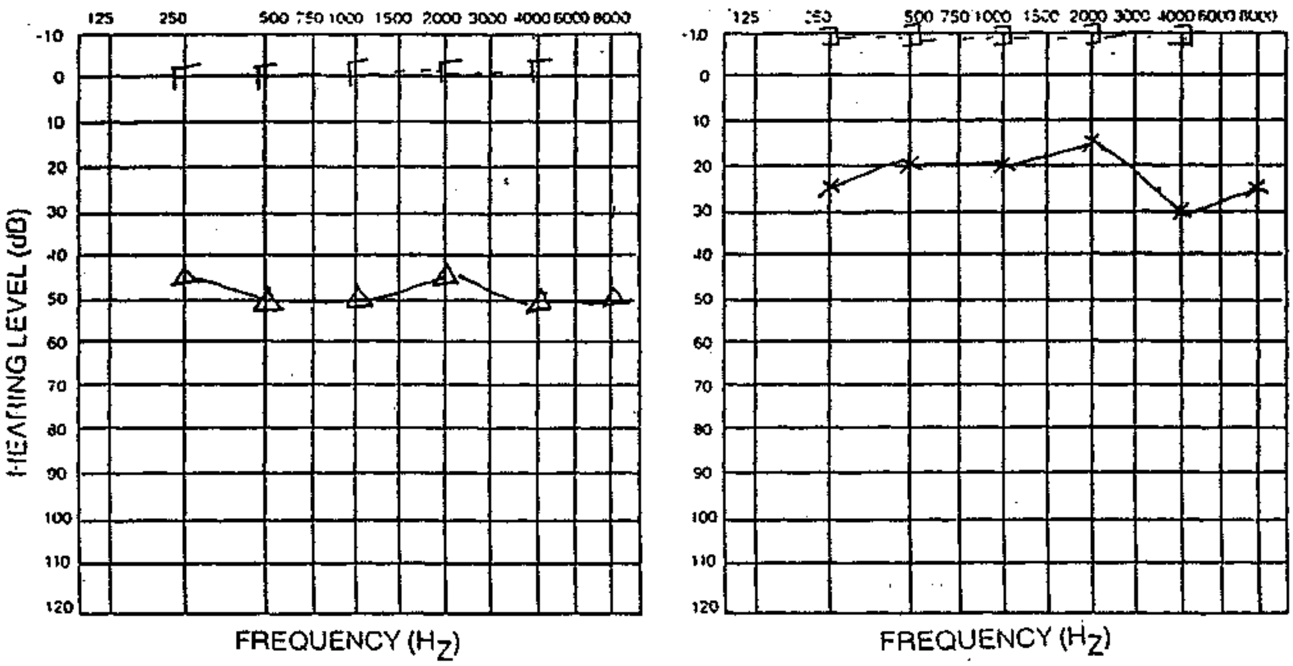
PUNE-TONE AUDIOGRAM



PUNE-TONE AUDIOGRAM

3. NAME – Miss. Y

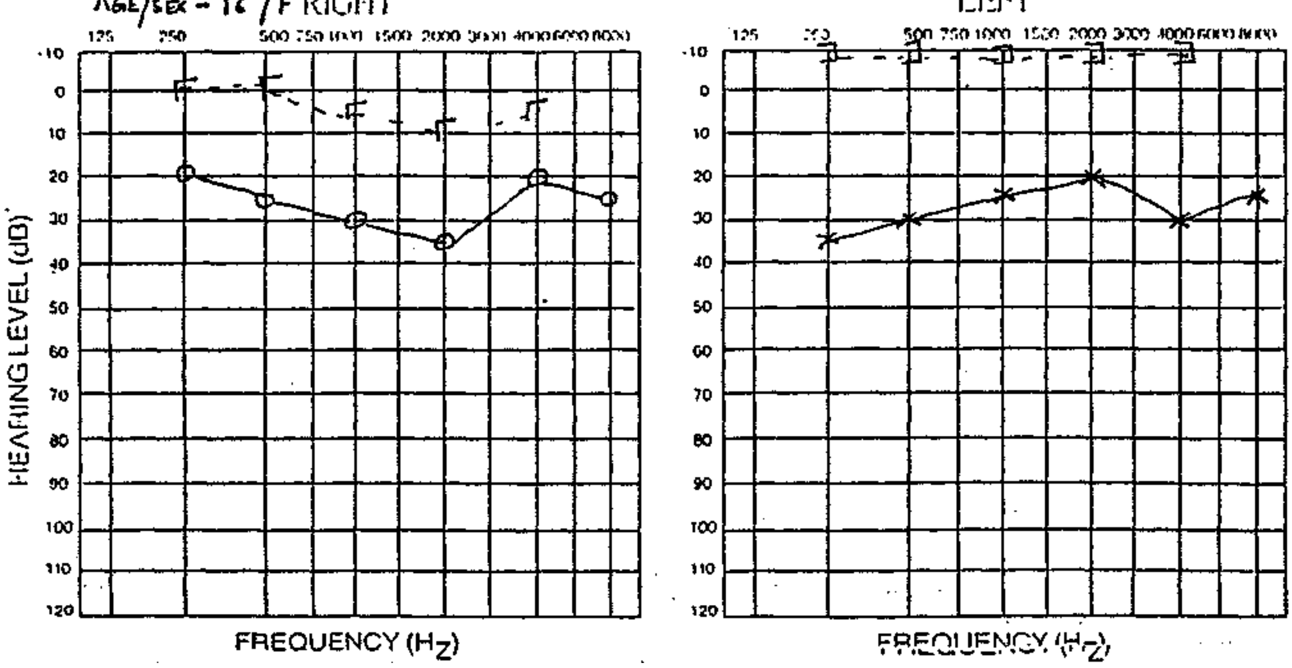
AGE/SEX – 3.4 / F RIGHT　　　　　　　　　LEFT

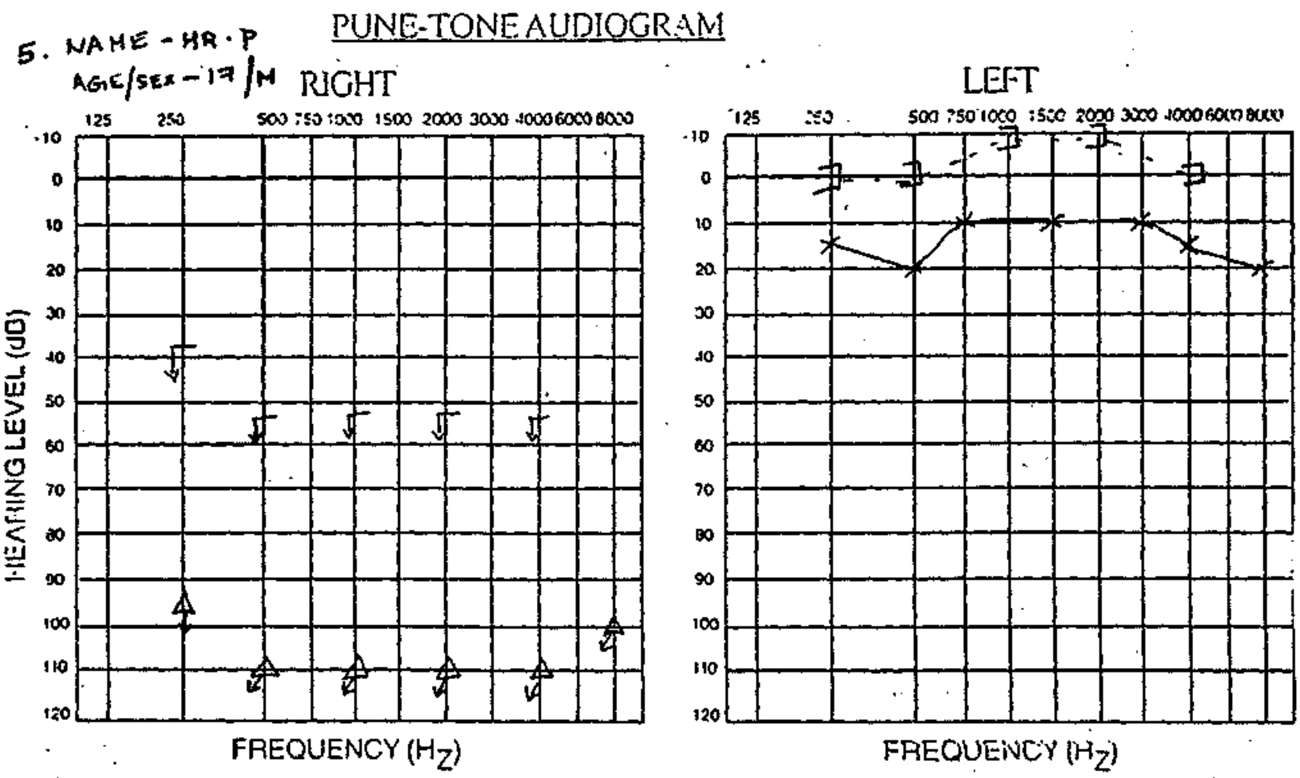


PUNE-TONE AUDIOGRAM

4. NAME – Miss. R

AGE/SEX – 16 / F RIGHT　　　　　　　　　LEFT





II Describe the possible immittance findings from the case history information given below :

1. A 17 year old male having hearing loss in the right ear for 6 years following a truck accident resulting in a.fractured skull, spinal fluid drainage from the right ear and subsequent meningitis.

2. This 15 year old youngster recently failed in the school hearing screening test for the first time. Complaint of excessive collection of wax in both the ears.

3. Nine year old with congenital renal abnormality which necessitated surgery and treatment with kanamycin. There is complaint of decreased hearing in left car.

4. A 50 year old male factory worker comes with a complaint of decreased hearing in both ears. History of exposure to loud noises for around 8 hours/day for the past 25 years.

III The ENT findings in certain cases are given below. Try to find out the possible immittance results in these cases.

1. A 16 year old female with a history of recurrent ear infections involving both ears dating back to infancy. ENT examination revealed atrophic tympanic membranes with missing incus bilaterally. The bilateral stapediomyringopexy is evidenced by the tympanic membrane being draped over the malleus and stapes head.

2. A young boy of 8 years with complaint of numerous ear aches and ear infections of both ears since infancy. ENT examination reveals a left patulous eustachian tube and a right tympanic membrane perforation.

3. "Dead" right ear since age of 5 following high fever. The case is now 7 years old. Followed in audiology and ENT clinics routinely. Good school performance with preferential seating. Latest ENT examination suggested the possibility of "malingering" based upon tuning fork tests.

4. A 7 year old girl child was struck on left side of the head above the ear with a baseball bat and admitted to hospital for 3 days with a probable concussion as well as a left haemotympanum. Subsequent ENT clinic visits revealed bilateral serous otitis media and suggested a left sided ossicular chain discontinuity.

5. A young 11 year old girl who showed normal findings on ENT examination, failed in hearing screening in school. Complaints of left ear pain. Has been showing poor performance in school recently and parents feel that the performance became poor after her favourite class teacher left the school.

IV From the immittance findings given below, predict the audiogram results.

1. A3 year old boy, on undergoing acoustic immittance measurements, showed 'B' type tympnograms and absence of acoustic reflexes in both ears.

2. A 30 year old female with As type tympanogram and no reflexes in both the ears.

4. Type A tympanograms, and normal acoustic reflexes except for 4K in a 65 year old male.

5. Type A tympanograms and acoustic reflexes within normal range in a 13 year old female who complaints of hearing disorder.

V. Using the immittance findings and air conduction thresholds predict the bone conduction thresholds.

		Rt	Lt		Rt	Lt
1.	AC	10	40	C	■	■
	BC	0	?	I	□	■
					'A' type	'C' type −380 daPa

		Rt	Lt		Rt	Lt
2.	AC	40	40	C	■	▨
	BC	0	?	I	■	▨
					'B' type	'A' type
					P.V-0.5cc	

		Rt	Lt		Rt	Lt
3.	AC	75	50	C	▨	■
	BC	0	45	I	■	▨
					'A' type	'A' type

		Rt	Lt		Rt	Lt
4.	AC	30	10	C	■	□
	BC	?	-10	I	■	□
					'A$_d$' type	'A' type
					SC-1.8cc	

		Rt	Lt		Rt	Lt
5.	AC	40	55	C	■	■
	BC	?	?	I	▨	■
					'A' type	'B' type
						P.V-0.4cc

		Rt	Lt		Rt	Lt
6.	AC	35	30	C	■	■
	BC	?	?	I	■	■
					'A$_s$' type	'C' type
					S.C-0.4cc	-180 daPa

		Rt	Lt		Rt	Lt
7.	AC	15	80	C	■	□
	BC	?	?	I	□	■
					'A' type	'A' type

		Rt	Lt		Rt	Lt
8.	AC	70	30	C	▨	■
	BC	?	?	I	■	▨
					'A' type	'A' type

	Rt	Lt		Rt	Lt
9. AC	35	10	C	□	□
BC	?	?	I	▨	▨
				'A' type	'A' type

	Rt	Lt		Rt	Lt
10. AC	25	25	C	□	□
BC	?	?	I	□	□
				'A' type	'A' type

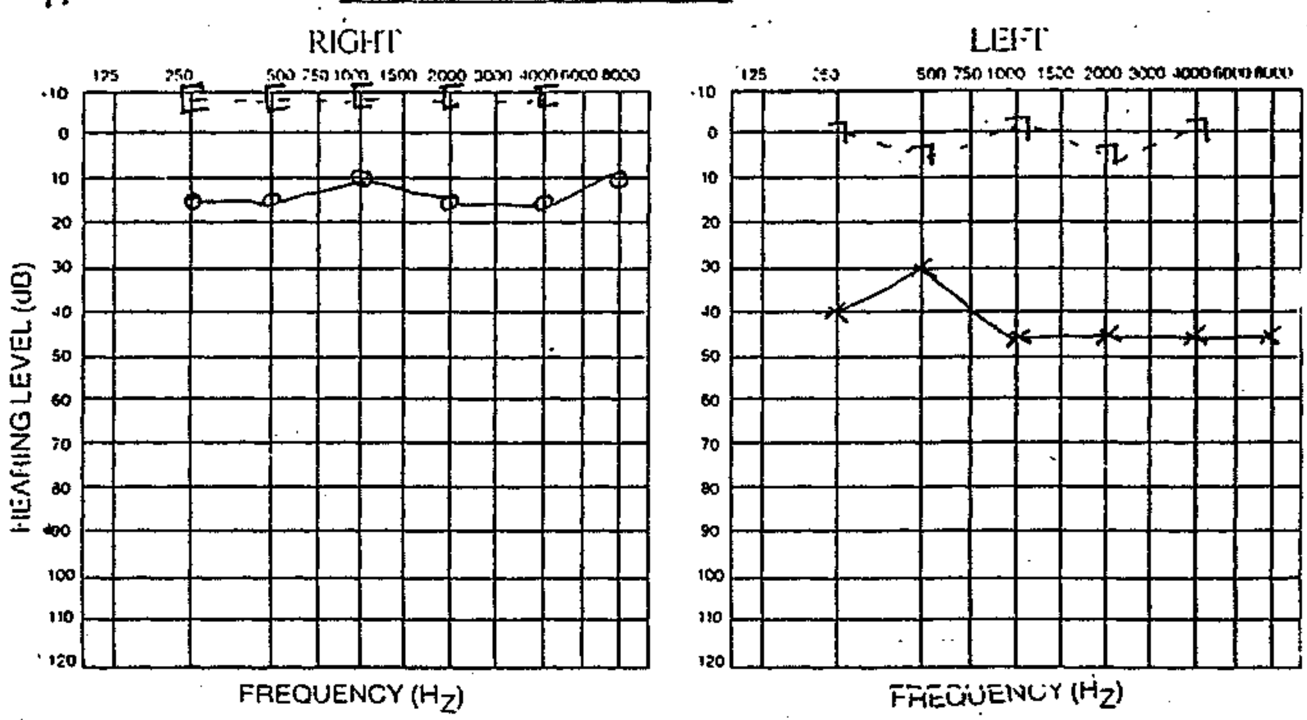
	Rt	Lt		Rt	Lt
11. AC	15	30	C	□	■
BC	?	?	I	□	■
				A	A

	Rt	Lt		Rt	Lt
12. AC	120NR	15	C	□	□
BC	?	?	I	■	■

VI Using the audiogram findings and immittance results predict the pathology.

1.

PUNE-TONE AUDIOGRAM



IMMITTANCE – Right ear – 'A' type, normal reflexes.
Left ear – Fluctuations in tympanometric line coinciding with the patient's breathing, absent reflexes.

		Rt	Lt
2.	AC	110	50
	BC	NR	15

Immittance - Right ear - 'A' type, no reflexes
Left ear - 'Ad' type, no reflexes.

		Rt	Lt
3.	AC	50	15
	BC	40	- 10

Immittance - Right ear A type, normal reflexes
Left ear -'A' type, normal ipsilateral reflexes, contralateral reflexes slightly elevated.

		Rt	Lt
4.			
	AC	40	50
	BC	-10	0

Immittance - both ears 'B' type, physical volume .5cc , no reflexes.

		Rt	Lt
5.			
	AC	15	10
	BC	- 10	-10

Immittance - ' A' type, no reflexes

6.

	Rt	Lt
AC	15	10
B C	- 10	-10

Immittance - Right 'A' type
Left 'B' type, physical volume 3.6 cc, no reflexes, reflex decay test positive for right ear.

7.

	Rt	Lt
AC	3 0	3o
BC	25-	-10

Immittance - Unable to build up air pressure.

8.

	Rt	Lt
AC	40	*30*
BC	20	- 10

Immittance - 'A' type, ipsilateral reflexes present within normal limits, no contralateral reflexes.

VII Given below are the case histories and puretone thresholds of few cases. Predict the immittance findings for these cases.

1. A 4 year old boy who is congenitally hearing impaired and has limited speech output. Puretone thresholds show profound hearing loss in both ears.

2. A 50 year old female, with history of discharge from the right ear. Also complaints of decreased hearing sensitivity in the same ear. Reports of normal hearing in the other ear. Puretone thresholds are follows :

	Rt	Lt
AC	35	15
BC	-10	0

3. A 49 year old male with the complaint of fullness in both the ears. Also reports ofhearing the echo of his own voice while speaking.

Puretone audiogram results.

	Rt	Lt
AC	45	50
BC	10	0

4. A 30 year old female with the complaint of hearing loss in the right ear following pregnancy. It is reported to be progressive in nature. No problem reported in the other
AC BC
ear. PTA- Rt - 50 - 10
- Lt - 20 - 10

5. A 26 year old adult male with the complaint of complete loss ofhearing in both ears following an attack of meningitis 8 years back, Rt Lt
AC 120NR 120NR
BC 50NR 50NR

6. A 65 year old man with myesthenia gravis , with the complaint of fullness and hearing loss in both ears.

	Rt	Lt
AC	30	40
BC	-10	-5

7. A 75 year old woman under insulin treatment for the past 15 years reports of decreased hearing in both ears.

	Rt	Lt
AC	25	45
BC	20	40

VIII Given below are the puretone audiogram findings and the corresponding immittance results. Check out whether these two correlate. Explain your answer.

PTA	Immittance
1. Bilateral SN loss	1. B type, absent reflexes
2. Bilateral SN loss	2. C type, absent reflexes
3. Unilateral profound loss	3. A type, reflexes present
4. Bilateral severe-profound loss	4. A type, reflexes present
5. Unilateral profound loss	5. A type, diagonal pattern of reflexes
6. Bilateral moderate hearing loss	6. A type, reflexes present
7. Bilateral normal hearing	7. A type, reflexes absent.
8. Bilateral moderate conductive loss with 2 K dip	8. A type, reflexes absent
9. Bilateral mild SN loss	9. A type, reflexes absent
10. Unilateral moderate conductive loss	10. A type, diagonal pattern
11. Bilateral moderate SN loss	11. As type, no reflexes

Answers

I. From the puretone audiograms, predict the possible acoustic immittance finding:

1) The audiogram suggests mild bilateral sensory-neural hearing loss. Tympanometry would show A type tympanograms and reflexes could be present within normal limits or it would be slightly elevated.

2) The right ear audiogram shows hearing within normal limits and left audiogram suggests mild to moderate conductive hearing loss. Therefore, one can expect A type tympanogram in right ear and abnormal tympanometric findings in the left ear. The acoustic reflexes will be absent in the left ear and in the right ear ipsilateral reflexes will be present but contralateral reflexes would be slightly elevated.

3) The audiograms are suggestive of bilateral conductive hearing loss. Therefore tympanometric results would show abnormal tympanograms and acoustic reflex would be absent in both ears.

4) This is also a case of conductive pathology and therefore one can expect the same immittance findings as that for the above case.

5) This case has profound loss in the right ear and normal hearing in the left ear. Both ears would show A type tympanograms and ipsilateral and contralateral reflexes would be absent in the right ear and left ear respectively. Contralateral reflexes of right ear and ipsilateral reflexes of left ear would be present within normal limits.

II.

1. The history is suggestive of sensoryneural loss in the right ear. Left ear may be normal. 'A' type tympanograms can be expected in both ears. Ipsilateral reflexes of left ear and contralateral reflexes of right ear should be present within normal limits.

2. Excessive collection of wax causes conductive hearing loss and therefore a 'B' type tympanogram and absence of reflexes can be expected in both ears.

3. The case history is suggestive of ototovisity. Therefore

a sensory neural loss can be suspected in the left ear. Right ear may be normal. Type A tympanogram will be obtained in both the ears. The ipsilateral reflexes of left ear and contralateral reflexes of right ear may be elevated or about depending on the severity of the loss in the left ear. The other reflexes should be with in normal limits.

4. From the case history, it is clear that it is a case of NIHL. A high frequency sensoryneural hearing loss is seen in these cases usually. Therefore normal tympanograms and elevated or absent acoustic reflexes may be expected (especially in high frequencies).

III.

1. This is a clear cut case of ossicular chain discontinuity. Therefore Ad type tympanograms and absent acoustic reflexes can be seen in this case.

2. Since the left ear has a patulous eustachian tube, during tympanometry one can notice the deflection of the needle as the patient breathes which is a typical finding in such cases and in right ear one would expect a B type tympanogram. Reflexes would be absent in both ears.

3. As the case is suspected to be malingering, normal tympanometric findings and reflexes within normal limits would confirm the diagnosis.

4. One can expect 'B' type tympanograms in the right ear and Ad type tympanograms in the left ear. Reflexes would be absent in both ears.

5. The symptoms presented by the case do not match with the ENT findings. Moreover as per the parents report, the child is upset about the departure of her favourite teacher. Therefore one can suspect non-organic hearing loss. If that is the case, normal immittance findings can be expected.

IV.

1. As the reflexes are absent and there is B type tympanogram, one can expect a bilateral moderate - moderately severe conductive hearing loss.

2. Bilateral conductive hearing loss of greater than 40 dB could be suspected.

3. Since acoustic reflexes are absent in both ears and A type tympanograms are present, it could be a bilateral sensoryneural hearing loss of greater than moderate degree. Another possibility is normal audiogram findings if there is a bilateral absence of stapedial tendon. Stapedius muscle is attached to the stapedial tendon. Therefore its absence would result in the absence of reflexes but tympanometric and audiogram findings would be normal.

4. As the tympanograms are normal and since acoustic reflex is present at all the frequencies except 4K, one can expect a loss at this frequency alone. Considering the age of the case and the 4K dip, it could be a case of presbyacusis.

5. As the immittance findings are normal, one would expect normal audiogram findings. However, the case is complaining of hearing disorder. So, it could be non-organic. In such a case, one can expect a mixed or sensory neural type of hearing loss and it will be of greater than moderate degree.

V.

1. BC threshold left ear - within normal limits.
2. BC threshold left ear - around 30-40 dB
3. BC threshold right ear - around 65-75 dB
4. BC threshold right ear - within normal limits.
5. BC threshold right ear- 30-40 dB
   BC threshold left ear - within normal limits-
6. BC threshold right ear - -within normal limits.
   BC threshold left ear - within normal limits.

7. BC threshold right ear - within normal limits.
   BC threshold left ear - within normal limits.
8. BC threshold right ear - around 60-70 dB
   BC threshold left ear - around 20-30 dB
9. BC threshold right ear - around 25-30 dB
   BC threshold left ear - within normal limits.
10. BC threshold right ear - around 15-25 dB
    BC threshold left ear - around 15-25 dB

VI

1. Right ear - Normal
   Left ear - This is a clear indication of patulous eustachian tube without any abnormality of tympanic membrane.

2. Right ear - No middle ear pathology. Pathology is either sensory or neural.
   Left ear - It could be ossicular chain discontinuity, flaccid, scarred or thin tympanic membrane.

3. Right ear - The PTA and immittance findings are suggestive of a cochlear pathology as the reflexes are present within normal limits in spite of moderate loss in the right ear. This is due to recruitment, commonly seen in cochlear pathology cases.

   Left ear - Normal.

4. The pathology is conductive in nature as the physical volume is reduced, it is probably due to wax in the ear canal.

5. Normal hearing subjects can show absence of reflexes but it could also be an indication of possible absence of stapedial tendon to which the stapedius muscle is attached.

6. Right ear probably has a retrocochlear pathology since RDT is showing positive results. The left ear could be having a perforated tympanic membrane as the physical volume is increased.

7. Inability to build up pressure in the ear canal is usually seen in cases with patulous eustachian tube along with a perforated tympanic membrane. The right ear also has an additional sensory or neural pathology as indicated by the mixed loss.

8. The absence of contralateral reflexes alone is usually due to collapsed ear canal. This can happen even if contralateral phones are not working.

VII

1. This is for suggestive of a sensoryneural loss. Therefore, one can expect 'A' type tympanogram and absent reflexes in both ears.

›

2. Right ear will show 'B' type tympanogram with no reflexes and left ear will show 'A' type tympanogram with normal reflexes.

3. There is probably a malfunctioning of the eustachian tube. Therefore, a 'C type tympanogram may be obtained with no reflexes.

4. Right ear PTA shows a 2K dip and the history is also suggestive of otosclerosis. An 'As' type tympanogram with absent reflexes may be seen in the right ear whereas left ear would show 'A' type tympanogram with normal reflexes.

5. "A* type tympanogram with absent reflexes in both ears.

6. Cases with myesthenia gravis have been reported to show negative middle ear pressures. So, similar findings may be expected here. Thus 'C type tympanograms with absent reflexes could be obtained in both ears.

7. Insulin dependent patients usually show low amplitude tympanograms. Reflexes would be present within normal limits.

VIII

1. It should be 'A' type tympanogram with normal reflexes.

2. For a sensory neural loss case, these findings are impossible. 'A' type with normal reflexes are expected in such cases.

3. Tympanometric results may be correct, but reflexes will not be present for a profound loss case. Depending on whether the loss is mixed or sensoryneural, 'inverted L' pattern or diagonal pattern can be obtained respectively. If it is a mixed loss, tympanometry will show a pathological type of tympanogram.

4. All the reflexes should be absent in this case, tympanometric results are correct.

5. This can occur when the loss is sensory neural.

6. Reflexes should be absent in both ears. Though an A type tympanogram can sometimes be seen in conductive loss cases, strictly speaking the tympanogram should be pathological.

7. These findings are possible. Though one might expect normal reflexes in a normal hearing case, some cases do show absence of reflexes. This does not necessarily indicate a pathological condition.

8. It is a possible finding. Though the PTA indicates otosclerosis, 'A' type tympanogram may be seen in such cases also.

9. The reflexes should either be present within normal limits or elevated in this case. It cannot be absent as the energy reaching the cochlea is sufficient to produce reflexes.

10. Strictly speaking, the tympanogram should show abnormal patterns though 'A' type can sometimes be seen in conductive loss cases. The diagonal reflex pattern will not be obtained in this case. It should be an inverted 'L' pattern.

11. 'As' type cannot be seen as it is a sensory neural loss, moreover reflexes need not be totally absent. It could be elevated also.

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