Acoustic Immittance Measures

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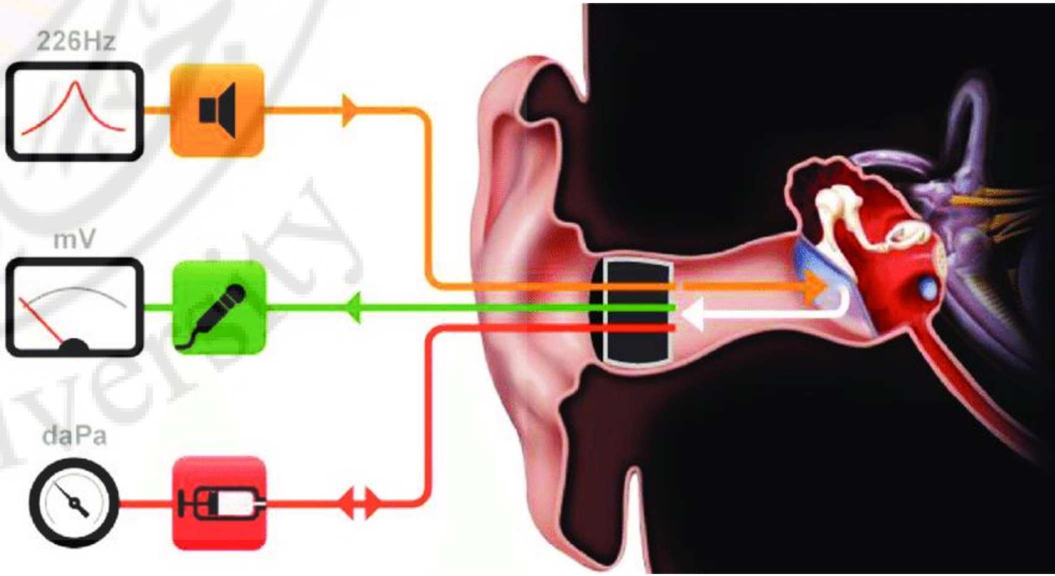
Introduction

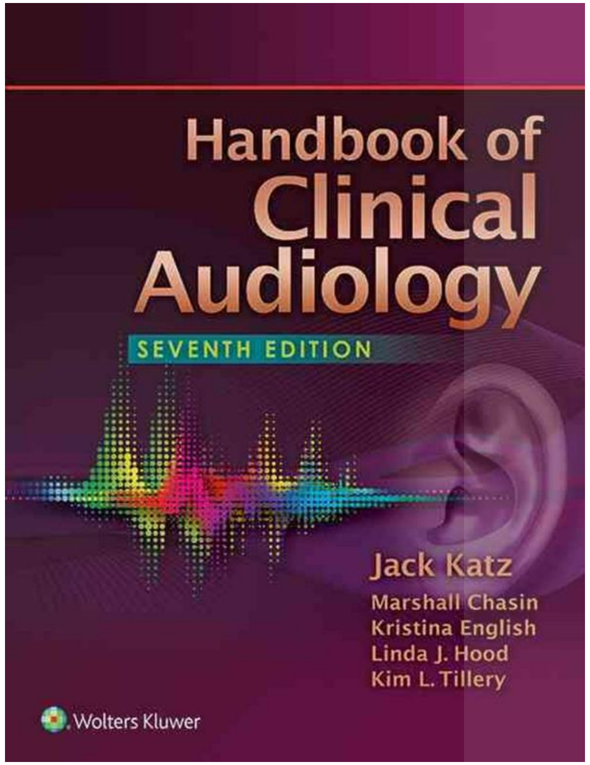
- Middle ear measurement is a fundamental component of the audiologic test battery.
- Tympanometry and acoustic reflex testing are the basic components of the middle ear test battery, which provides information about the middle ear, cochlea, auditory nerve (cochlear nerve, cranial nerve VIII), auditory brainstem, and facial nerve (cranial nerve VII). Therefore, the middle ear test battery is useful as a **cross-check** with other physiologic and behavioral tests
- This course explores the topic of immittance measurement in clinical audiology.
- Our Learning objectives are:
  - To understand the importance of immittance measures in diagnosis of ear disorders
  - Be able to describe different test protocols and integrate them into daily clinical practice

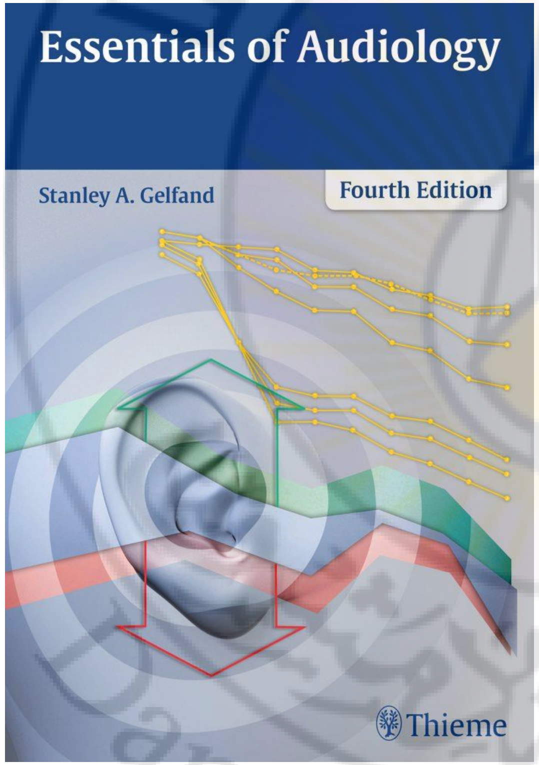
Main Topics

- Review of the anatomy and physiology of conductive system
- Overview of physical principles of the Immittance measures
- Instrumentation and calibration
- Single-frequency Tympanometry
- Multi-Frequency Tympanometry
- Wideband Tympanometry
- Eustachian tube function tests
- Acoustic stapedial reflexometry



References


Handbook of Clinical Audiology
SEVENTH EDITION
Jack Katz
Marshall Chasin
Kristina English
Linda J. Hood
Kim L. Tillery
Wolters Kluwer


Essentials of Audiology
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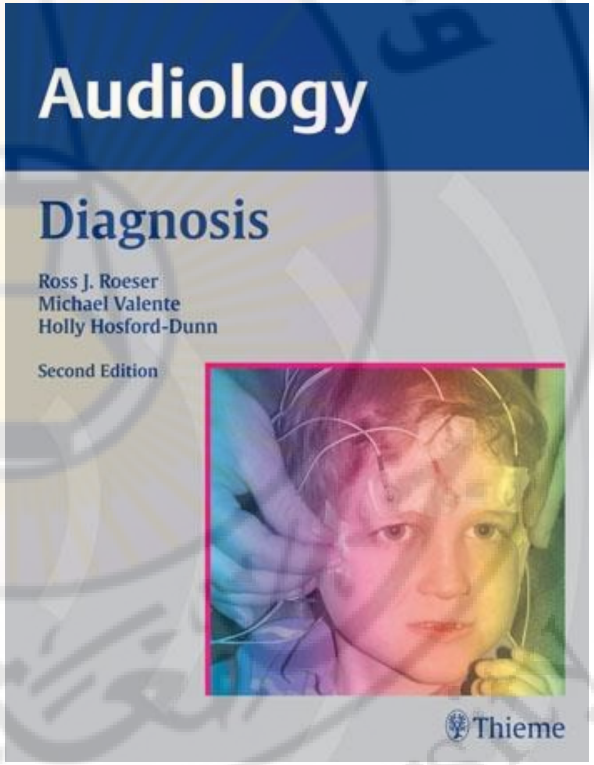
Fourth Edition
Thieme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Diagnosis
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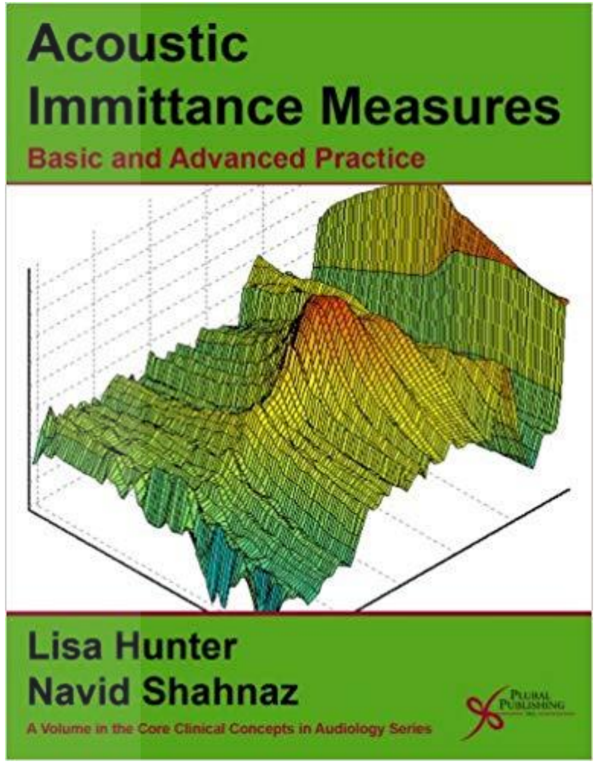
Acoustic Immittance Measures
Basic and Advanced Practice
Lisa Hunter
Navid Shahnaz
A Volume in the Core Clinical Concepts in Audiology Series

E. references

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Assessment

- Active participation in the class
- Final exam
    - Multiple choice questions
    - fill-in-the-blank questions
    - short answer questions

1. Review of the anatomy and physiology of conductive system

The human auditory system can be divided anatomically into two subsystems:

Peripheral auditory system

Central auditory system

It can be further subdivided *anatomically* into four divisions:

Outer ear

Middle ear

Inner ear

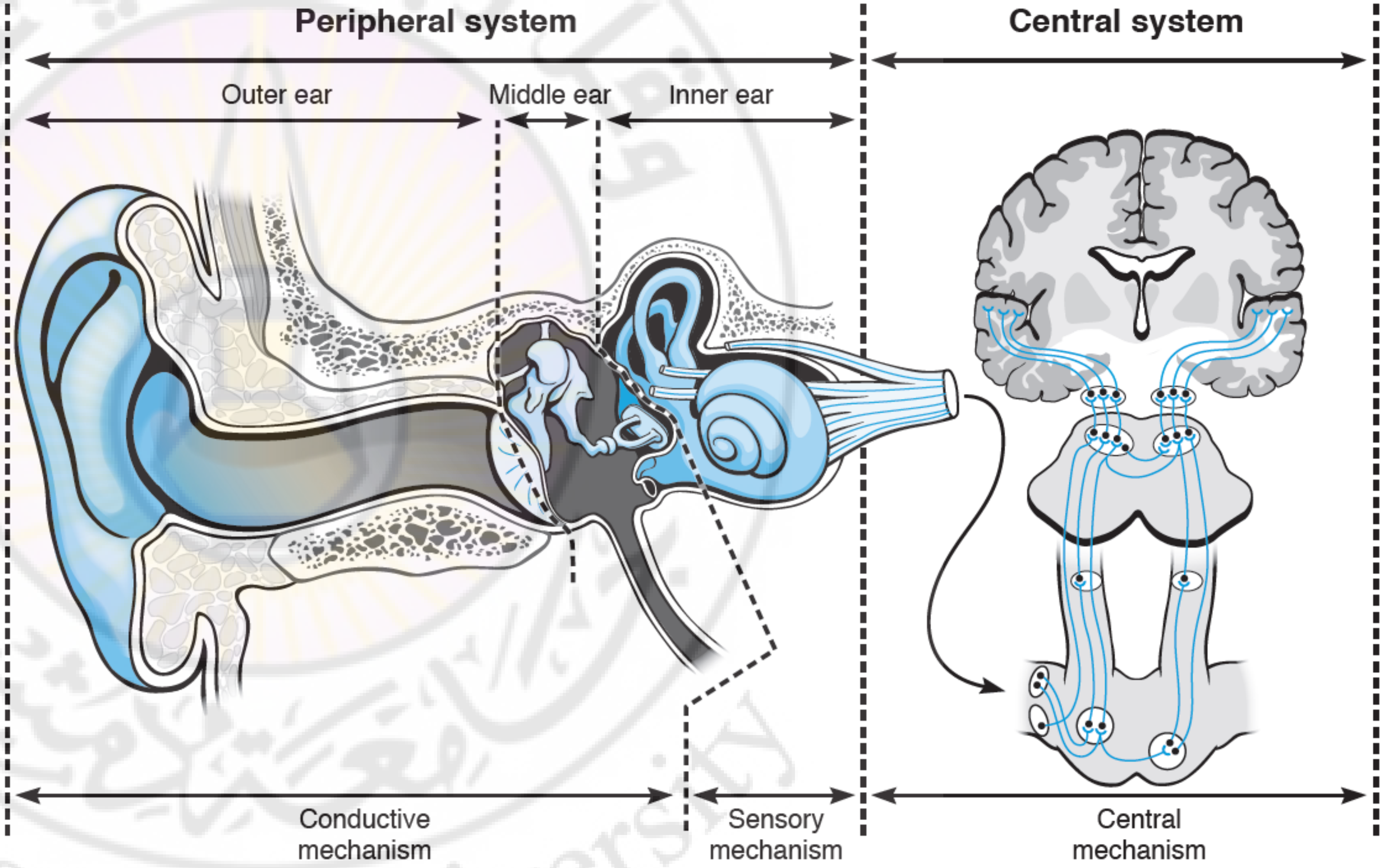
Central auditory system

Functionally, the auditory system is comprised of three components:

The conductive mechanism

The sensory mechanism

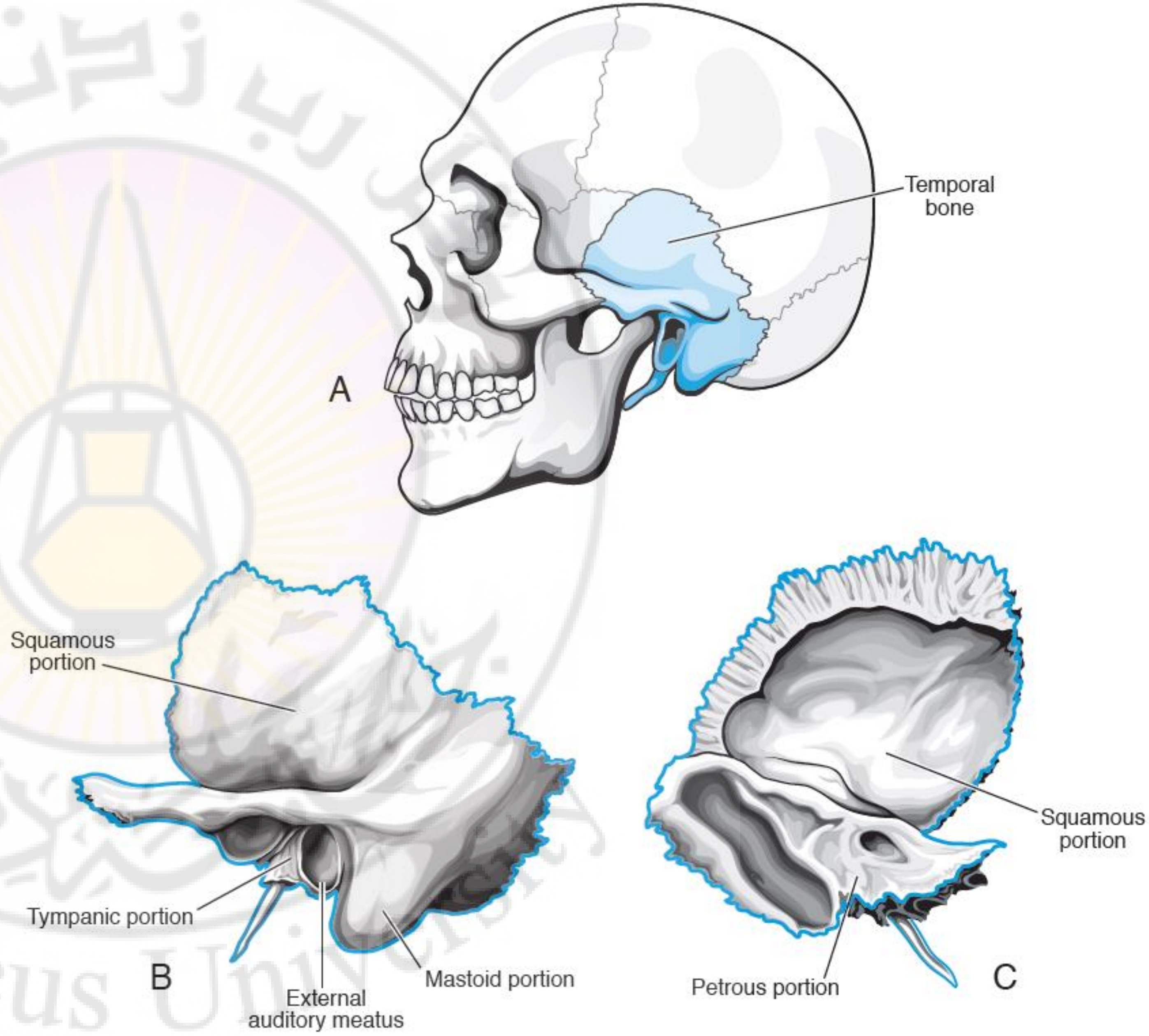
The central mechanism



Human temporal bone

Almost all of the **peripheral auditory mechanism** is located in the **temporal bone**, a paired cranial bone of the skull that comprises the major portion of the lateral base and sides of the braincase.

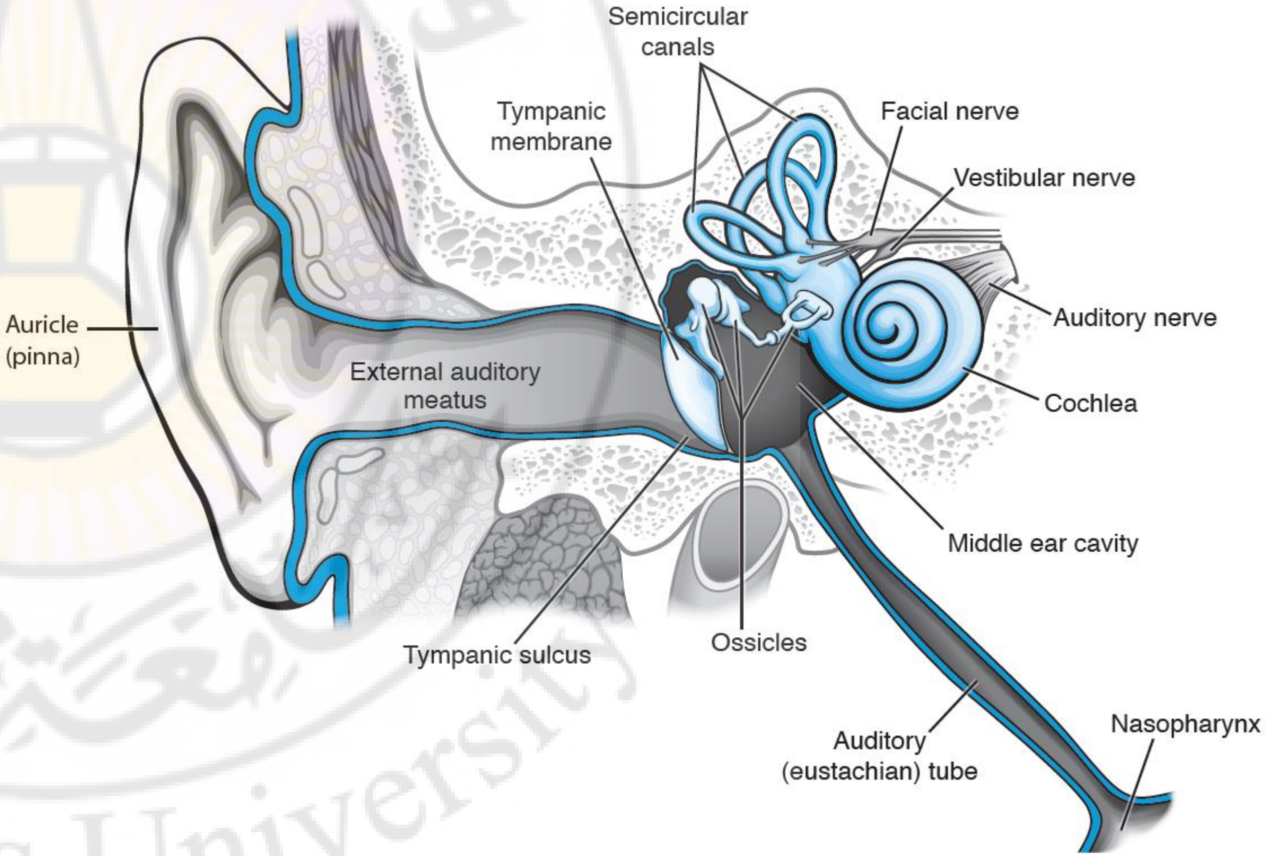
Each temporal bone consists of four portions. The **squamous** portion contains the opening of the external auditory meatus (i.e., outer ear canal). The **mastoid** portion is behind the auricle and contains numerous air-filled spaces (i.e., **air cells**). Part of the **tympanic** portion forms a section of the external auditory meatus. The **petrous** portion is located at the base of the skull and houses the essential parts of the organs of hearing and equilibrium.



Structures of the outer ear

The **outer ear** represents the outermost portion of the auditory system and consists of the **auricle** (or **pinna**) and the **external auditory meatus** (or **outer ear canal**).

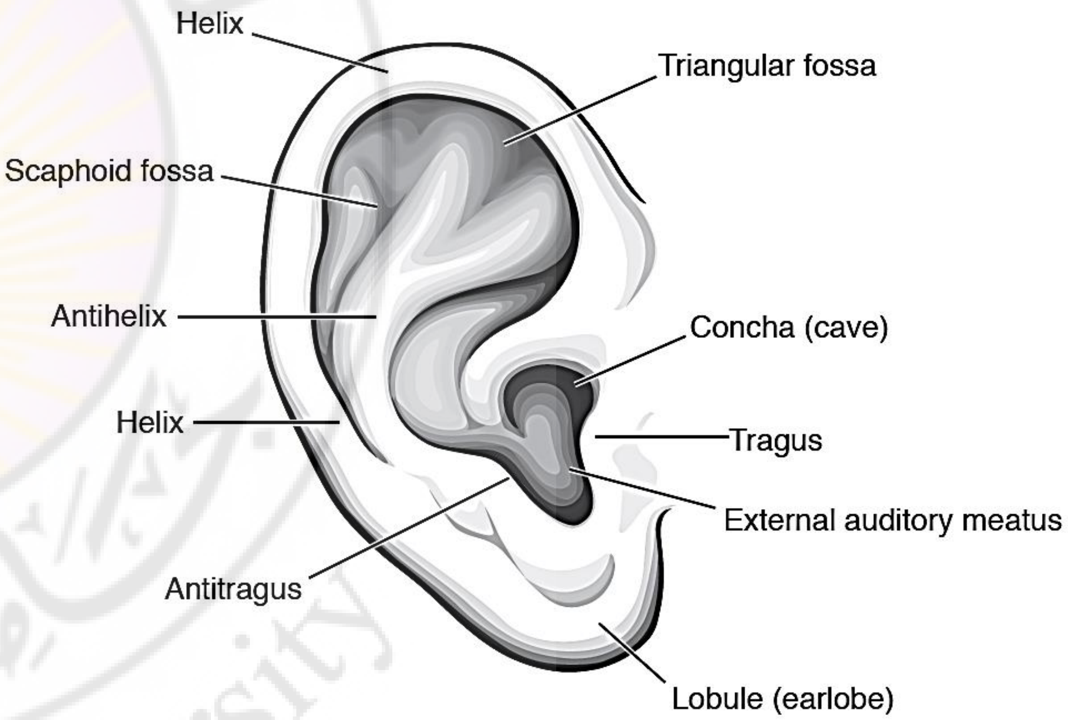
The auricle is the outermost portion of the conductive and overall auditory mechanism. It is composed of soft tissue and cartilage that form a cup around the entrance to the external auditory meatus, and its skin is continuous with the skin of the meatus.



Structures of the outer ear

The surface of the auricle is uneven and contains pits, depressions, ridges, and grooves.

The **concha** is the deepest depression on the auricle; it leads directly to and forms the opening of the external auditory meatus. The **helix** is the rimlike ridge on the periphery of the auricle. The ridge just inside the helix, called the **antihelix**, follows a similar course as the helix. Depressions on the auricle include the **scaphoid fossa**, which lies between the helix and the antihelix, and the **triangular fossa**, which is medial to the scaphoid fossa in the superior portion of the auricle between the helix and the antihelix. The **tragus** is a small flap of cartilage on the anterior wall of the external auditory meatus. The **antitragus** lies just opposite the tragus and forms the inferior boundary of the concha. The most inferior landmark on the auricle is the **lobule** (i.e., lobe); it is composed of soft tissue and is highly vascular.



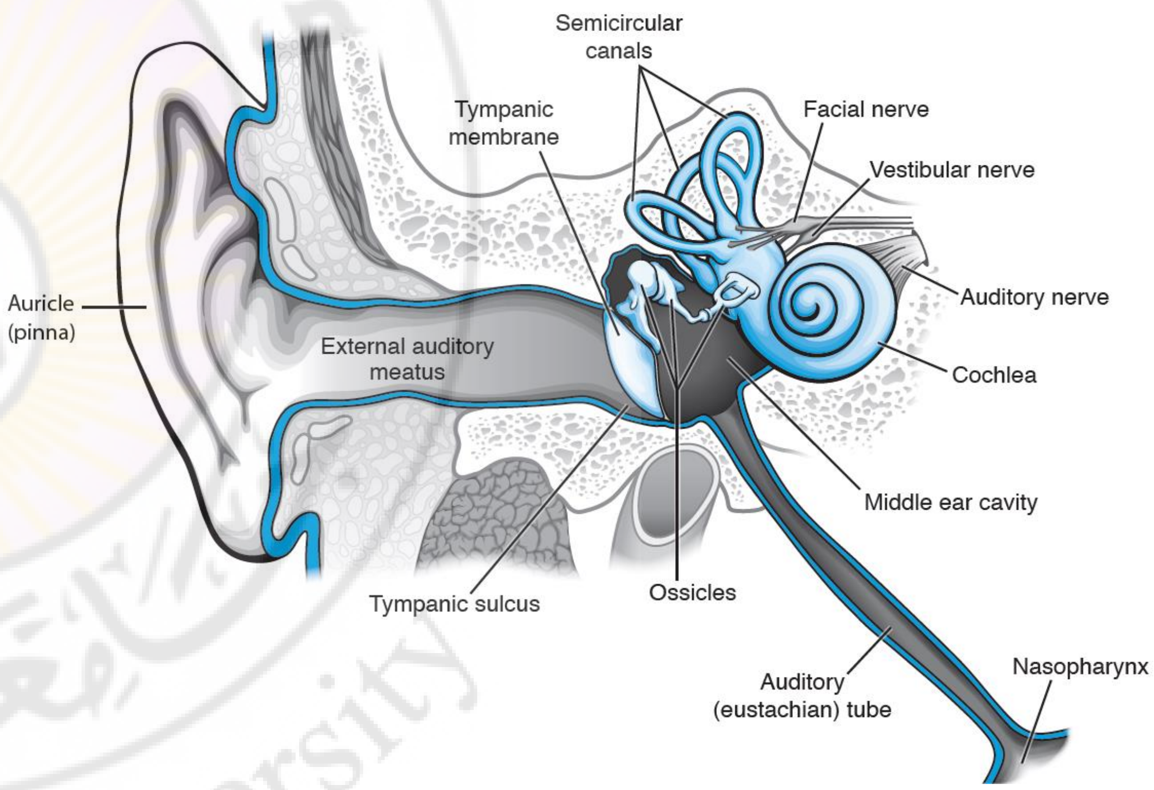
Structures of the outer ear

External auditory meatus leading from the auricle to the tympanic membrane; approximately 25 to 35 mm long, rather narrow (5 to 9 mm in diameter); and S shaped. The external auditory meatus protects the tympanic membrane from the outside atmosphere.

The **lateral one-third** of the canal, the portion toward the auricle, is composed of **cartilage**, whereas **the medial two-thirds** (toward the tympanic membrane) contain **bone**.

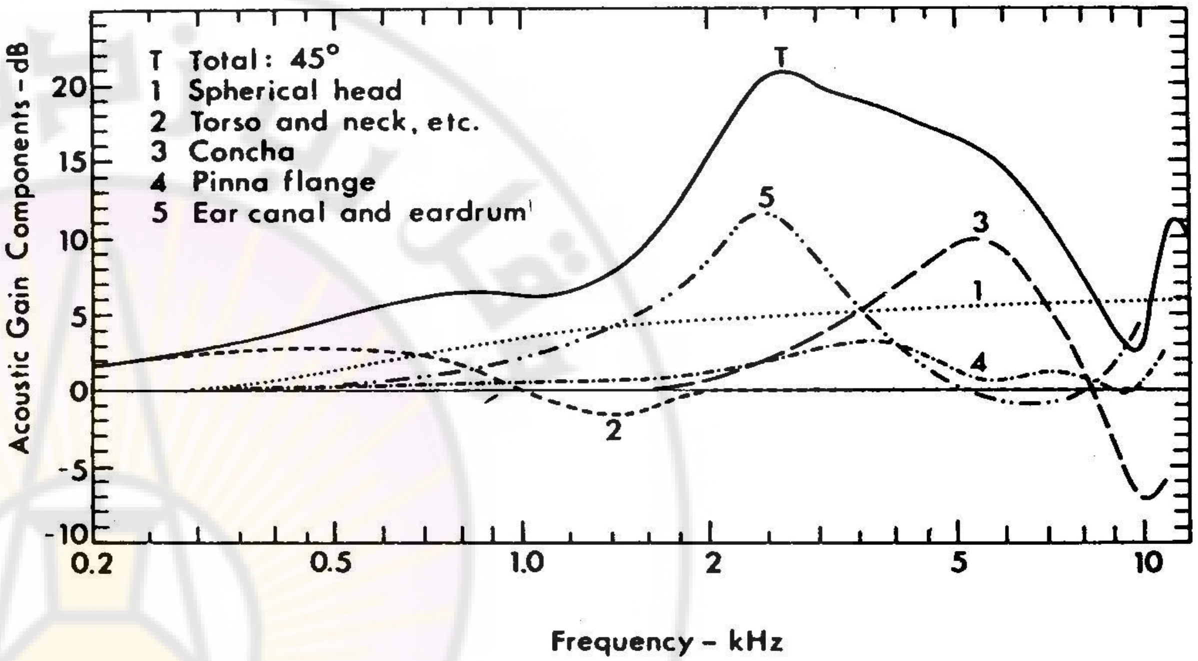
Two sets of **glands, ceruminous (i.e., wax secreting) and sebaceous (i.e., oil producing),** line the skin of the cartilaginous portion of the canal.

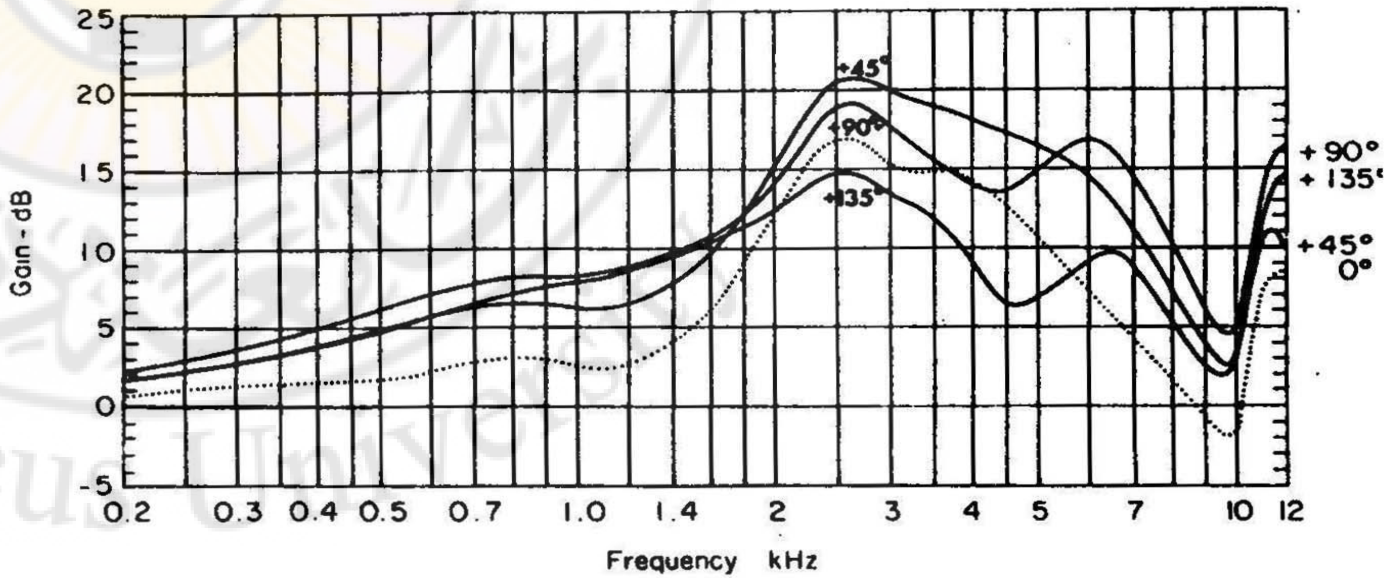
The cartilaginous portion of the canal nearest the auricle is also lined with **hairs**. Along with cerumen, these hairs protect the tympanic membrane against insects and other foreign bodies.



Outer ear has a **resonant frequency** that is dependent upon its physical properties, and changes the spectrum of incoming sounds.

Its resonant frequency averages approximately **2700 Hz**, with considerable variability among individuals.





Tympanic membrane (eardrum)

Tympanic membrane is an elastic structure that separates the outer ear from the middle ear cavity.

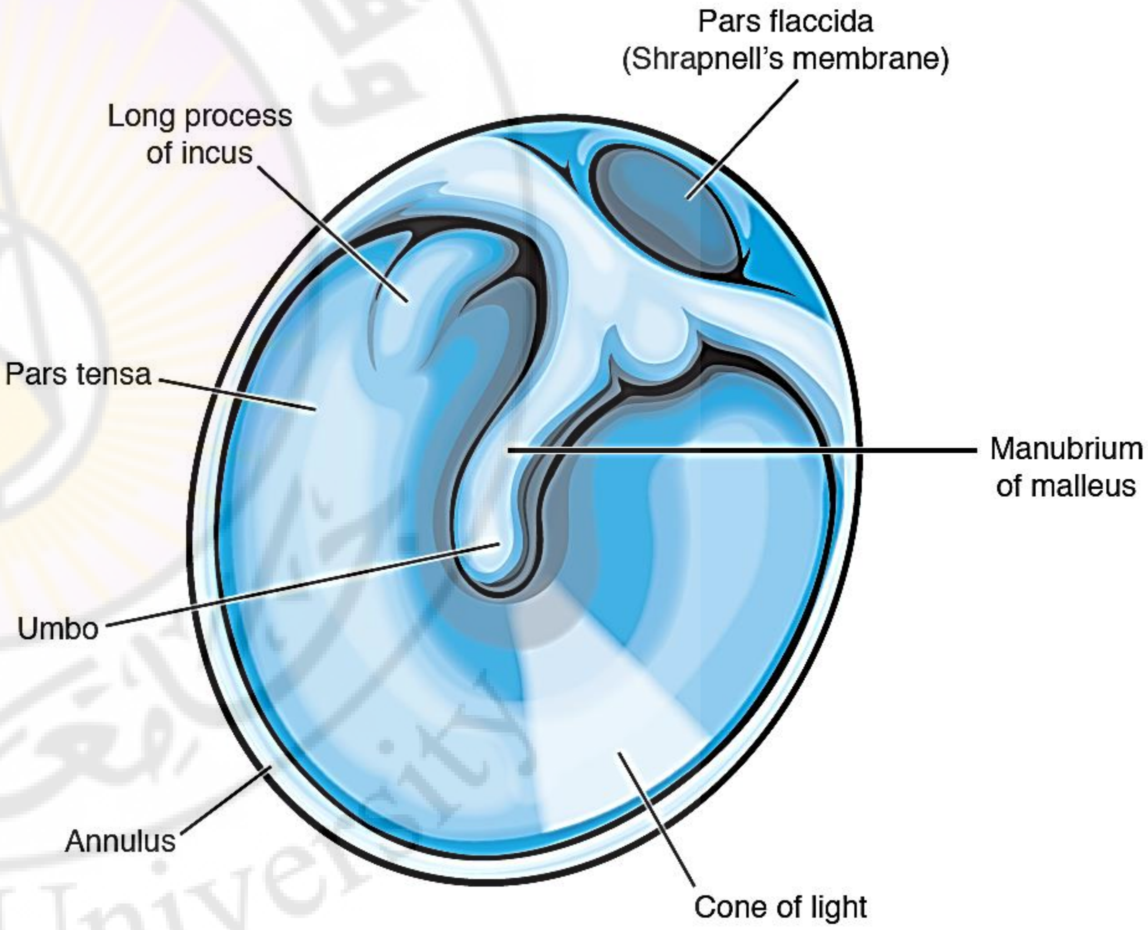
It is surrounded by fibrous tissue called the **annulus**, which fits tightly into the **tympanic sulcus**, a groove in the bony wall of the external auditory meatus.

The tympanic membrane is composed of three layers of tissue:

(a) an outer, cutaneous layer

(b) a middle, fibrous layer

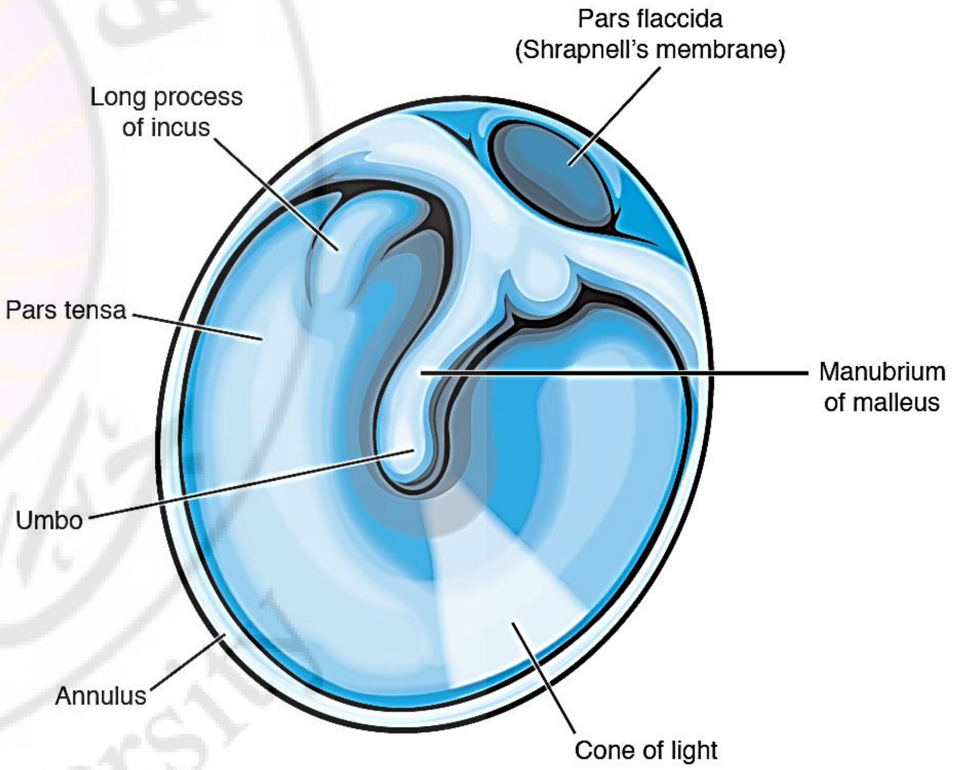
(c) inner, mucous membrane layer



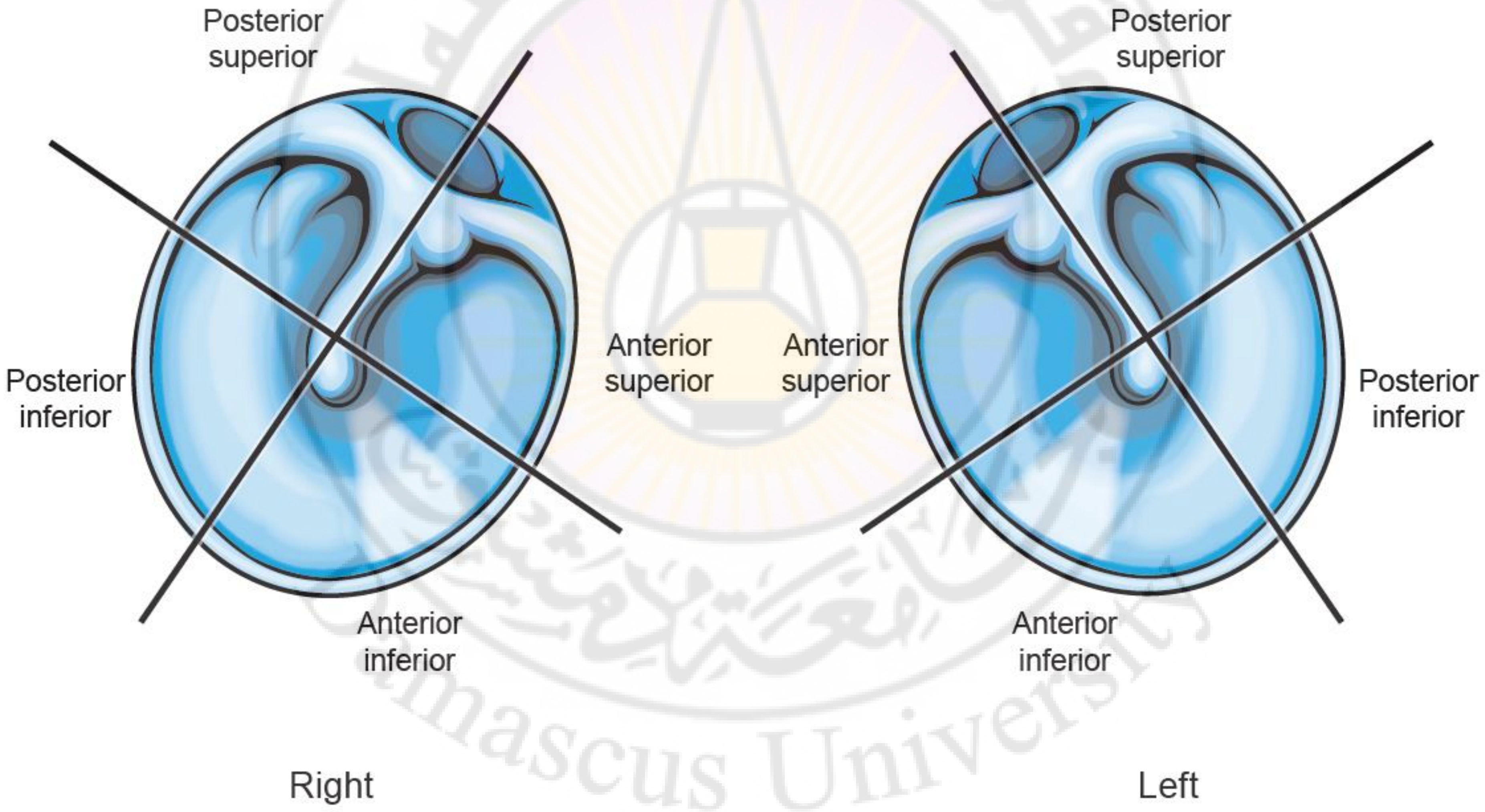
Tympanic membrane (eardrum)

The **pars tensa** is the largest portion of the tympanic membrane, containing numerous fibers that contribute to the stretched nature of this part of the membrane. In contrast, the **pars flaccida** (also called **Shrapnell's membrane**) is a small triangular area on the superior portion of the membrane that contains very few fibers and therefore is flaccid.

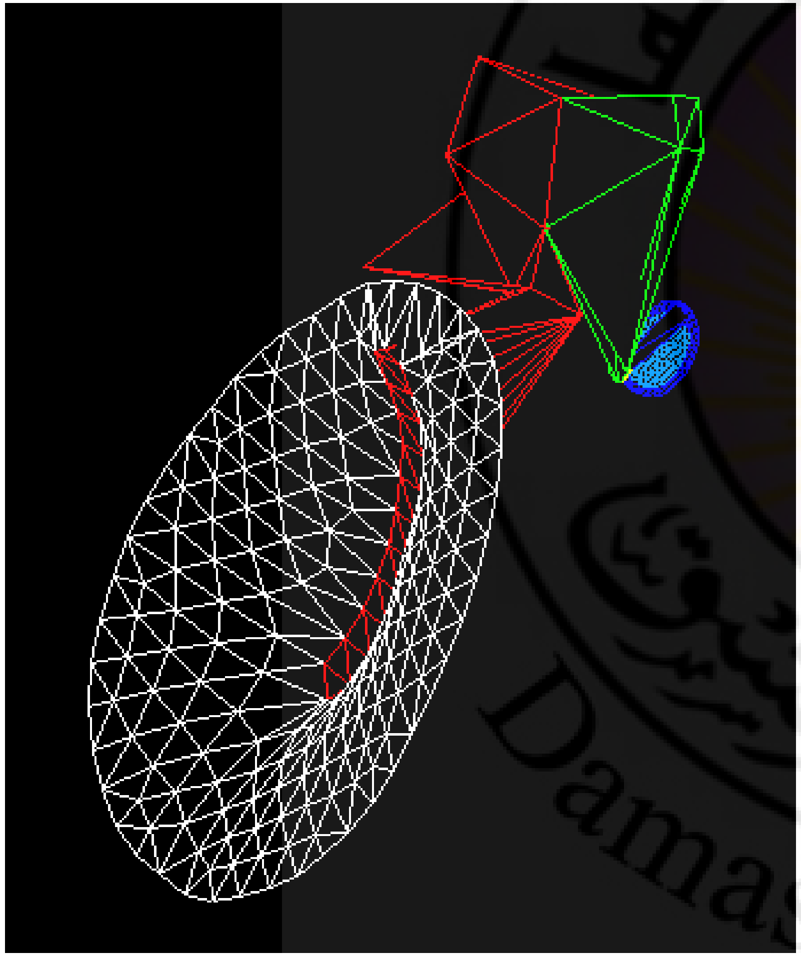
The **umbo** is the center point of the tympanic membrane, representing the projection from the manubrium of the malleus. The **cone of light** (a reflected spot of light) radiates from the umbo toward the periphery of the tympanic membrane when it is viewed with an otoscope or videootoscope,. The **malleus**, the most lateral bone of the ossicular chain in the middle ear, is attached to the fibrous layer of the tympanic membrane and is responsible for pulling the tympanic membrane medially toward the middle ear, thus causing its concave shape when viewed from the external auditory meatus.

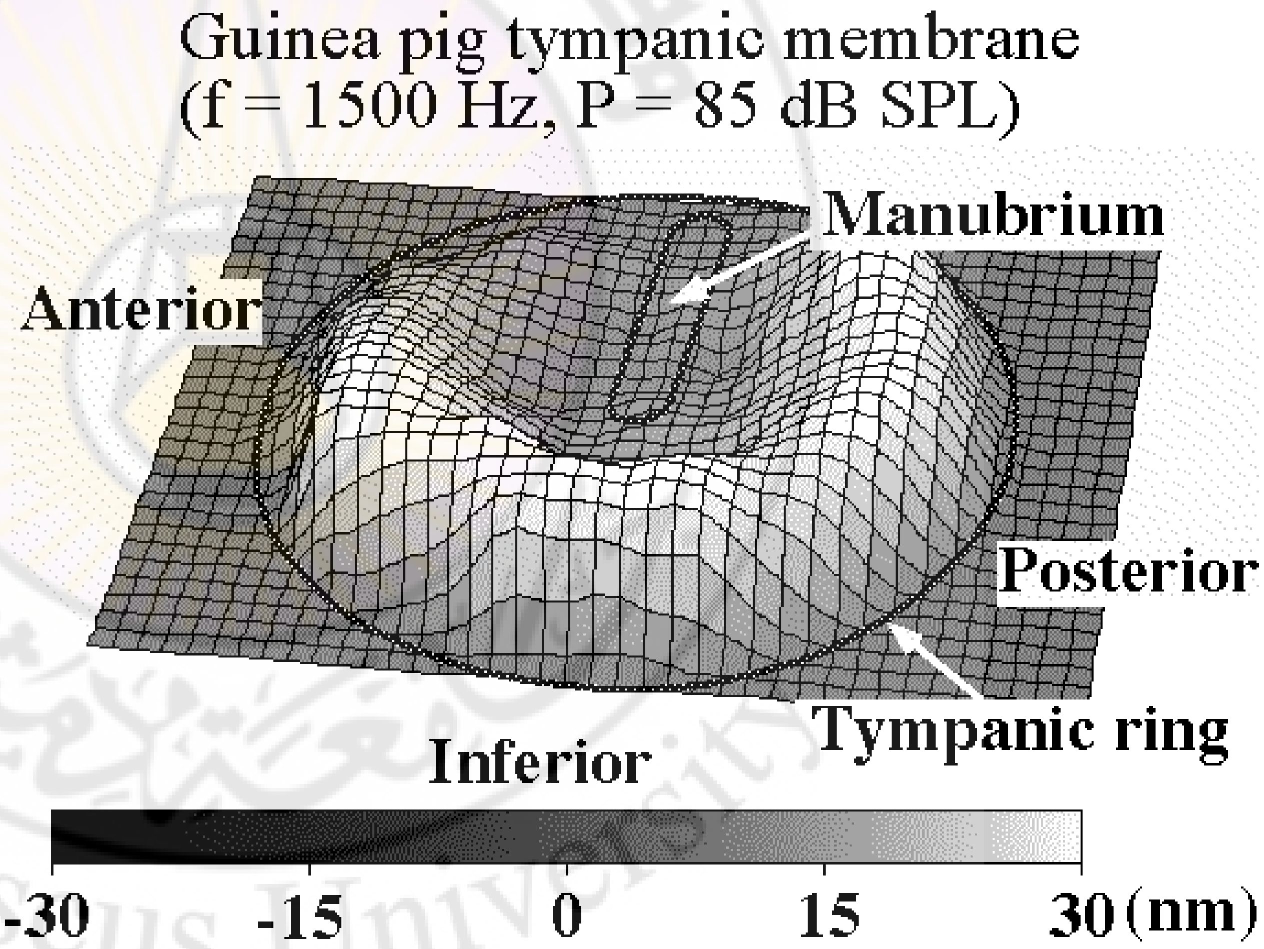


Division of the tympanic membrane into quadrants

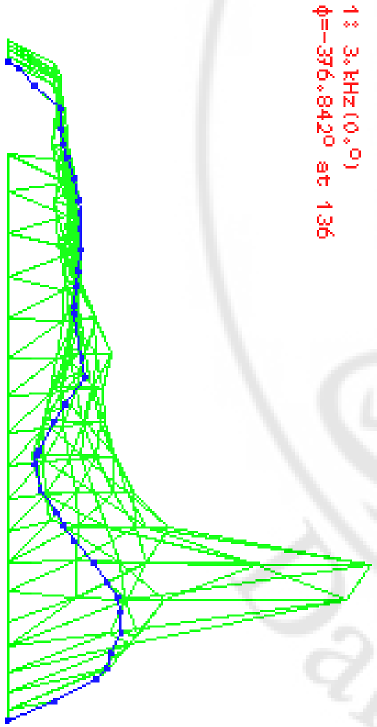


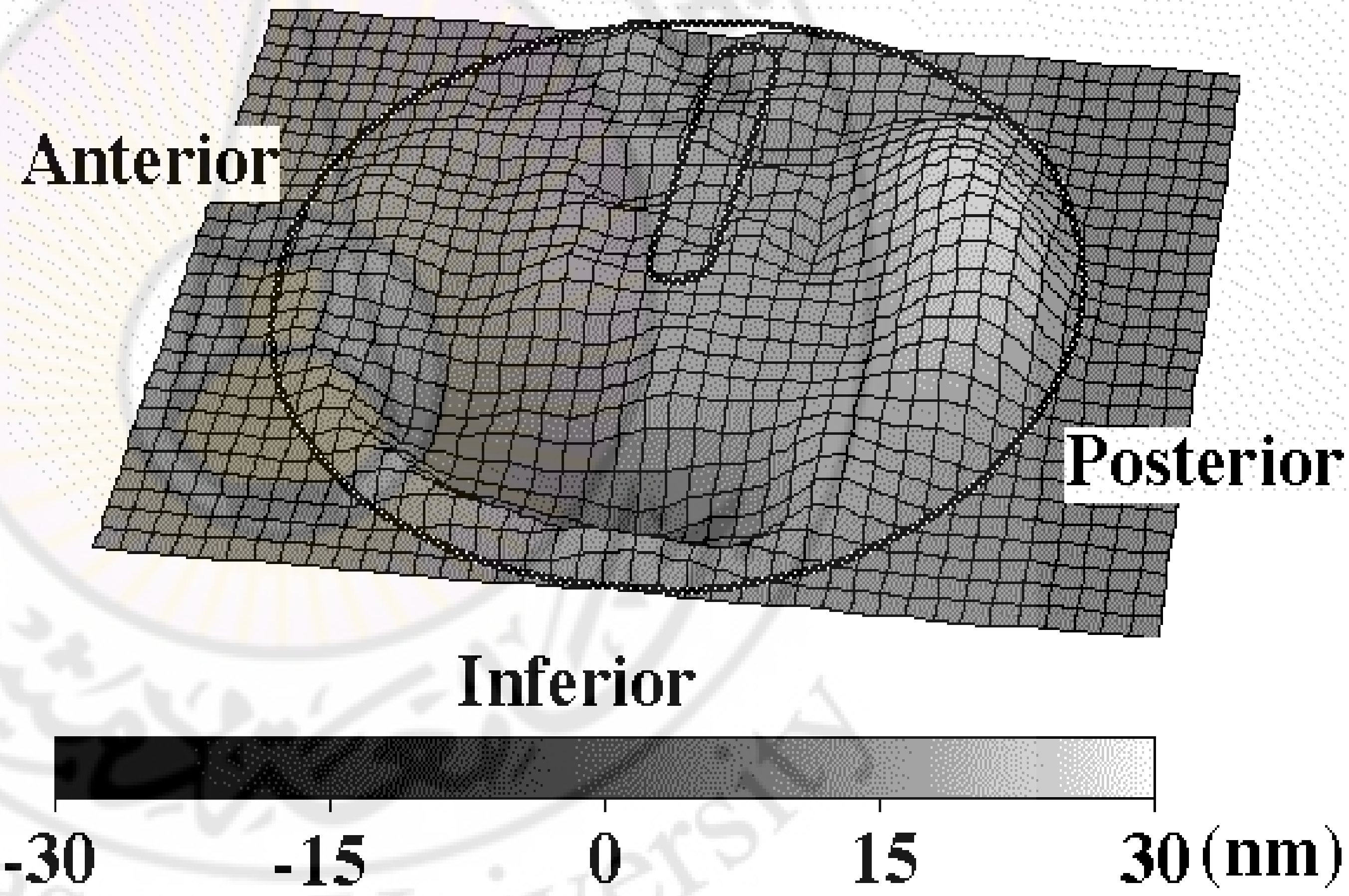
TM movement

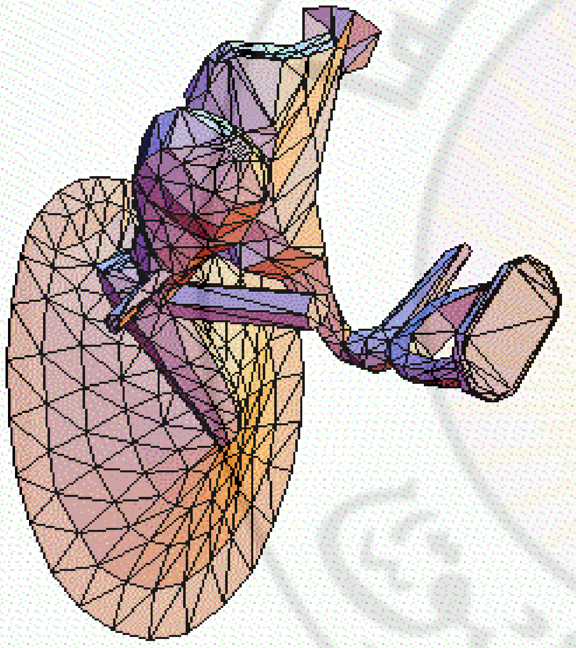



Guinea pig tympanic membrane
(f = 1500 Hz, P = 85 dB SPL)
Manubrium
Anterior
Posterior
Tympanic ring
Inferior
-30
-15
0
15
30 (nm)

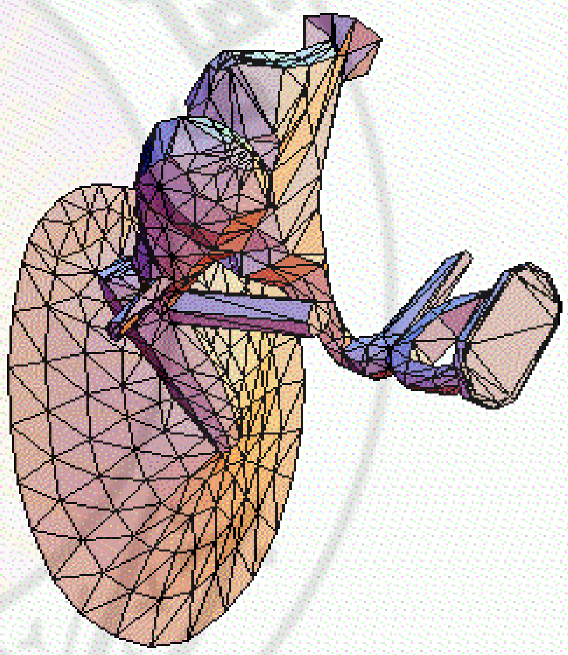
Guinea pig tympanic membrane
(f = 2500 Hz, P = 70 dB SPL)







High frequency

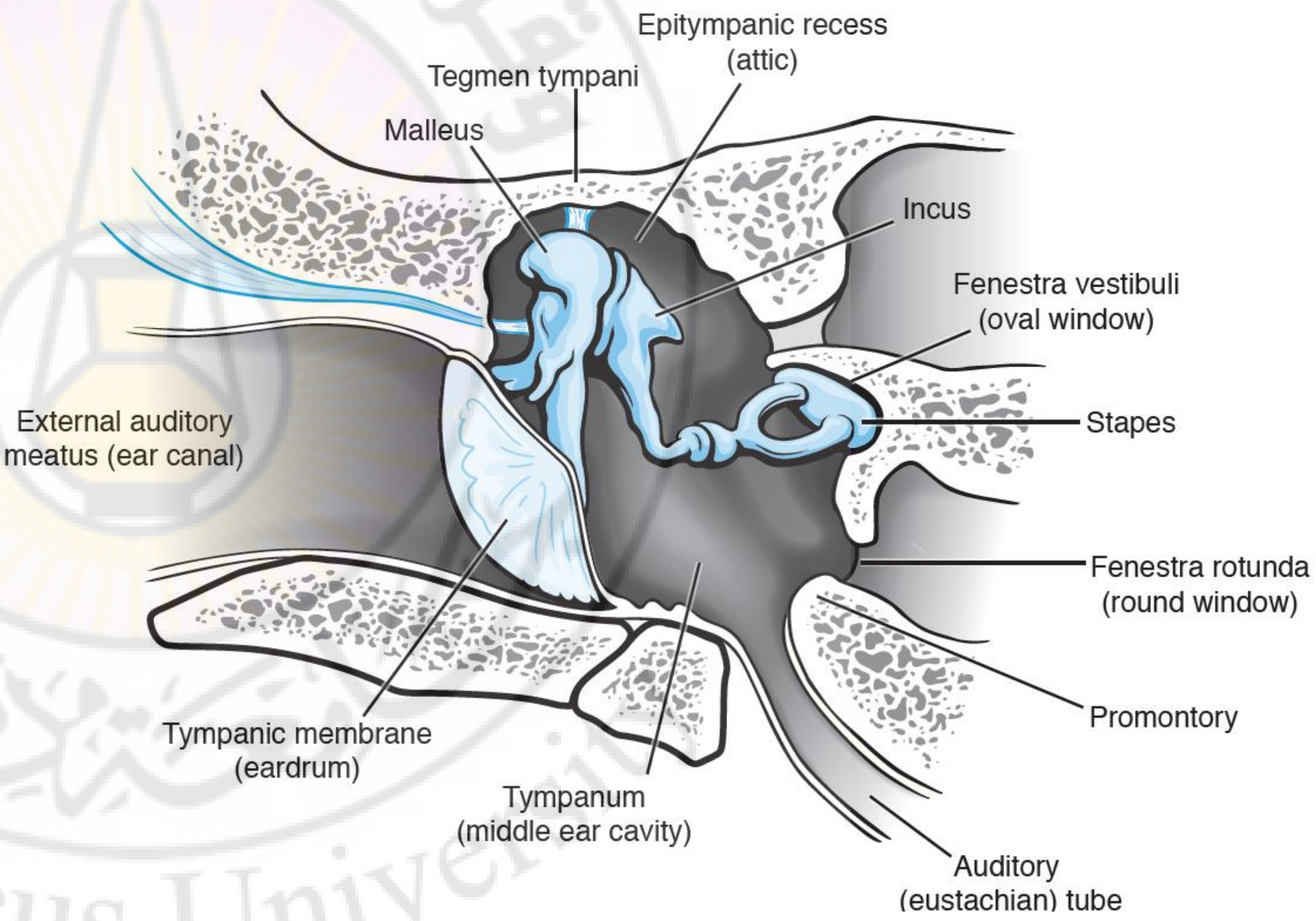


Low Frequency

The middle ear space

Airborne sound is transduced to mechanical energy as a result of the collection of sound energy by the tympanic membrane and subsequent movement of the three tiny ossicles within the middle ear.

The adult middle ear is a hollow, air-filled cavity approximately 0.5 inches (1.5 cm) high and wide and about 0.25 inches (0.5 cm) in depth (lateral to medial) located behind the tympanic membrane.

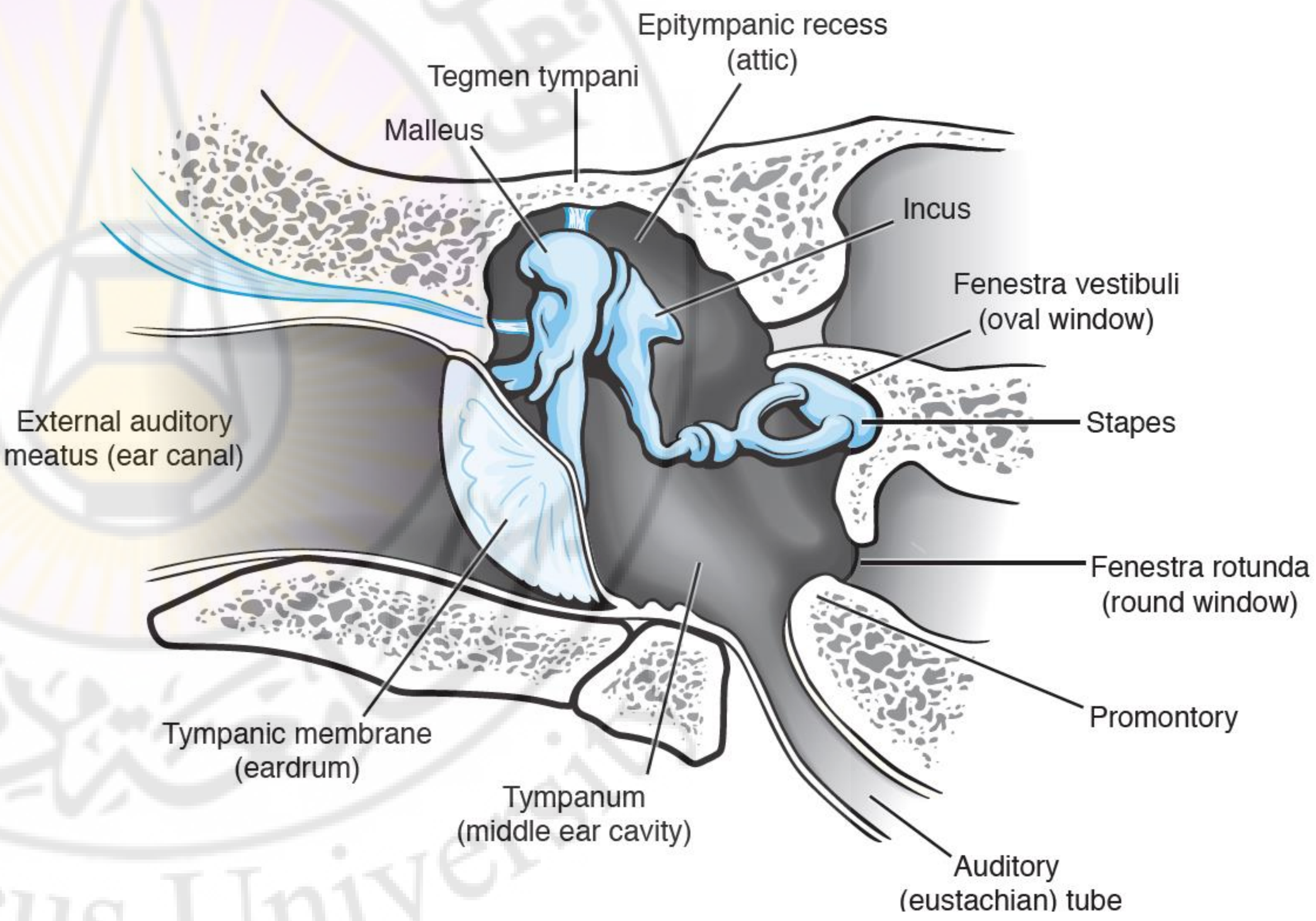


The middle ear space

The most medial portion of the middle ear cavity separates the middle ear from the inner ear.

It contains two openings into the inner ear: the **oval window** (fenestra vestibuli) and the smaller **round window** (fenestra rotunda), which lies inferior to it.

It also contains the **promontory**, a bump below the round window that allows extra room on the inner ear side for the first turn of the inner ear's cochlea.

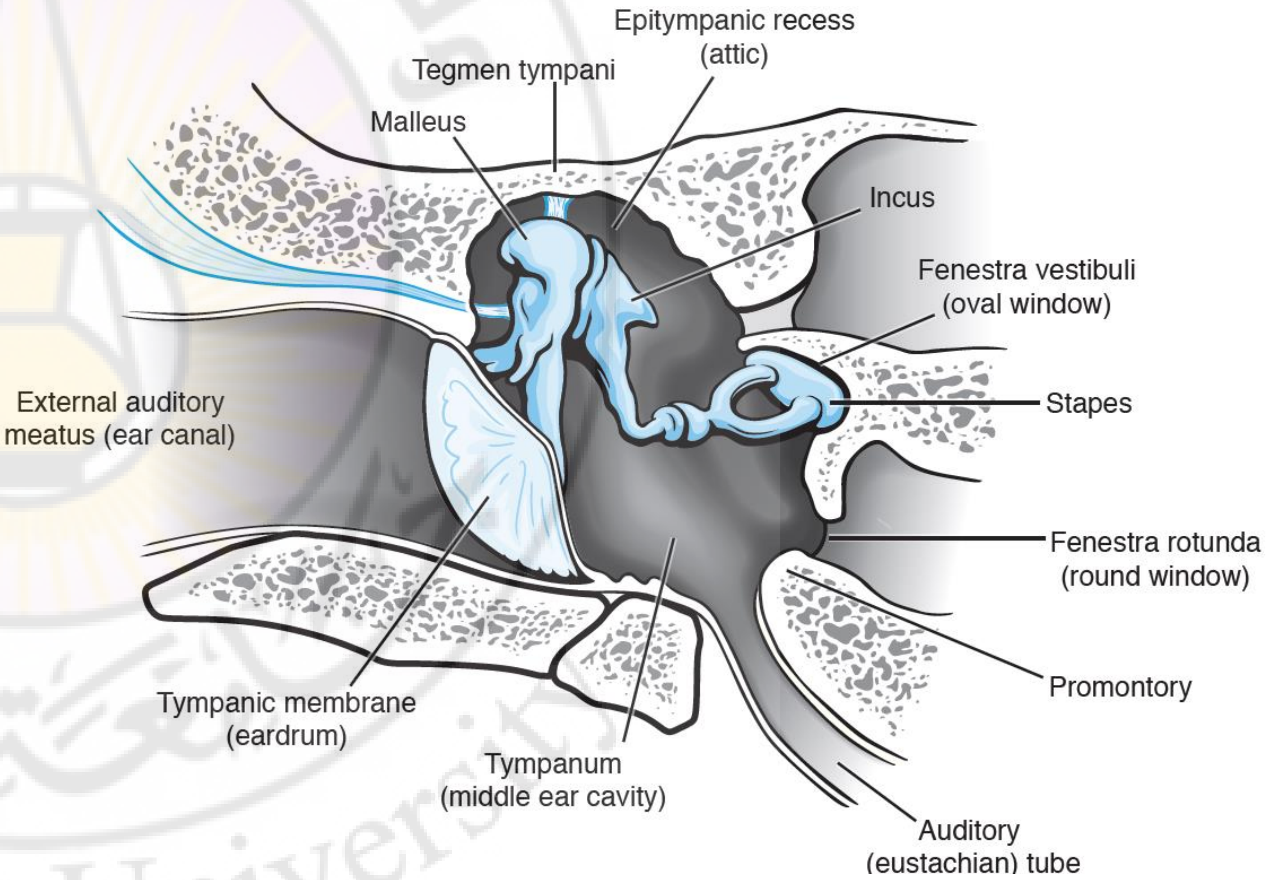


The middle ear space

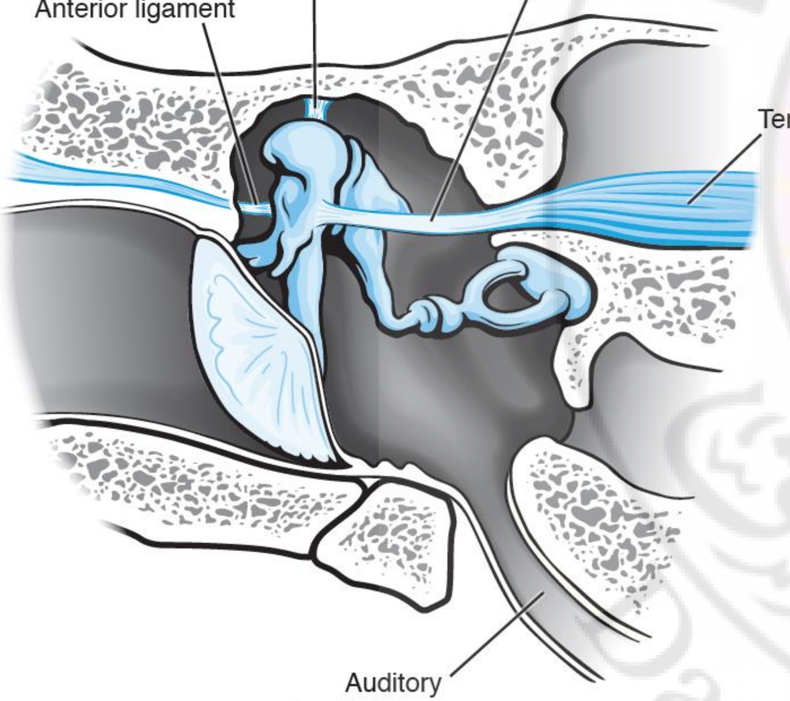
Superior to the oval window is **cranial nerve VII (facial nerve)** as it passes through the middle ear.

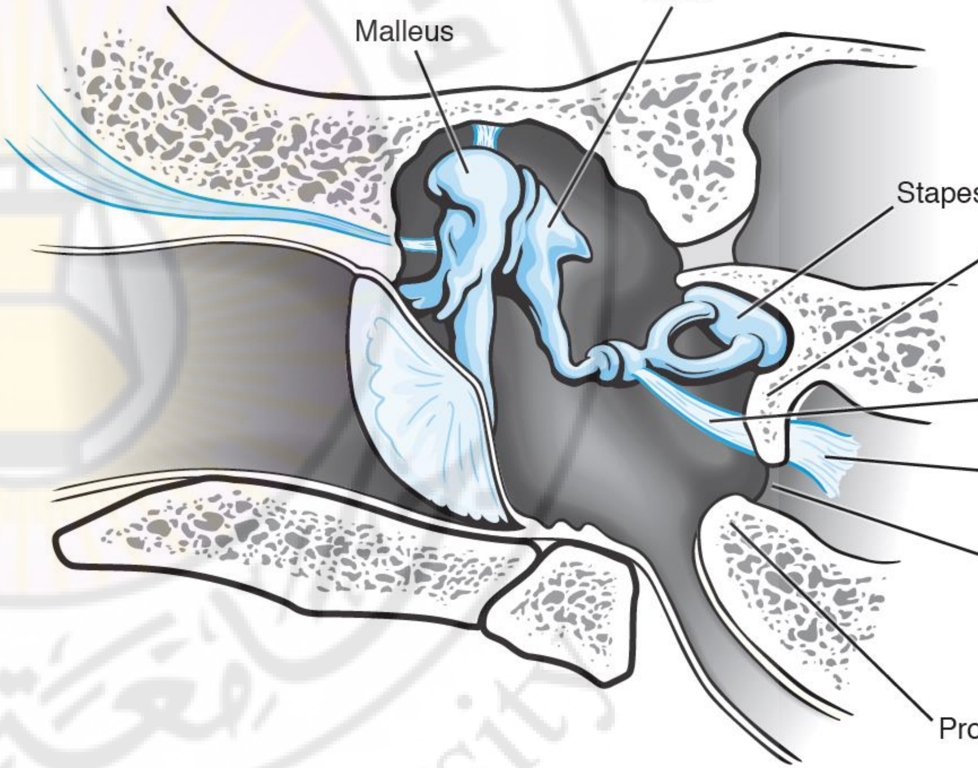
The **chorda tympani**, a branch of the facial nerve, passes through the middle ear (between the ossicles) and carries information about the sense of taste from the anterior portion of the tongue to the central nervous system.

The lateral side of the middle ear cavity is formed largely by the **tympanic membrane**, as well as a section of bone superior to the membrane in the **epitympanic recess (attic)** region of the middle ear cavity.



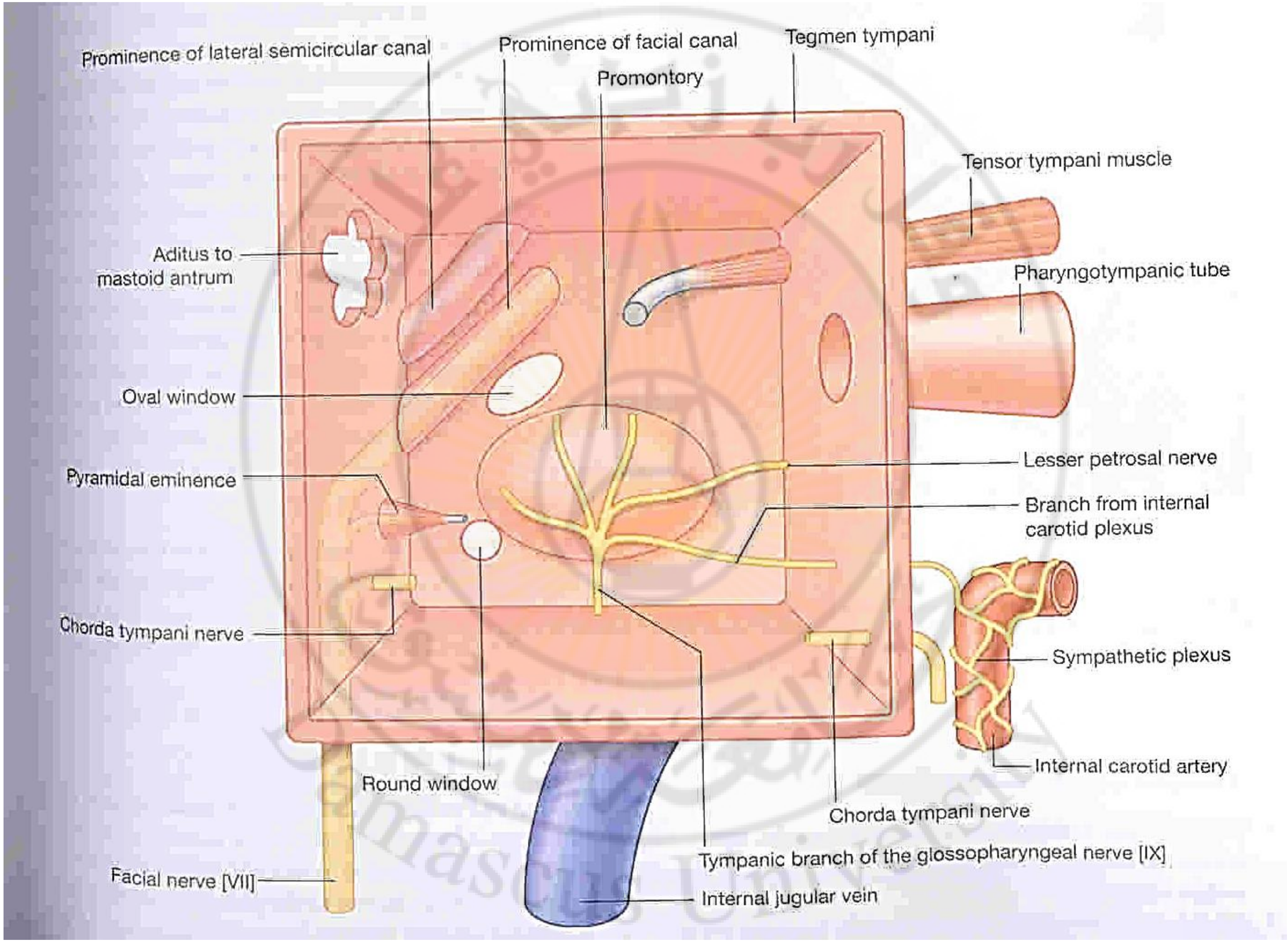
Location of the stapedius and tensor tympani muscles





The **tensor tympani muscle** is contained within a small cavity in the portion of the **temporal bone** that forms the anterior side of the middle ear cavity

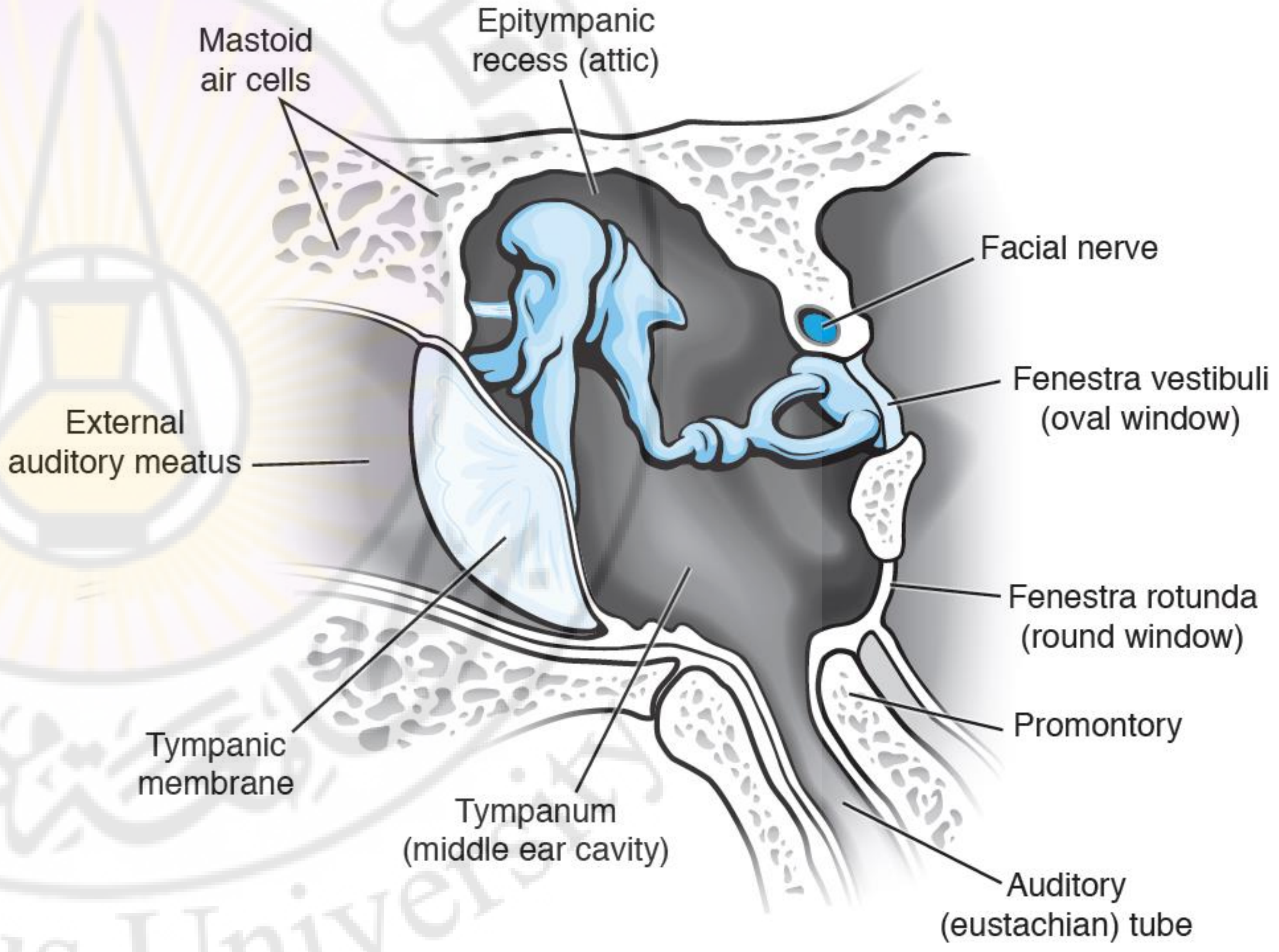
The posterior side of the middle ear cavity contains the **pyramidal eminence**, in which lies the middle ear's **stapedius muscle**


Prominence of lateral semicircular canal
Prominence of facial canal
Tegmen tympani
Promontory
Tensor tympani muscle
Aditus to
mastoid antrum
Pharyngotympanic tube
Oval window
Lesser petrosal nerve
Pyramidal eminence
Branch from internal
carotid plexus
Chorda tympani nerve
Sympathetic plexus
Internal carotid artery
Round window
Chorda tympani nerve
Tympanic branch of the glossopharyngeal nerve [IX]
Facial nerve [VII]
Internal jugular vein

Auditory (Eustachian) tube

In the inferior, medial portion of the tympanic cavity lies the orifice (i.e., internal opening) to the **auditory (Eustachian) tube**, which is approximately 35 mm long in adults and connects the middle ear cavity to the nasopharynx, the superior portion of the pharynx (i.e., throat) just above the velum (i.e., soft palate).

Although the auditory tube is usually in a closed position, the muscles in the nasopharynx open it during swallowing, yawning, and sneezing.

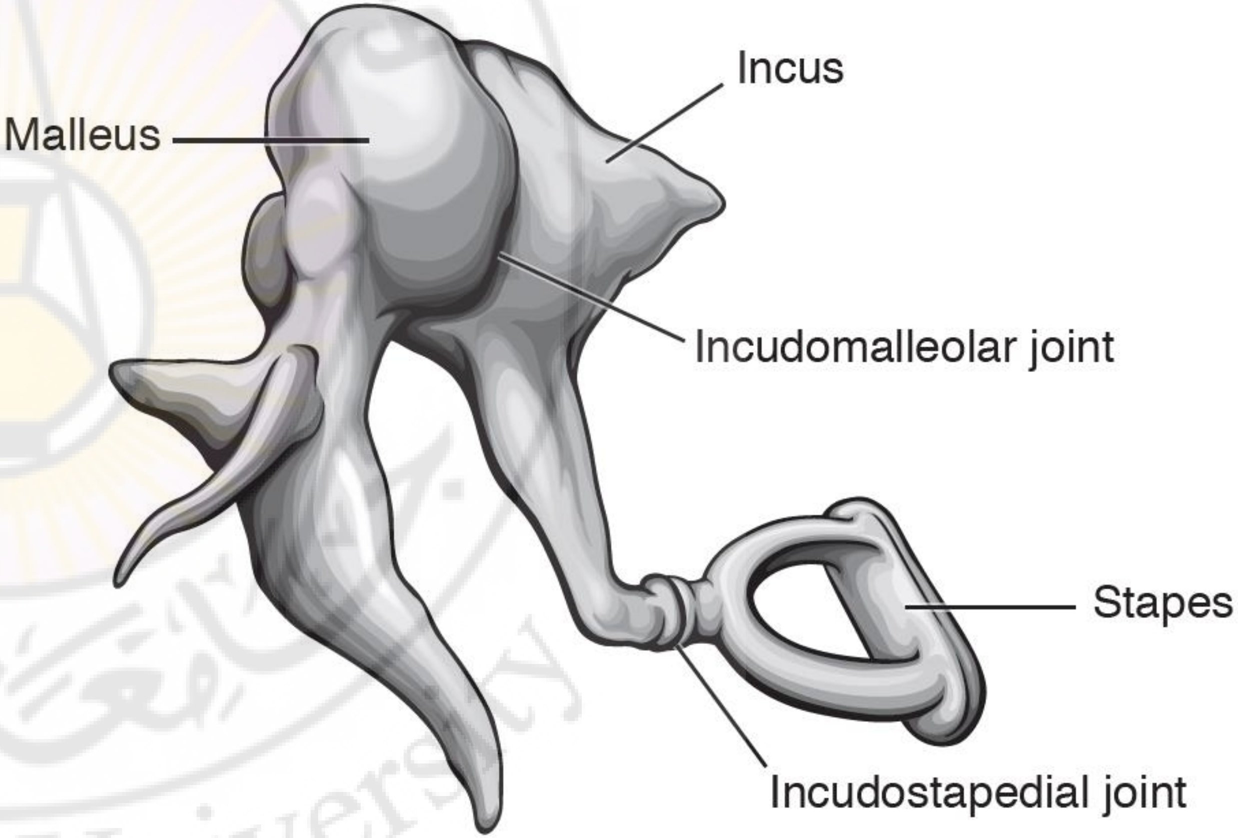


Ossicular chain and connecting joints

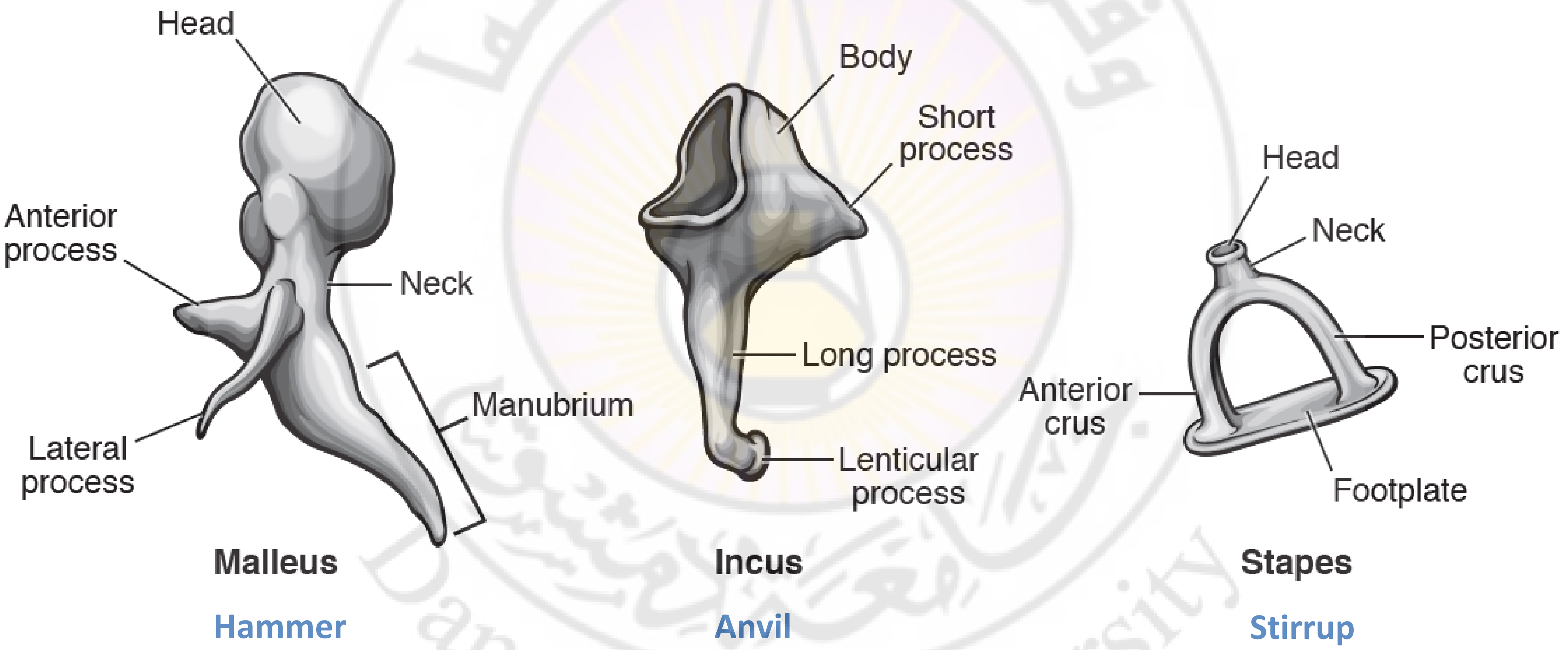
Three small bones (the smallest in the human body) called the ossicles (or ossicular chain) cross the middle ear cavity from its lateral wall to its medial wall for the purpose of transmitting the vibrations of the tympanic membrane to the inner ear mechanism, where the sensory end organ of hearing is located.

The ossicles are held in place by ligaments.

Joining the ossicles to each other are joints: the malleus and incus articulate with each other through the **incudomalleolar** joint, and the incus and stapes articulate through the **incudostapedial** joint



Anatomy of the ossicles: Malleus, Incus, and Stapes



Stapedius muscle connects to the neck **of the stapes** and, on contraction, causes an increase in stiffness of the ossicular chain.

وقل رب زدني علما

جامعة دمشق

Damascus University

Impedance Mismatch

The footplate of the stapes rests in the oval window, contacting the dense fluid of the inner ear called **perilymph**.

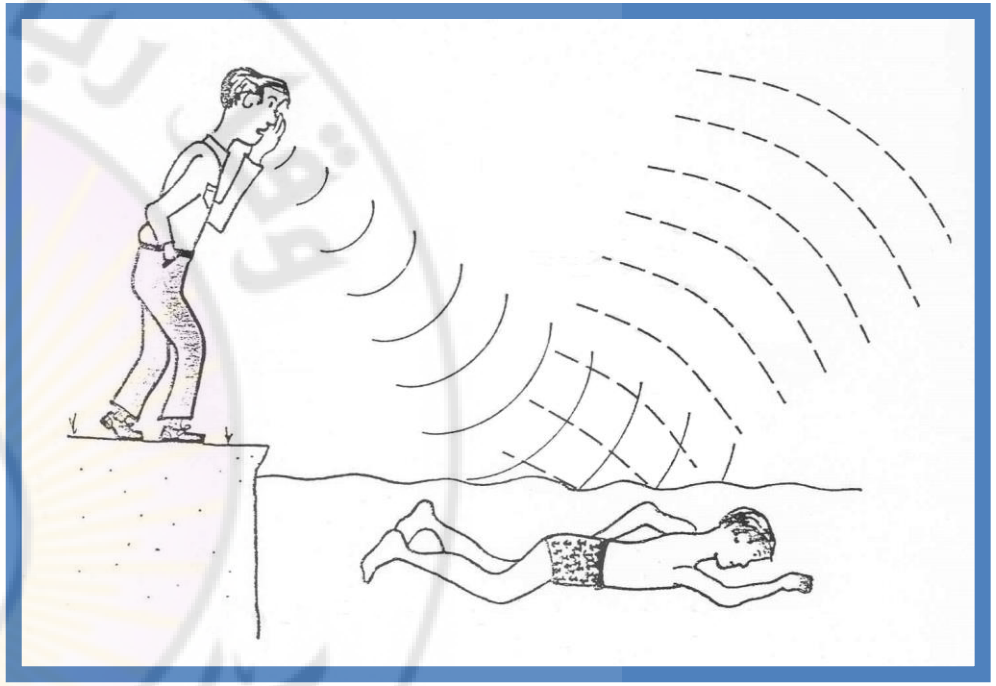
As with all fluids, perilymph has very high impedance (i.e., opposition to energy flow by a medium). When sound reaches a high-impedance medium, little is absorbed, with the majority reflected away.

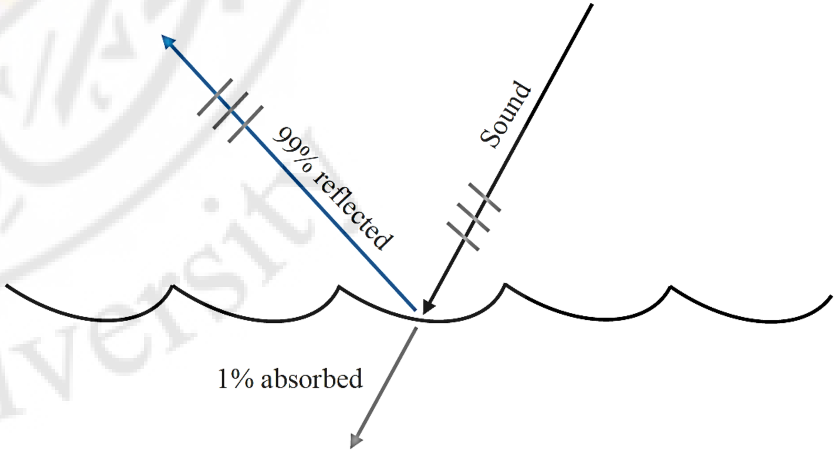
Impedance of any medium is determined by three characteristics of the medium:

Mass

Stiffness

Resistance.





Middle ear Impedance matching

The **impedance-matching function** consists of three mechanical advantages that dramatically increase the energy per unit area at the fenestra vestibuli relative to the energy per unit area at the tympanic membrane.

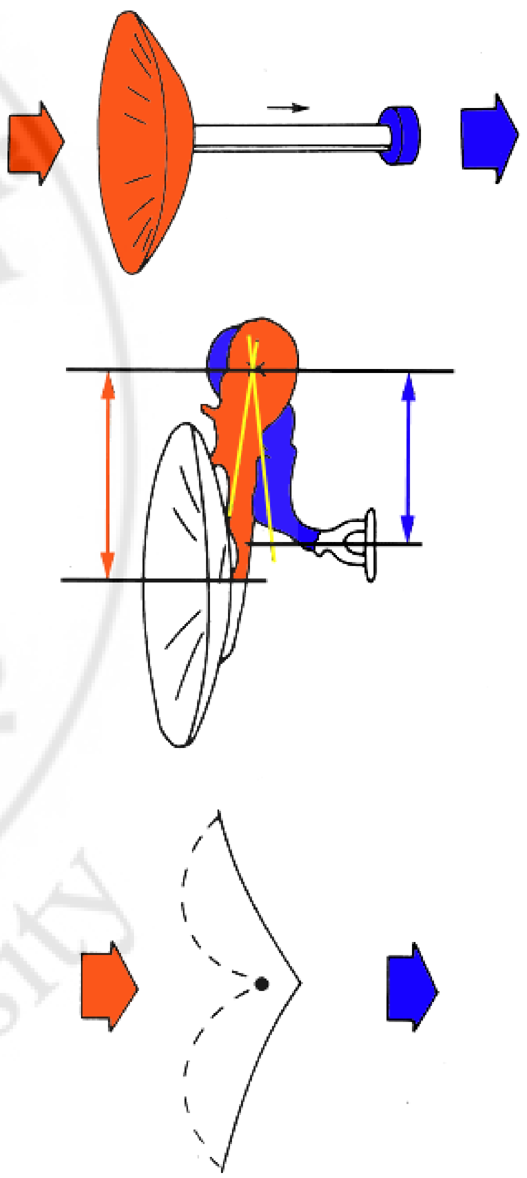
The three factors are:

(a) the condensation effect (or areal ratio),

(b) the lever action of the malleus and incus, and

(c) the curved-membrane buckling mechanism of the tympanic membrane.

Together these factors are referred to as the **middle ear transformer** (or impedance-matching transformer).



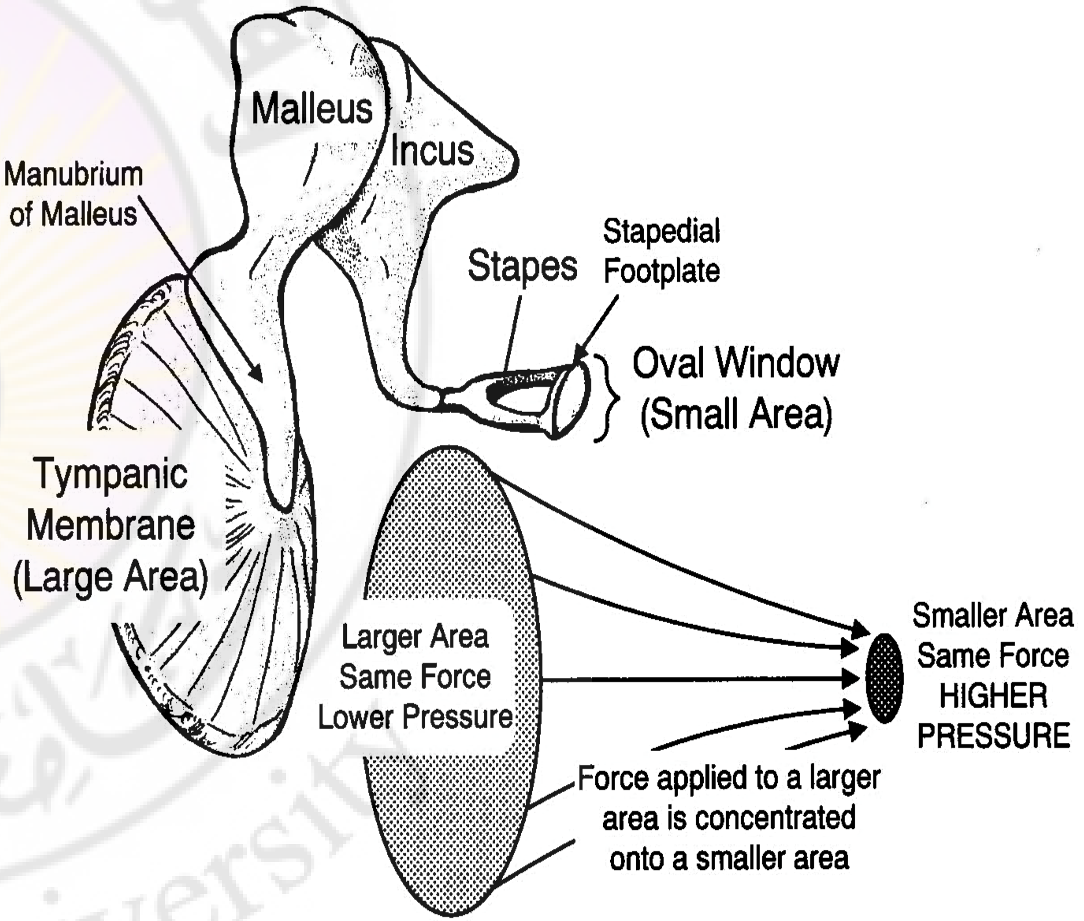
Condensation Effect (Areal Ratio)

The effective area of the tympanic membrane (i.e., pars tensa) is approximately 17 times larger than that of the footplate of the stapes.

Therefore, sound transferred through the middle ear is collected over the relatively large effective area of the tympanic membrane and applied to the relatively small area of the footplate of the stapes through the ossicular chain.

Because pressure is equivalent to force per unit of area (p=F/A), if force is held constant and area is reduced, there must be an increase in pressure. This is called the condensation effect (or **areal ratio**).

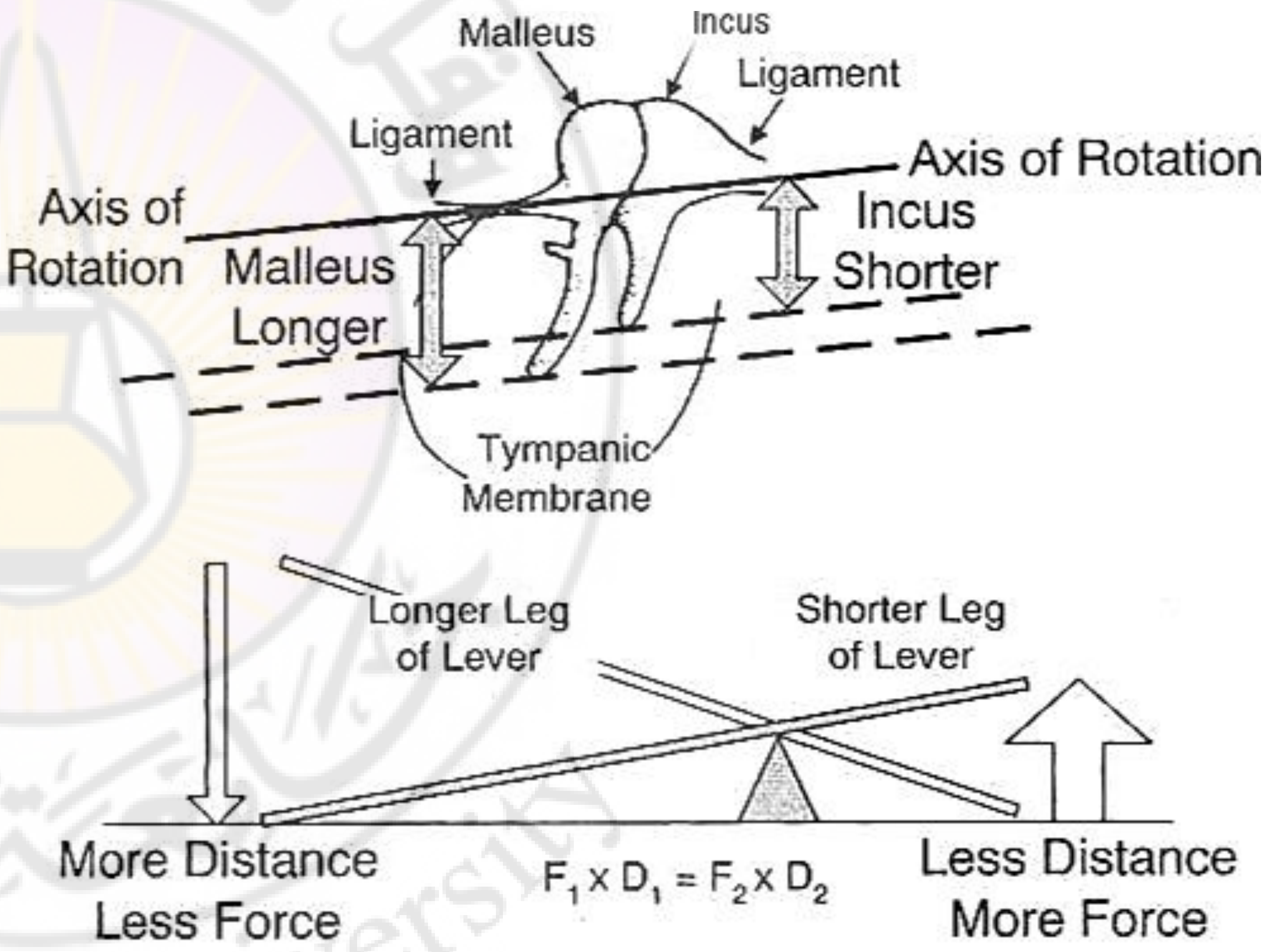
The increase in sound pressure is equivalent to an approximately 24.6 dB improvement in auditory sensitivity.



Lever Action of Malleus and Incus

In the middle ear, the malleus and incus form a lever, with the manubrium of the malleus being 1.3 times the length of the long process of the incus, resulting in movement reduction from the malleus to the incus in a ratio of 1.3 to 1.

This advantageous lever ratio results in sound amplification of **approximately 2 dB** as sound energy crosses the ossicular chain

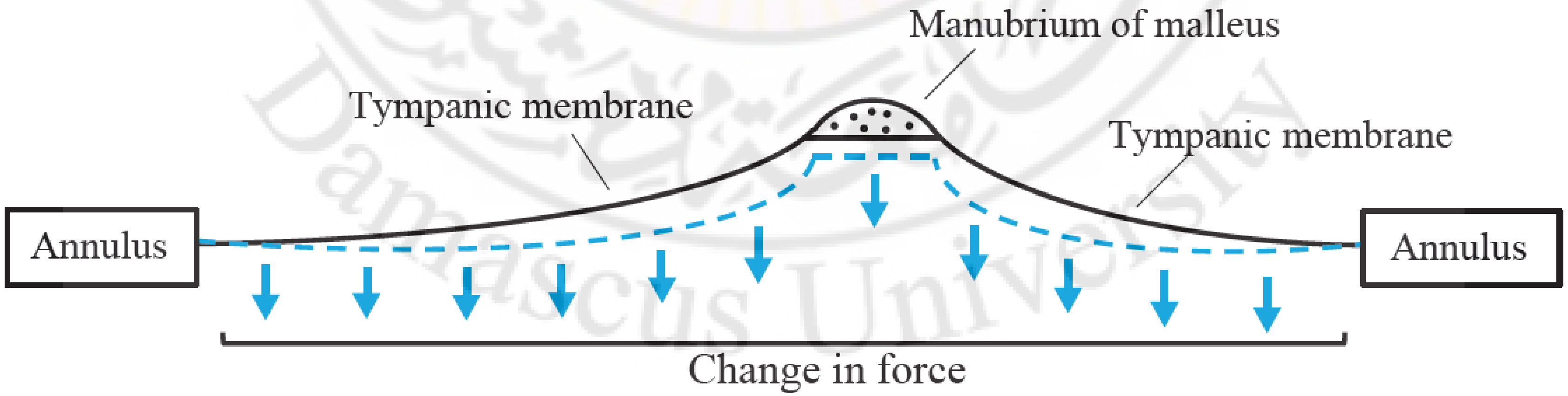


Curved-Membrane Buckling Principle

With the outside edge of the tympanic membrane firmly attached to the annulus and the membrane curving medially to attach to the manubrium of the malleus, the reaction to force is quite different in areas between the annulus and the manubrium than at the manubrium itself.

A given change in force will result in greater displacement of the tympanic membrane than the manubrium of the malleus. The displacement is less at the manubrium, so the force will be greater; that is, the tympanic membrane itself acts as a lever, with the manubrium of the malleus as a fulcrum (i.e., pivot).

Because the edges of the membrane are held firmly by the annulus, they cannot move, enabling the two portions of the tympanic membrane to act in a lever-like manner in force transfer. This mechanical action is estimated to **increase force by a factor of two.**



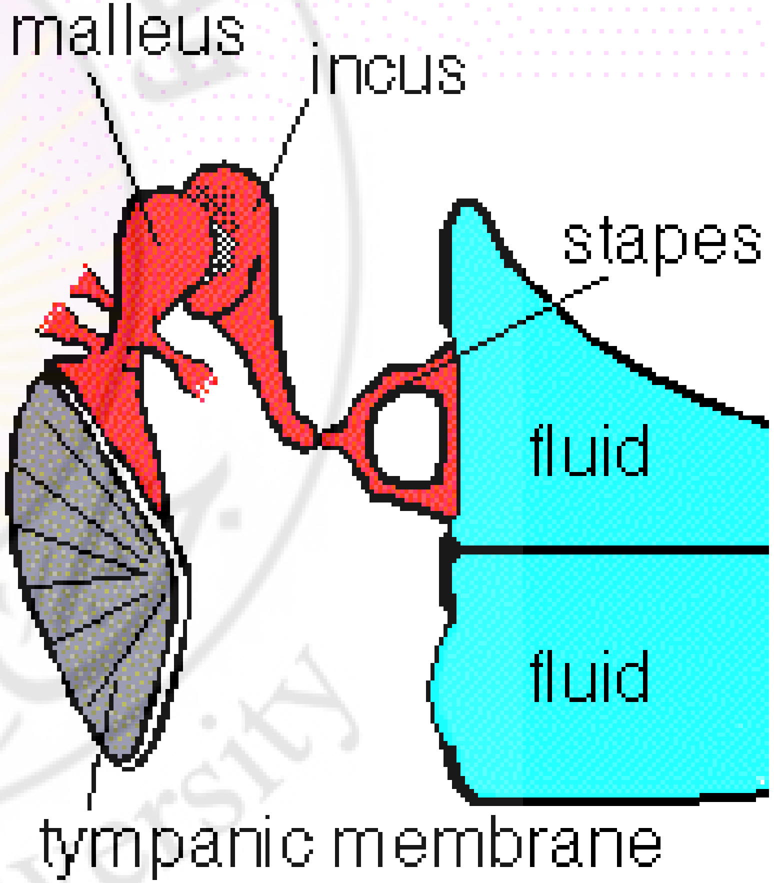
In summary…

The transformer action of the middle ear provides approximately **32.9 dB of gain** through the three mechanical advantages described. This efficiently and effectively matches the impedance of air to that of the cochlear fluids.

17 (areal ratio) x 1.3 (lever ratio) x
2 (tympanic membrane buckling ratio) = 44.2

To convert to decibel sound pressure level (dB SPL), we apply the following formula:

$20 (\log 10_{10} 44.2) = 20(1.645) = 32.9$ dB SPL

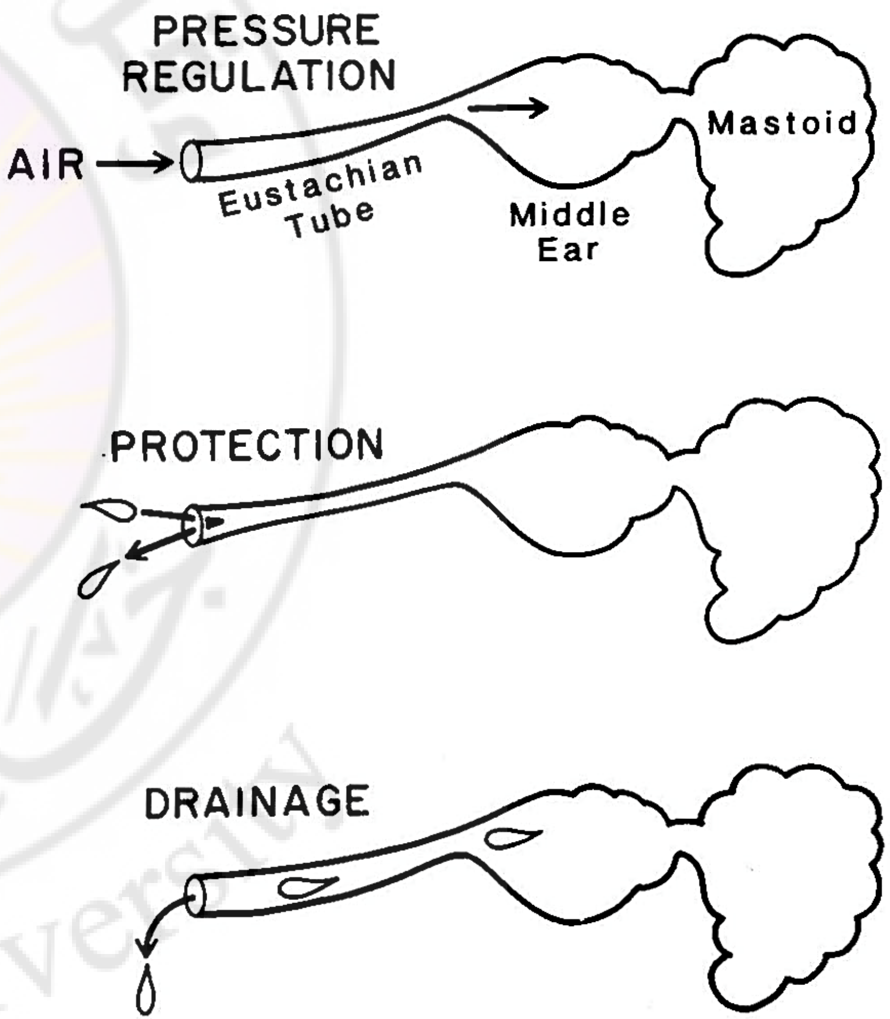


Auditory (Eustachian) Tube function

(a) Equalize air pressure on the lateral and medial sides of the tympanic membrane,

(b) Provide the air supply needed for metabolism of the middle ear's tissues, and

(c) Drain middle ear secretions into the nasopharynx.



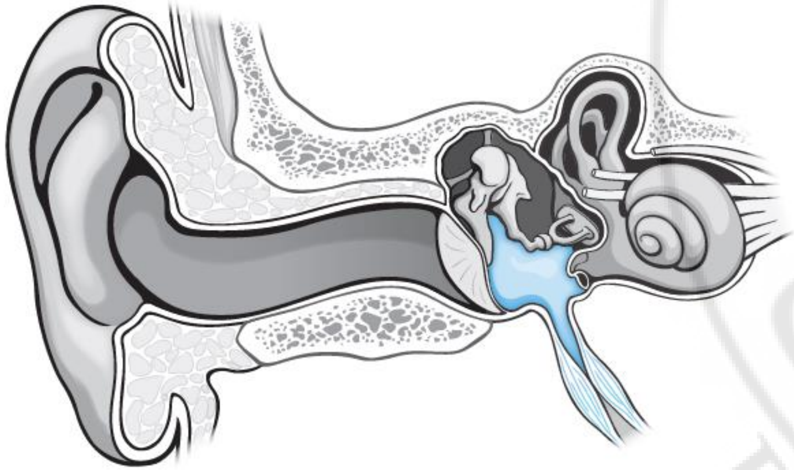
Auditory (Eustachian) Tube function

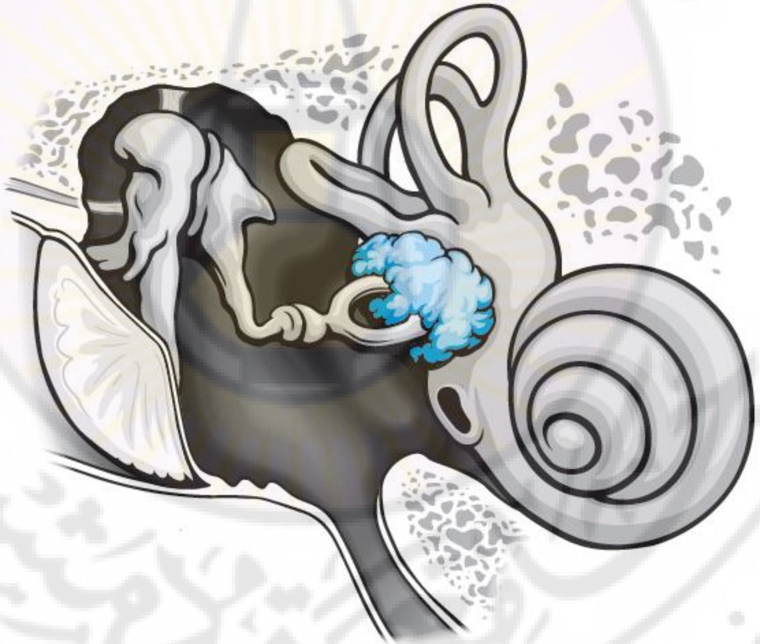
The auditory tube of a child is significantly shorter, straighter, and more horizontal than an adult's tube.

Moreover, children spend more time than adults in a reclining position, which reduces the efficiency of this tube, and they have a higher incidence of upper respiratory infections and allergic reactions.

These factors result in children being more susceptible to middle ear problems than adults.

Pathologies of the conductive system impacts its Impedance!





دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Otoacoustic Emissions

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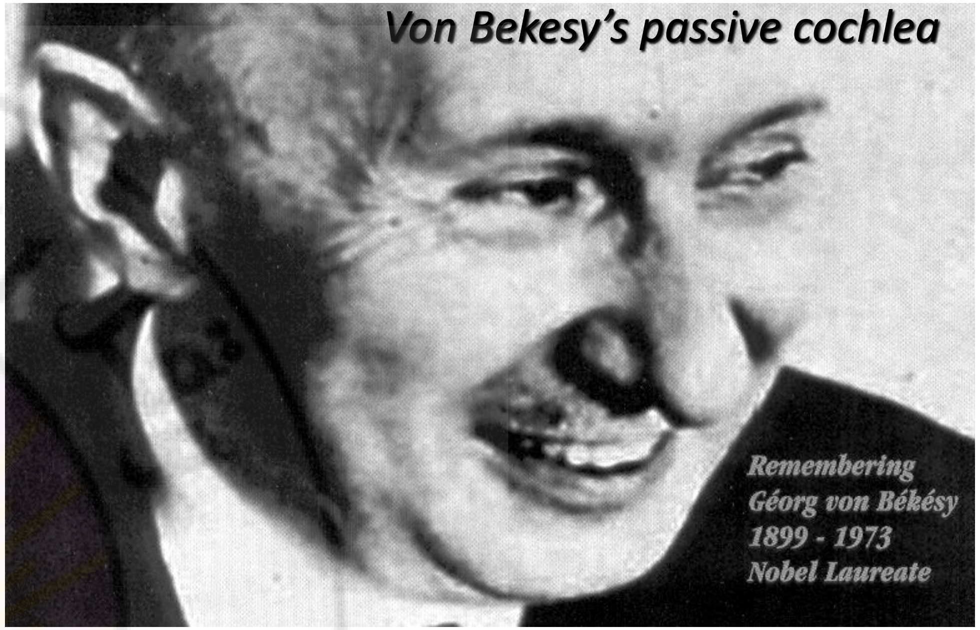
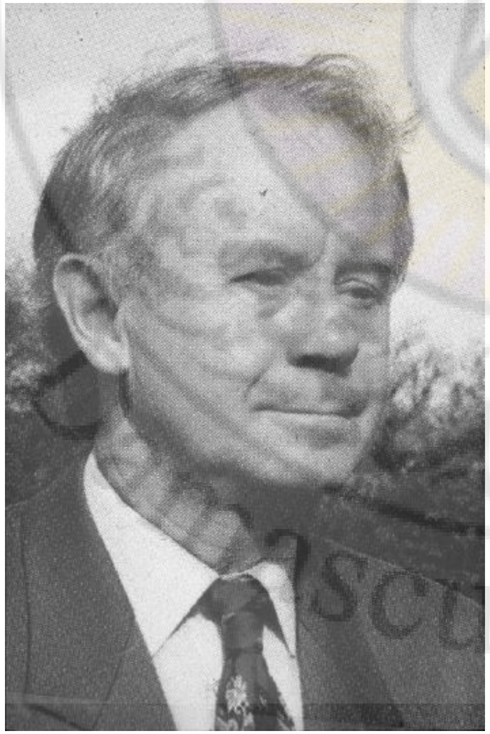
Introduction

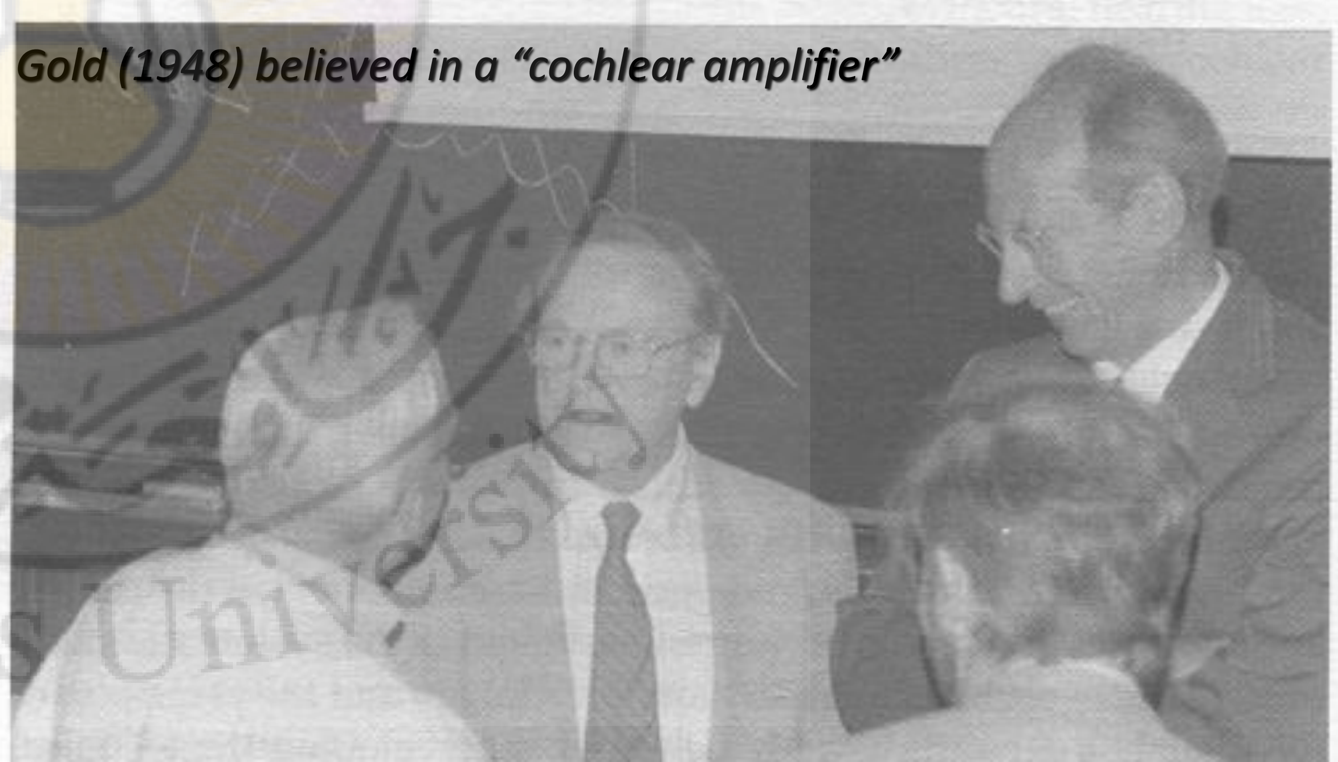
- OAEs are sounds that result from energy generated in the cochlea that are propagated through the middle ear and into the ear canal where they can be measured using a sensitive microphone.

History

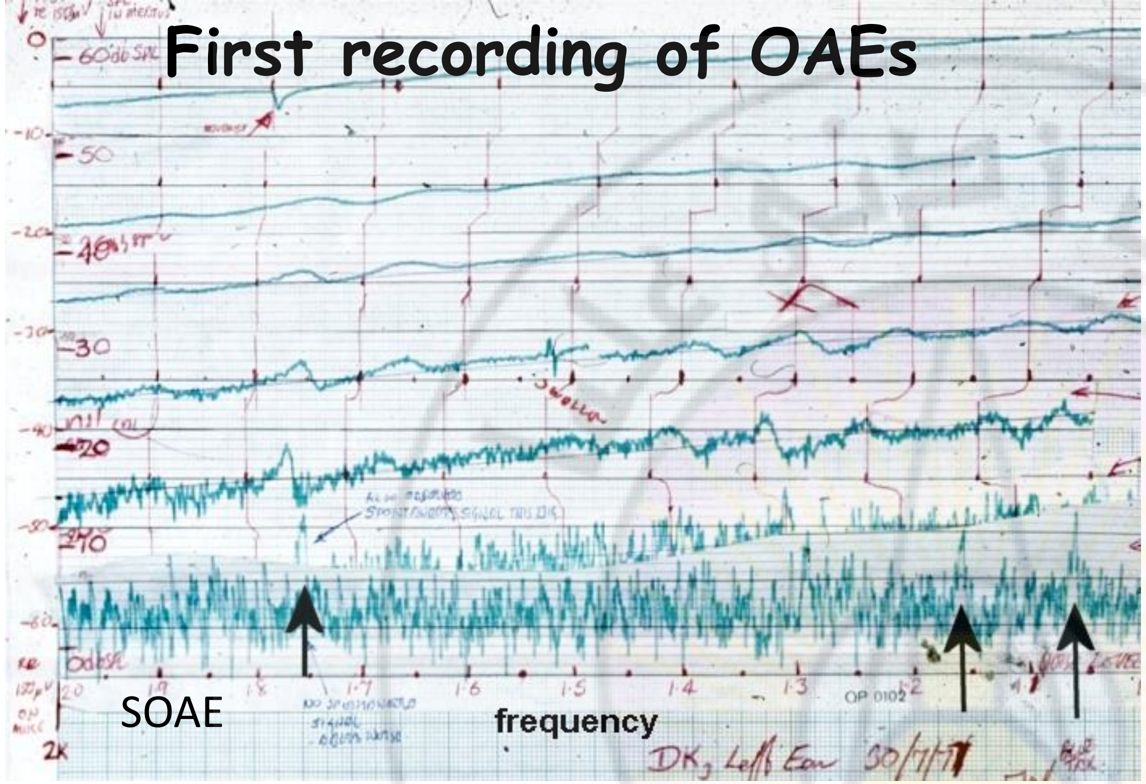
- OAEs were first described by **David Kemp** in 1978, and since that time, OAEs have become a standard part of the diagnostic test battery and a screening for hearing loss.

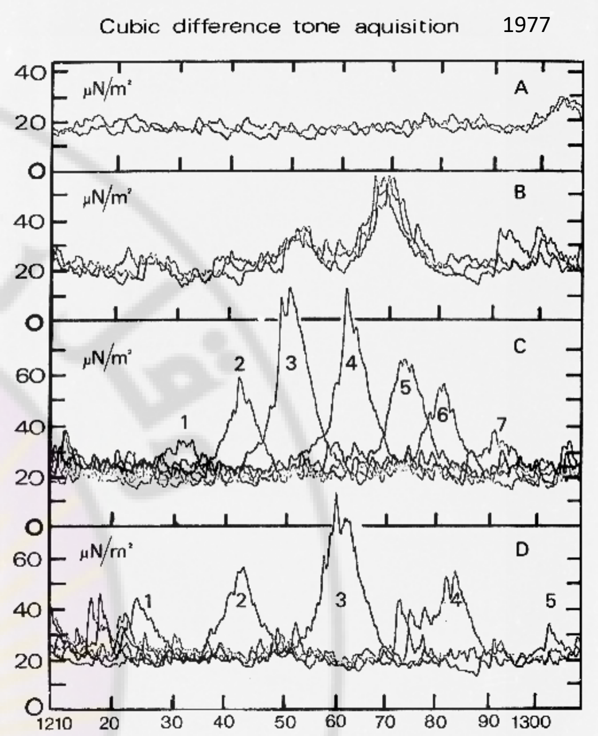






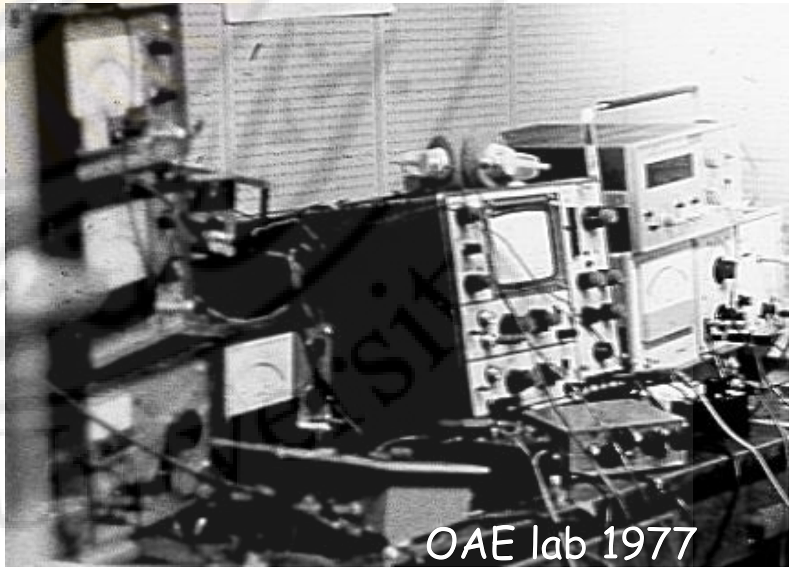
First recording of OAEs





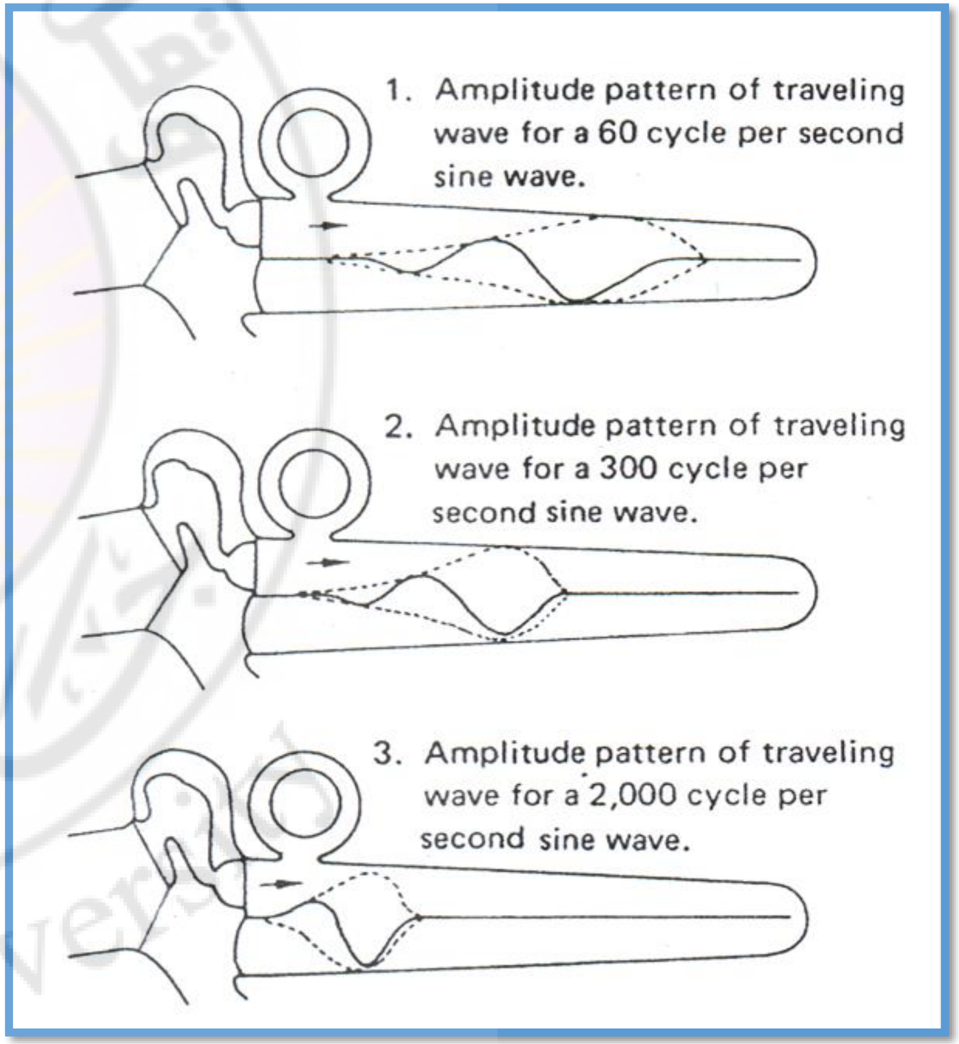
DPOAE

TEOAE



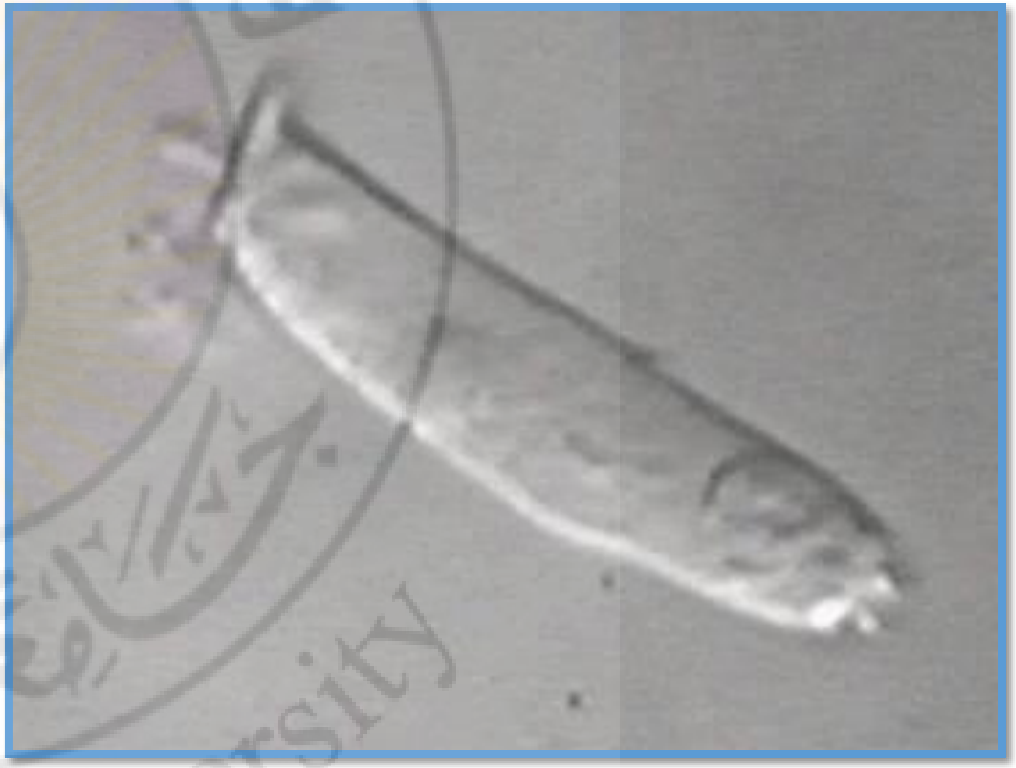
Hypotheses Of OAE Generation

- A healthy, living cochlea demonstrates nonlinear behavior and refined frequency specificity at low stimulus levels, similar to the characteristics demonstrated by individual hair cells and auditory nerve fibers.
- Active biologic mechanisms, often referred to as the **"cochlear amplifier"** are believed to be responsible for the nonlinear characteristics of cochlear responses, as well as the *exceptional sensitivity* and *frequency selectivity* seen in a healthy cochlea as compared to a damaged or dead cochlea.



Hypotheses Of OAE Generation

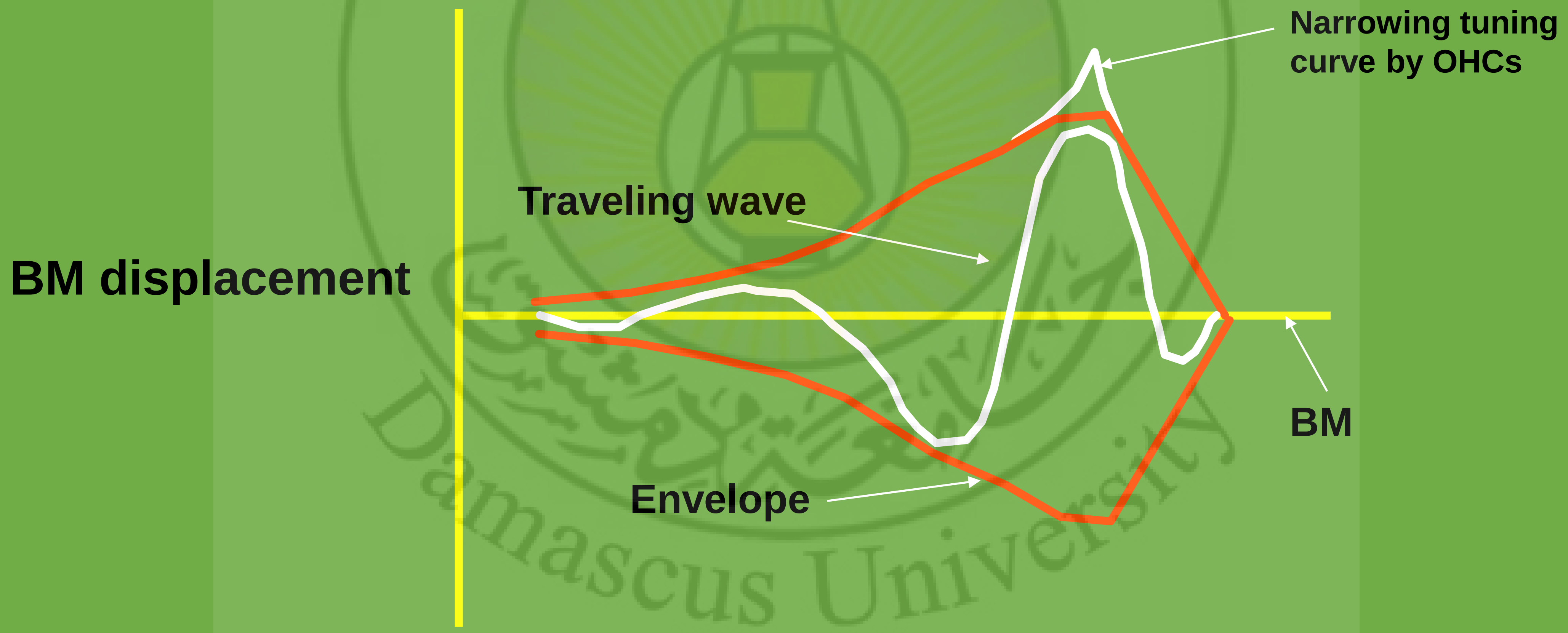
- The cochlear amplifier is hypothesized to contribute additional energy that enhances the vibration of the basilar membrane at the peak of the traveling wave, particularly at low stimulus levels (Davis, 1983).
- Evidence indicates that outer hair cells (OHCs) contribute to this process.
- OAEs measured in the ear canal are thought to be a byproduct of the cochlear amplifier and normal OHC function.

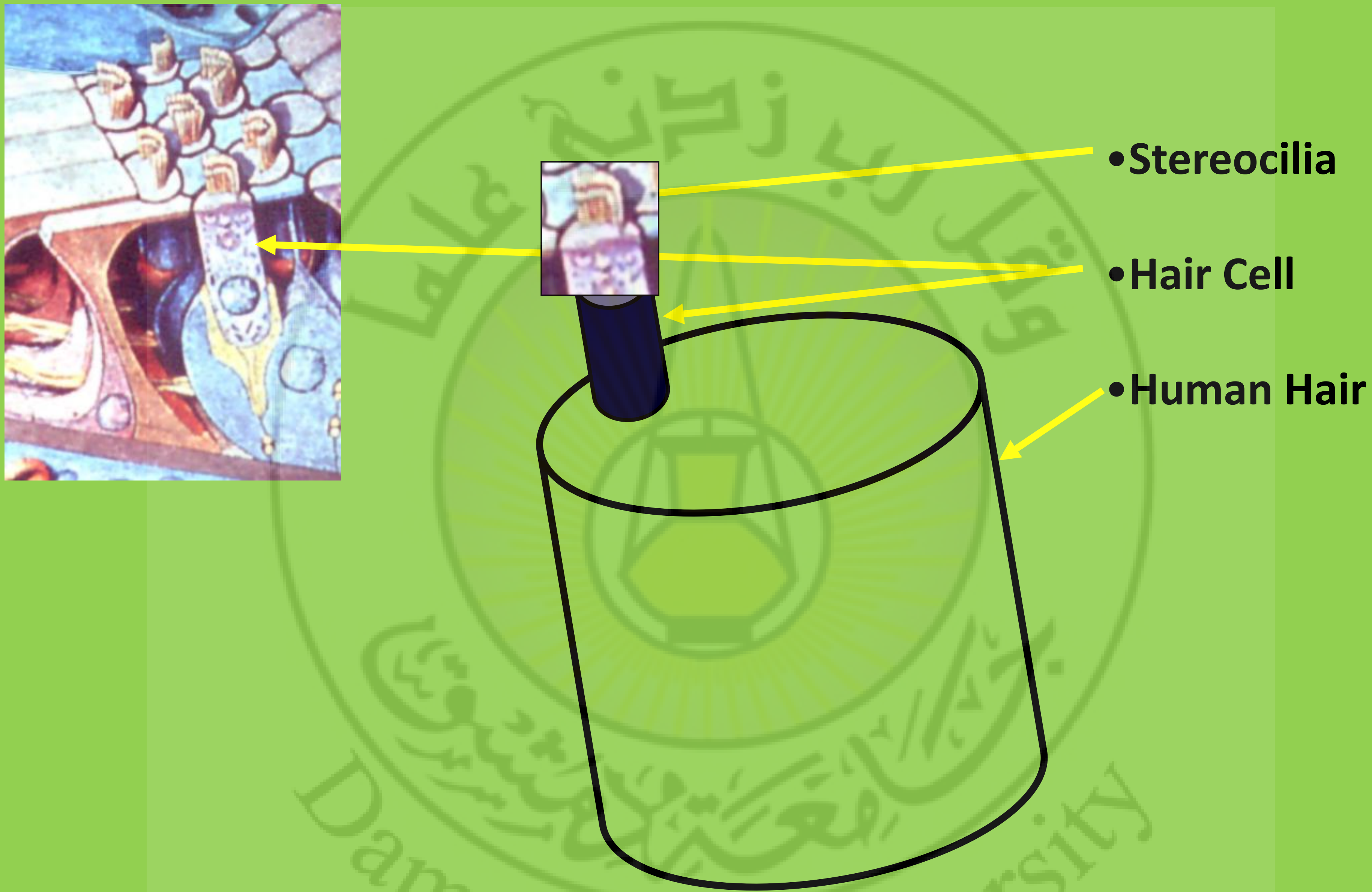


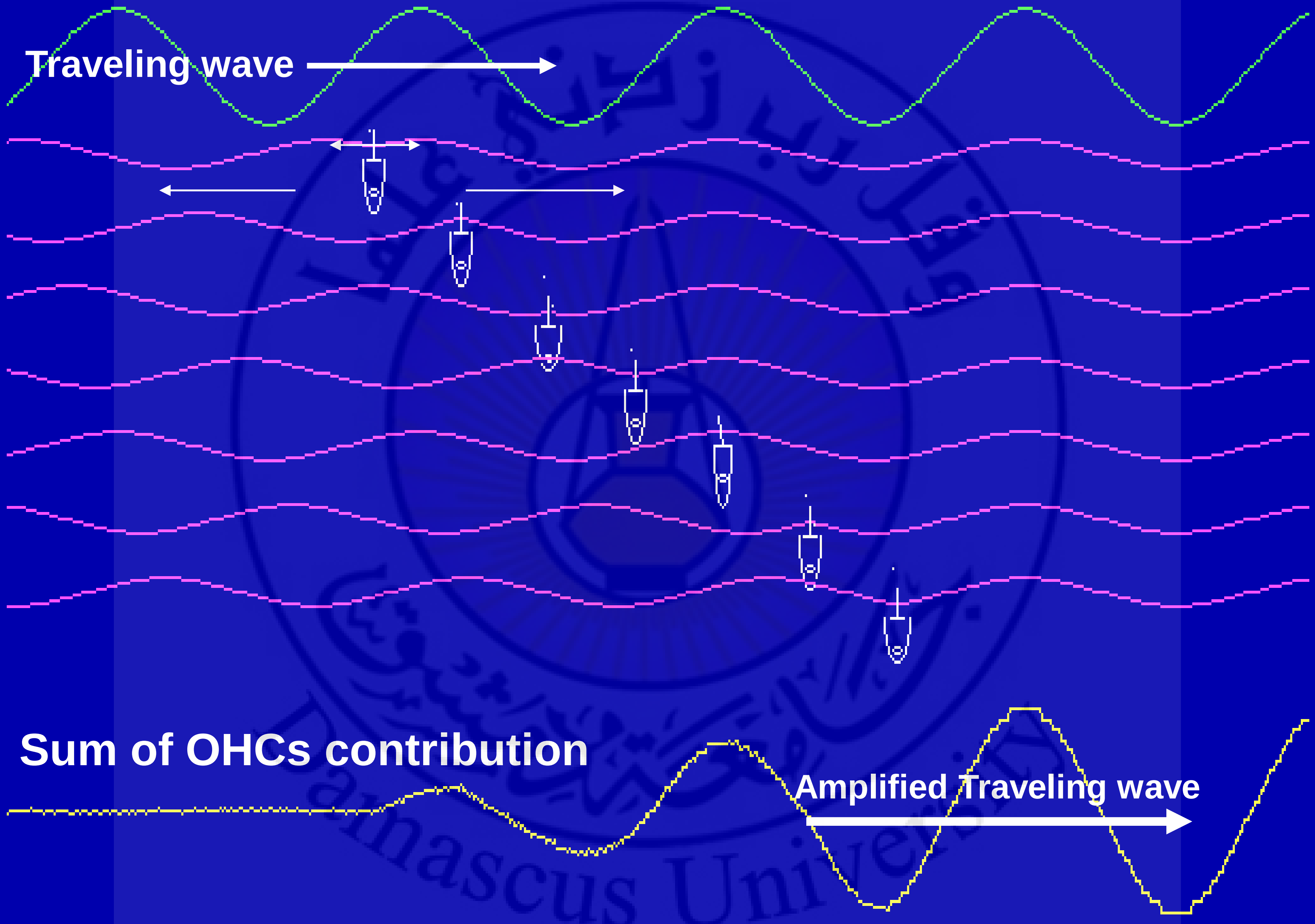
OHCs:

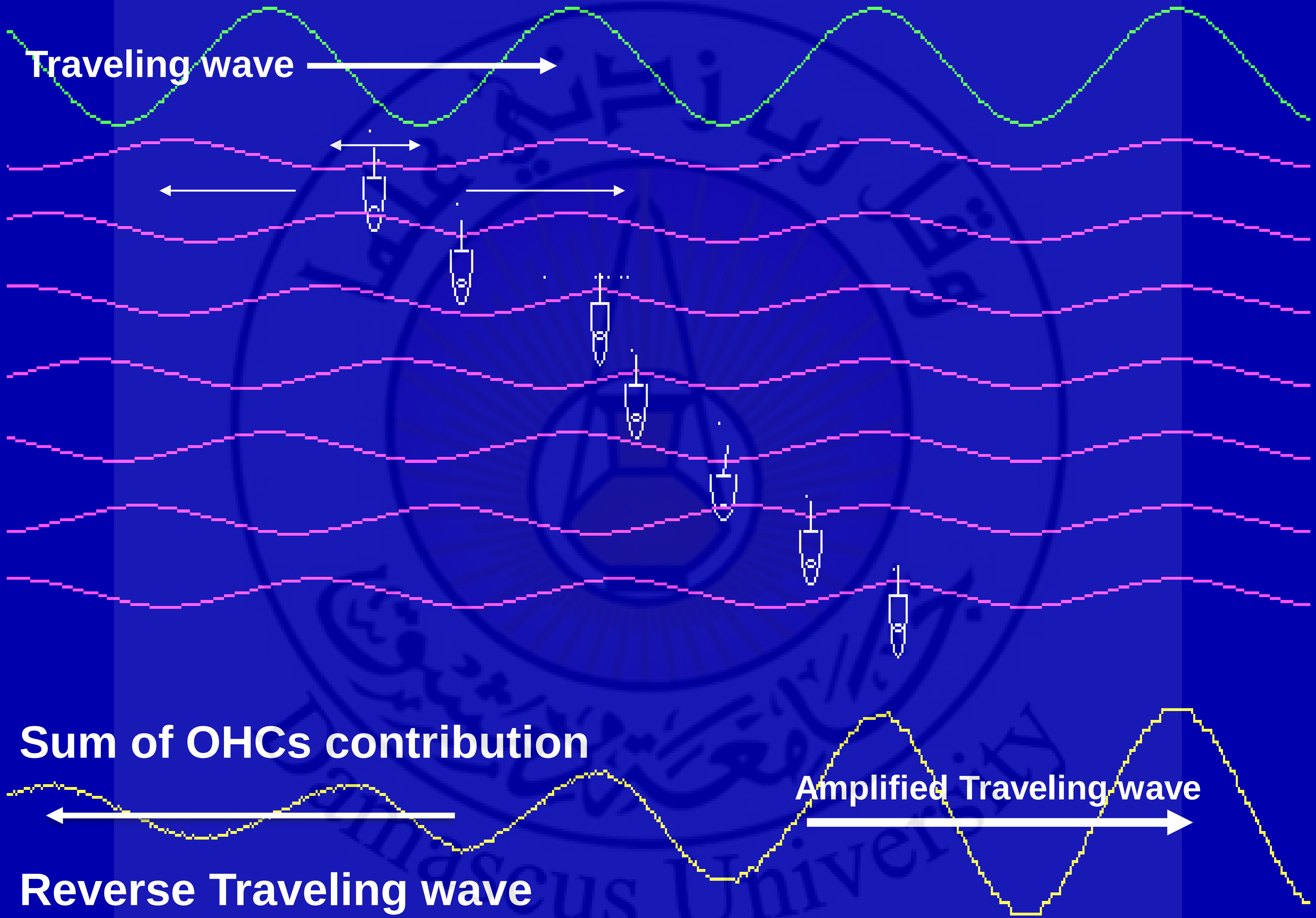
- Exceptional sensitivity
- frequency selectivity

Investigators have reported reduced auditory sensitivity, broader tuning, and abnormal response growth when OHCs are damaged or missing



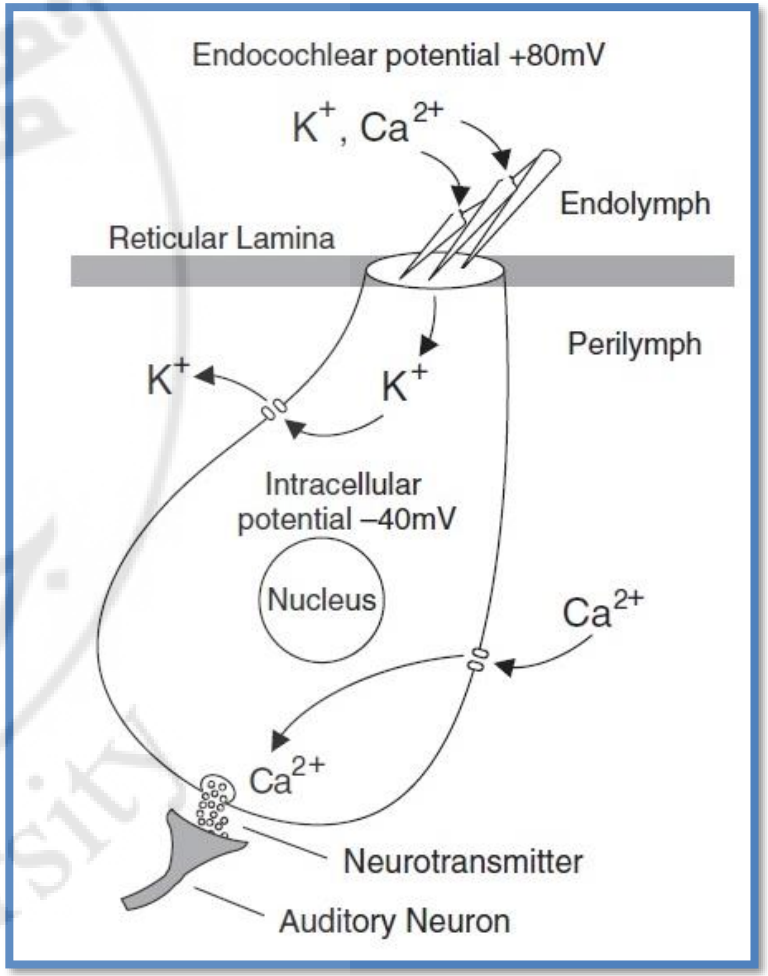

•Stereocilia
•Hair Cell
•Human Hair


Traveling wave
Sum of OHCs contribution
Amplified Traveling wave


Traveling wave
Sum of OHCs contribution
Amplified Traveling wave
Reverse Traveling wave

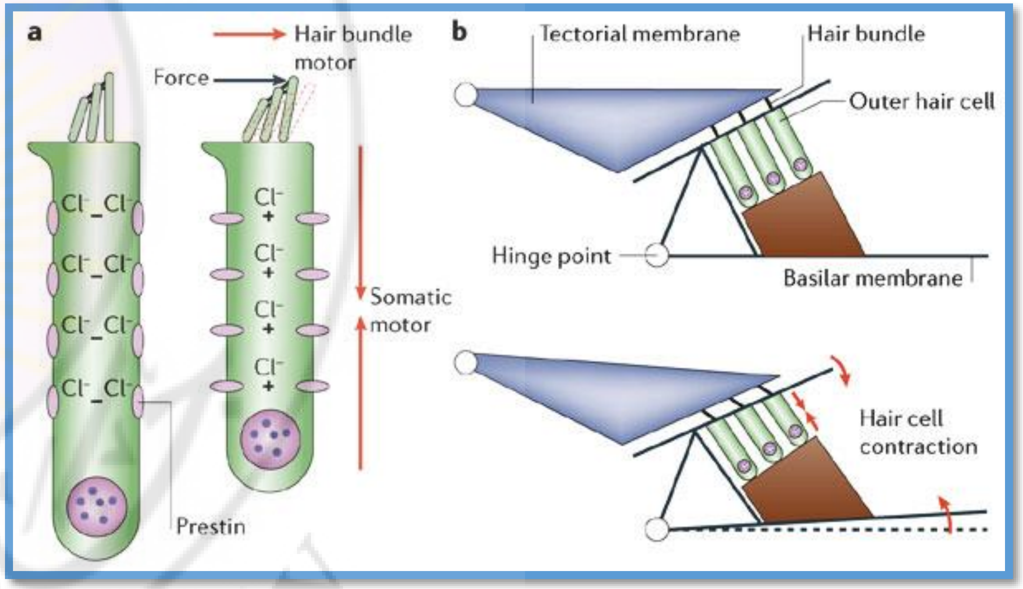
OAEs and Outer Hair Cells

- OAEs are a pre-neural phenomenon and can be measured even when the eighth nerve has been severed.
- Unlike neural responses, OAEs are unaffected by stimulus rate, and reverse polarity along with the stimulus.
- OAEs, particularly those evoked using low stimulus levels, are vulnerable to such agents as acoustic trauma, hypoxia, and ototoxic medications, which cause hearing loss and damage to OHCs.
- OAEs do not appear to be vulnerable to selective loss of inner hair cells (IHCs).



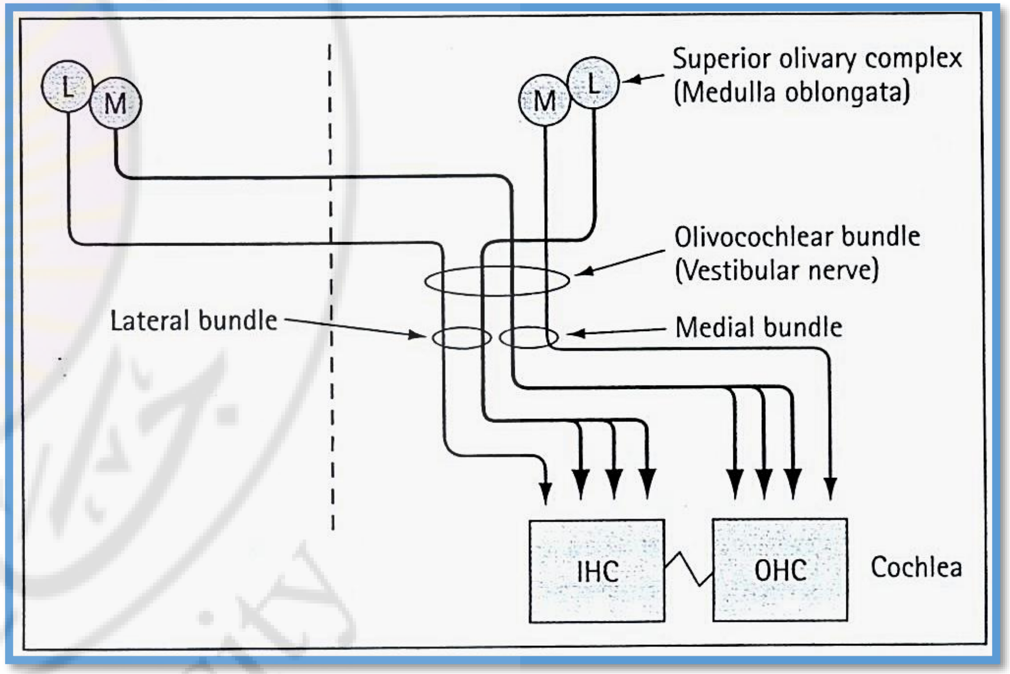
OHCs' role in the cochlear amplifier

- Two hypotheses regarding the OHCs' role in the cochlear amplifier have been explored:
  - Somatic motility of OHCs and
  - Nonlinear mechanics of the OHC stereocilia bundle.
- OHCs demonstrate rapid changes in length in response to electrical stimulation.
- **"Prestin"** is the molecular motor responsible for somatic OHC motility.
- OAEs measured in nonmammalian species, whose hair cells are not capable of somatic motility, have been attributed to **active hair bundle movements** of the hair cell stereocilia.



OHCs’ role in the cochlear amplifier

- OHCs receive the majority of the ear’s efferent innervation, which may act as a regulatory system that allows higher neurologic centers to exert control over cochlear processes such as OHC motility.
- Direct electrical stimulation of efferent fibers has been shown to reduce or enhance OAE responses.
- Indirect stimulation of the efferent system by means of ipsilateral, contralateral, or binaural sound stimulation has also been shown to alter OAE levels



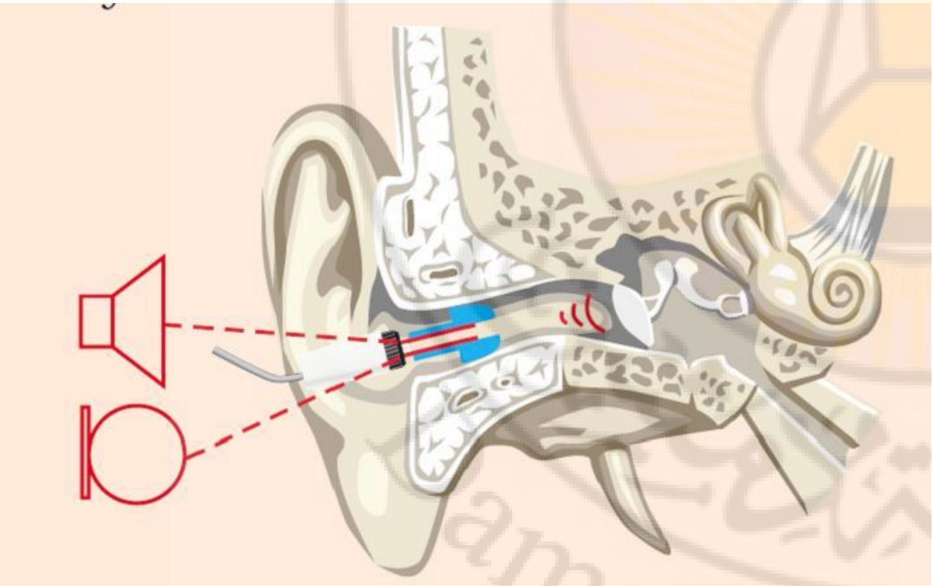
Measurement of OAEs

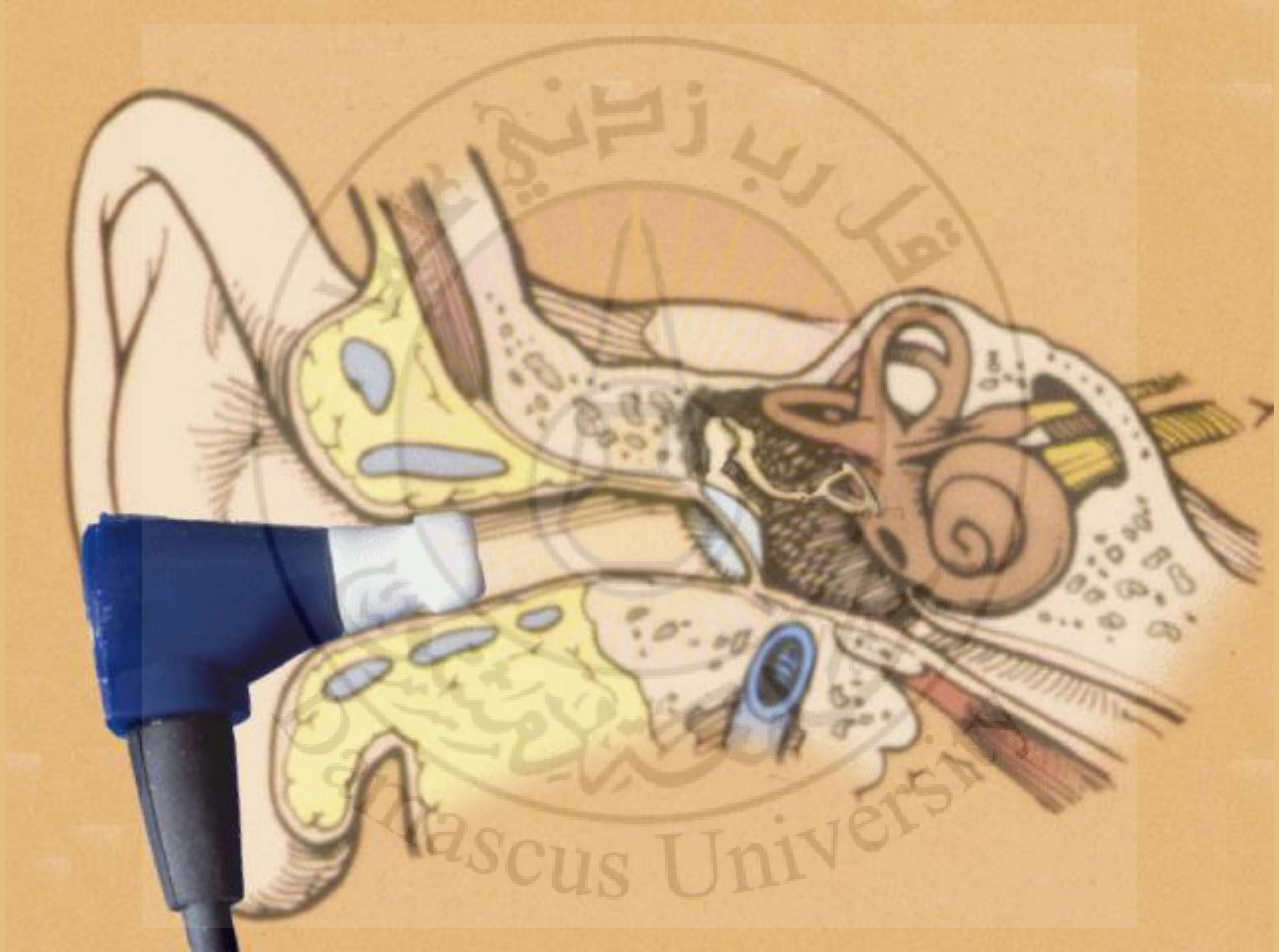
- A general recording setup for measuring OAEs includes a sensitive, miniature microphone that fits in the ear canal.
- Typically, the microphone is housed in a small probe that is coupled to the ear with a foam or rubber tip.
- The probe contains one or two speakers that allow for presentation of sound stimuli.
- The microphone measures the OAE coming from the ear and, in the case of some OAEs, also measures the stimuli presented to the ear.
- The output of the microphone is then amplified.
- Typically, the amplified output is sampled via an analog-to-digital converter, housed either in a computer or in a stand-alone piece of equipment.
- The output is then appropriately analyzed for the type of OAE.

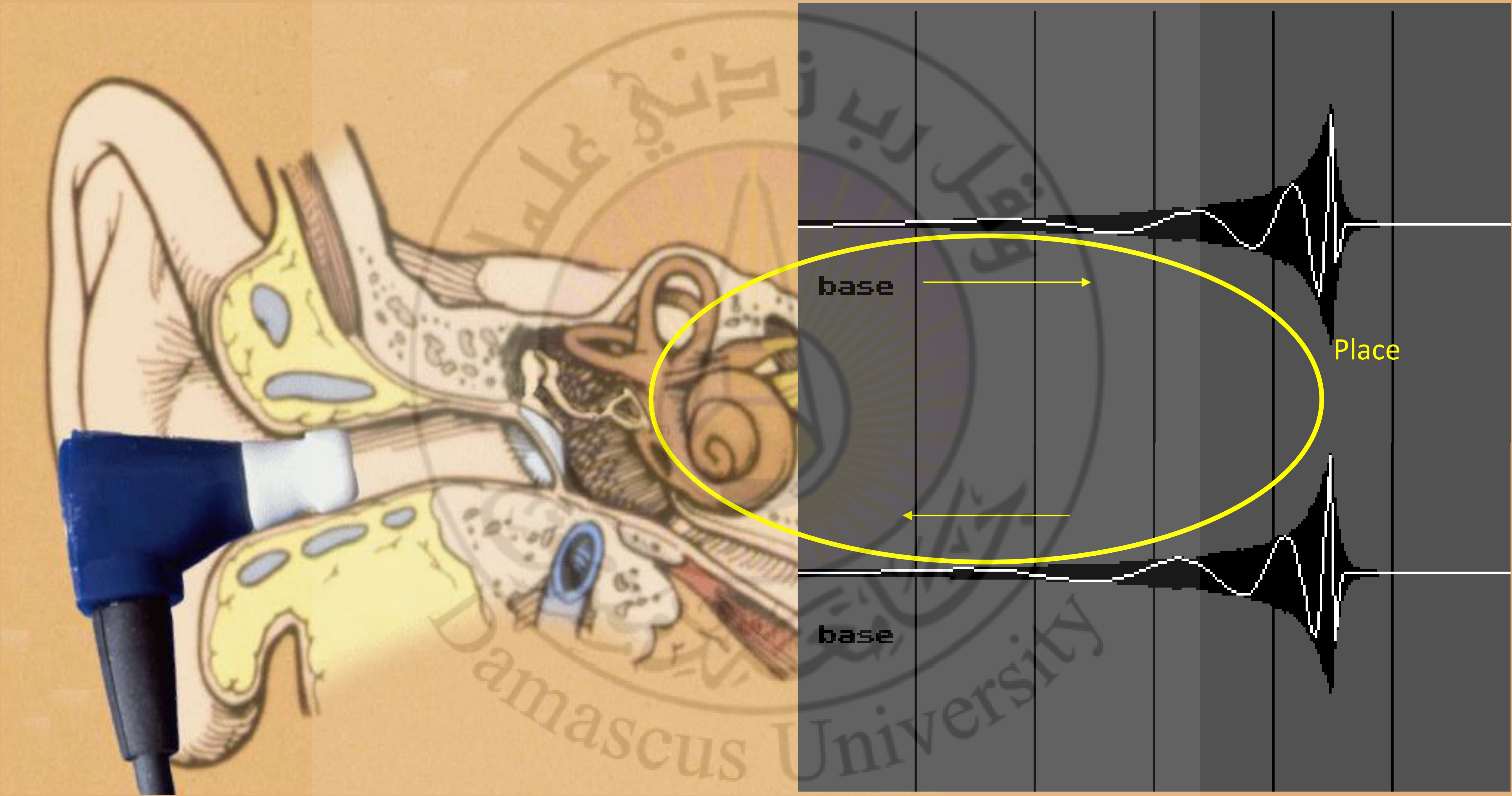
Measurement of OAEs

Signal Generator(s) — Transducer(s) and Microphone (Ear Tip)

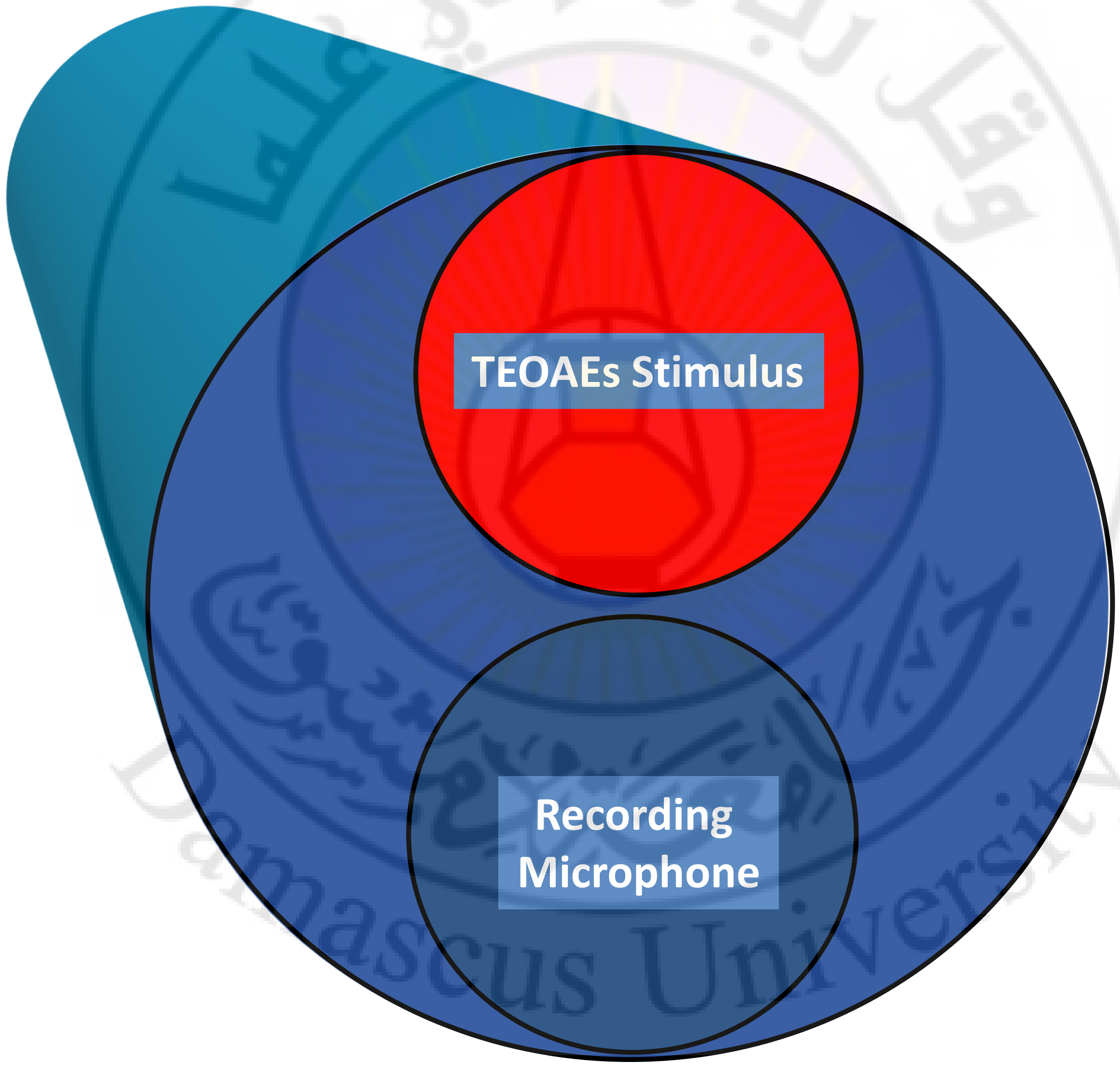
Transducer(s) and Microphone → Amplifier and Filter → ADC and Averager → Display / Printer



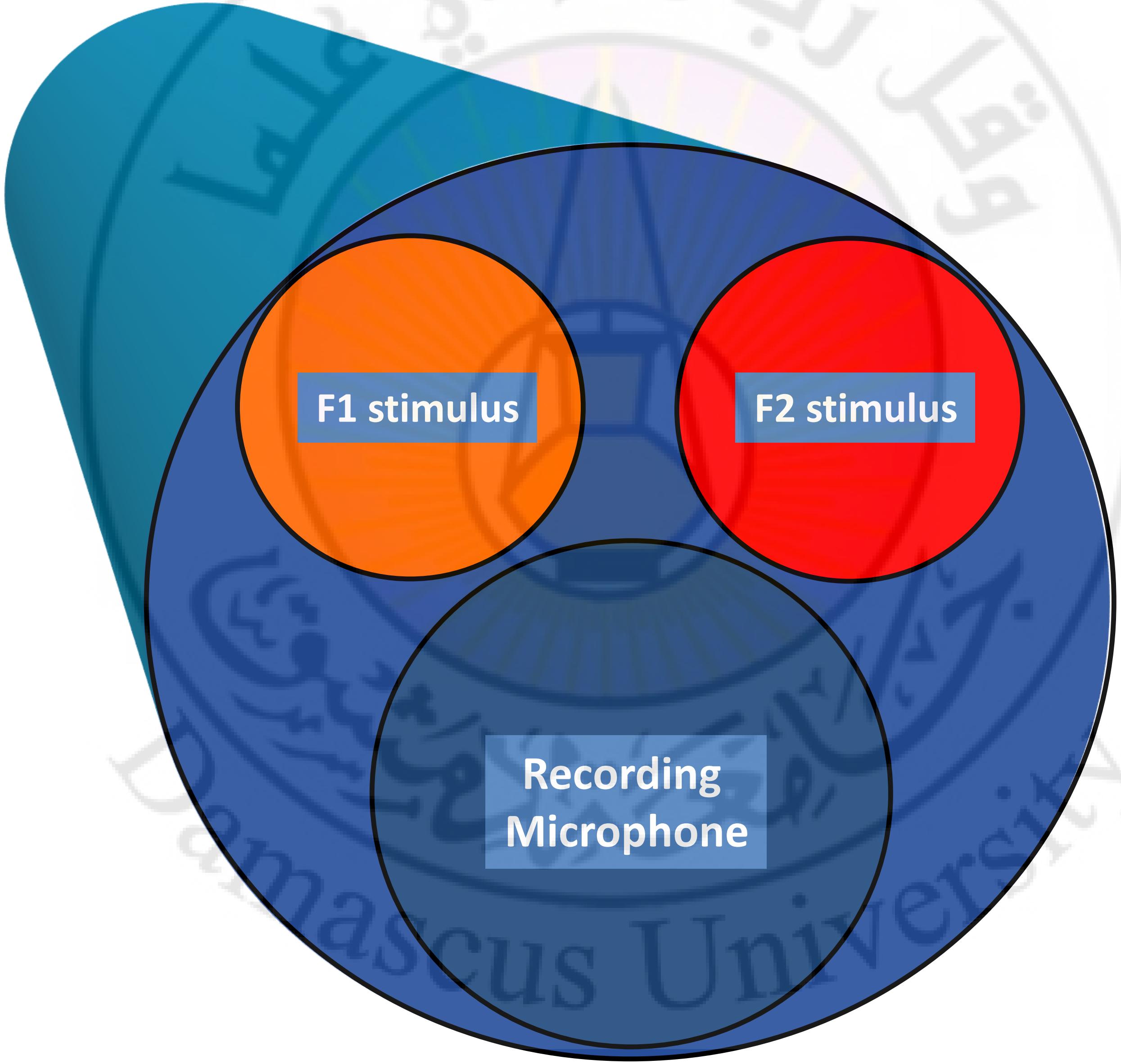



base
Place
base

TEOAE Probe design



DPOAEs Probe design



دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Acoustic Immittance Measures

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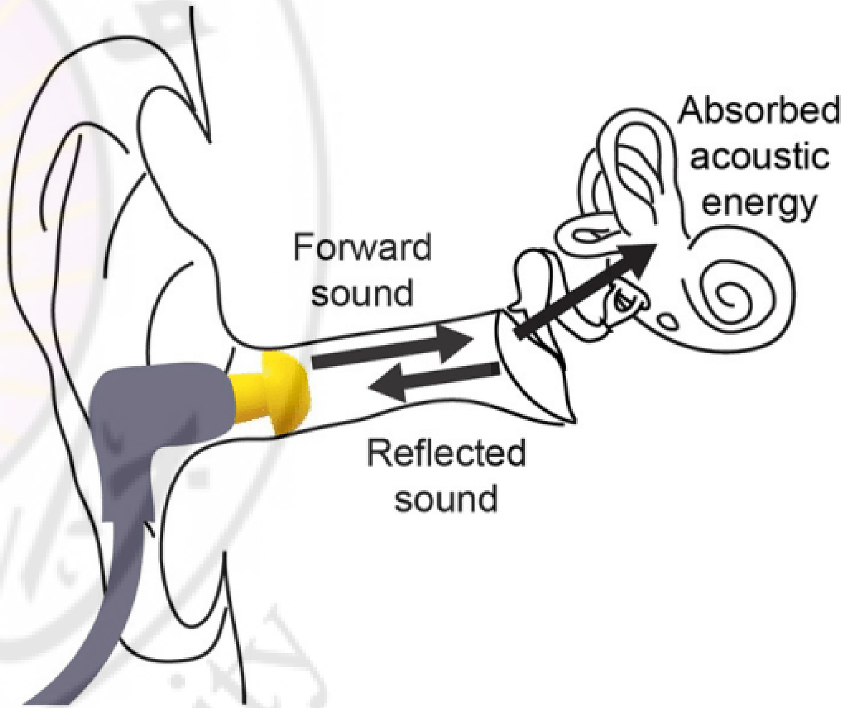
2. Overview of physical principles of the Immittance measures

Introduction

Because sounds must be transmitted from a low-impedance air medium in the ear canal to a higher impedance fluid medium (the labyrinth) for humans to hear, it is important to understand whether the middle ear is providing effective sound transmission.

In fact, without the middle ear, humans would only be able to hear very loud sounds via bone conduction, since soft to moderate sounds would be reflected back by the tissues and bone of the head.

The middle ear transmits the most energy to the cochlea in the frequency range of 1,000 to 4,000 Hz and is matched to the frequency region in which the majority of speech cues are carried.



Terminology: Acoustic Immittance

- ***Acoustic immittance*** is a general term that describe the various aspects of ***acoustic admittance*** **(Ya),** and ***acoustic impedance*** **(Za)**.
  - **Za** is the term used to express the **opposition to sound flow** through an acoustic system (in acoustic ohms).
  - **Ya** refers to the **ease of sound flow** through an acoustic system (in acoustic mmhos).

$$Z_a = \frac{1}{Y_a}$$

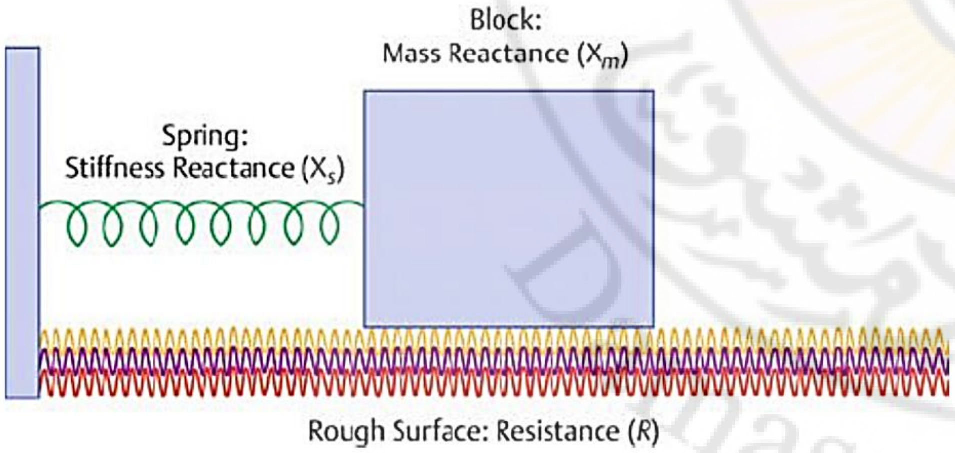
$$Y_a = \frac{1}{Z_a}$$

- Za and Ya are direct reciprocals. If an acoustic system like the human middle ear has a high Ya, it has a low Za. Conversely, if the middle ear has a low Ya, it has a high Za.

- Although both terms have been used to describe acoustic measures of middle ear function, current commercially available acoustic immittance instruments typically provide measures of Ya.

Immittance components

- The immittance of the ear is derived from its various sources of mechanical and acoustical stiffness (springiness), mass, and friction (resistance).



Stiffness

- Volume of air
- Tympanic Membrane
- Tendons and ligaments of ossicles
- Contractions of the middle ear muscles

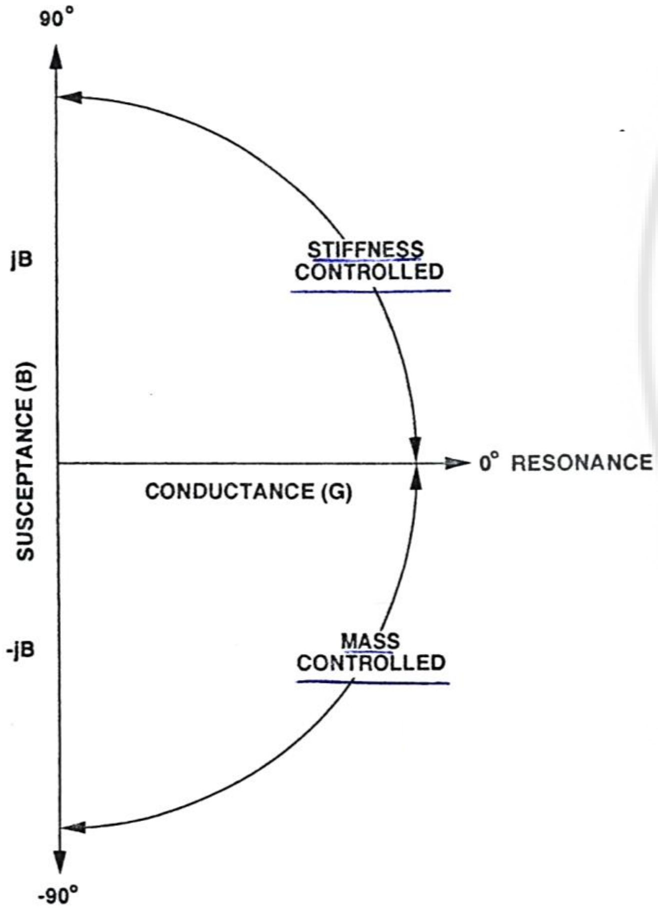
Mass

- Ossicles
- Pars flaccida of TM
- Perilymph

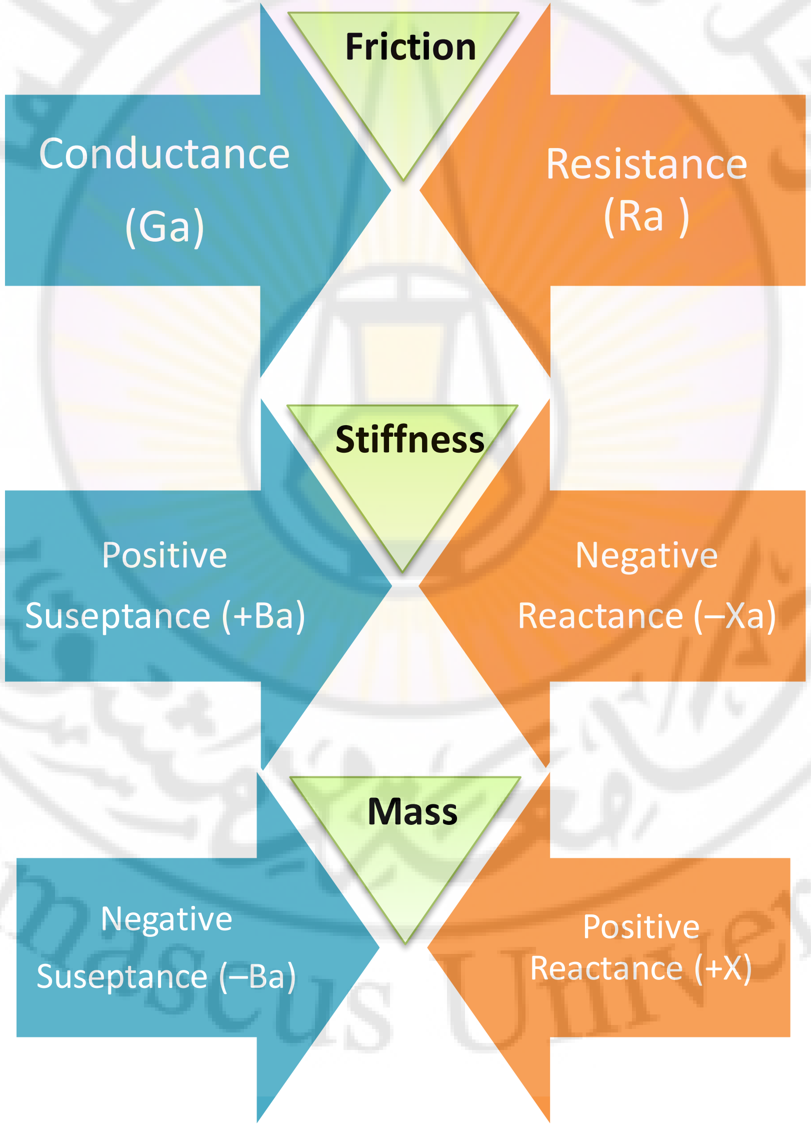
Friction

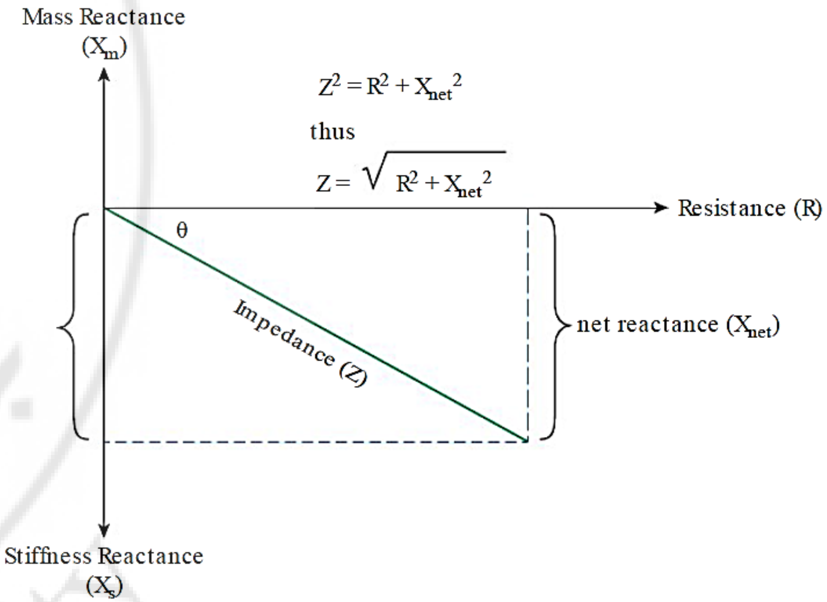
- Ossicular joints
- Mucous membrane of the M.E
- Tympanic membrane
- Annular ligament
- Cochlear fluids (Perilymph)

Admittances vs. Impedance



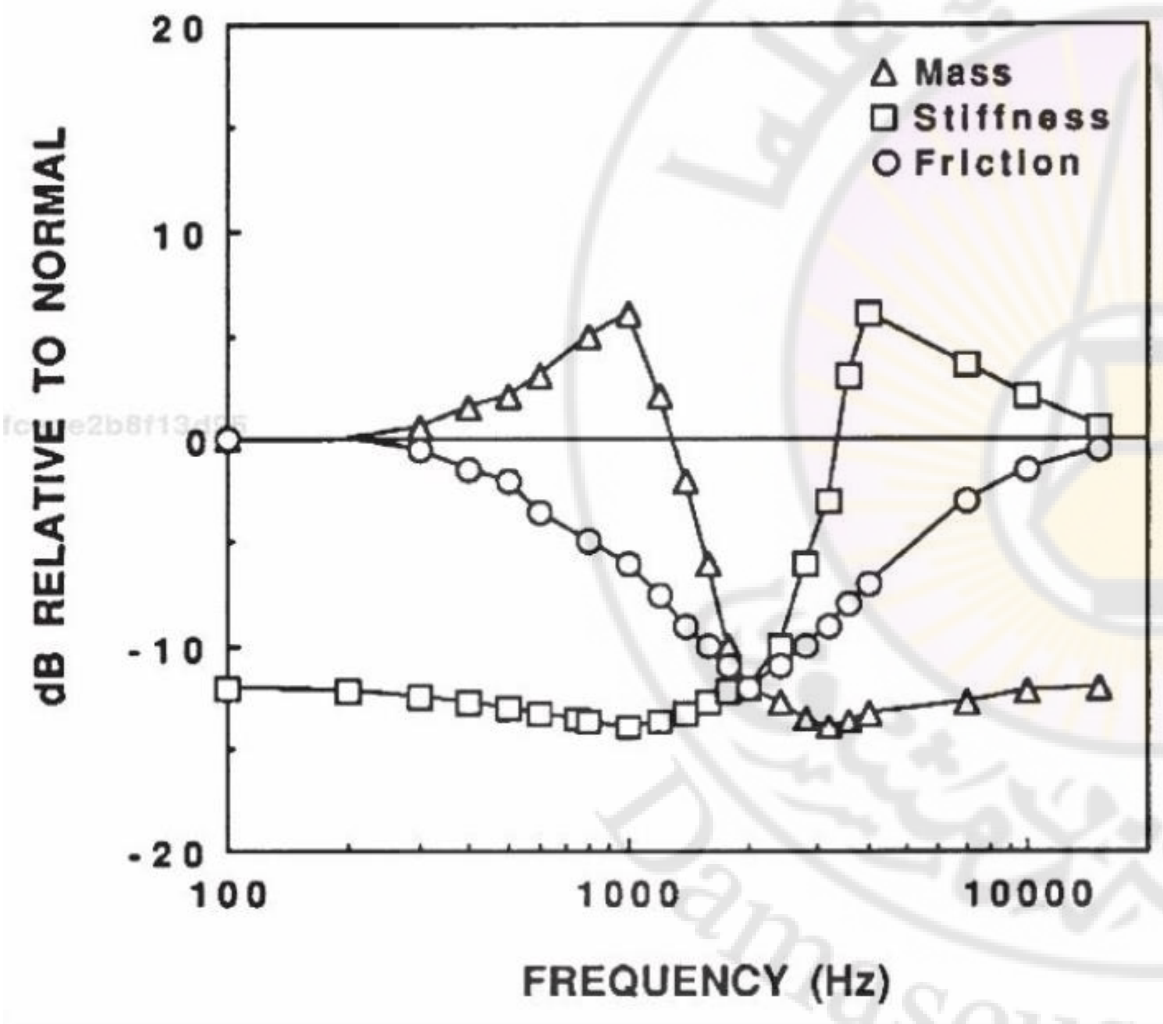
$$Ya = Ga + [Ba + (-Ba)]$$





$$Z = Ra + [Xa + (-Xa)]$$

Effect of increasing the stiffness, mass, and friction on hearing ability



Stiffness

- Volume of air
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- Perilymph

Friction

- Ossicular joints
- Mucous membrane of the M.E
- Tympanic membrane
- Annular ligament
- Cochlear fluids (Perilymph)

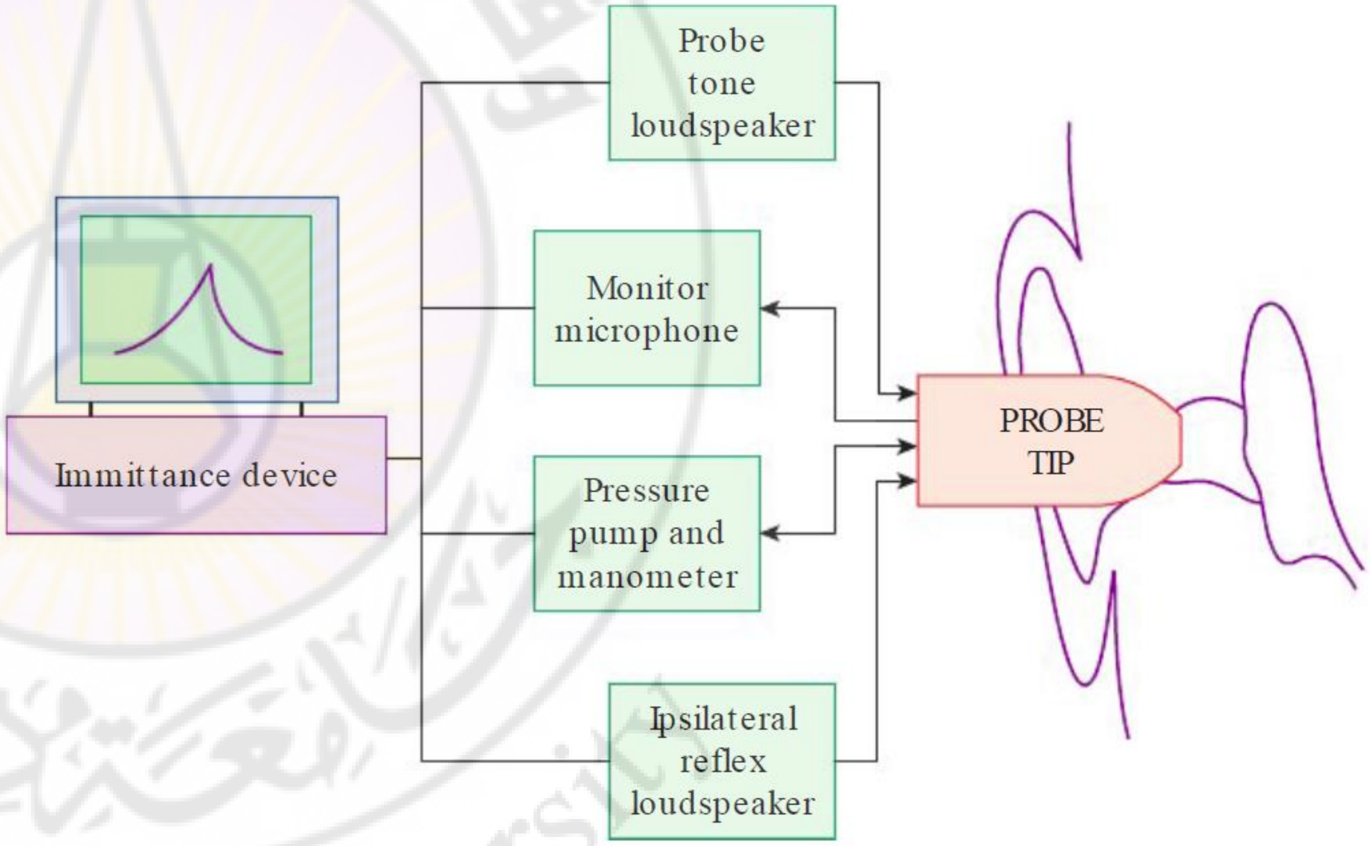
Admittances or Impedance?

- Currently available immittance instruments typically measure **admittance (Ya)**, rather than impedance. Because:
  - The ear canal volume between the probe tip and TM does not affect the shape of admittance tympanograms.
  - The shape of admittance tympanograms is more susceptible to changes in middle ear condition compared with impedance tympanograms, and therefore, better classification of tympanograms is possible.

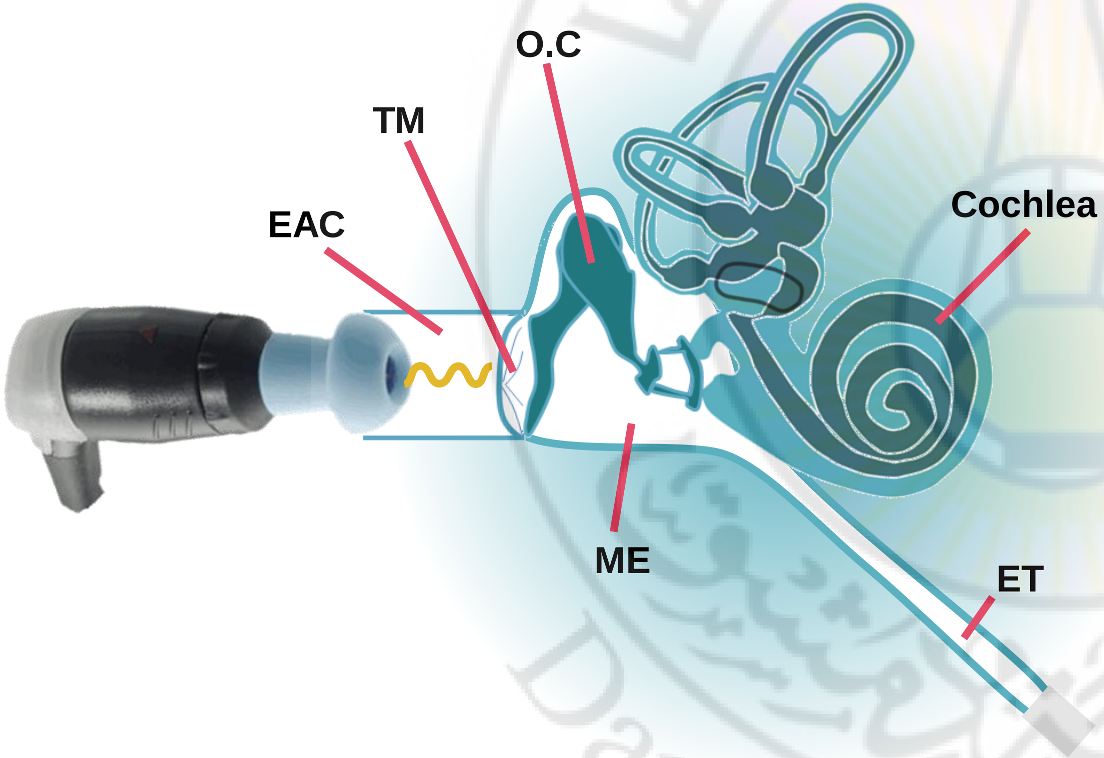
3. Instrumentation and calibration

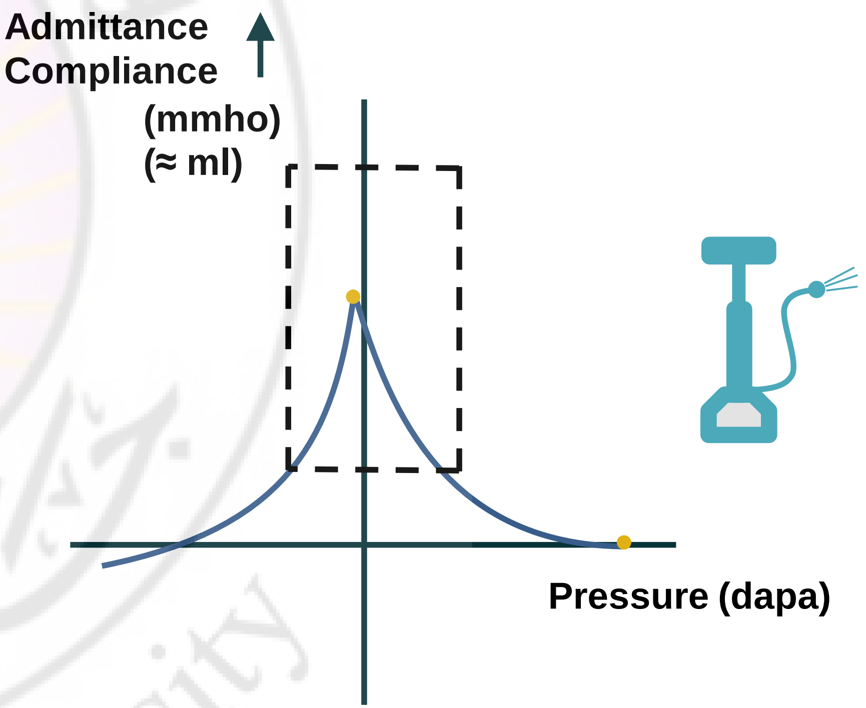
Major components of a clinical acoustic immittance device

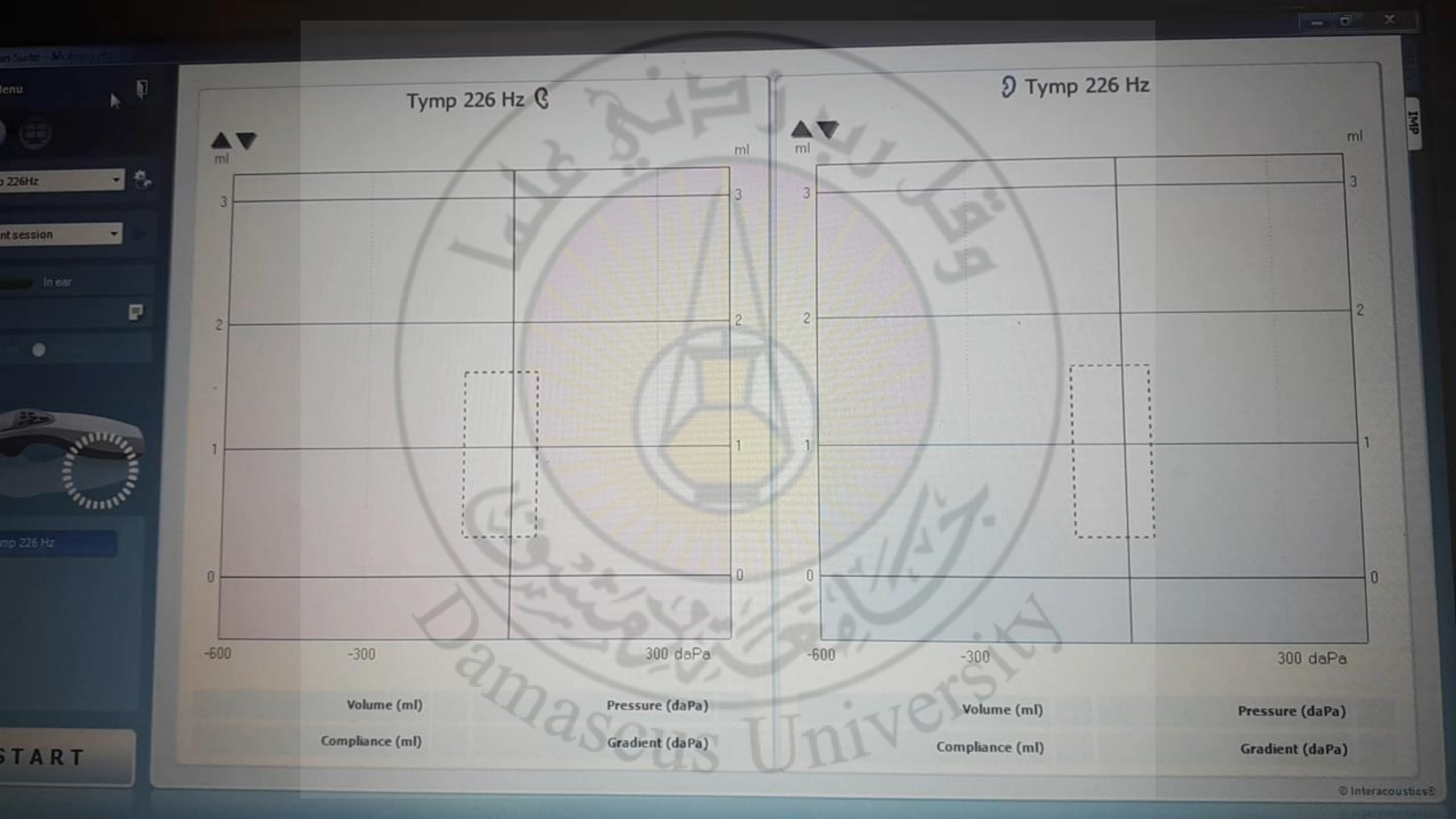
- Probe & Probe tip & probe tube
- Pneumatic system
- Acoustic immittance measurement system
- Acoustic-reflex activator system
- Recording device



Tympanometry is an objective, physiological measure of acoustic admittance of the middle ear as a function of air pressure in a sealed ear canal.







Tymp 226 Hz
ml
3
2
1
0
-600
-300
300 daPa
Volume (ml)
Pressure (daPa)
Compliance (ml)
Gradient (daPa)
Tymp 226 Hz
ml
3
2
1
0
-600
-300
300 daPa
Volume (ml)
Pressure (daPa)
Compliance (ml)
Gradient (daPa)
START
In ear
© Interacoustics®
Damascus University

Classification of Instruments

- **Type 1:**

This instrument shall have the capability for measurement-plane and compensated static immittance and tympanometry under manual and automatic control of air pressure, and for the measurement of ipsilateral and contralateral acoustic reflexes. A Type 1 instrument shall be capable of generating noise and pure-tone acoustic reflex-activating signals.

- **Type 2:**

This instrument shall have the capability for compensated static immittance and tympanometry under manual or automatic control of air pressure, and for the measurement of ipsilateral or contralateral acoustic reflexes. A Type 2 instrument shall be capable of generating pure-tone acoustic reflex-activating signals.

Classification of Instruments

- **Type 3:**

This instrument shall have the capability for static immittance, tympanometry, and for monitoring an acoustic reflex at a specified activating-signal intensity level.

- **Type 4:**

This category of special-purpose immittance instruments may have the capability for static immittance measurements alone, for tympanometry alone, for acoustic-reflex measurements alone, or for any combination of these or other acoustic measurements within the external auditory meatus.


tympstar pro
Tympanometry
Left Ear
Right
Ready
Admittance
Pressure
Test 1 - 226 Hz
gsi
SCREENER
TYMP
REFLEX
ETF
MORE
EXAMINER
PATIENT
DATA ERASE
MANUAL
HOLD
STOP
START
STIMULUS
INTENSITY
PRESENT
PRINT
DATA TRANSFER
CONFIGURE


AA222
Audio Traveller
Interacoustics
F1
F2
F3
F4
F5
F6
Back
Talk Forward
Frequency Decr
Frequency Incr
Tone Switch
Store
no response
Mic
Tone
function
HL dB
off


MAICO

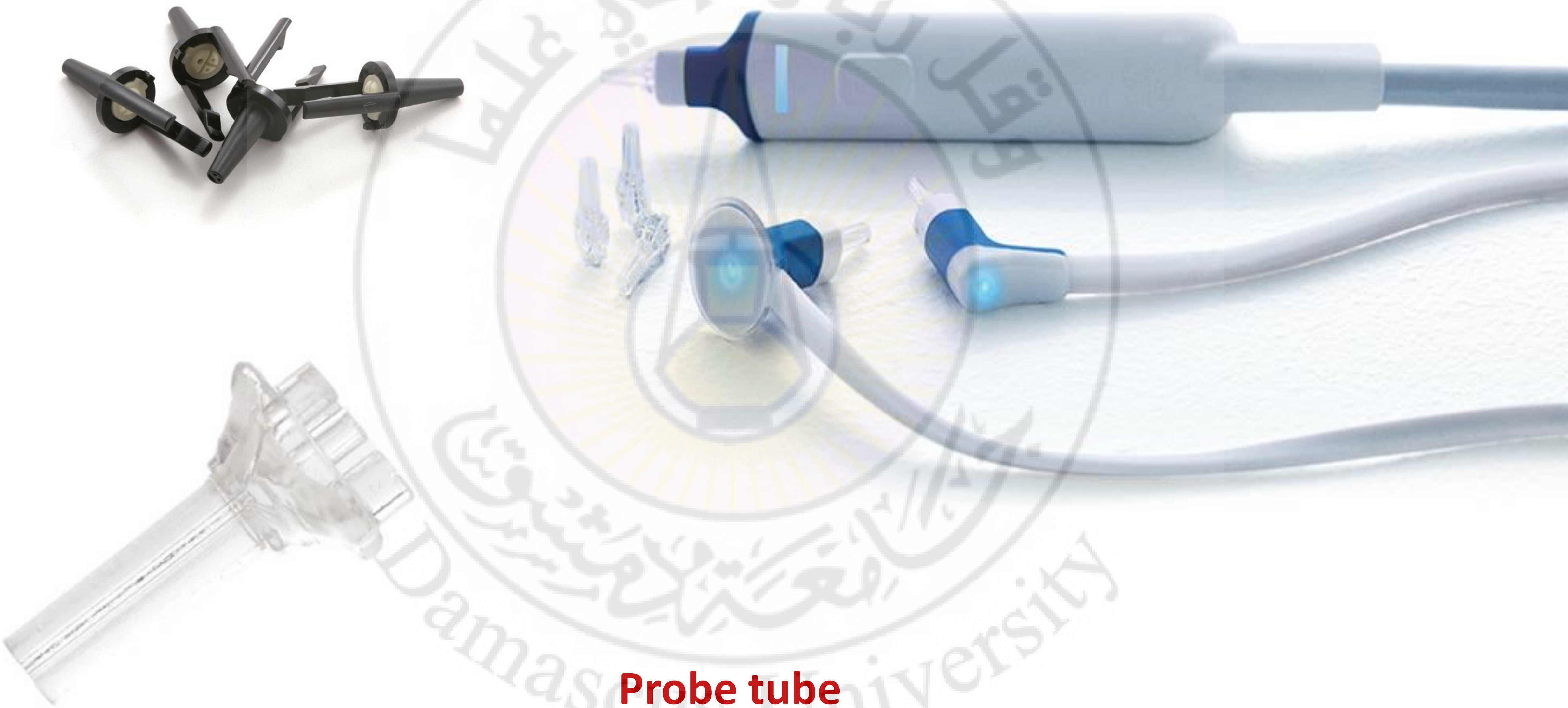

Stimulus
Ext. Range
Power
Status
Leak
1
2
3
4
5
Select
Main Menu
Tymp.
Reflex
Threshold
Manual Mode
Alt. Select
Setup
Auto Test
Escape
Continue
Auto Mode
Air Release
Ext. Range
MADSEN
ZODIAC 901
MADSEN
Maintenance of Electronic Technology
M.E.T
Damascus University


MADSEN Zodiac
Special
Previous Curve
Next Curve
Change Type
otometrics


Interacoustics
MT10
Screening Tympanometer
Pk: 1.2ml/-4daPa
Gr: 59
ECV
0.9
-400 -200 0 daPa 200


Titan
2cc
Charge
Titan Spare Power

Probe tip or Ear Tip



Probe tube

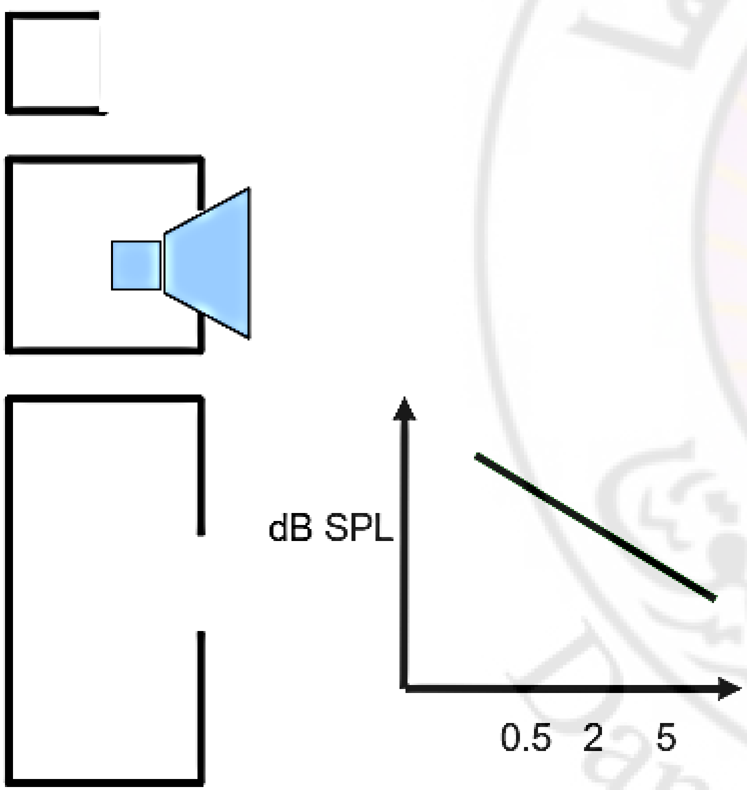
Calibration

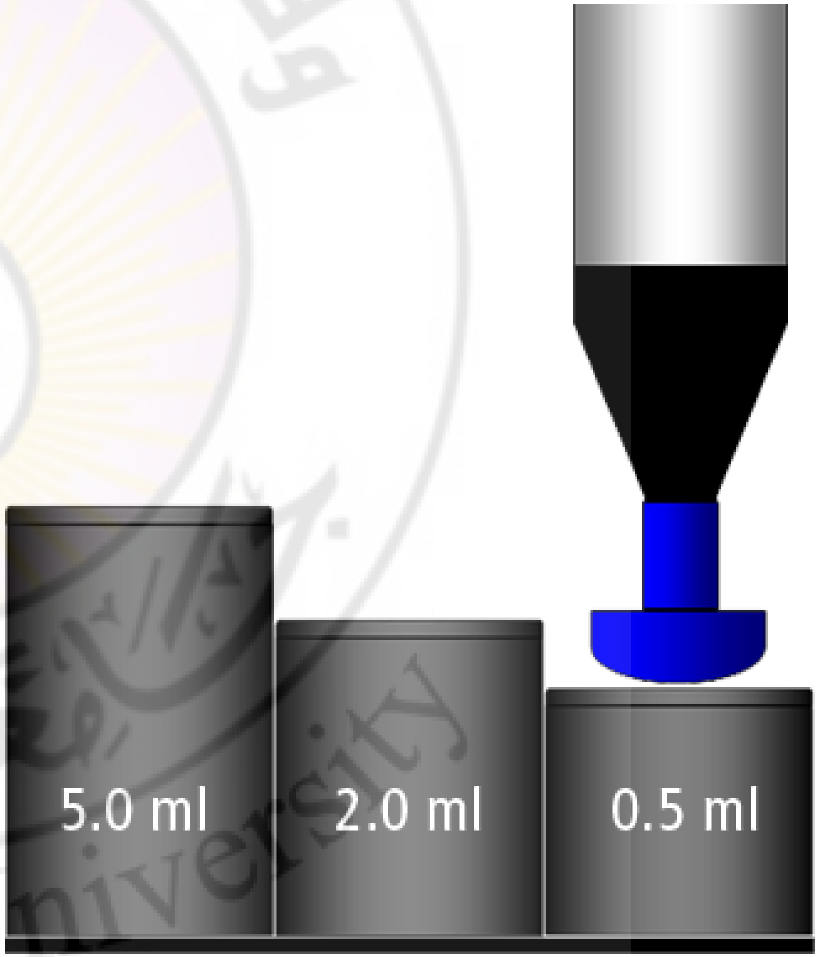
- In order to accurately estimate middle ear admittance, all measurement systems should be calibrated in **couplers** with a volume close to the human ear canal (approximately 1 to 2 cc).

- Under standard reference conditions using a probe tone of 226 Hz, the volume of trapped air in a hard-walled cavity is equal to the acoustic volume of that same cavity.

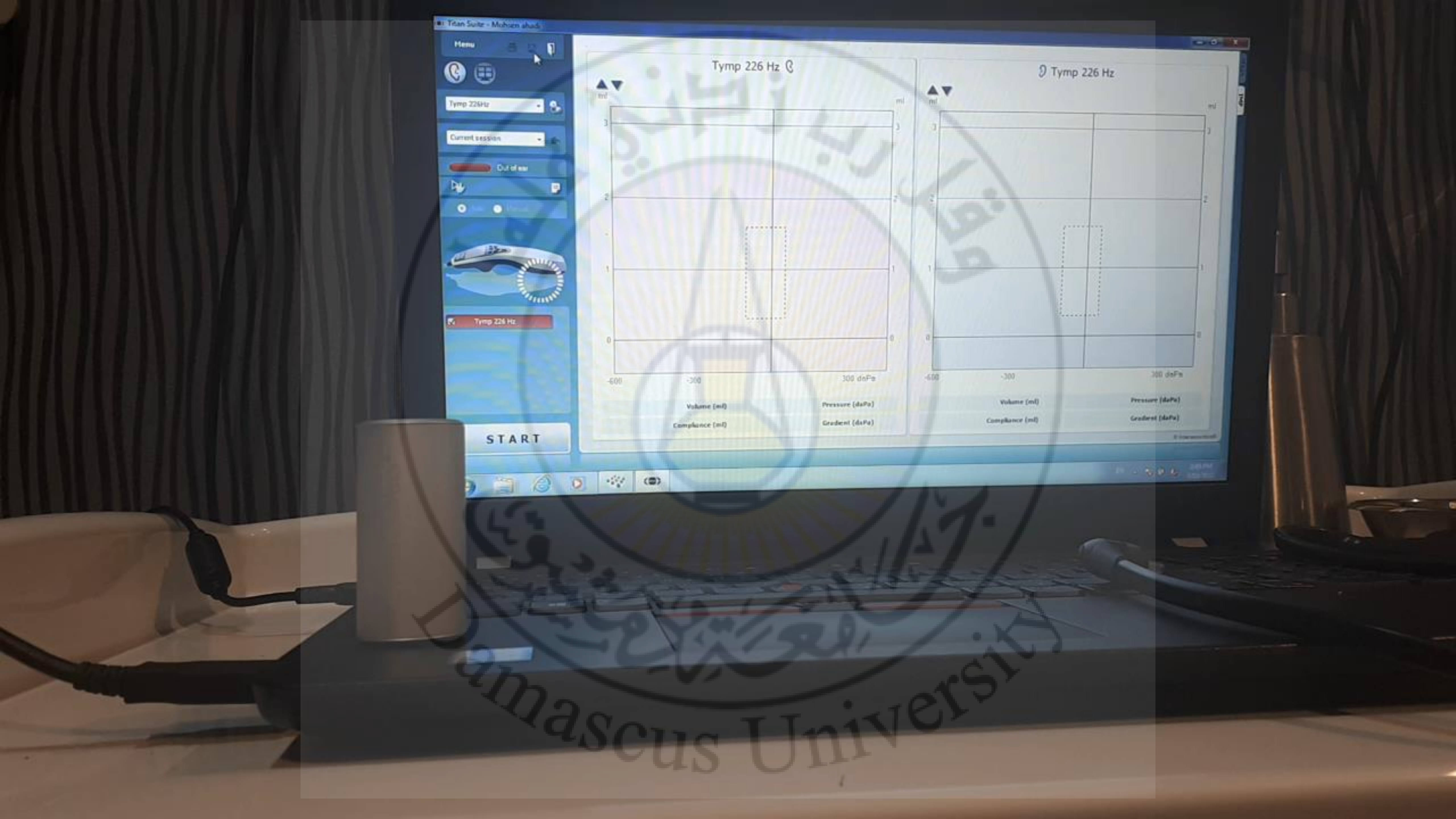
- In other words, **at 226 Hz**, 1 cubic centimeter (cc) or milliliter (mL) of trapped air equals the acoustic admittance of 1 mmho in a hard-walled cavity. This equivalency is the reason that some tympanometers measure admittance in cc or mL.

Calibration Cavity





0.5, 2 and 5 cc cavities calibrates 226 Hz
0.5 and 2 cc cavities calibrates 678 Hz
0.5 cc cavity calibrates 1000 Hz


Titan Suite - Mohsen ahadi
Menu
Tymp 226Hz
Current session
Out of ear
Tymp 226 Hz
START
Tymp 226 Hz
Tymp 226 Hz
Volume (ml)
Pressure (daPa)
Compliance (ml)
Gradient (daPa)
Volume (ml)
Pressure (daPa)
Compliance (ml)
Gradient (daPa)


Titan
Charge
Titan Spare Power
2cc

Acoustic Immittance Measures

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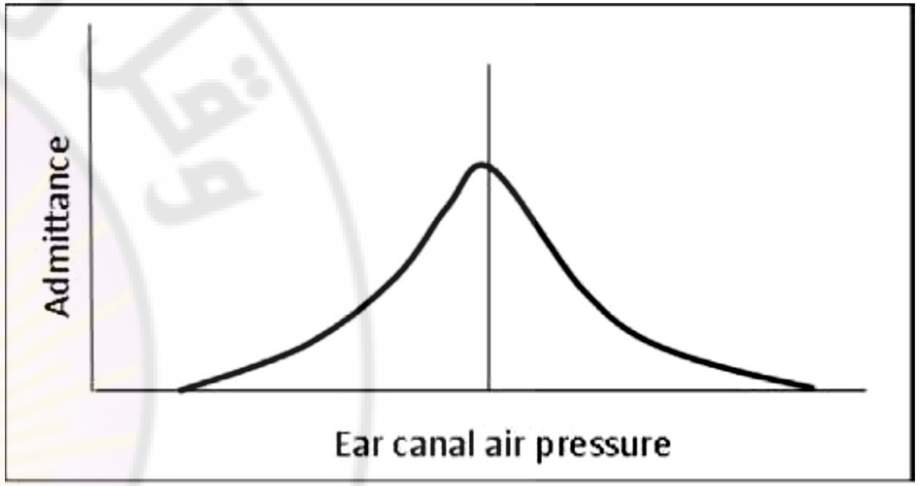
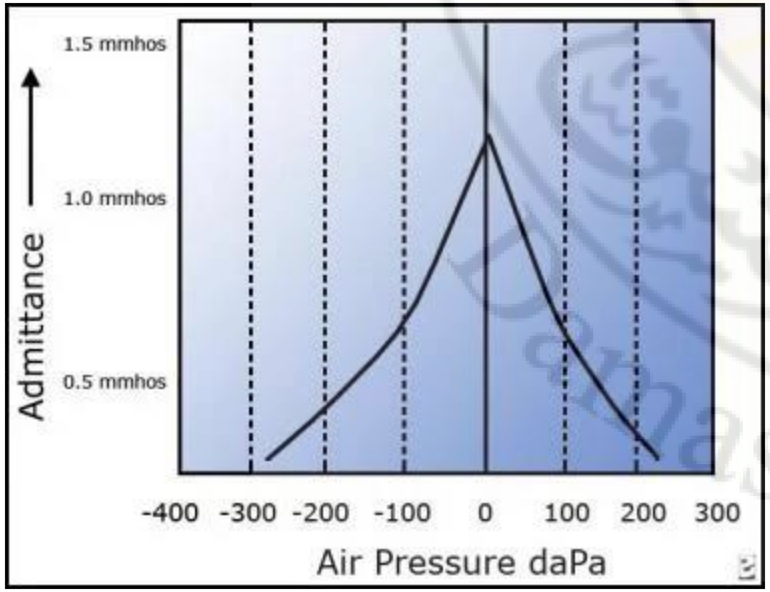
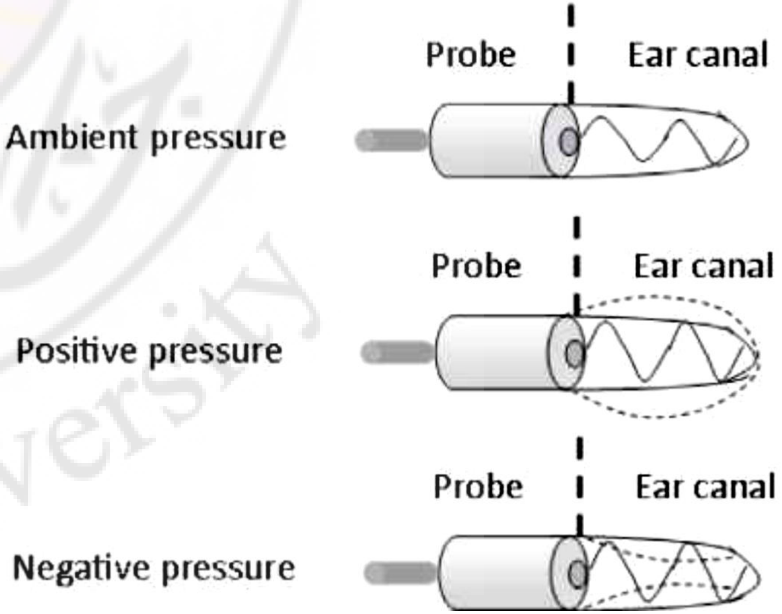
4. Single-frequency Tympanometry

Single-frequency (226 Hz) Tympanometry

- **Tympanometry** involves measuring the acoustic admittance of the ear with various amounts of air pressure in the ear canal (Usually between +200 to -400 dapa). The amount of air pressure is expressed in terms of dekapascals (daPa)





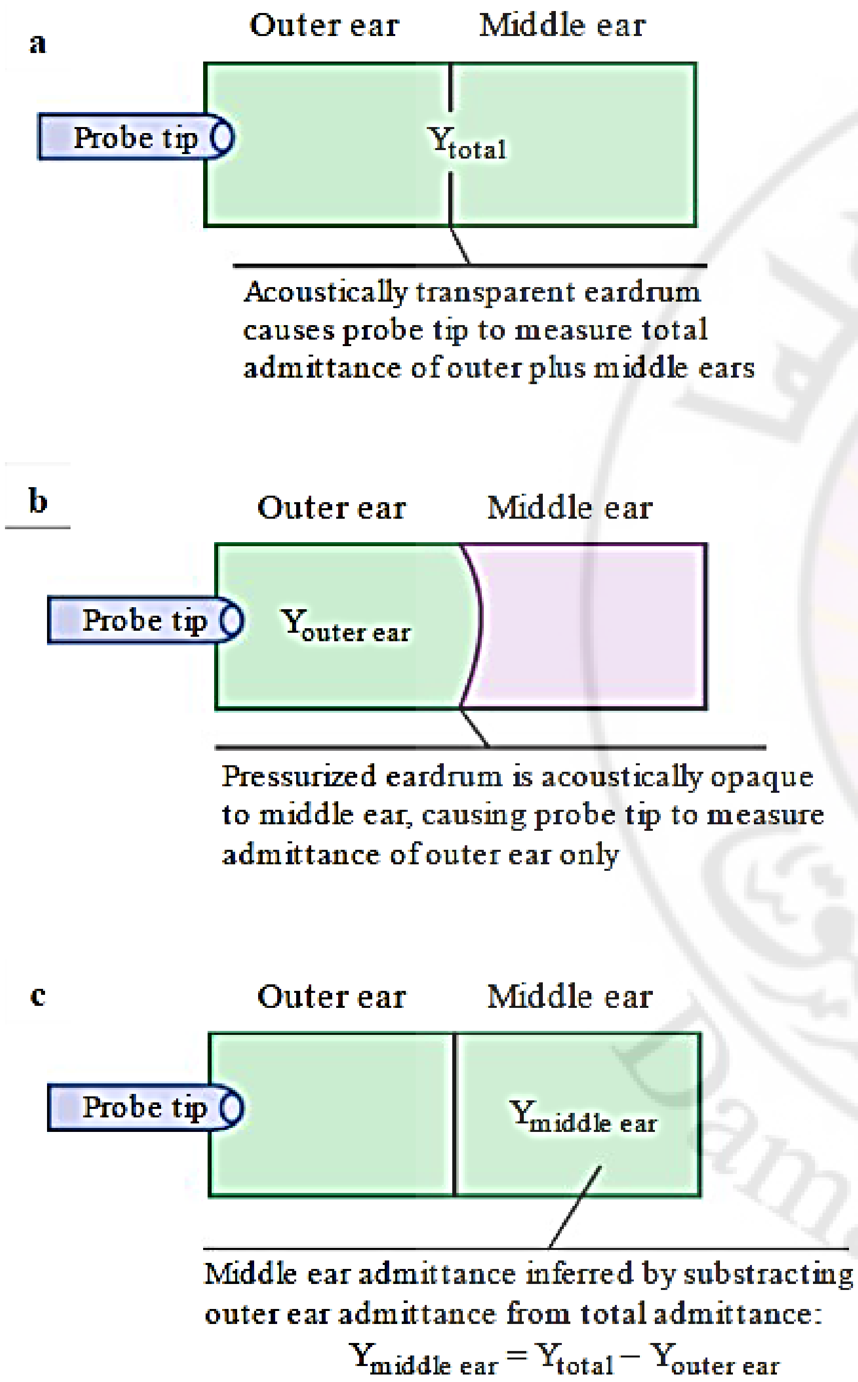


Why 226 Hz?

- 226 Hz is superior to other probe-tone frequencies in identifying or differentiating among middle ear pathologies.
- To avoid microphone nonlinearities at high frequencies
- To allow a higher probe-tone level without eliciting an acoustic reflex
- To avoid interference with the 50-Hz line frequency used in Europe.

- The low-frequency probe primarily assess the **stiffness** characteristics of the middle ear transmission system. The most common pathology of the middle ear affecting stiffness is middle ear effusion.

Immittance at the Plane of the Eardrum

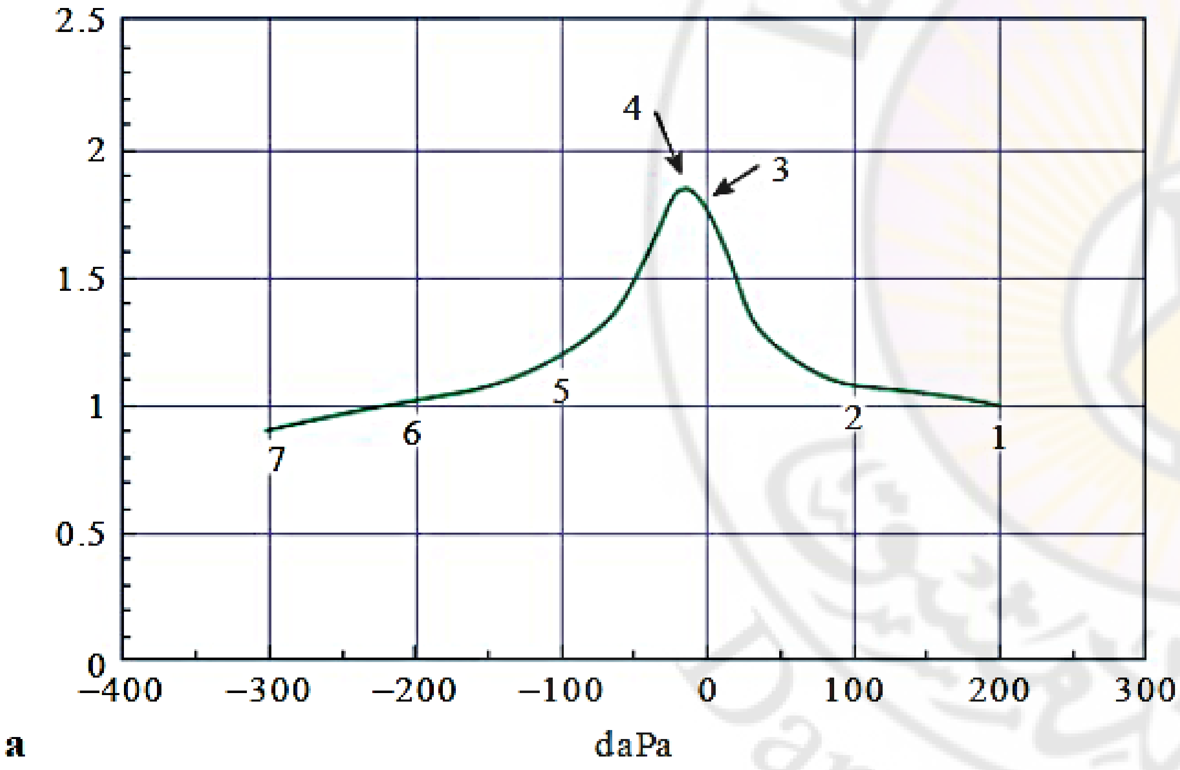


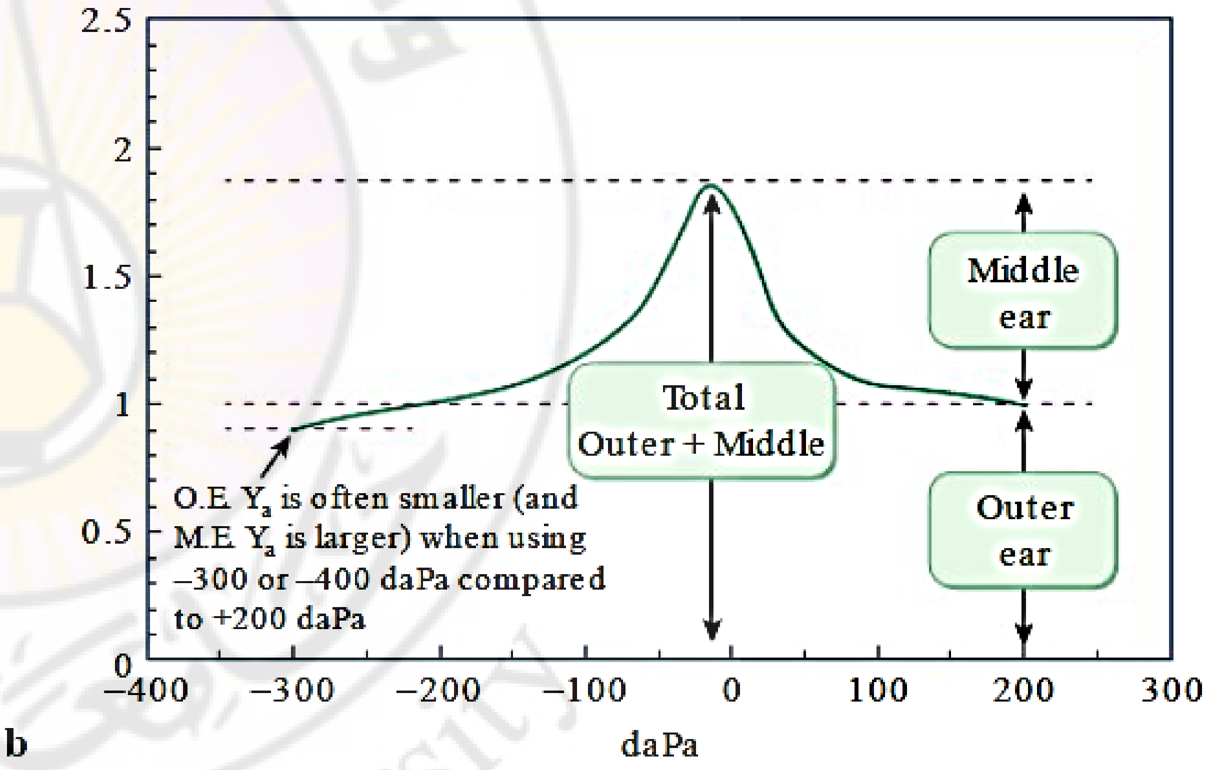
$$Y_{TOTAL} = Y_{OE} + Y_{ME}$$

$$Y_{ME} = Y_{TOTAL} - Y_{OE}$$

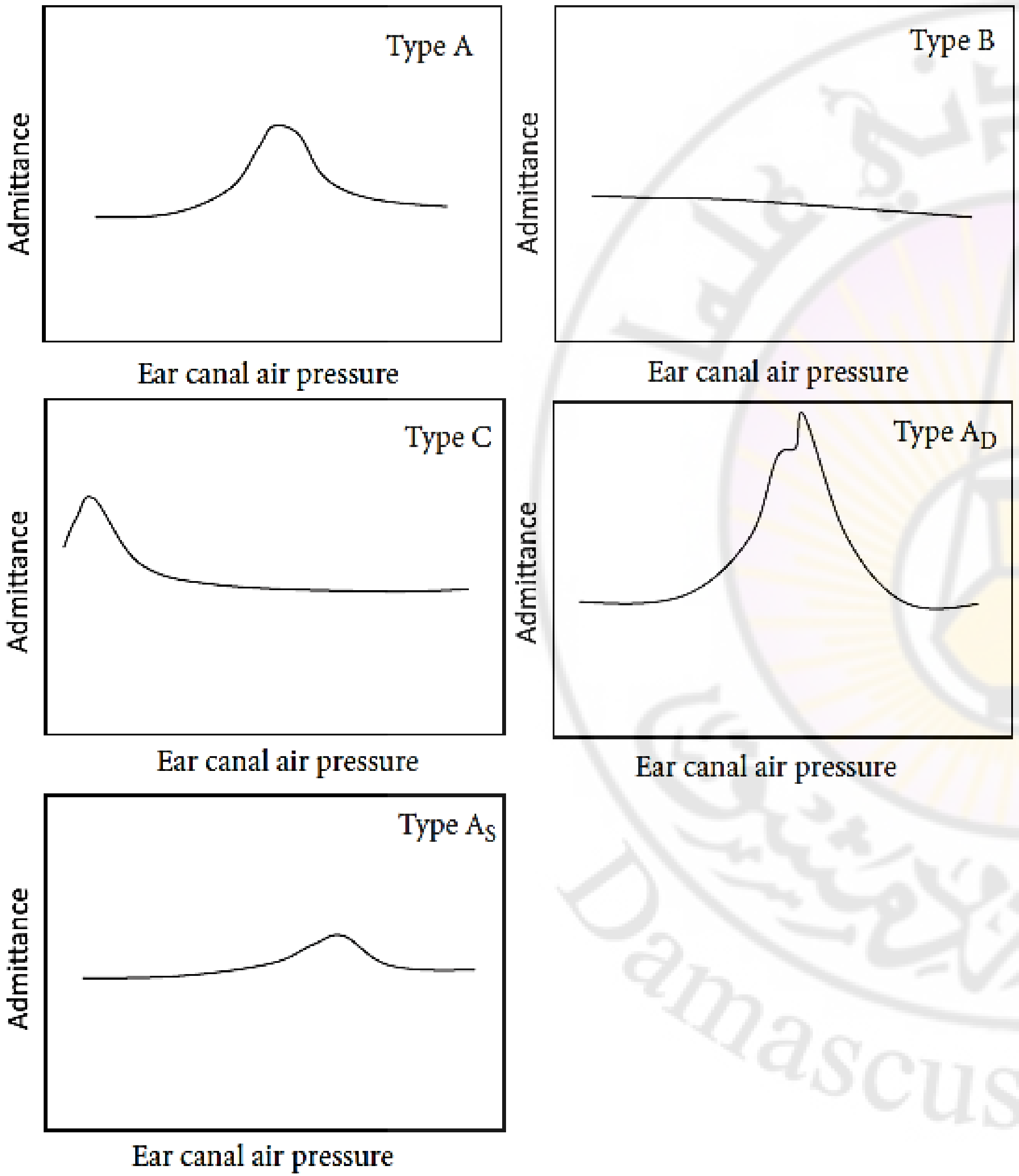
- Y_{me} = Peak compensated static acoustic admittance or shortly; Static admittance

What is Tympanogram?





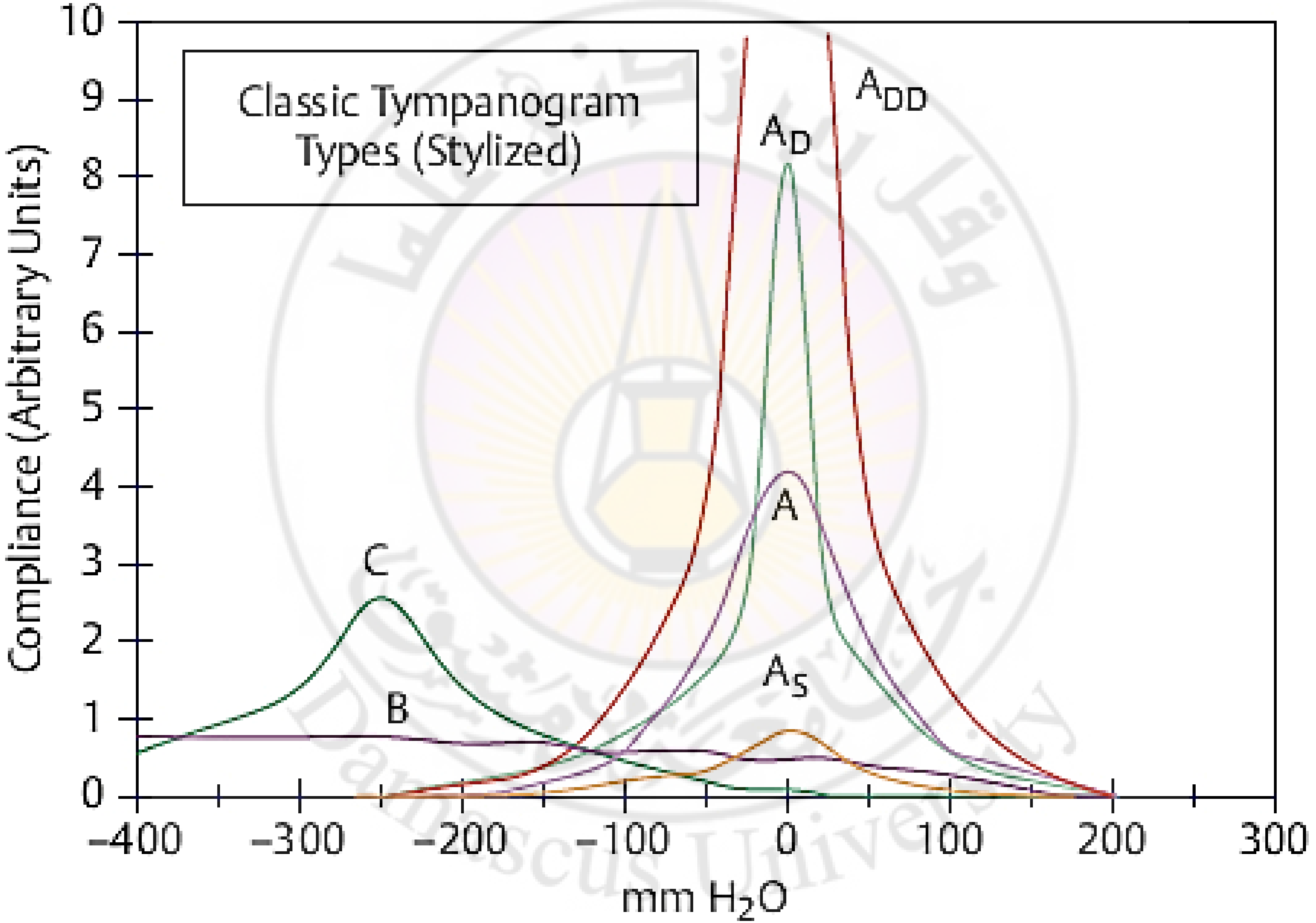
Qualitative analysis of Tympanograms



Lidén–Jerger Model

- Lidén–Jerger classification scheme for tympanometric shapes, based on qualitative analysis of the **height** and **location** of the primary peak.

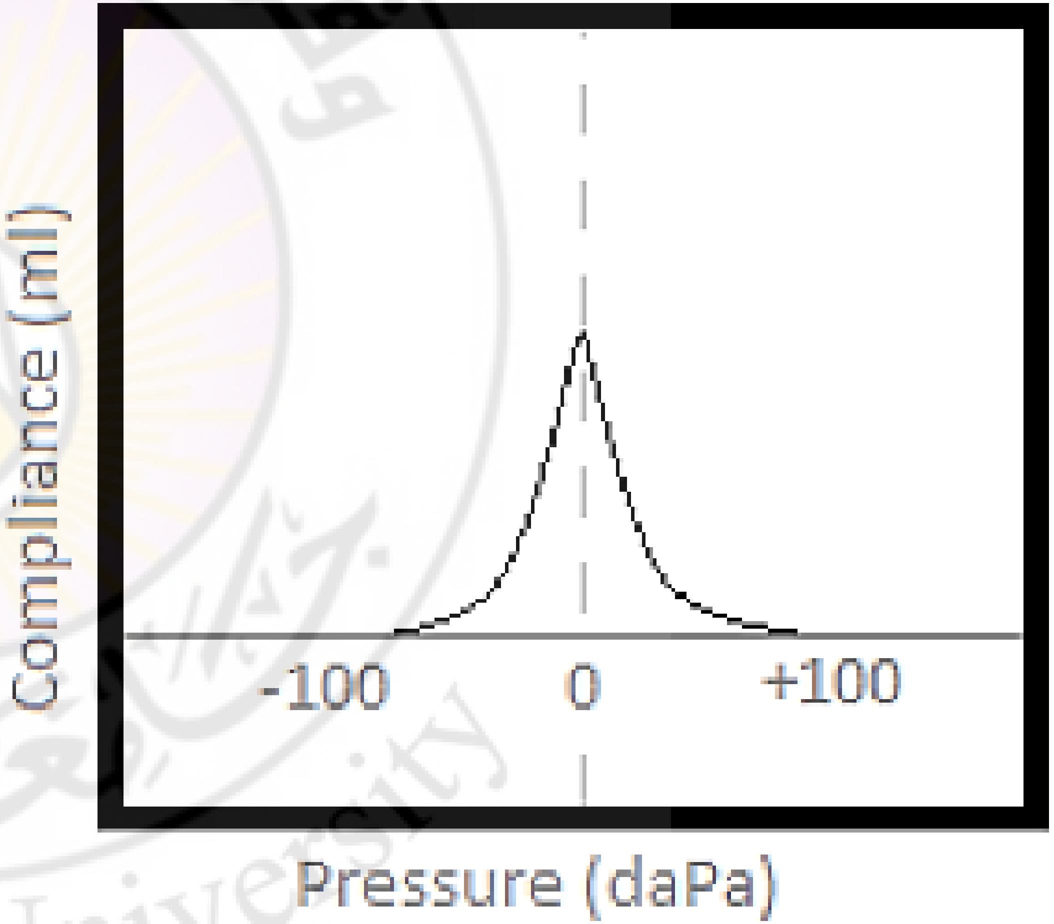
- **A (An)**
- **As**
- **Ad**
- **C**
- **B**


Classic Tympanogram
Types (Stylized)
Compliance (Arbitrary Units)
mm H_2O
A_{DD}
A_D
A
A_S
B
C
10
9
8
7
6
5
4
3
2
1
0
–400
–300
–200
–100
0
100
200
300

TYPE A

TYPE A

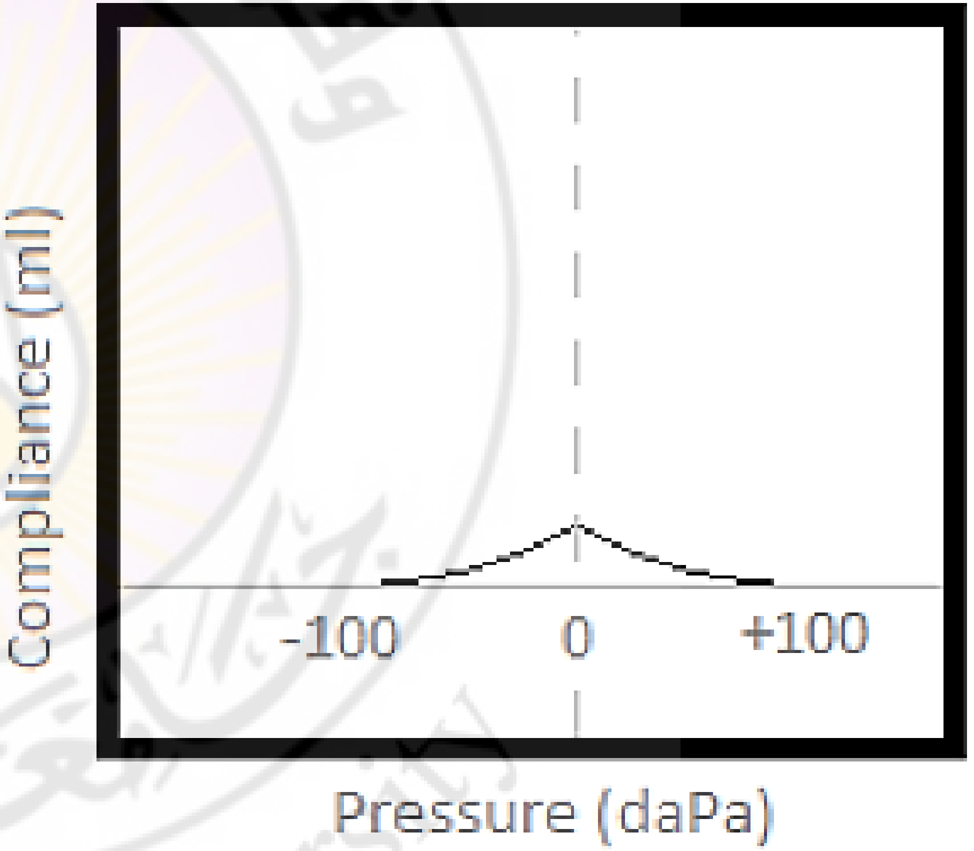
- Peak is between +/- 100 daPa
- Admittance from 0.3-1.6 mmho
- Suggests normal middle ear functioning (as well as those with otosclerosis)



TYPE AS

TYPE AS

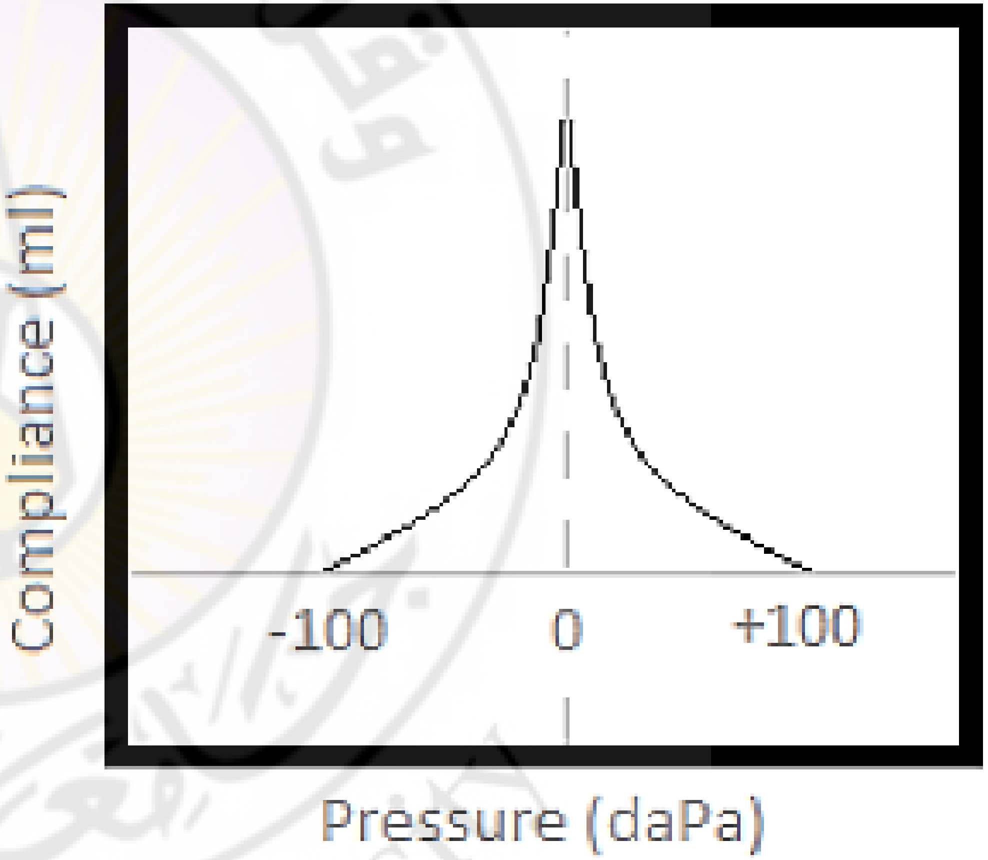
- Peak is between +/- 100 daPa
- Admittance is less than 0.3 mmho (shallow peak)
- Suggests a less compliant (more stiff) middle ear system:
  - Otosclerosis
  - Otitis media



TYPE AD

TYPE AD

- Peak is between +/- 100 daPa
- Admittance is more than 1.6 mmho (deep peak)
- Suggests a highly compliant (Less stiff) middle ear system:
  - Scarred or flaccid eardrums
  - Ossicular Interruptions

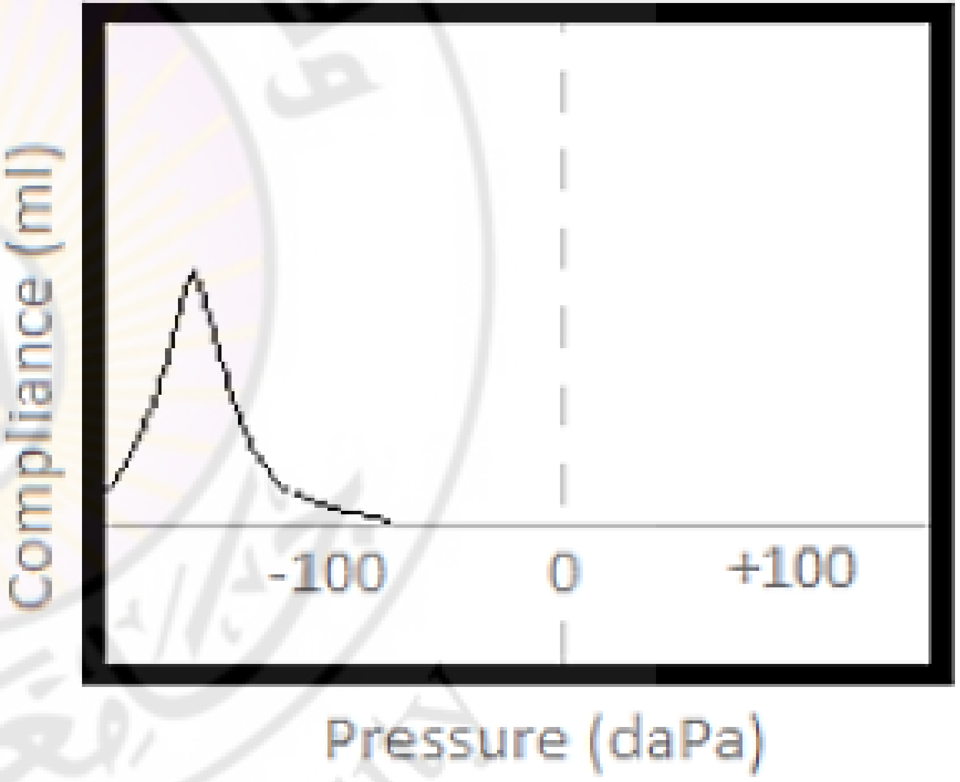


The type ADD tympanogram was so deep that the peak was off-scale, and was found in ears with ossicular discontinuities.

TYPE C

TYPE C

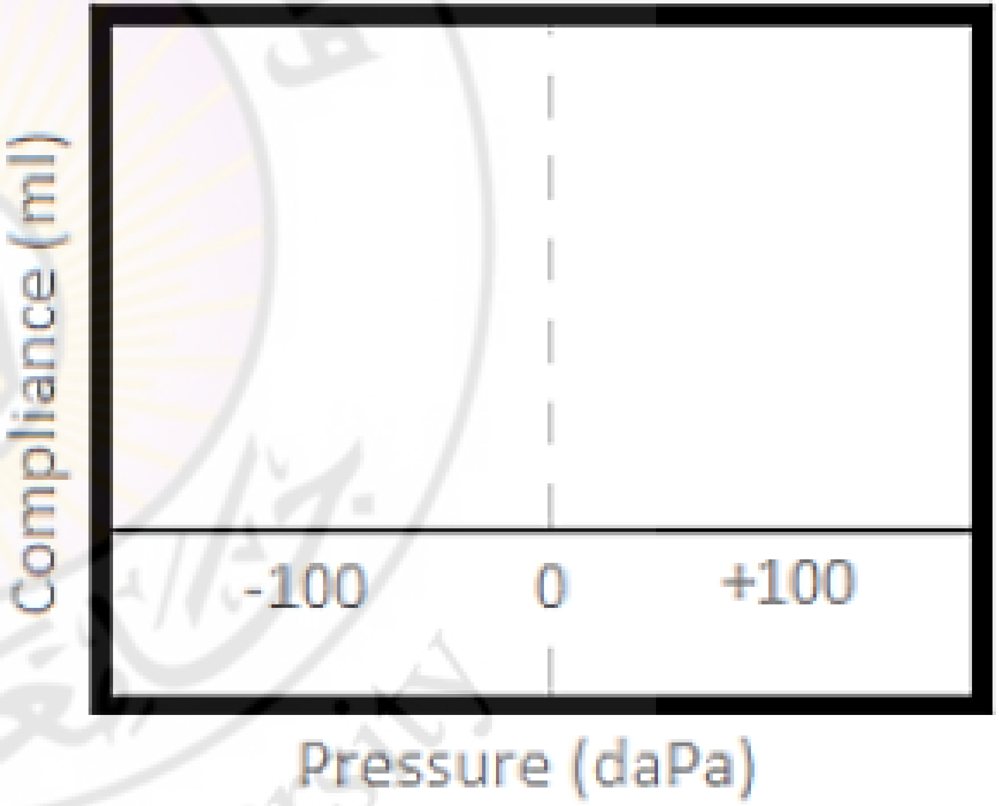
- Peak is below – 100 daPa
- Admittance from 0.3-1.6 mmho
- Suggests Eustachian Tube dysfunction (often seen just before or after effusion)



TYPE B

TYPE B

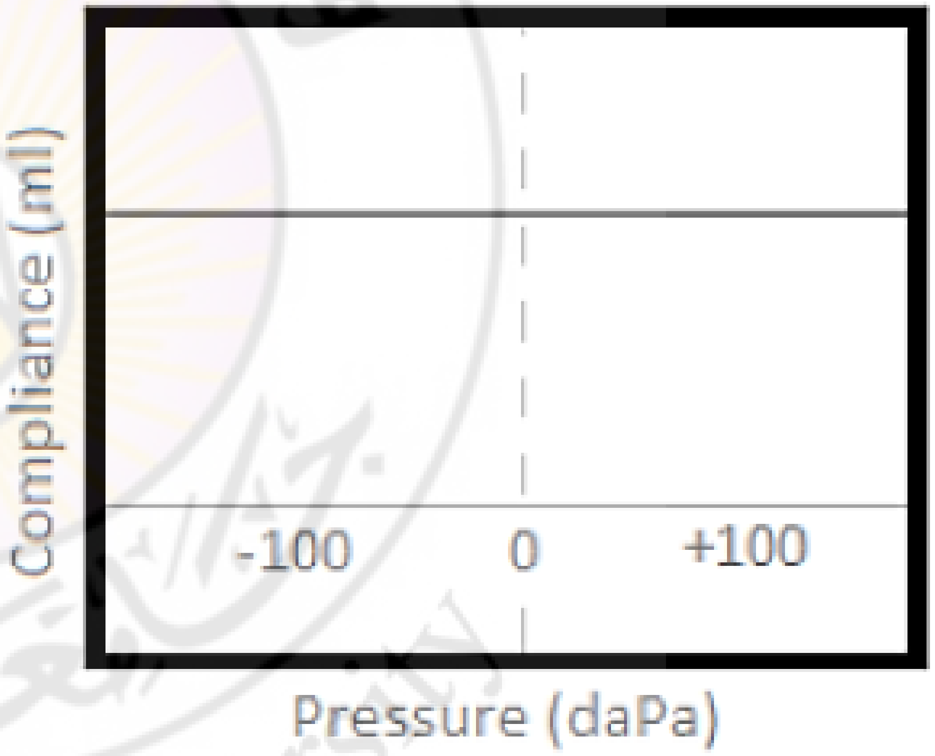
- There is no identifiable peak
- Ear canal volume is normal
- Suggests middle ear involvement from fluid (middle ear effusion)

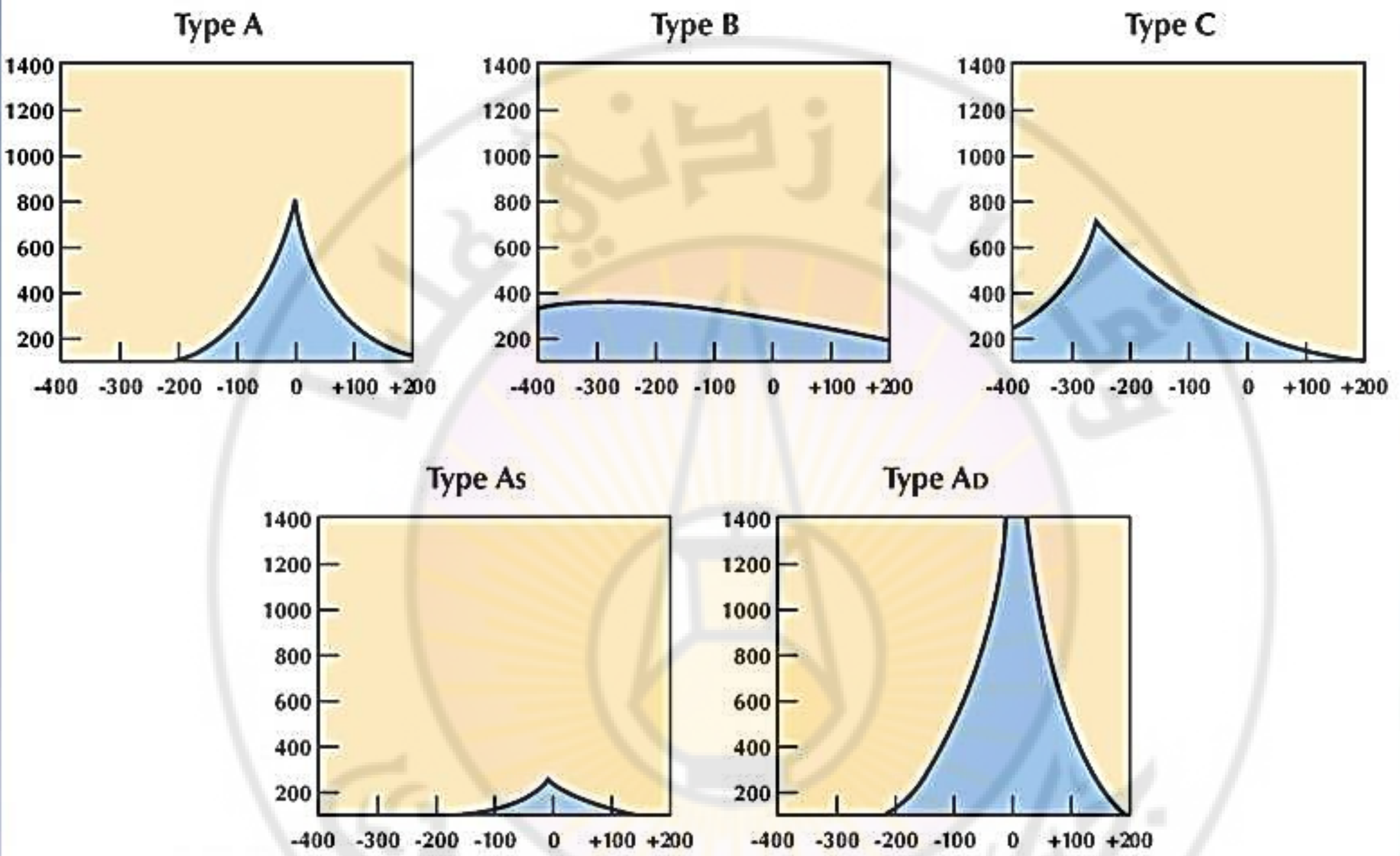


TYPE B-HIGH

TYPE B-HIGH

- There is no identifiable peak
- Equivalent ear canal volume exceeds normal limits; much larger than 1.5 cc
- Suggests middle ear involvement from a perforation or patent grommet (VT)





Type	Implications
Type A	Normal tympanogram/ sensorineural hearing loss where conductive mechanism is normal.
Type B	Flat curve, no change in compliance with pressure changes. Seen in fluid in the middle ear.
Type C	Maximum compliance in negative pressure. Seen in eustachian tube obstruction.
Type As	Compliance is lower at or near ambient air pressure. Seen in otosclerosis or malleus fixation.
Type Ad	High compliance at or near ambient pressure. Seen in ossicular discontinuity.

Quantitative analysis of Tympanograms

1. Equivalent Ear Canal Volume (Vea or Vec)

2. Peak-Compensated Static Acoustic Admittance (Ytm)

3. Tympanometric Peak Pressure (TPP)

4. Tympanometric Gradient and Width (TW)

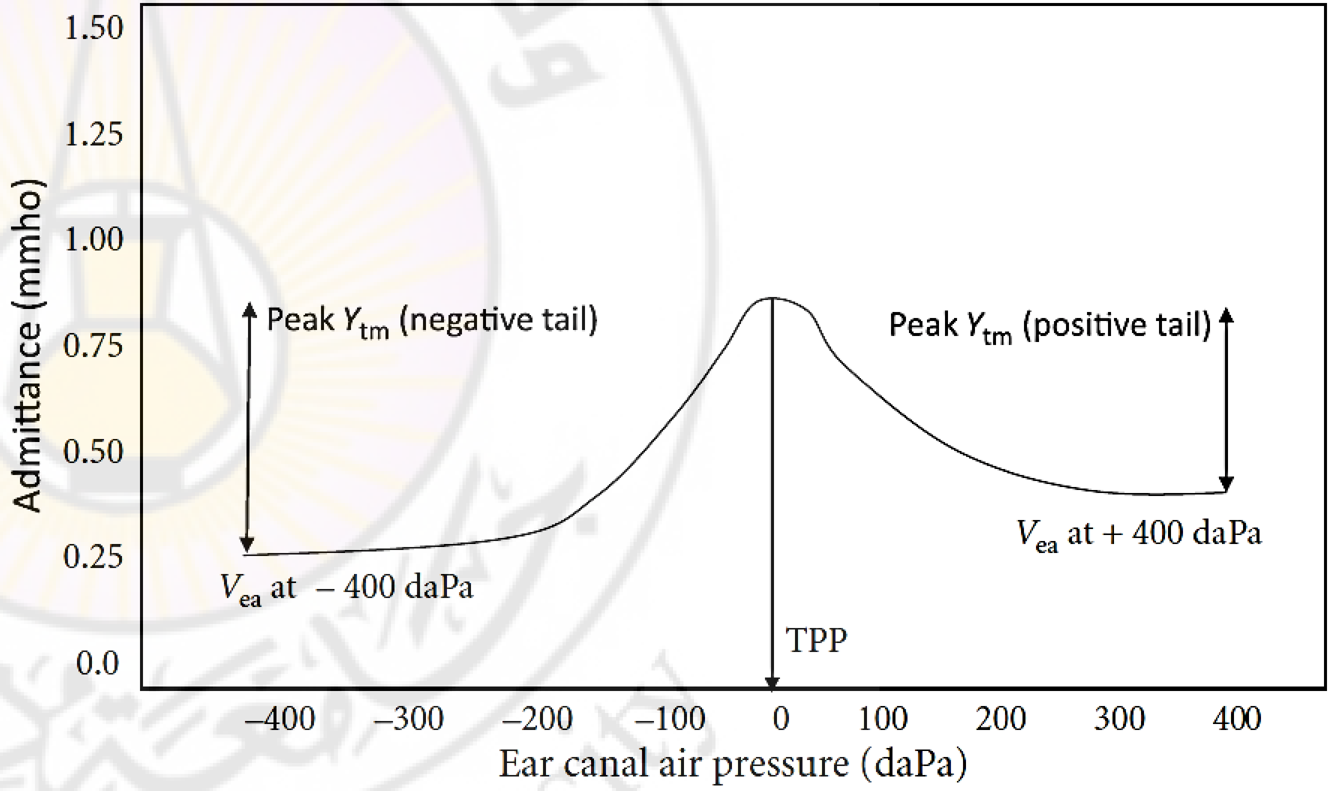
1. Equivalent Ear Canal Volume (Vea or Vec)

- Accuracy of the middle-ear admittance estimate relies on obtaining an accurate estimate of the "equivalent" ear canal admittance (volume).
- Because the admittance of the volume of air in the ear canal contributes to the total middle-ear admittance measurement it must be subtracted out to determine the admittance of the middle ear alone.
- This process is called **tympanometric "compensation"** and is used to the determine admittance of the middle ear at the plane of the TM (Ytm)

Generally, if an open path to the TM can be visualized, cerumen blockages of less than 50% do not affect tympanometry measurements, although the volume will be less than for a clear ear canal.

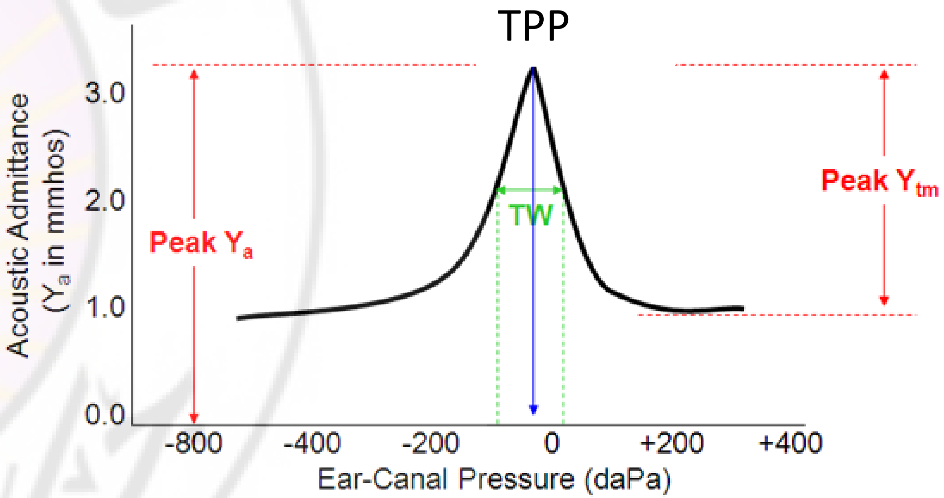
Equivalent Ear Canal Volume (Vea or Vec)

- This measure is called **"equivalent ear canal volume"** because under standard reference conditions using a probe tone of 226 Hz, the volume of trapped air in a hard-walled cavity is equal to the acoustic volume of that same cavity.
- In other words, 1 cubic centimeter (cc) or milliliter (mL) of trapped air equals the acoustic admittance of 1 mmho in a hard-walled cavity.
- This equivalency is the reason that some tympanometers measure admittance in cc or mL.

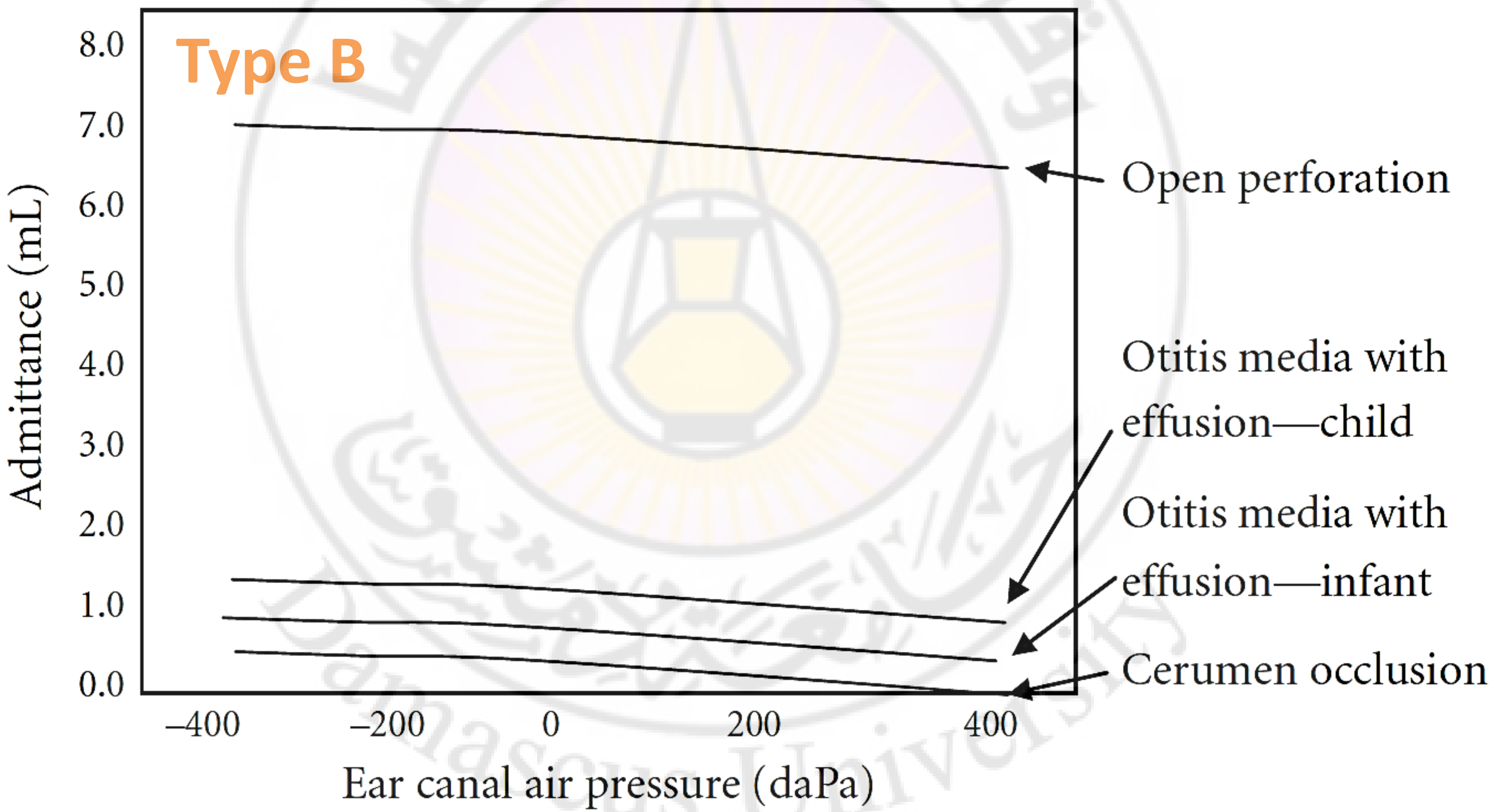


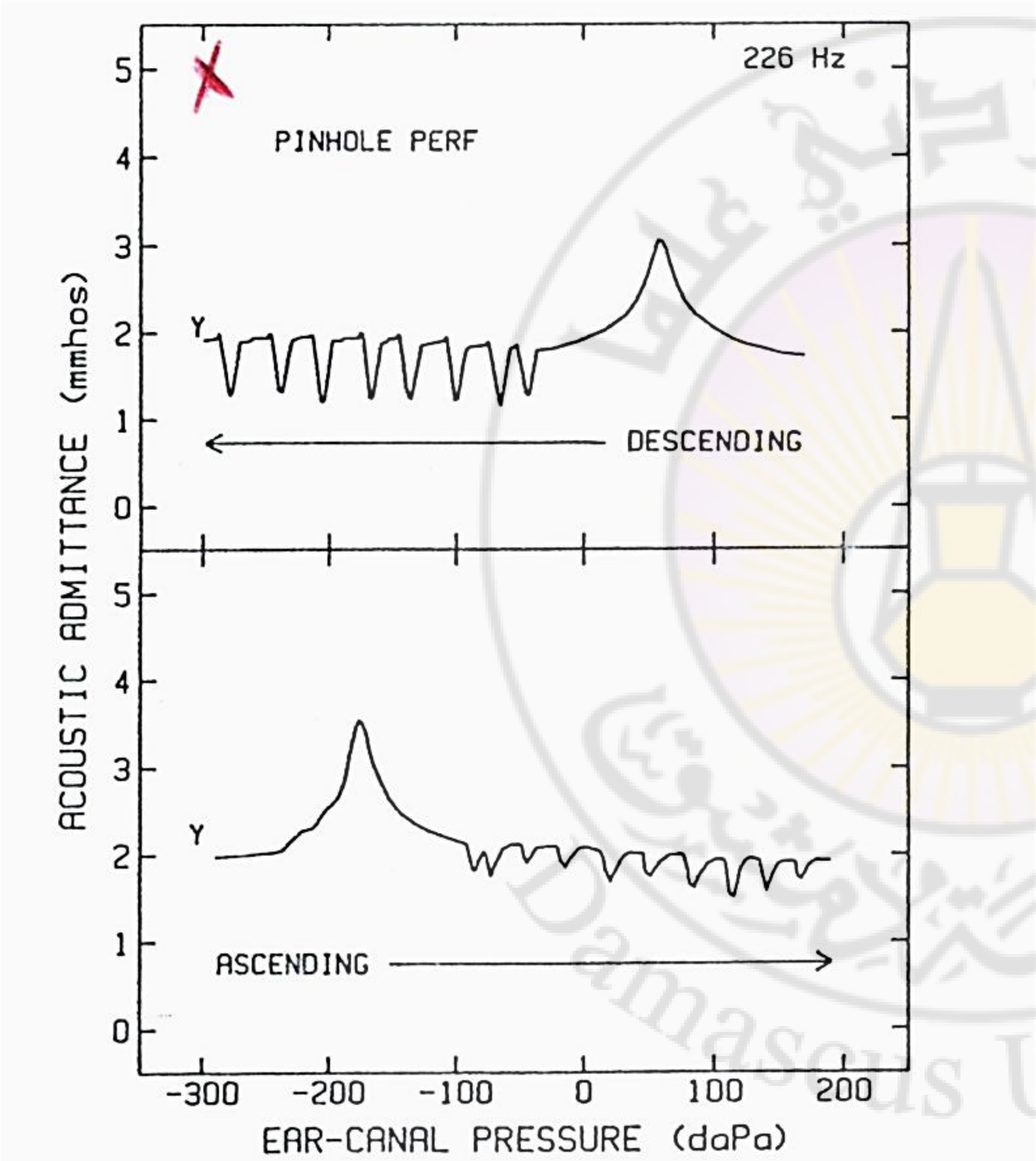
Equivalent Ear Canal Volume (Vea or Vec)

- Estimating the Vec based on positive or negative tails?
- Baseline Function
- Normal values depends on gender and age
- Inter ear difference (87% correlation)
- Inter-ear difference of more than 0.5 cc in children and more than 1 cc in adults are significant



Effects of different conditions on ear canal volume





Observation of normal volume in pinhole perforations!

Ear canal volume

- Tympanometry estimates of ECV over-estimate the actual volume
- As static pressure increases from -400 daPa to 200 daPa the magnitude of the error increases
- **Ear canal volume measured with a 660 Hz probe tone is more accurate than the standard 220 Hz tone**

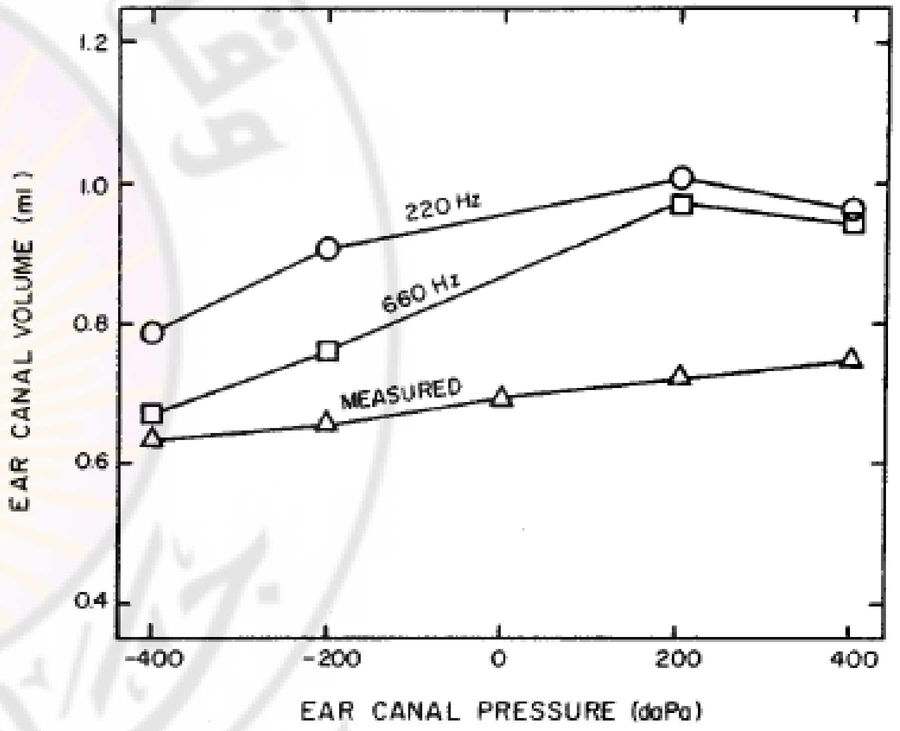
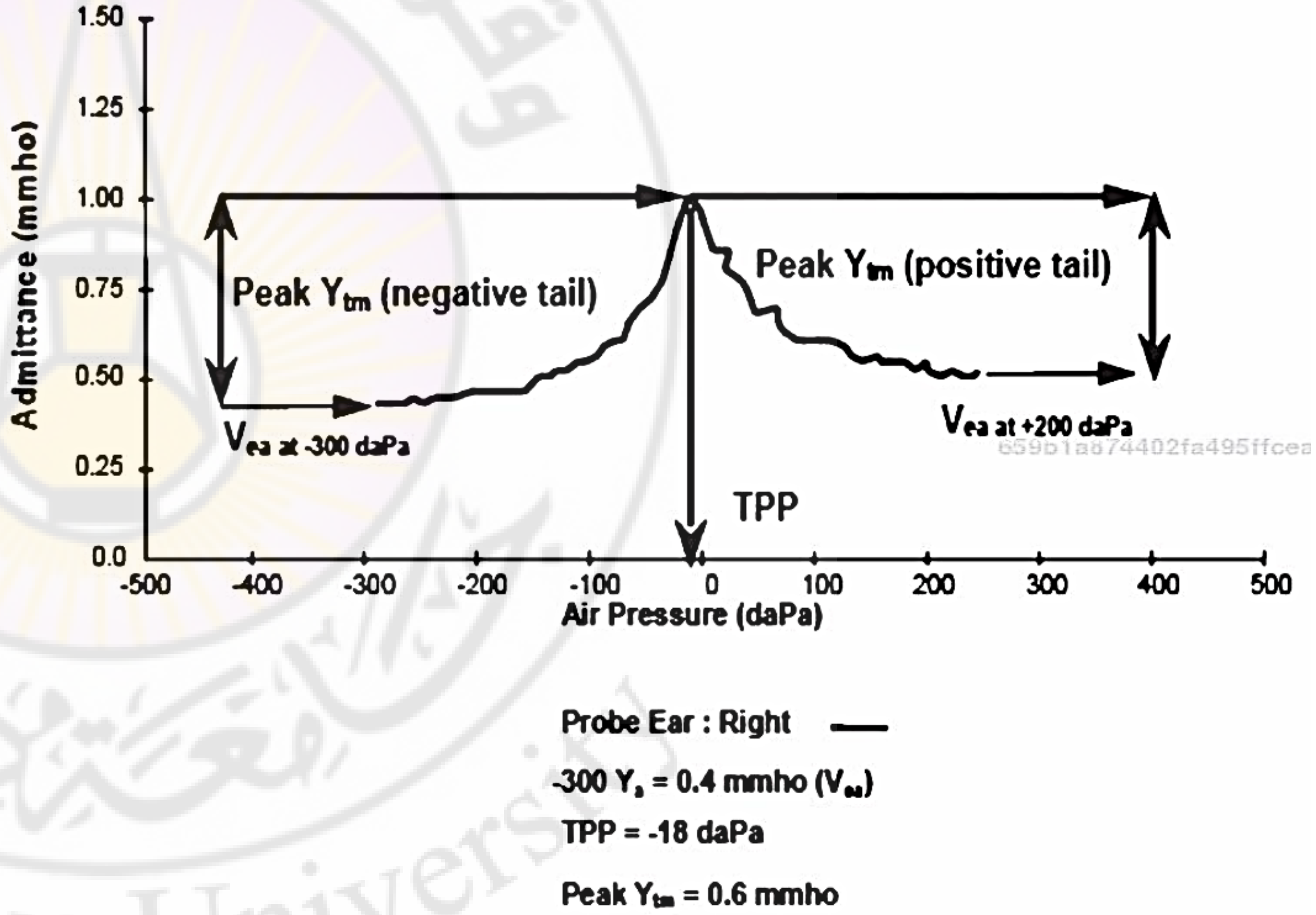


FIGURE 2. Mean ear canal volumes (in ml) for static ear canal pressures between ±400 daPa. The triangle at 0 daPa represents the mean alcohol volume measurement, and the remaining triangles represent the mean alcohol volume adjusted for changes in ear canal volume with changes in ear canal pressure measured using the gas-law procedure. Tympanometric estimates are shown for the 220-Hz (circles) and the 660-Hz (squares) probe frequencies.

2. Peak-Compensated Static Acoustic Admittance (Ytm)

- The peak of the tympanogram after subtraction of Vea is called the "peak-compensated static acoustic admittance" or, more commonly, **static admittance (Ytm).**



Peak-Compensated Static Acoustic Admittance (Ytm)

- Normal limits (0.3-1.6)
- Women less than man
- Newborns ➢ children ➢ adults
- No inter-ear difference
- Increasing the pump speed cause increasing the Ytm
- Negative pump pressure direction cause to decrease the Ytm
- Several recording attempts in same session cause to increase the Ytm
- Different mass or stiffness dominant pathologies can have overlapping effects on Ytm
- Diagnostic value alone is limited

Table 7.1 Representative 90% normal ranges for peak static acoustic admittance (mmhos) using 220 and 226 Hz probe tones

Source	90% Normal range
Adults	
Wiley (1989)	0.37–1.66
Children	
Silman, Silverman, & Arick (1992)	0.35–1.25
Infants and Toddlers ≥ 6 months	
Roush et al (1995)	
6–12 months	0.20–0.50
12–18 months	0.20–0.60
18–24 months	0.20–0.70
6–12 months	0.20–0.50
Calandruccio, Fitzgerald, & Prieve (2006)	
6–12 months	0.16–0.60
2 years	0.21–1.03

Table 7.3 Differences in 90%normal ranges for peak static acoustic admittance (mmhos) at slow and fast pump speeds[a]

Pumpspeed	Adults[b]	Children (3–5 years)[c]
Slow (≤ 50 daPa/s)	0.50–1.75	0.35–0.90
Fast (200 daPa/s)	0.57–2.0	0.40–1.03

[a]Modified from Van Camp et al (1986).

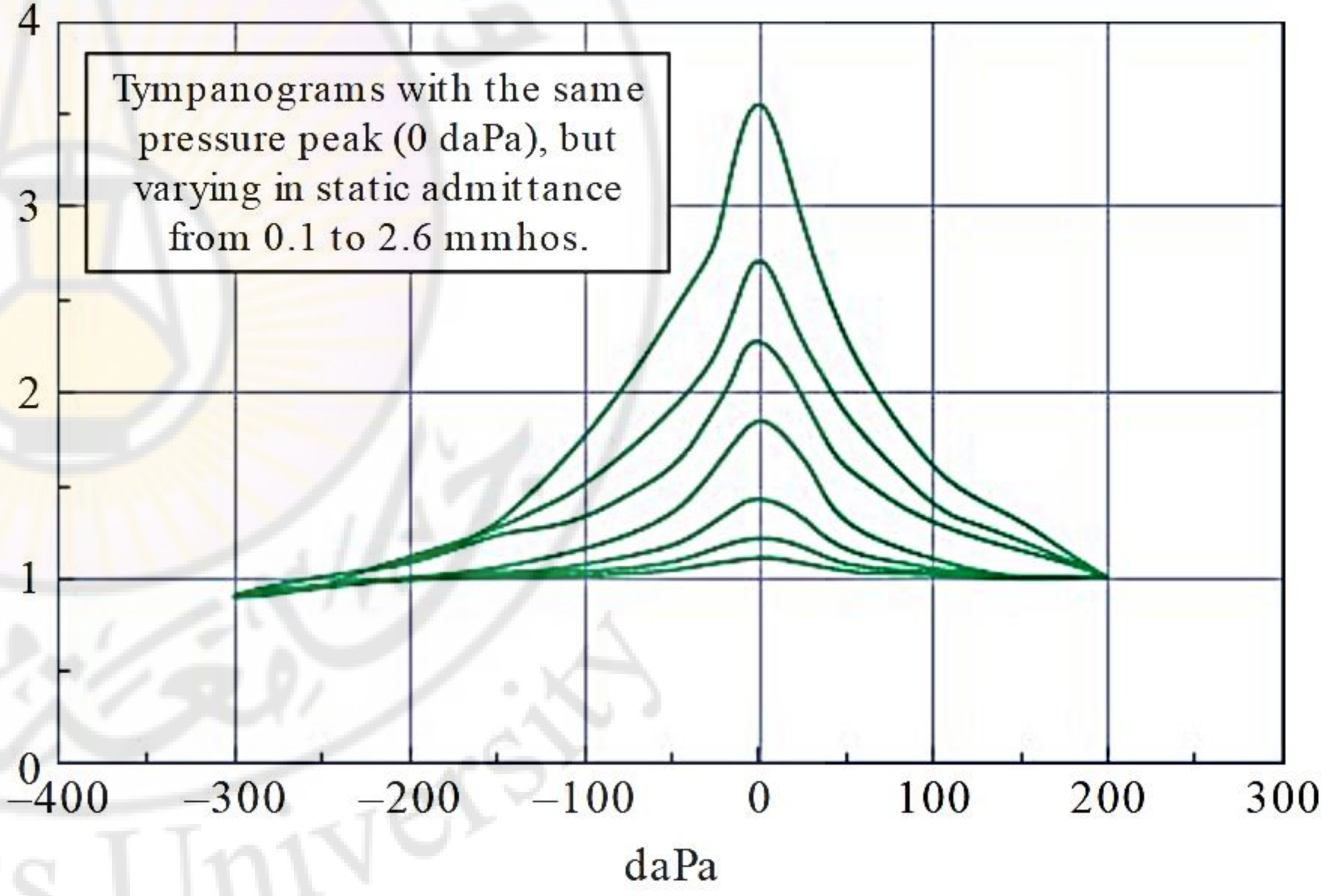
[b]Based on data from Wilson, Shanks, and Kaplan (1984a).

[c]Based on data from Koebsell and Margolis (1986).

Peak-Compensated Static Acoustic Admittance (Ytm)

- Abnormally low static acoustic admittance corresponds to abnormally high impedance and is generally associated with disorders such as otitis media, cholesteatoma, and otosclerosis.

- On the other hand, abnormally high static admittance (and thus abnormally low impedance) is often associated with disorders such as ossicular discontinuity.



3. Tympanometric Peak Pressure (TPP)

- the ear canal air pressure at which the peak of the tympanogram occurs is the TPP.
- Because Ytm reaches its highest value when the pressures on both sides of the TM are equal, TPP is an indicator, but not a direct measure, of the pressure in the middle-ear space.
- In fact, TPP overestimates the actual middle-ear pressure by as much as 100%. A TPP of −300 daPa, for example, could occur with actual middle ear pressure of only −150 daPa.

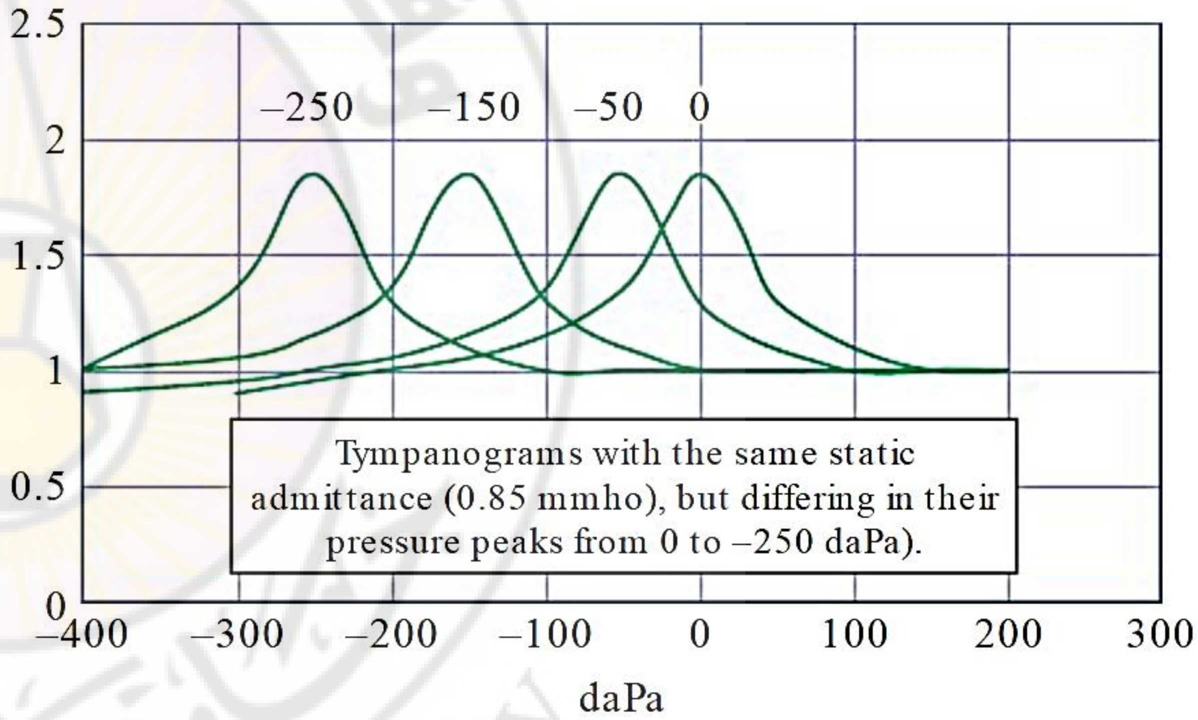
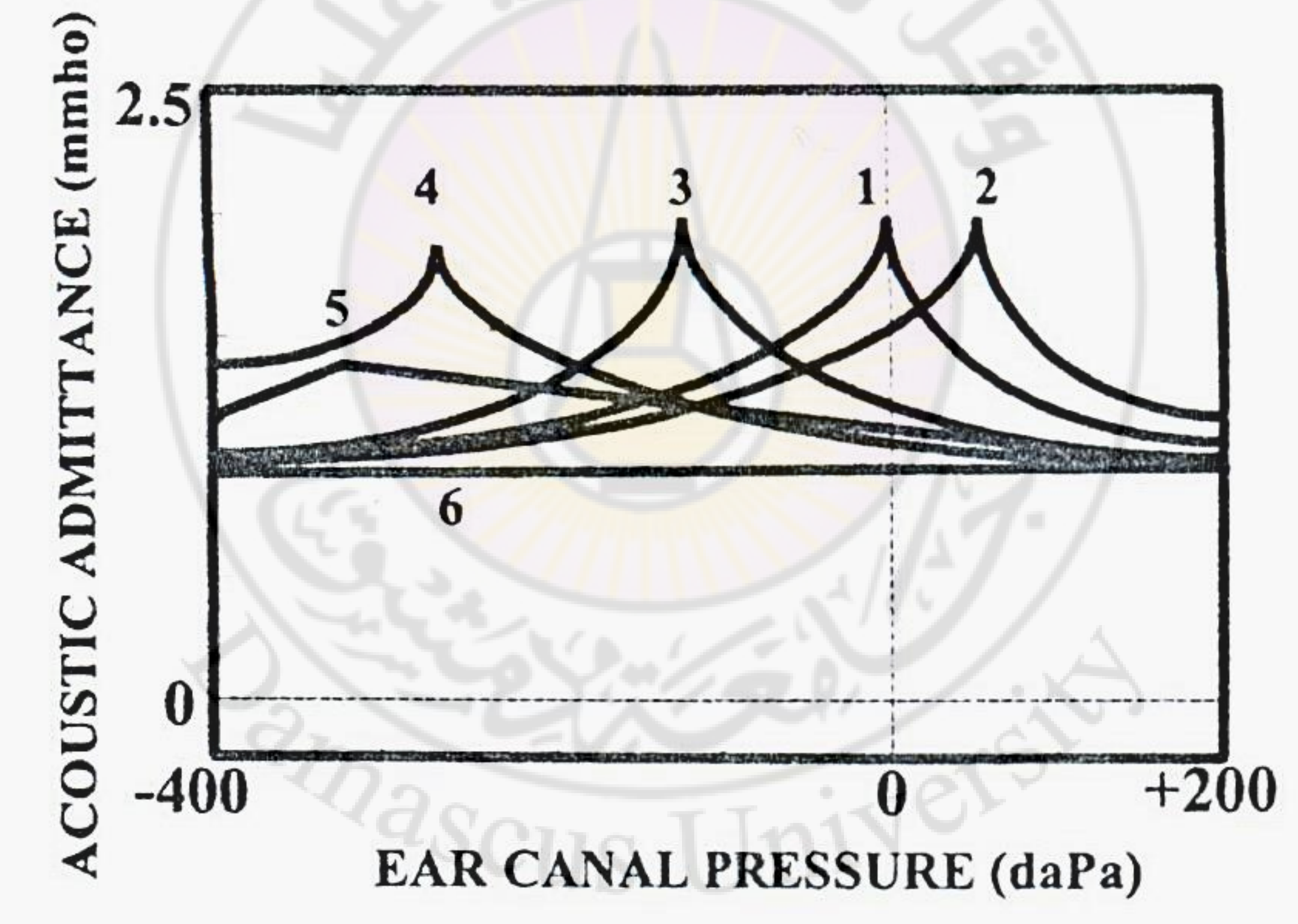


Fig. 7.9 Examples of tympanograms with tympanometric peak pressures of 0 daPa, –50 daPa, –150 daPa, and –250 daPa.

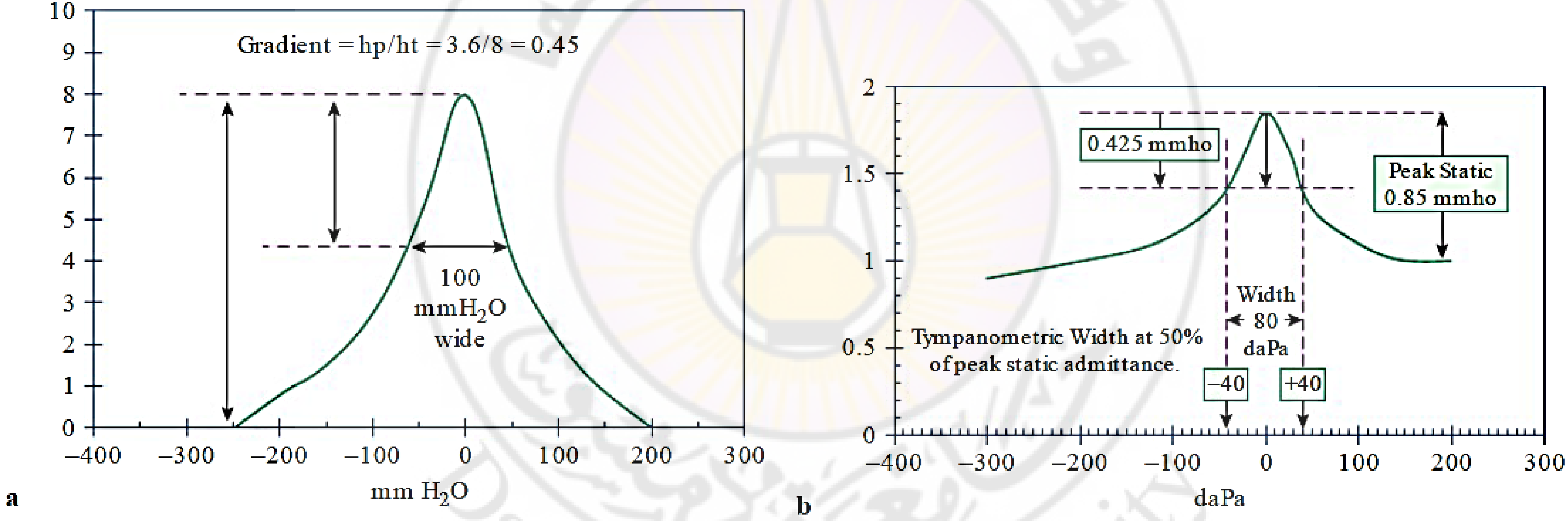
TPP or MEP?

- Evaluation of Eustachian tube function
- Monitoring the progress of Otitis media
- Positive MEP in Acute otitis media
- Non-pathological negative MEP in almost 25% of children
- Height of the tympanogram should not affect, if there is no fluid in the middle ear
- Factors that can affect MEP:
  - **Change in pressure pump direction (pinhole perforations)**
  - **Pump speed**

Ex Vacuo theory



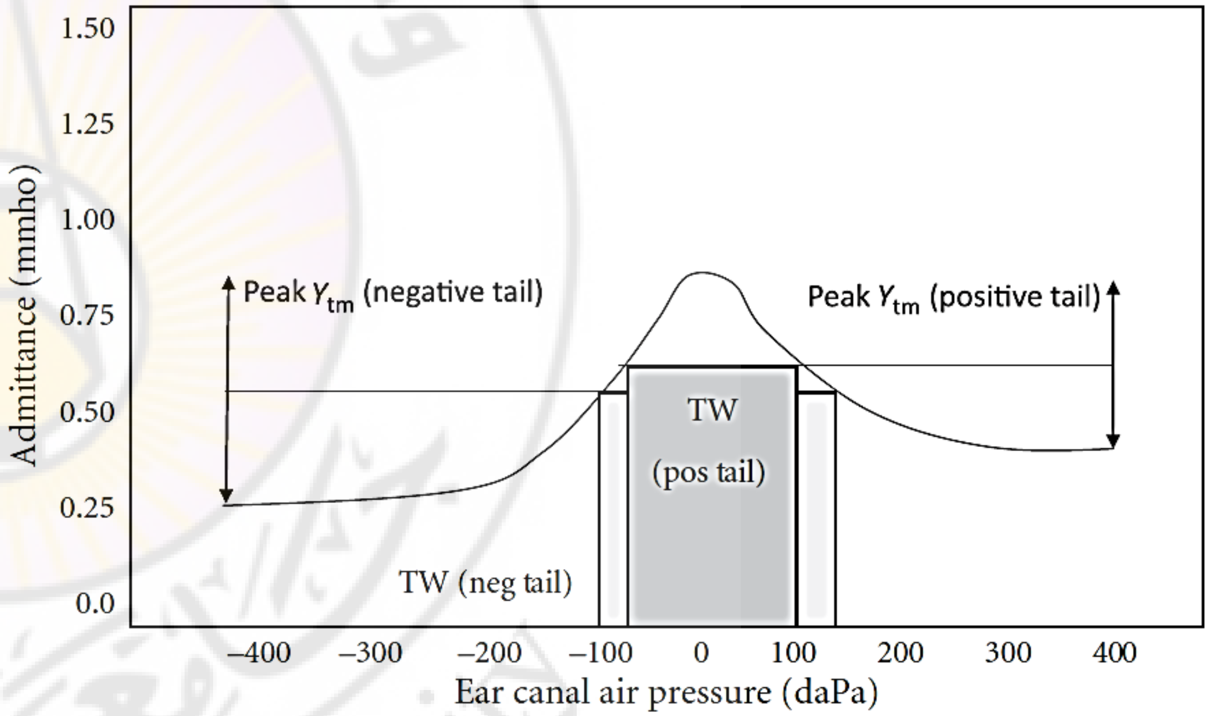
4. Tympanometric Width (TW) and Gradient



The flatness (versus peakedness) of a tympanogram can be quantified by its gradient, and tympanometric width which describes the **relationship of its height and width.**

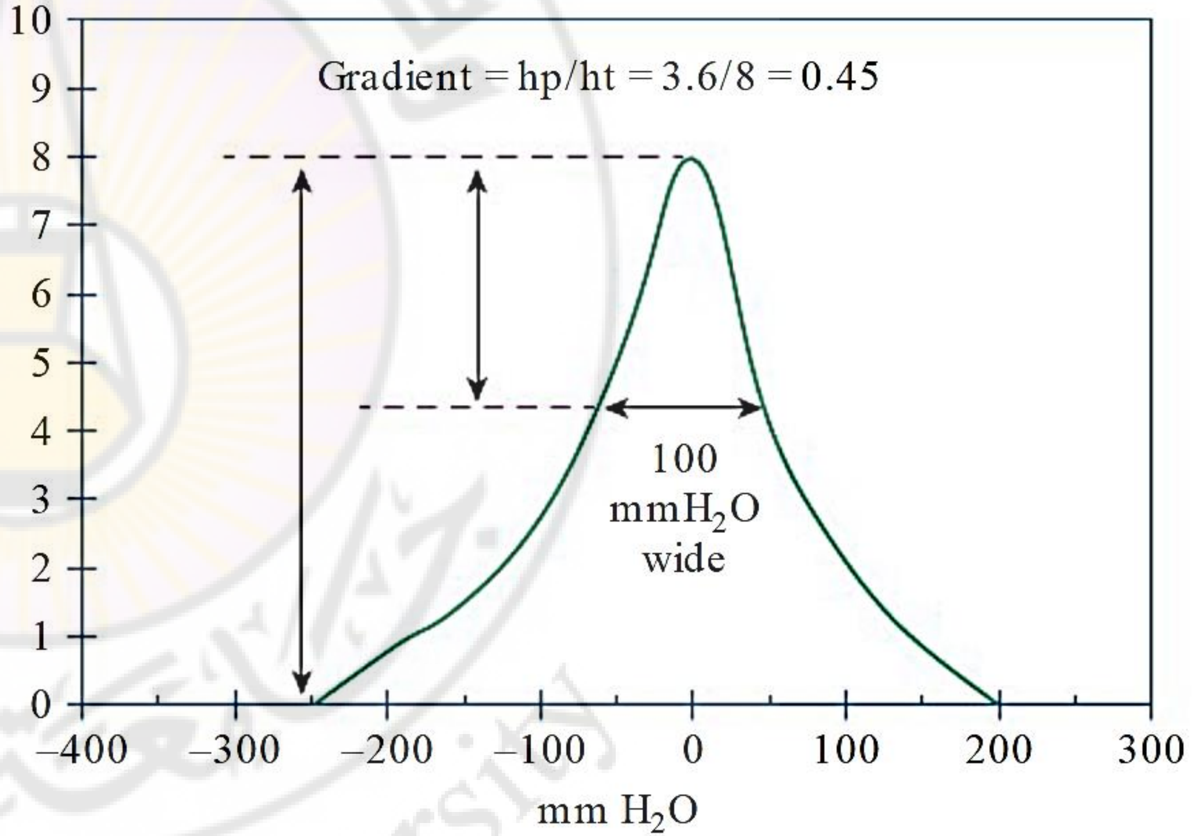
Tympanometric Width (TW)

- TW: $Y_{TM}/2$
- Normal range:
  - Newborns: 235 dapa
  - Children: 200 dapa
  - Adults: 50-110 dapa
- Not related to gender
- In adults population increases with age progress
- Fixation cause narrowing of TW
- Effusion cause widening of TW



Gradient

- (1) Draw a horizontal line where the width of the tympanogram is 100 mm daPa
- (2) Measure the height of the peak above this line (hp), as well as the total height (ht) of the tympanogram from its peak to its baseline.
- (3) Find the gradient by dividing hp/ht



- **<0.2 : abnormally Low**

Normative Values for Tympanometry Measurements at 226 Hz for Adults

Study	Gender (N)		Y_{tm} (SA) + mmho	TW + daPa	TPP daPa	V_{ea} + (cm^3)
Roup et al. (1998)	M	Mean	0.87	59.8	−26.18	1.40
20–30 yr	*N* = 51	SD	0.46	17.3	31.66	0.32
		90% Range	0.30–1.80	35.0–87.0	−110.00 to 9.0	1.00–2.10
	F	Mean	0.58	73.9	−27.75	1.18
	N = 51	SD	0.27	17.2	23.50	0.22
		90% Range	0.30–1.12	45.0–107.0	−80.0 to −3.0	0.80–1.60
	Overall	Mean	0.72	66.9	−29.96	1.29
	N = 102	SD	0.40	18.6	27.76	0.29
		90% Range	0.30–1.19	32.8–95.0	−103.50 to 4.2	0.90–1.80
Wiley et al. (1996)	M	Mean	0.72	73		1.49
48–90 yr	*N* = 825	SD				
		90% Range	0.2–1.60	35–125		1.0–2.20
	F	Mean	0.62	76		1.28
	N = 1,322	SD				
		90% Range	0.2–1.40	40–120		0.9–1.90
	Overall	Mean	0.66	75		1.36
	N = 2,147	SD				
		90% Range	0.2–1.50	35–125		0.9–2.0

Peak-compensated static admittance, Y_{tm}; tympanometric width, TW; tympanometric peak pressure, TPP; equivalent ear canal volume, V_{ea}.

Developmental and Aging Effects

- Static admittance increases, ear canal volume increases, and TW decreases from infancy up to age 6 years.
- These changes are because of the increase in ear canal and middle-ear space, which make the middle-ear system more compliant with increased age.
- These changes continue into adulthood, especially for ear canal volume.
- Young adults aged 20 to 30 years have larger ear canal volume and narrower TW relative to children.
- Older adults (48 to 90 years) have lower static admittance, higher ear canal volume, and lower TW than younger adults.

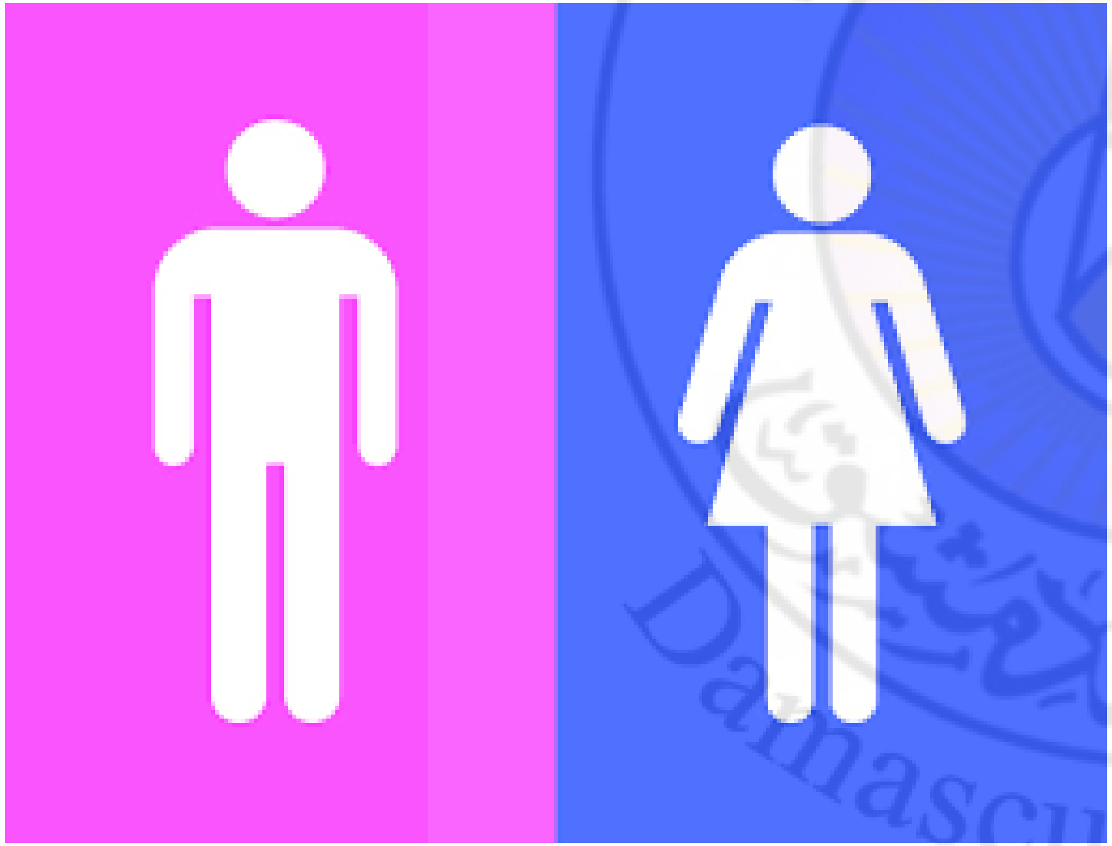
Table 7.2 Ninety percent ranges for peak static acoustic admittance (mmhos) among older adults from two large-sample studies

Age (years)	Wiley et al (2005)[a]	Golding et al (2007)
48 (49)[b]–59	0.2–1.5	0.3–2.2
60–69	0.2–1.6	0.3–2.1
70–79	0.0–1.8	0.2–2.2
≥ 80	0.0–2.0	0.2–2.5

[a]Combined across right and left ears using baseline examination data.

[b]Range: 48–59 in Wiley et al (2005), and 49–59 in Golding et al (2007).

Sex effects on tympanometric parameters



- Males have a higher static admittance and ear canal volume and narrower TW than females.

Effects of Middle-Ear Pathologies

	Y	TW	Volume	Mass	Springiness	Resonant Frequency
Middle-ear effusion	Low	Wide	Normal	↑	↓	Low
Monomer or ossicular discontinuity	High	Narrow	Normal	↑	↑	Low
Perforation	Flat or variable	–	High	–	–	–
Tympanosclerosis	Normal to low	Normal	Normal	↑	↓	Low
Cholesteatoma	Low	Wide	Normal		↓	Low
Lateral ossicular fixation	Low	Wide	Normal	–		High
Medial ossicular fixation (otosclerosis)	Normal	Normal/narrow	Normal		↓	Normal to high

Common Middle Ear Pathology and the Characteristics of Y-226 Tympanograms Frequently Associated With Them[a]

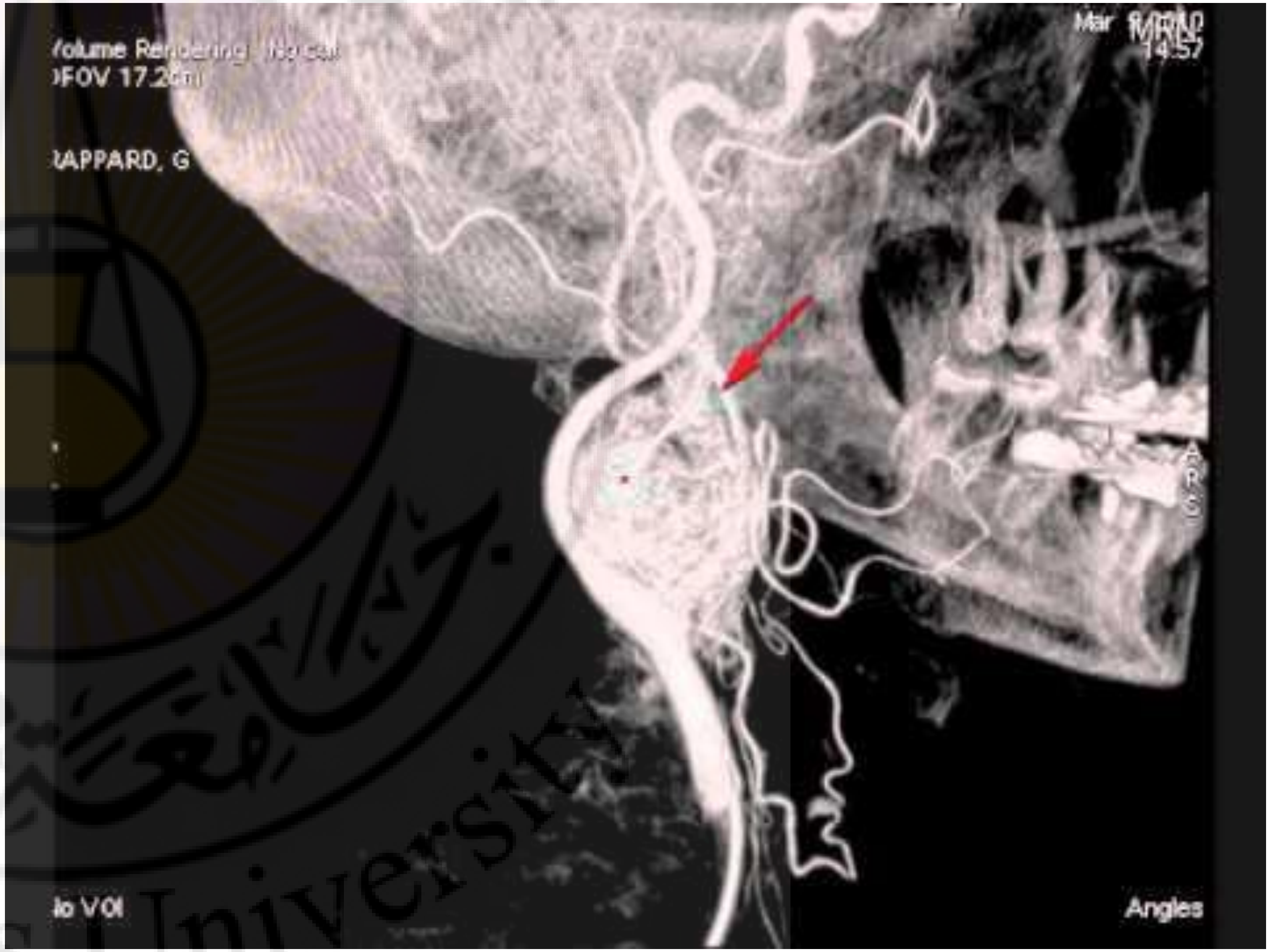
Pathology	V_{ea}	Y_{tm}	TW	TPP
Early ME effusion	Normal	Reduced	Widened	Normal/positive
ME effusion	Normal	Reduced/flat	Widened	Negative/CNT
Ossicular discontinuity	Normal	Increased	Normal	Normal
TM pathology	Normal	Increased	Normal	Normal
Otosclerosis	Normal	Normal/reduced	Normal/reduced	Normal
Malleus fixation	Normal	Reduced/flat	Increased	Normal
ET blockage	Normal	Normal	Normal	Negative
Open PE tubes	Increased	Flat	CNT	CNT
TM perforation	Increased	Flat	CNT	CNT
Cerumen blockage	Decreased	Flat	CNT	CNT

[a]V_{ea}, equivalent ear canal volume; Y_{tm}, peak compensated static acoustic admittance; TW, tympanogram width; TPP, tympanogram peak pressure; ME, middle ear; TM, tympanic membrane; ET, eustachian tube; PE, pressure equalization; CNT, cannot test.

Vascular Pulsing

Although most tympanograms are smooth, they sometimes have regular ripples or undulations that are synchronized with the patient’s pulse, which is their origin .

Medical referral is indicated when vascular pulsing is present on the tympanogram because it tends to occur in patients with glomus **jugular tumors.**



Limitations of 226 Hz tympanometry

- Pattern in different pathologies
- Effects of more lateral pathologies and coexistent pathologies
- Overlapping the values
- High sensitivity and low specificity

دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Acoustic Immittance Measures

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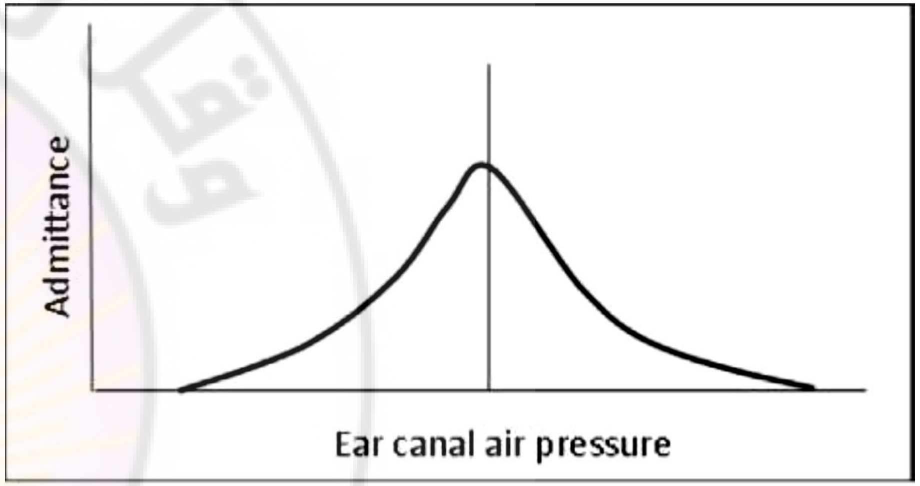
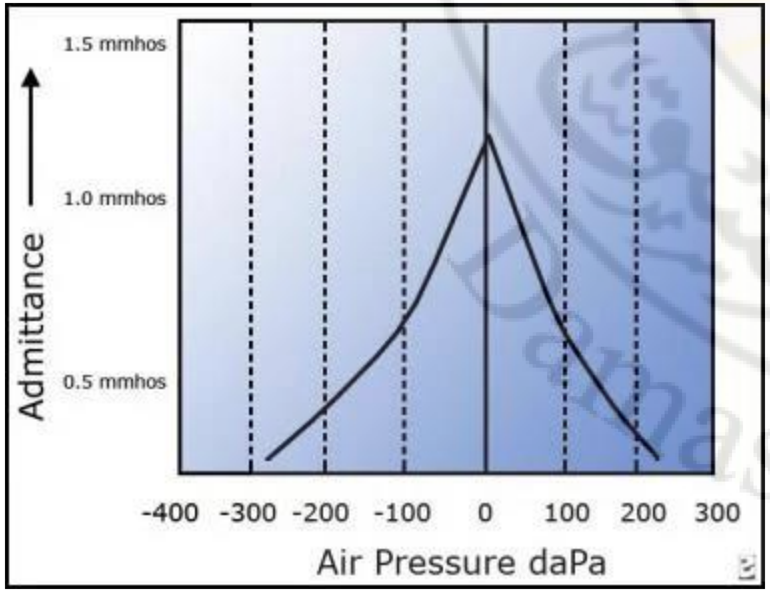
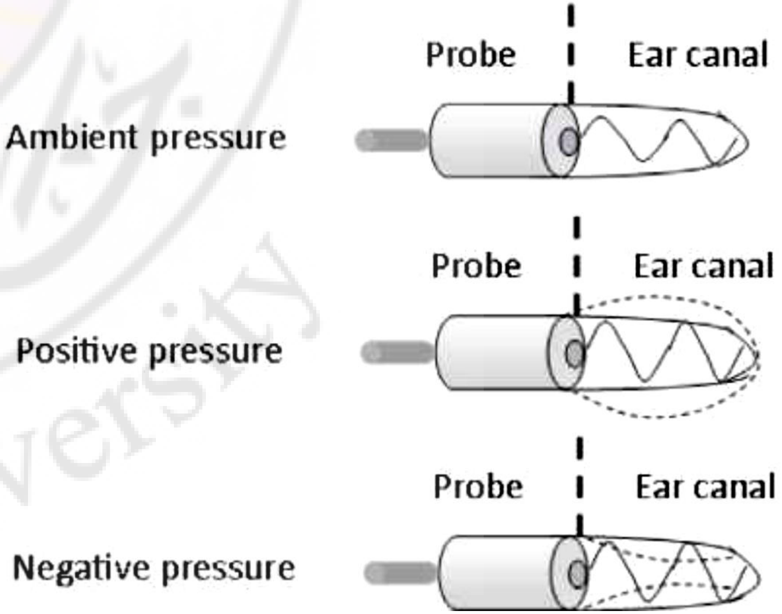
4. Single-frequency Tympanometry

Single-frequency (226 Hz) Tympanometry

- **Tympanometry** involves measuring the acoustic admittance of the ear with various amounts of air pressure in the ear canal (Usually between +200 to -400 dapa). The amount of air pressure is expressed in terms of dekapascals (daPa)



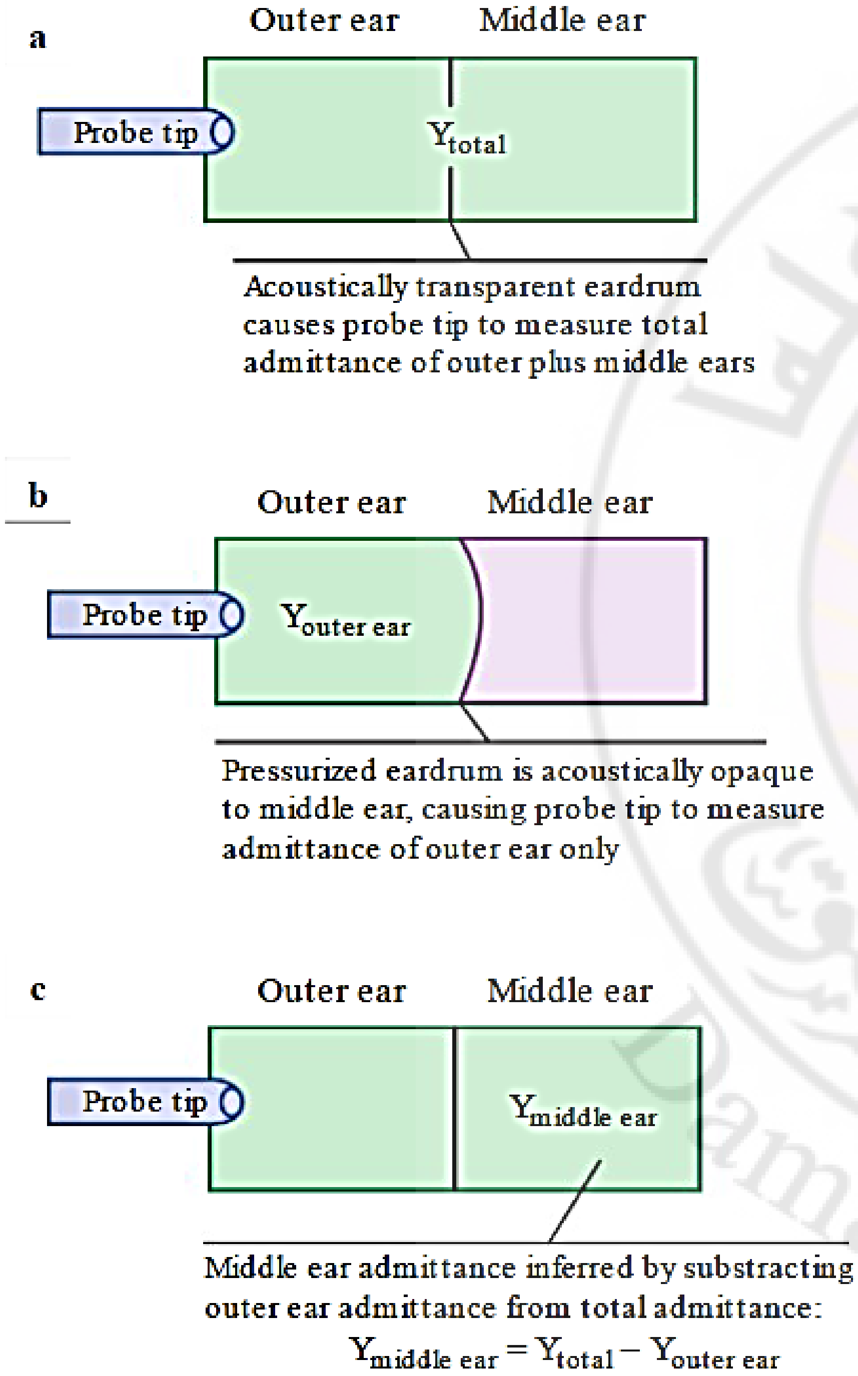




Why 226 Hz?

- 226 Hz is superior to other probe-tone frequencies in identifying or differentiating among middle ear pathologies.
- To avoid microphone nonlinearities at high frequencies
- To allow a higher probe-tone level without eliciting an acoustic reflex
- To avoid interference with the 50-Hz line frequency used in Europe.

- The low-frequency probe primarily assess the **stiffness** characteristics of the middle ear transmission system. The most common pathology of the middle ear affecting stiffness is middle ear effusion.



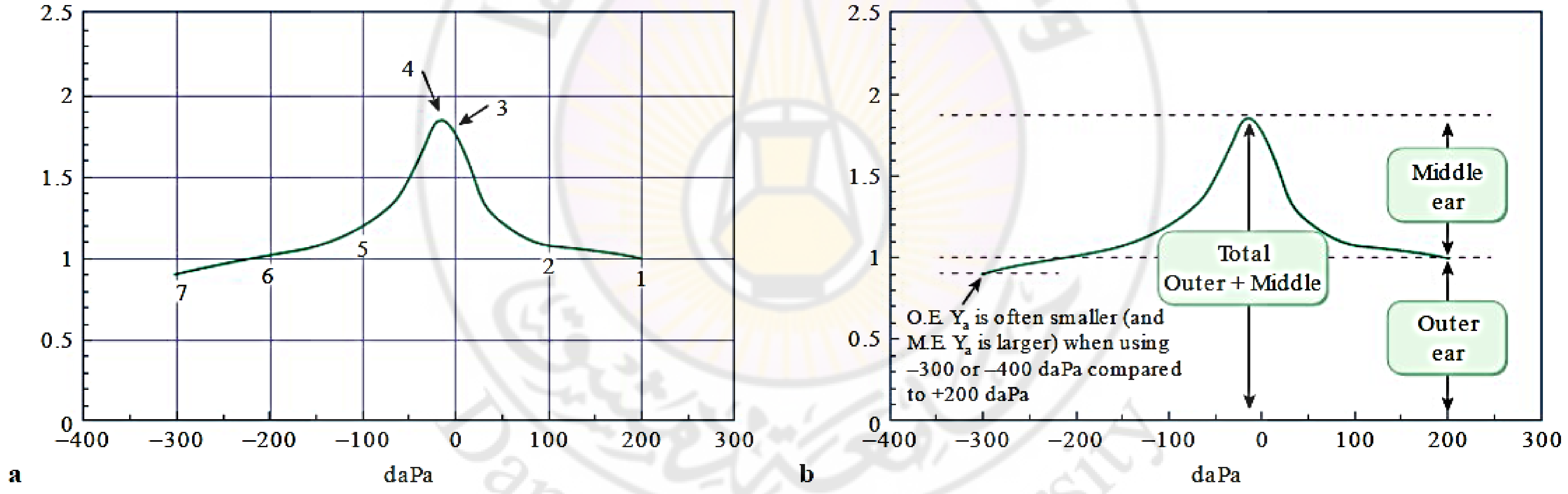
Immittance at the Plane of the Eardrum

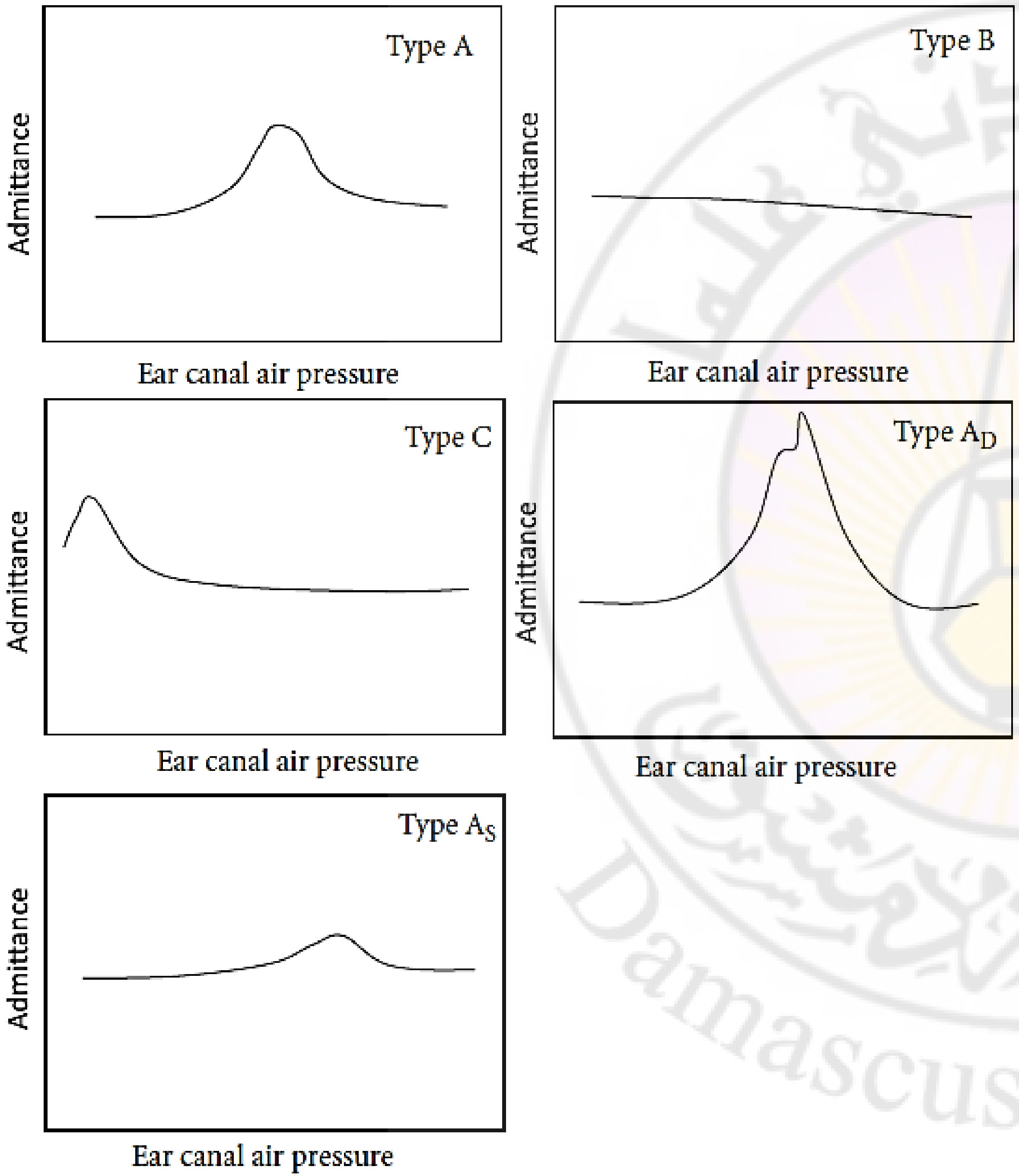
$$Y_{TOTAL} = Y_{OE} + Y_{ME}$$

$$Y_{ME} = Y_{TOTAL} - Y_{OE}$$

- Y_{me} = Peak compensated static acoustic admittance or shortly; Static admittance

What is Tympanogram?

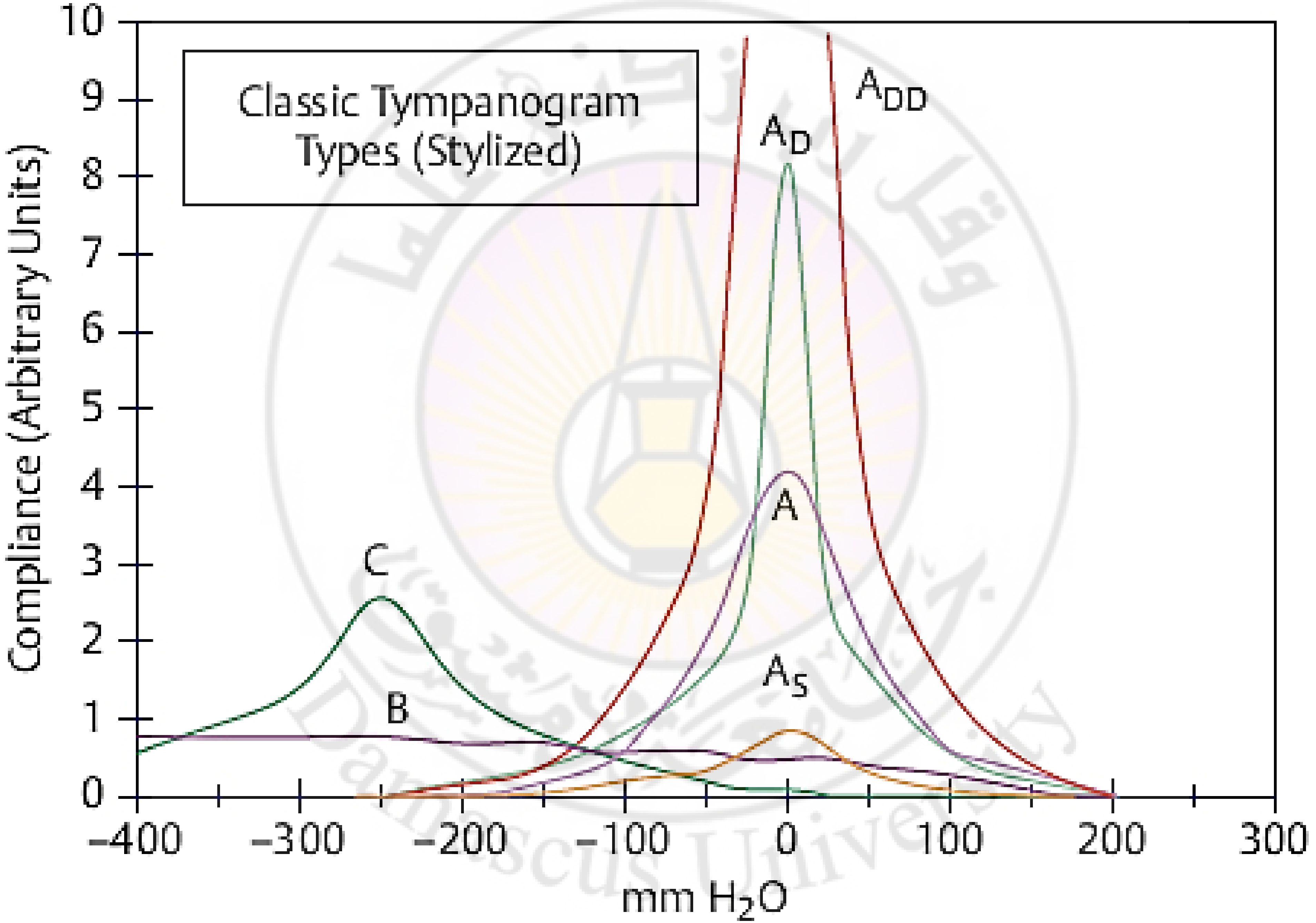




Qualitative analysis of Tympanograms

Lidén–Jerger Model

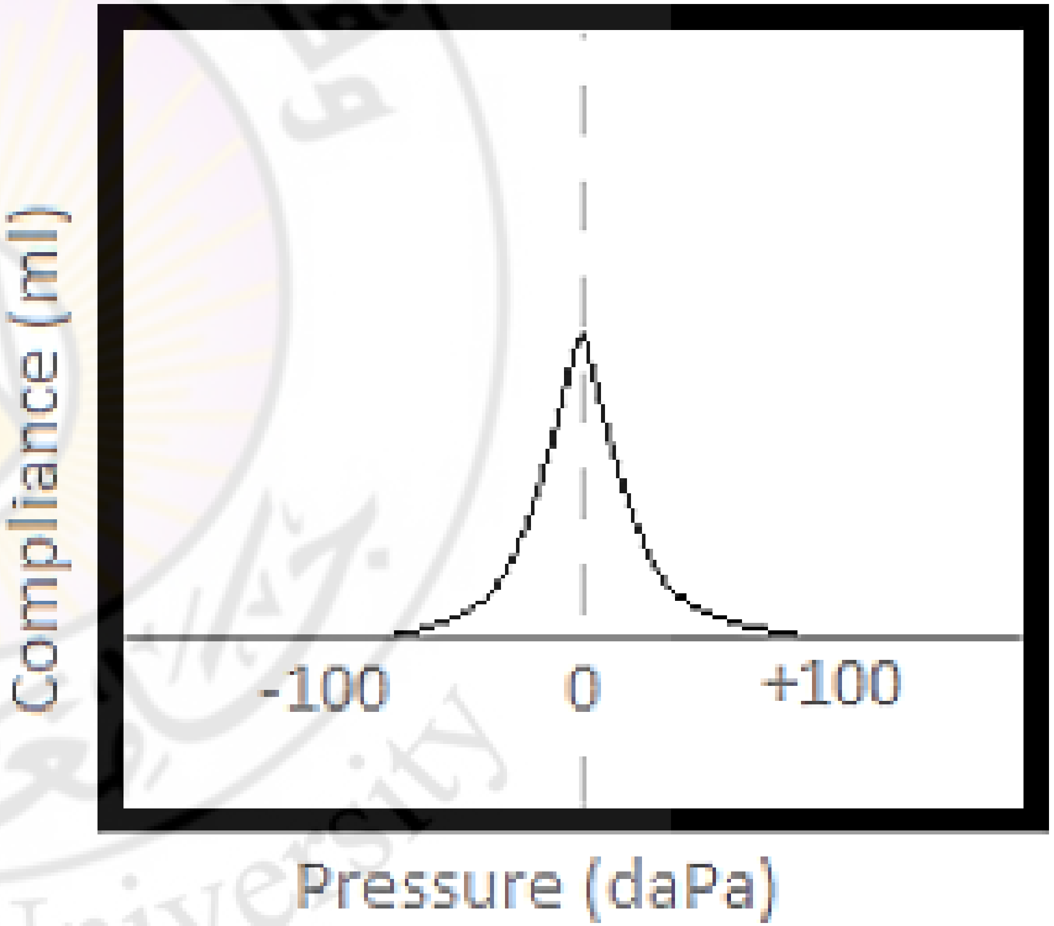
- Lidén–Jerger classification scheme for tympanometric shapes, based on qualitative analysis of the **height** and **location** of the primary peak.
- **A (An)**
- **As**
- **Ad**
- **C**
- **B**


Classic Tympanogram Types (Stylized)
Compliance (Arbitrary Units)
mm H_2O
A_{DD}
A_D
A
A_S
B
C
10
9
8
7
6
5
4
3
2
1
0
–400
–300
–200
–100
0
100
200
300

TYPE A

TYPE A

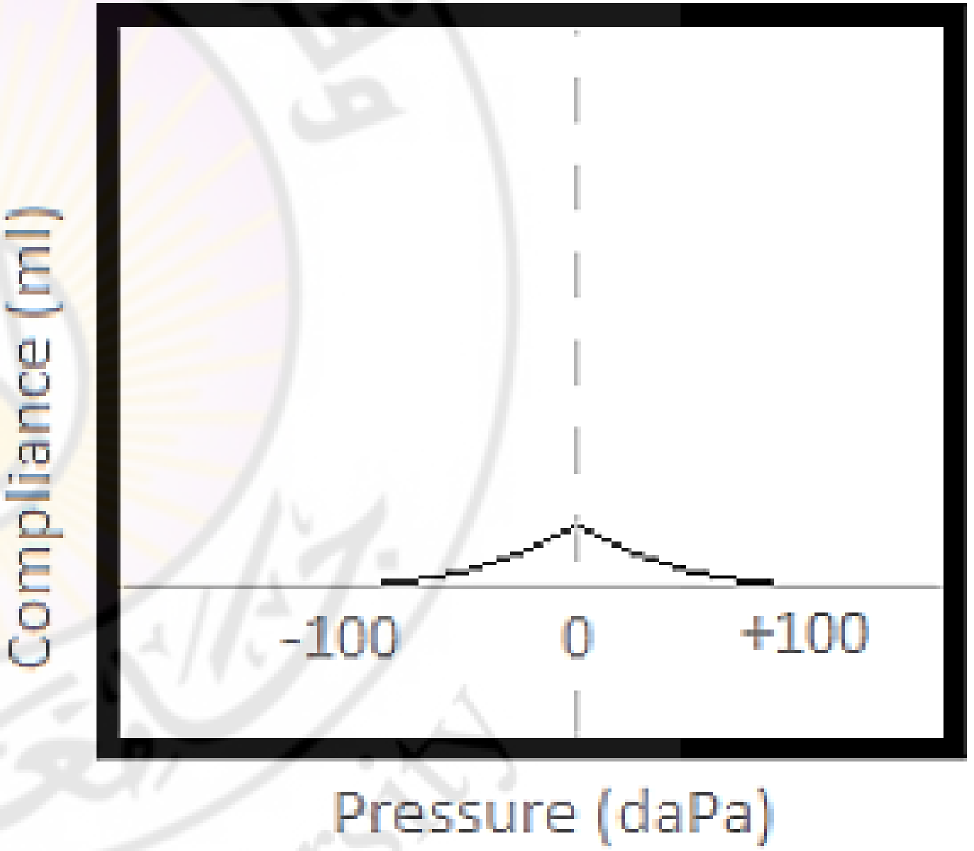
- Peak is between +/- 100 daPa
- Admittance from 0.3-1.6 mmho
- Suggests normal middle ear functioning (as well as those with otosclerosis)



TYPE AS

TYPE AS

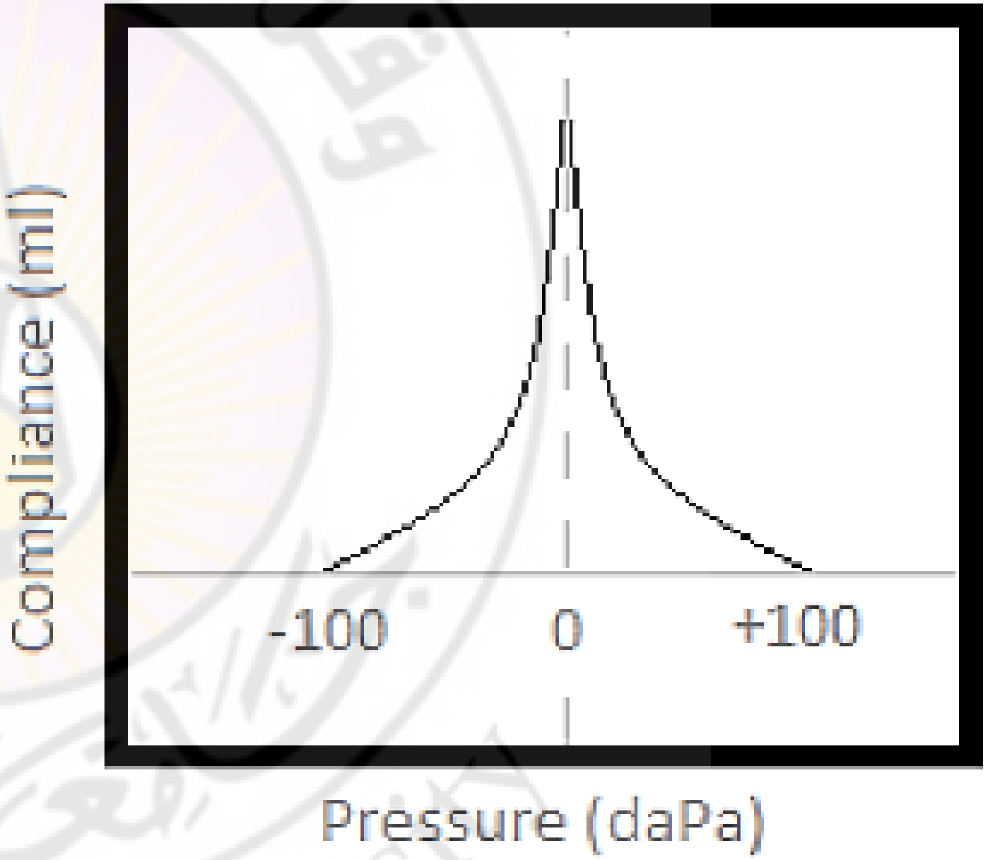
- Peak is between +/- 100 daPa
- Admittance is less than 0.3 mmho (shallow peak)
- Suggests a less compliant (more stiff) middle ear system:
  - Otosclerosis
  - Otitis media



TYPE AD

TYPE AD

- Peak is between +/- 100 daPa
- Admittance is more than 1.6 mmho (deep peak)
- Suggests a highly compliant (Less stiff) middle ear system:
  - Scarred or flaccid eardrums
  - Ossicular Interruptions



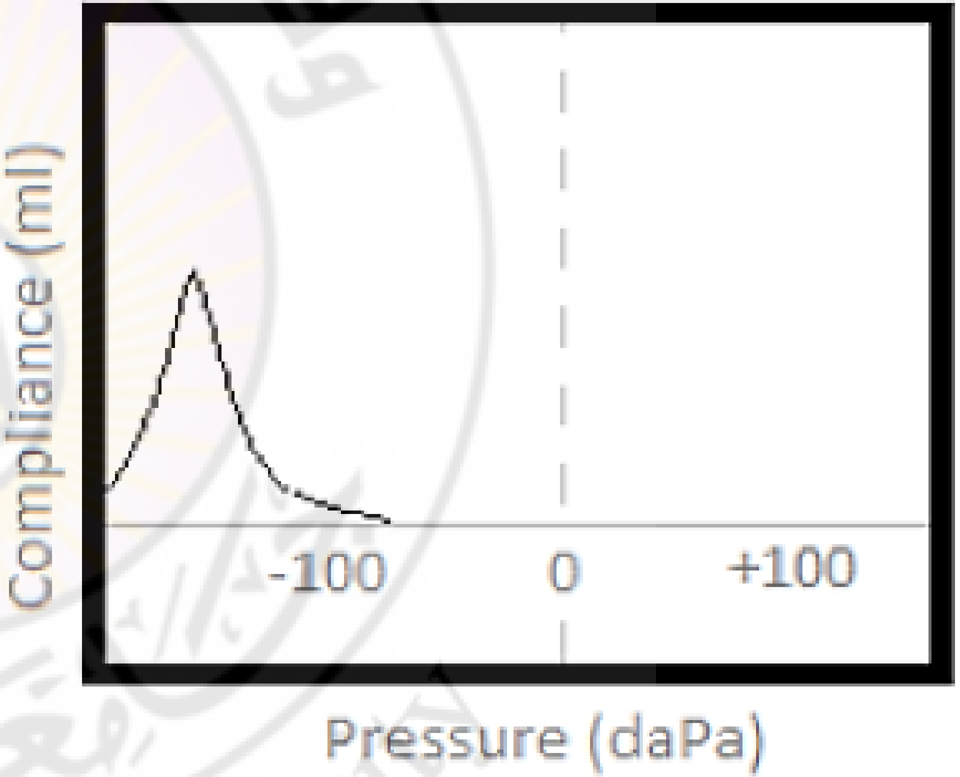
The type ADD tympanogram was so deep that the peak was off-scale, and was found in ears with ossicular discontinuities.

TYPE C

TYPE C

- Peak is below – 100 daPa
- Admittance from 0.3-1.6 mmho

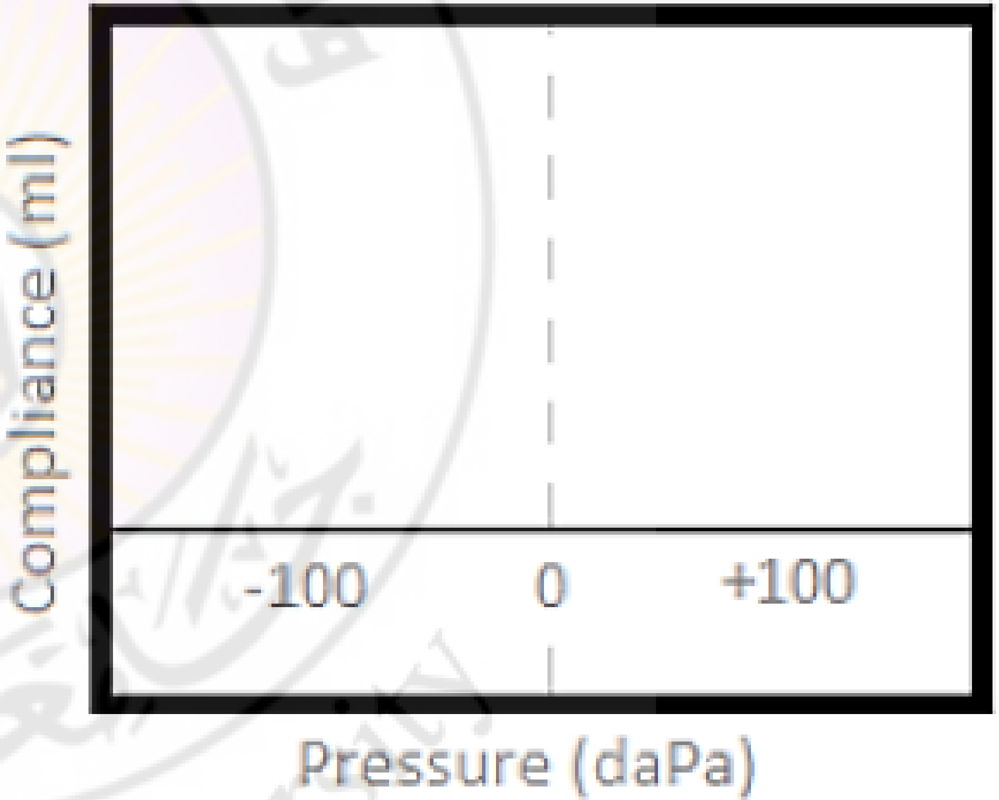
- Suggests Eustachian Tube dysfunction (often seen just before or after effusion)



TYPE B

TYPE B

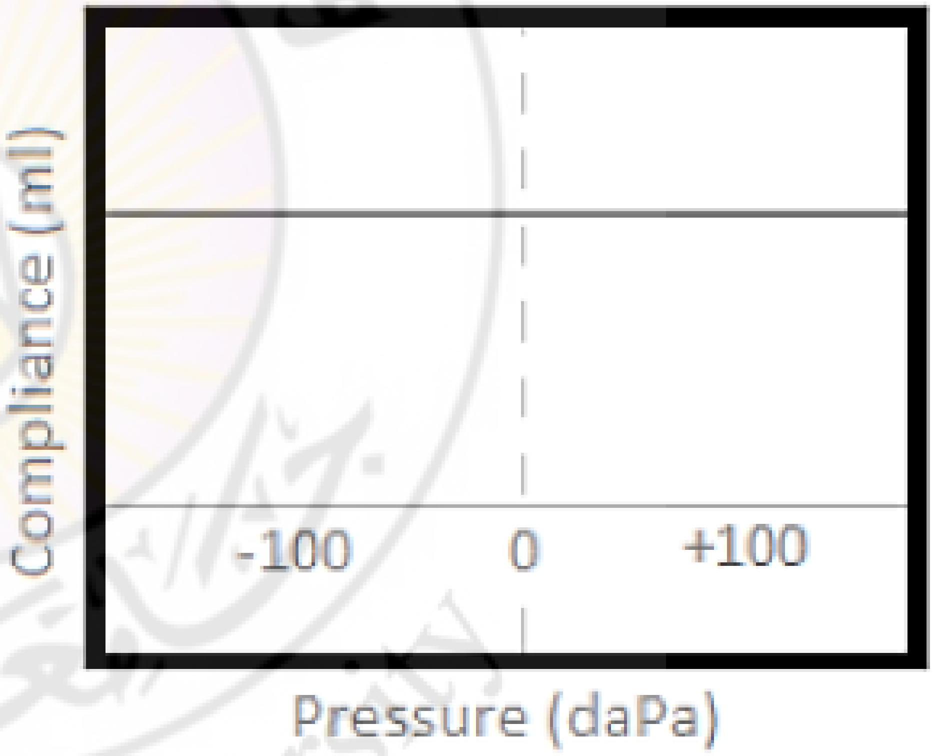
- There is no identifiable peak
- Ear canal volume is normal
- Suggests middle ear involvement from fluid (middle ear effusion)

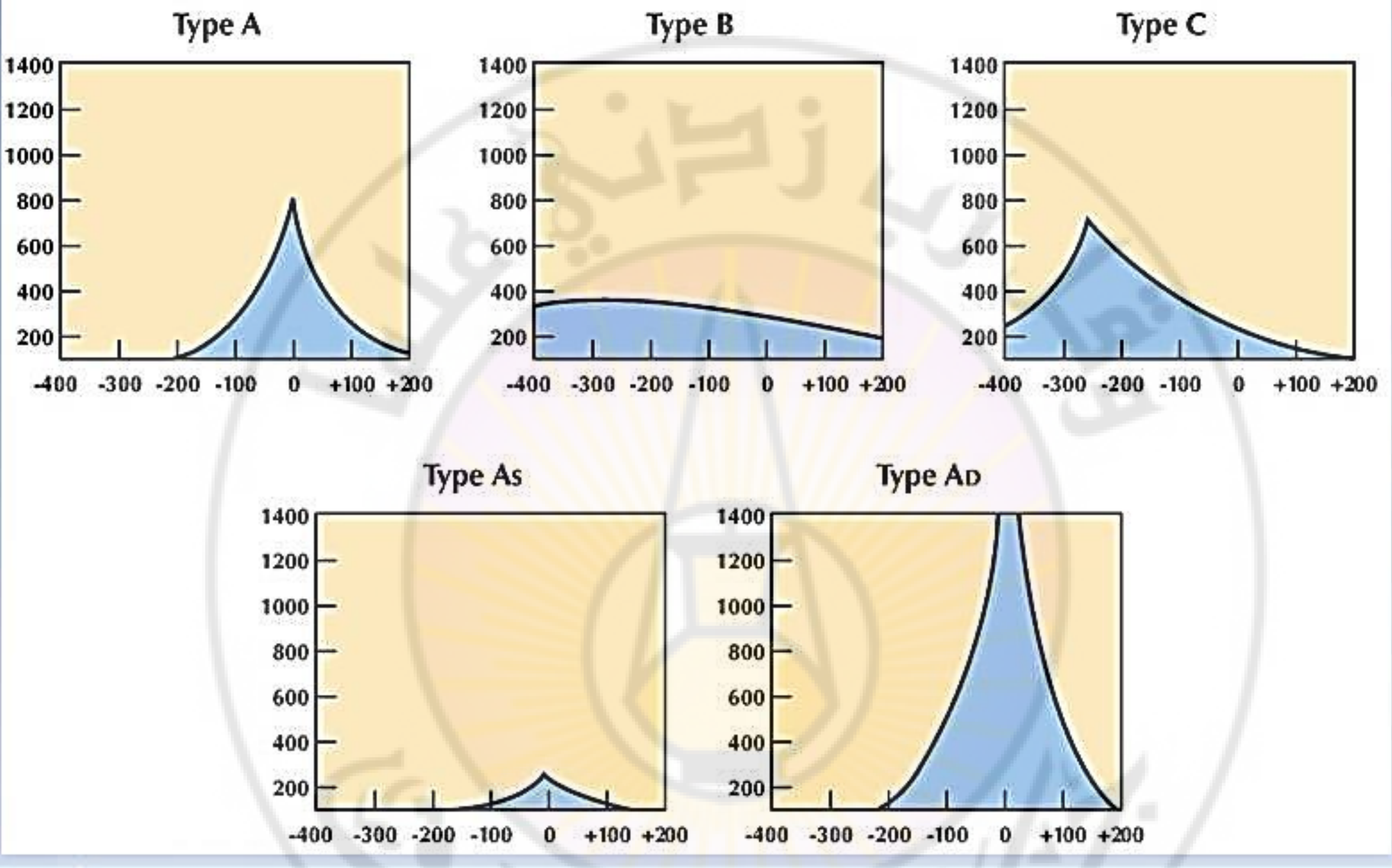


TYPE B-HIGH

TYPE B-HIGH

- There is no identifiable peak
- Equivalent ear canal volume exceeds normal limits; much larger than 1.5 cc
- Suggests middle ear involvement from a perforation or patent grommet (VT)





Type	Implications
Type A	Normal tympanogram/ sensorineural hearing loss where conductive mechanism is normal.
Type B	Flat curve, no change in compliance with pressure changes. Seen in fluid in the middle ear.
Type C	Maximum compliance in negative pressure. Seen in eustachian tube obstruction.
Type As	Compliance is lower at or near ambient air pressure. Seen in otosclerosis or malleus fixation.
Type Ad	High compliance at or near ambient pressure. Seen in ossicular discontinuity.

Quantitative analysis of Tympanograms

1. Equivalent Ear Canal Volume (Vea or Vec)
2. Peak-Compensated Static Acoustic Admittance (Ytm)
3. Tympanometric Peak Pressure (TPP)
4. Tympanometric Gradient and Width (TW)

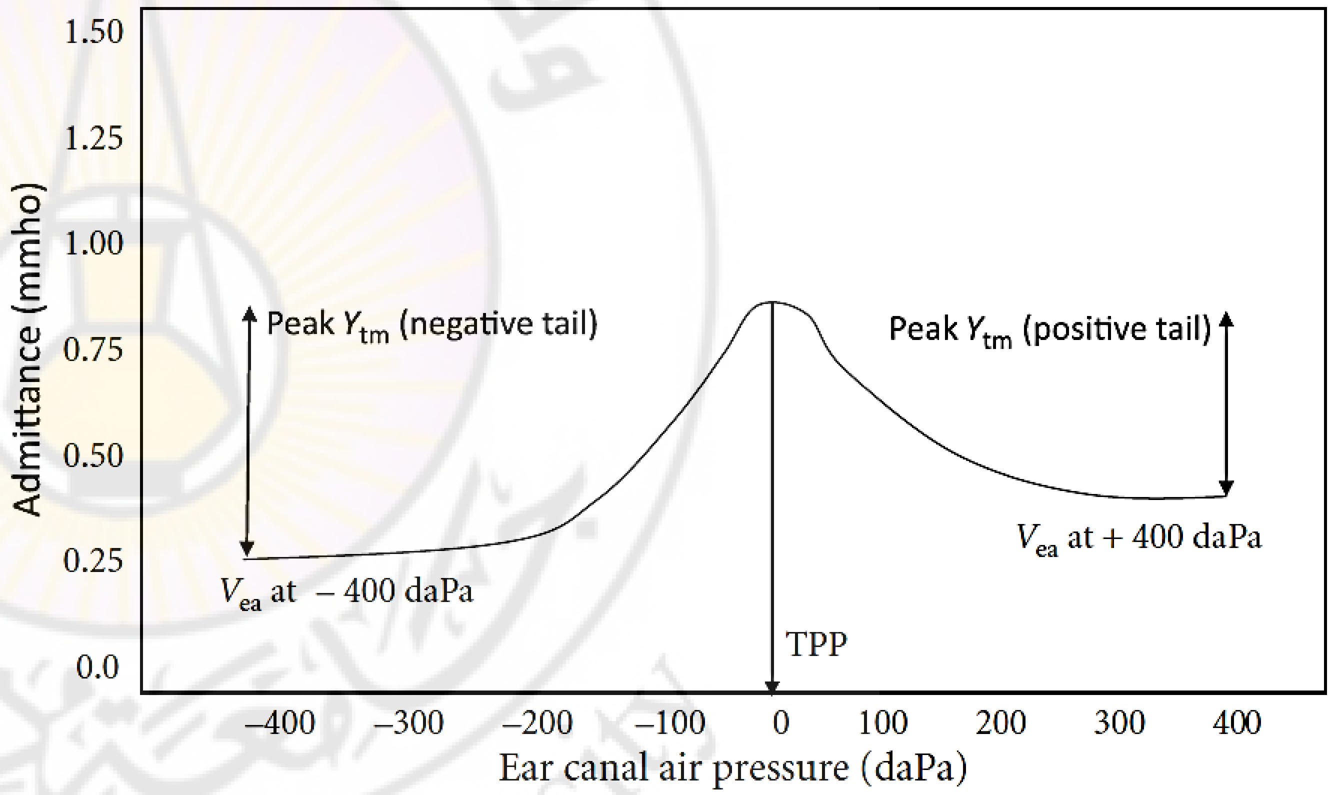
1. Equivalent Ear Canal Volume (Vea or Vec)

- Accuracy of the middle-ear admittance estimate relies on obtaining an accurate estimate of the “equivalent” ear canal admittance (volume).
- Because the admittance of the volume of air in the ear canal contributes to the total middle-ear admittance measurement it must be subtracted out to determine the admittance of the middle ear alone.
- This process is called **tympanometric “compensation”** and is used to the determine admittance of the middle ear at the plane of the TM (Ytm)

Generally, if an open path to the TM can be visualized, cerumen blockages of less than 50% do not affect tympanometry measurements, although the volume will be less than for a clear ear canal.

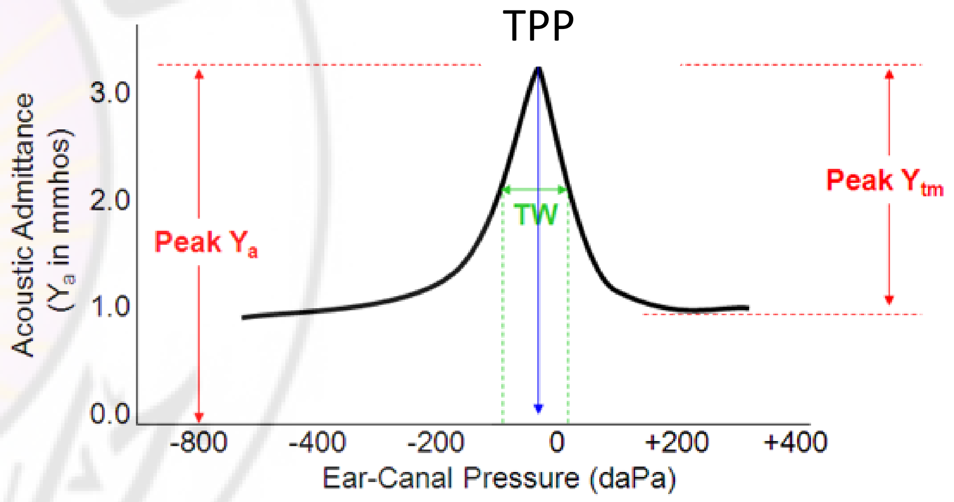
Equivalent Ear Canal Volume (Vea or Vec)

- This measure is called **"equivalent ear canal volume"** because under standard reference conditions using a probe tone of 226 Hz, the volume of trapped air in a hard-walled cavity is equal to the acoustic volume of that same cavity.
- In other words, 1 cubic centimeter (cc) or milliliter (mL) of trapped air equals the acoustic admittance of 1 mmho in a hard-walled cavity.
- This equivalency is the reason that some tympanometers measure admittance in cc or mL.

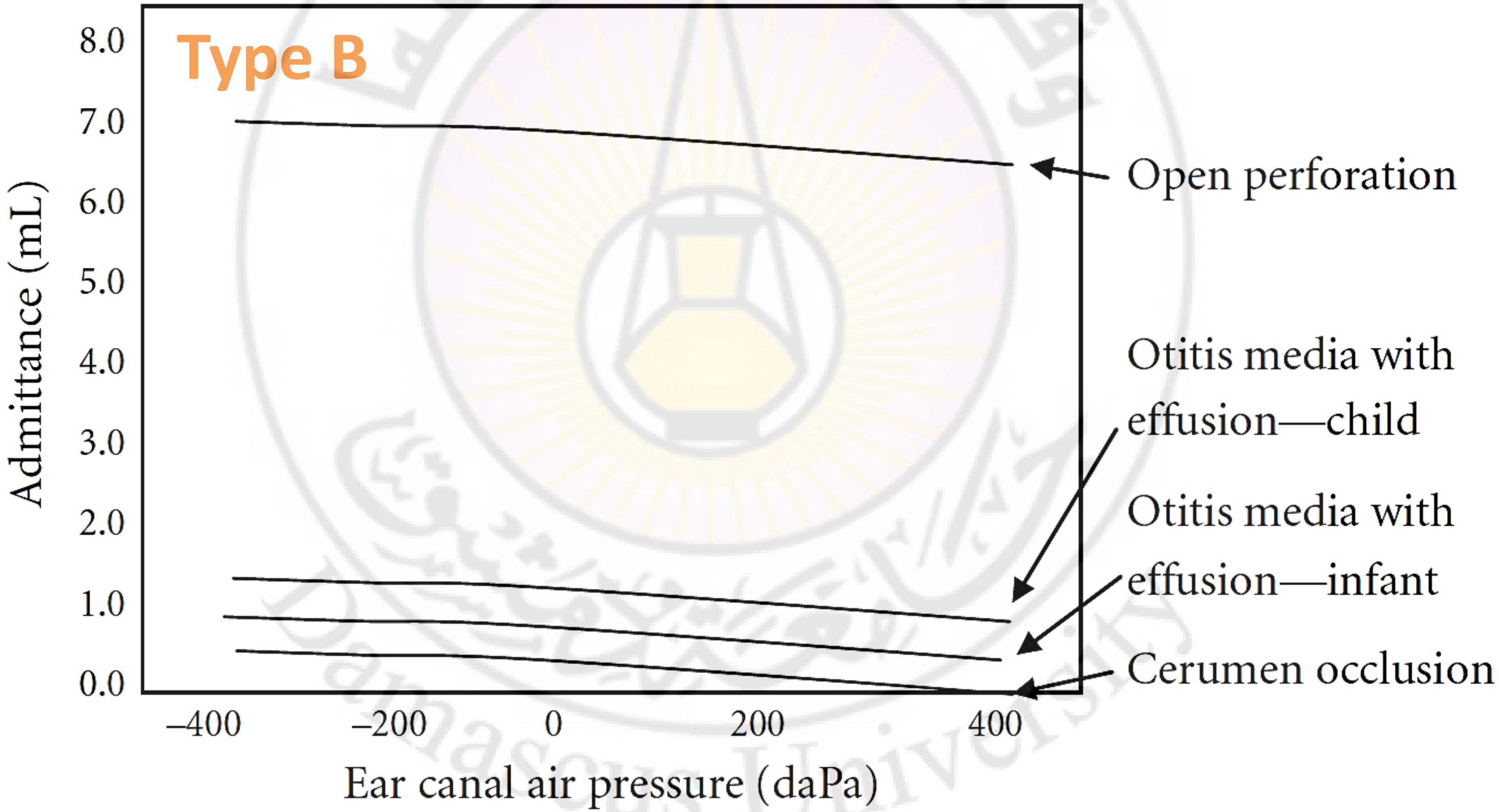


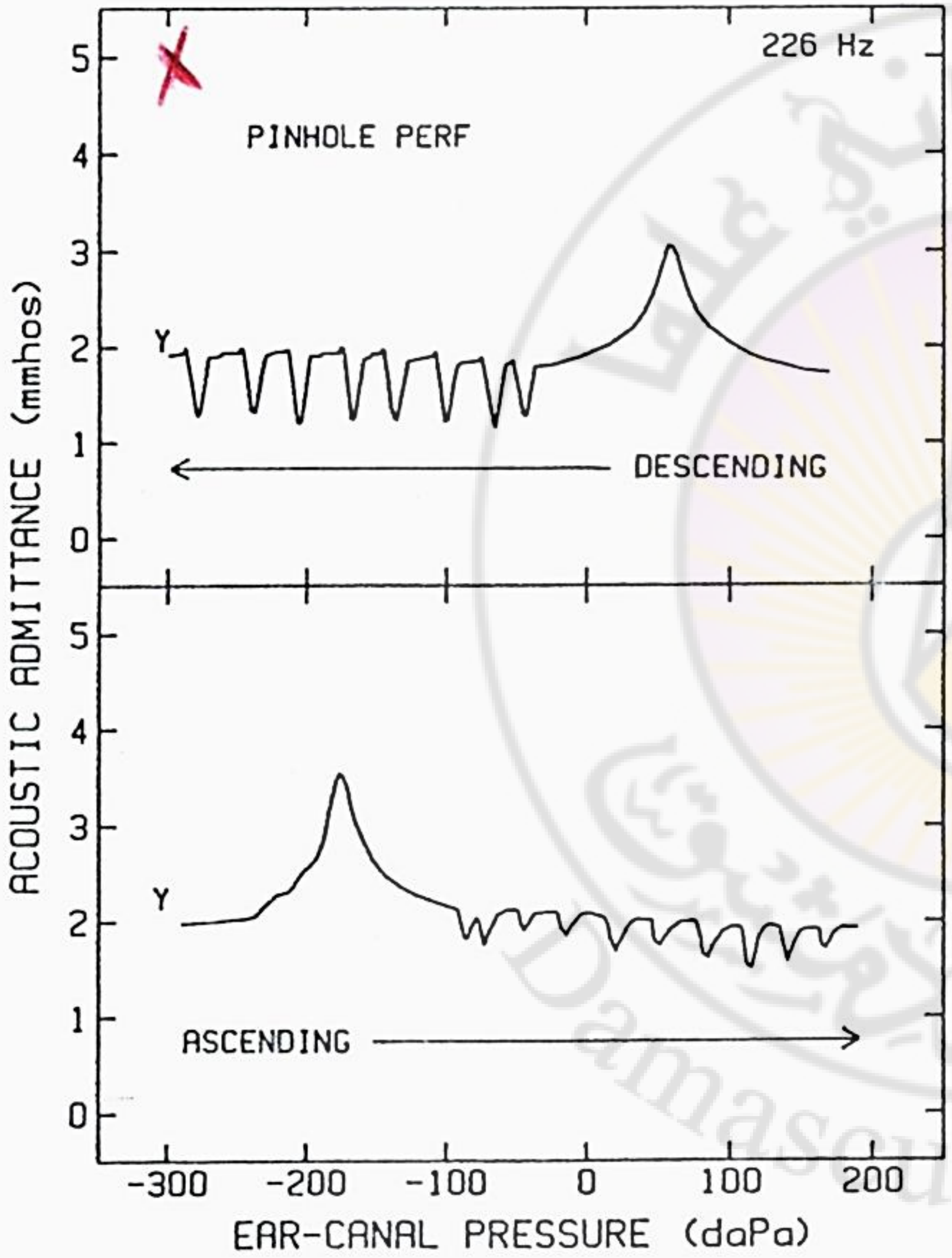
Equivalent Ear Canal Volume (Vea or Vec)

- Estimating the Vec based on positive or negative tails?
- Baseline Function
- Normal values depends on gender and age
- Inter ear difference (87% correlation)
- Inter-ear difference of more than 0.5 cc in children and more than 1 cc in adults are significant



Effects of different conditions on ear canal volume





Observation of normal volume in pinhole perforations!

Ear canal volume

- Tympanometry estimates of ECV over-estimate the actual volume
- As static pressure increases from -400 daPa to 200 daPa the magnitude of the error increases
- **Ear canal volume measured with a 660 Hz probe tone is more accurate than the standard 220 Hz tone**

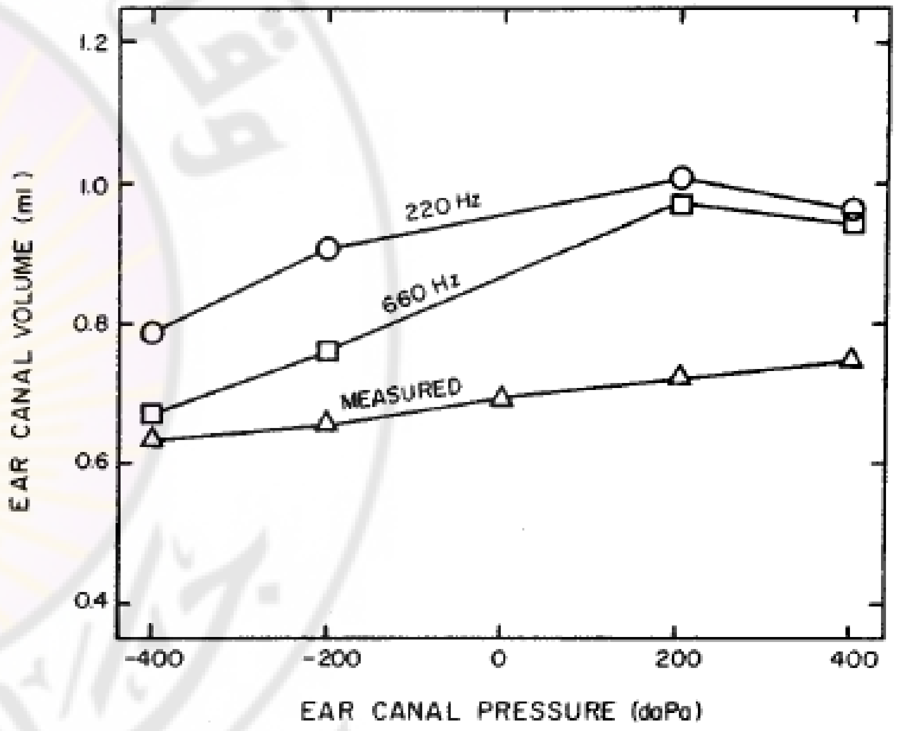
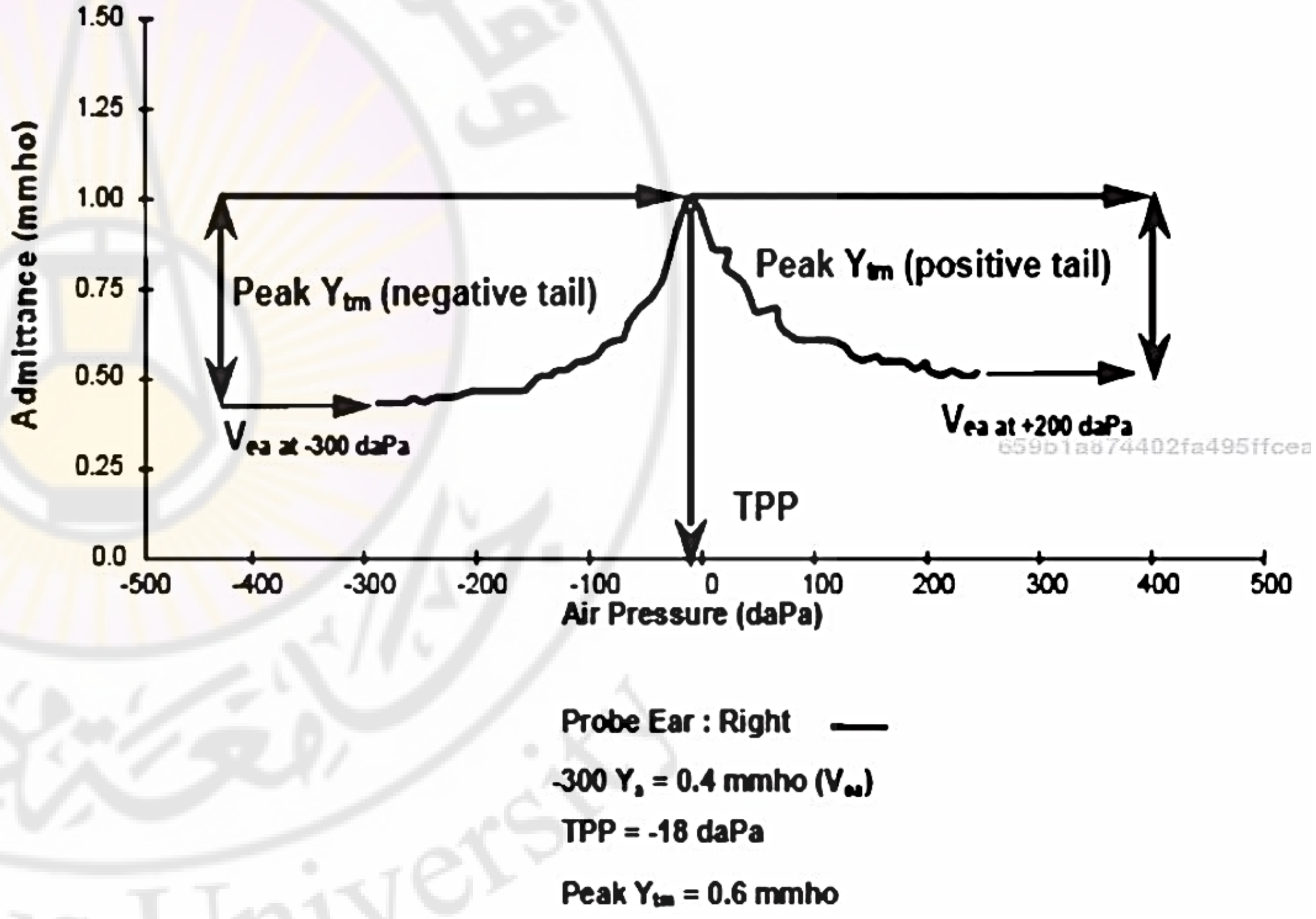


FIGURE 2. Mean ear canal volumes (in ml) for static ear canal pressures between ±400 daPa. The triangle at 0 daPa represents the mean alcohol volume measurement, and the remaining triangles represent the mean alcohol volume adjusted for changes in ear canal volume with changes in ear canal pressure measured using the gas-law procedure. Tympanometric estimates are shown for the 220-Hz (circles) and the 660-Hz (squares) probe frequencies.

2. Peak-Compensated Static Acoustic Admittance (Ytm)

- The peak of the tympanogram after subtraction of Vea is called the "peak-compensated static acoustic admittance" or, more commonly, **static admittance (Ytm).**



Peak-Compensated Static Acoustic Admittance (Ytm)

- Normal limits (0.3-1.6)
- Women less than man
- Newborns ➢ children ➢ adults
- No inter-ear difference
- Increasing the pump speed cause increasing the Ytm
- Negative pump pressure direction cause to decrease the Ytm
- Several recording attempts in same session cause to increase the Ytm
- Different mass or stiffness dominant pathologies can have overlapping effects on Ytm
- Diagnostic value alone is limited

Table 7.1 Representative 90% normal ranges for peak static acoustic admittance (mmhos) using 220 and 226 Hz probe tones

Source	90% Normal range
Adults	
Wiley (1989)	0.37–1.66
Children	
Silman, Silverman, & Arick (1992)	0.35–1.25
Infants and Toddlers ≥ 6 months	
Roush et al (1995)	
6–12 months	0.20–0.50
12–18 months	0.20–0.60
18–24 months	0.20–0.70
6–12 months	0.20–0.50
Calandruccio, Fitzgerald, & Prieve (2006)	
6–12 months	0.16–0.60
2 years	0.21–1.03

Table 7.3 Differences in 90%normal ranges for peak static acoustic admittance (mmhos) at slow and fast pump speeds[a]

Pumpspeed	Adults[b]	Children (3–5 years)[c]
Slow (≤ 50 daPa/s)	0.50–1.75	0.35–0.90
Fast (200 daPa/s)	0.57–2.0	0.40–1.03

[a]Modified from Van Camp et al (1986).

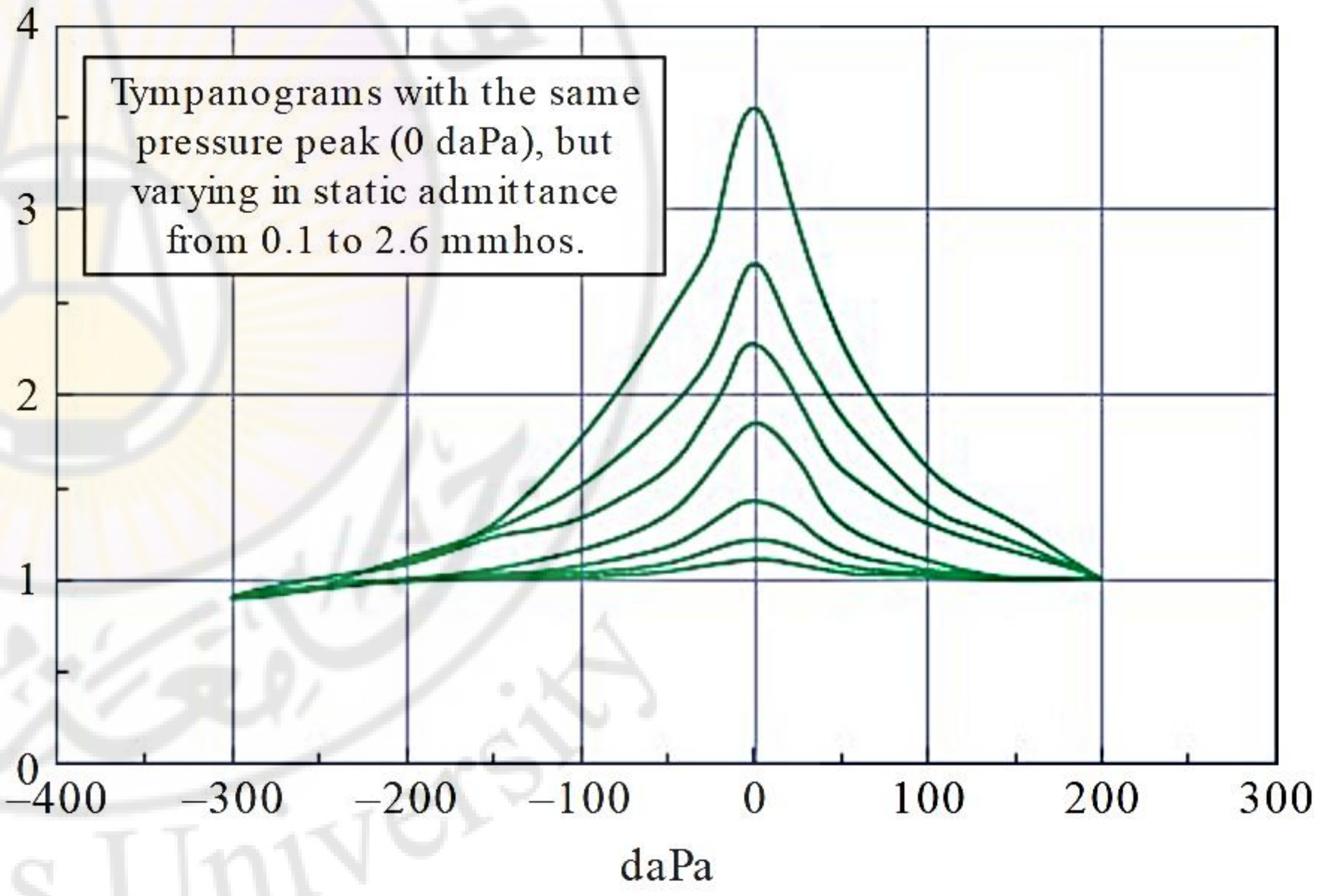
[b]Based on data from Wilson, Shanks, and Kaplan (1984a).

[c]Based on data from Koebsell and Margolis (1986).

Peak-Compensated Static Acoustic Admittance (Ytm)

- Abnormally low static acoustic admittance corresponds to abnormally high impedance and is generally associated with disorders such as otitis media, cholesteatoma, and otosclerosis.

- On the other hand, abnormally high static admittance (and thus abnormally low impedance) is often associated with disorders such as ossicular discontinuity.



3. Tympanometric Peak Pressure (TPP)

- the ear canal air pressure at which the peak of the tympanogram occurs is the TPP.
- Because Ytm reaches its highest value when the pressures on both sides of the TM are equal, TPP is an indicator, but not a direct measure, of the pressure in the middle-ear space.
- In fact, TPP overestimates the actual middle-ear pressure by as much as 100%. A TPP of −300 daPa, for example, could occur with actual middle ear pressure of only −150 daPa.

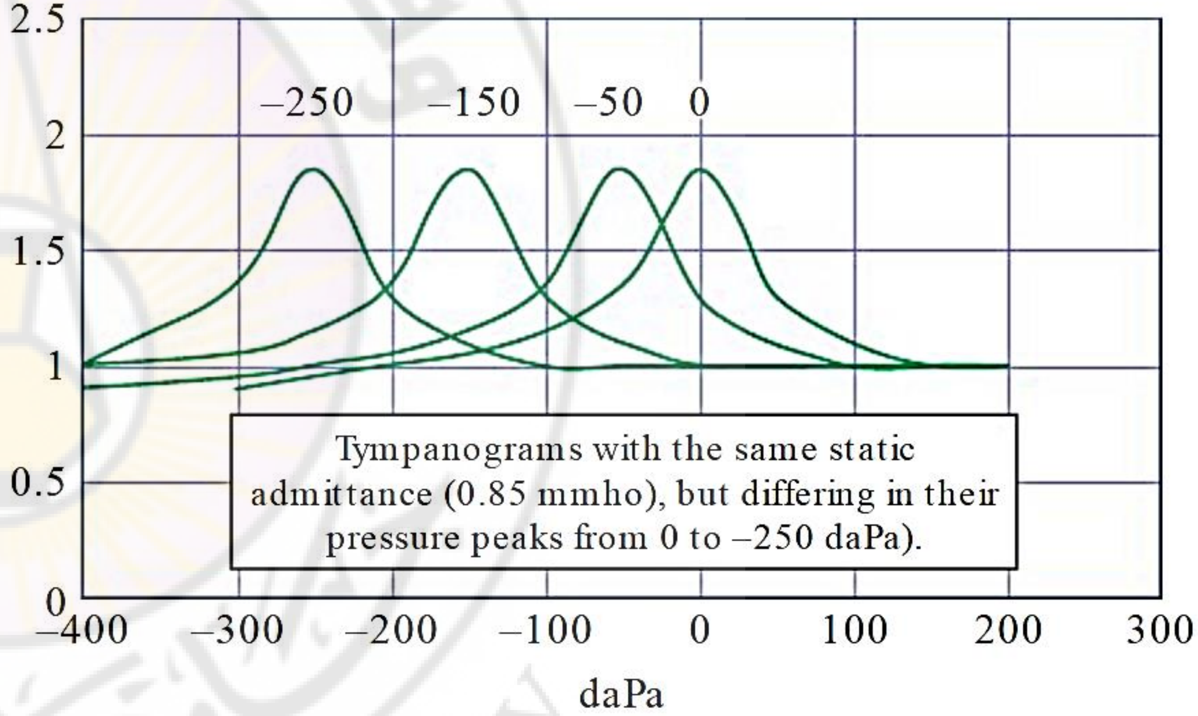
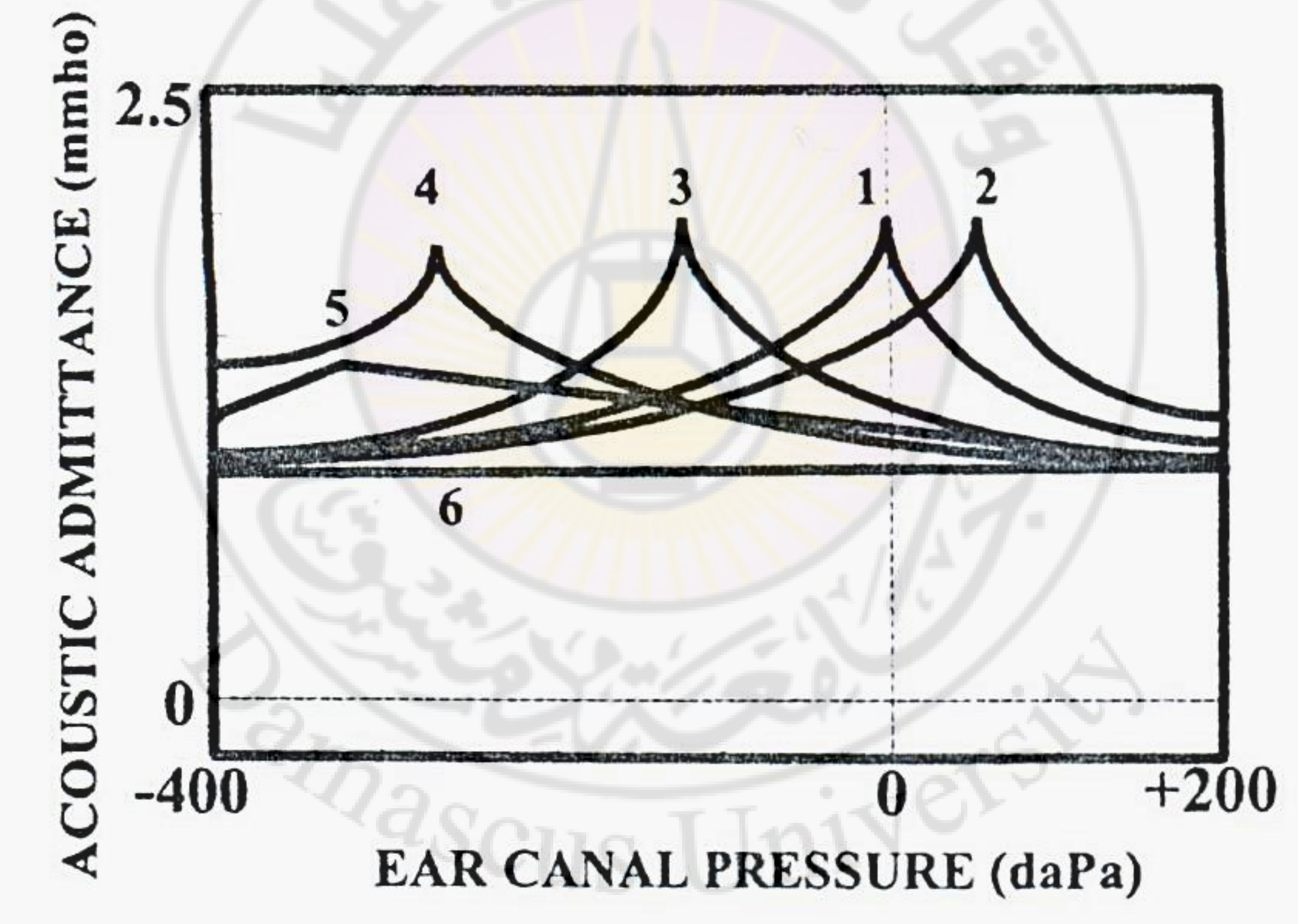


Fig. 7.9 Examples of tympanograms with tympanometric peak pressures of 0 daPa, –50 daPa, –150 daPa, and –250 daPa.

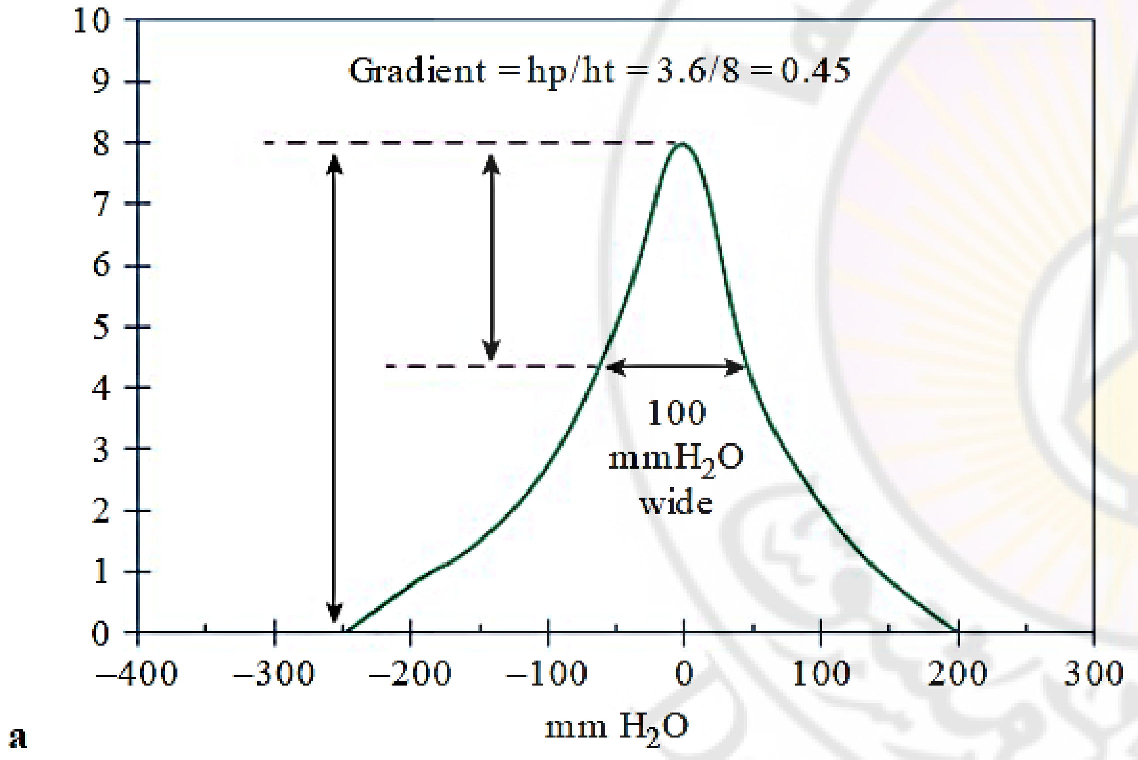
TPP or MEP?

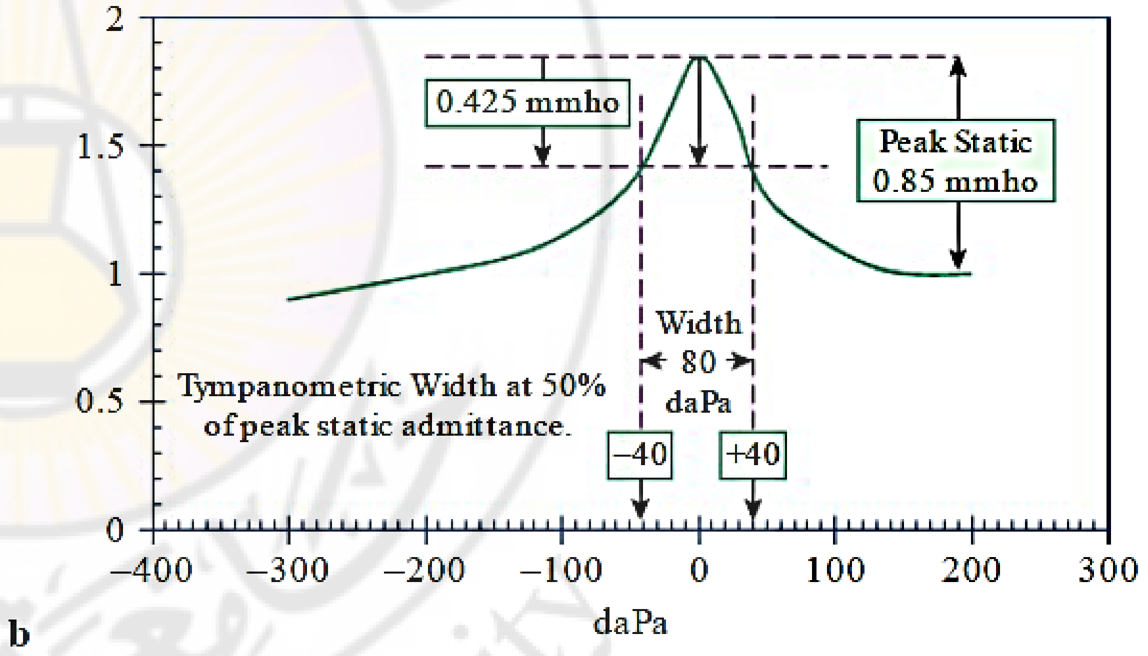
- Evaluation of Eustachian tube function
- Monitoring the progress of Otitis media
- Positive MEP in Acute otitis media
- Non-pathological negative MEP in almost 25% of children
- Height of the tympanogram should not affect, if there is no fluid in the middle ear
- Factors that can affect MEP:
  - **Change in pressure pump direction (pinhole perforations)**
  - **Pump speed**

Ex Vacuo theory



4. Tympanometric Width (TW) and Gradient

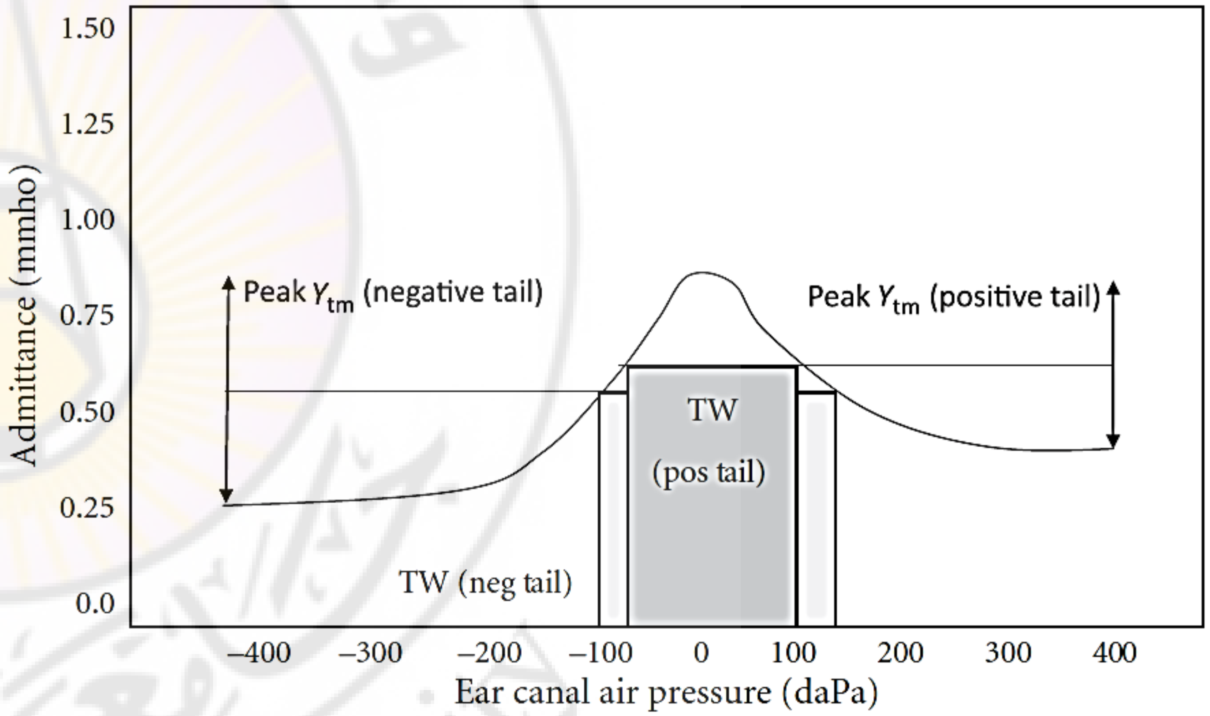




The flatness (versus peakedness) of a tympanogram can be quantified by its gradient, and tympanometric width which describes the **relationship of its height and width.**

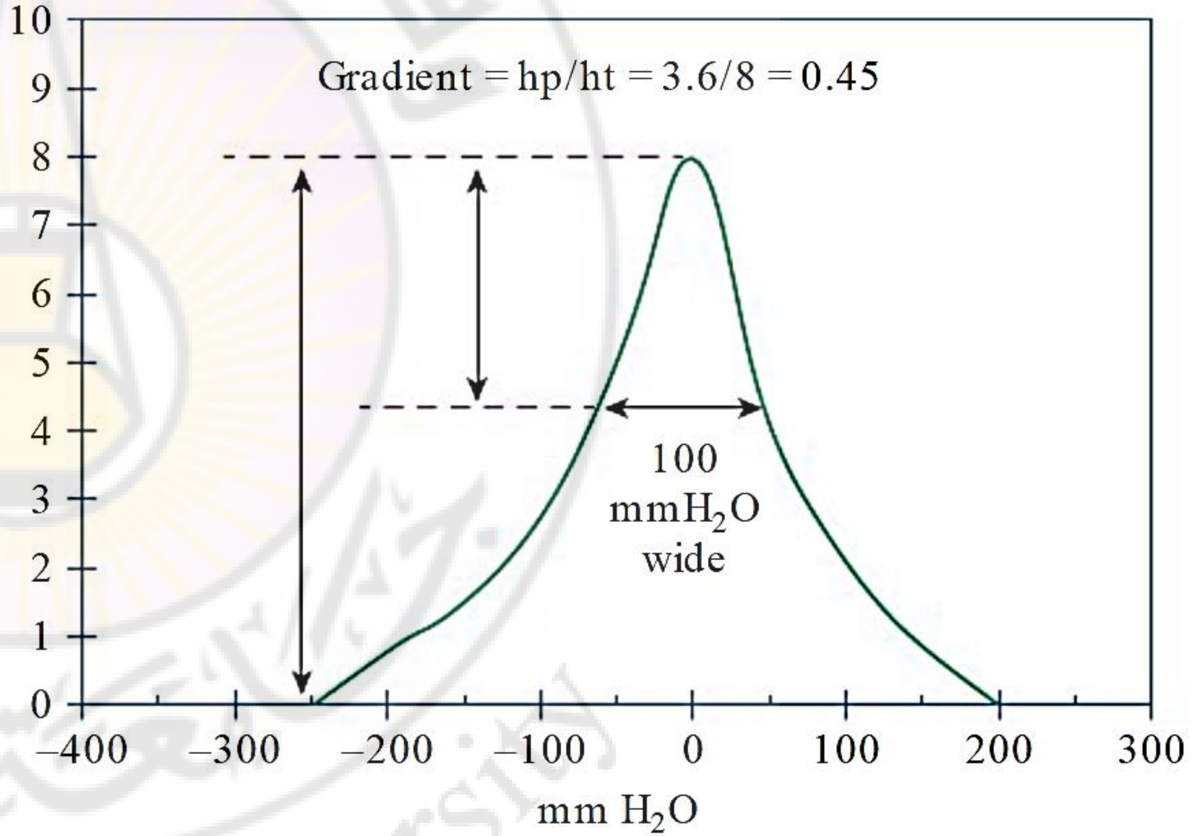
Tympanometric Width (TW)

- TW: $Y_{TM}/2$
- Normal range:
  - Newborns: 235 dapa
  - Children: 200 dapa
  - Adults: 50-110 dapa
- Not related to gender
- In adults population increases with age progress
- Fixation cause narrowing of TW
- Effusion cause widening of TW



Gradient

- (1) Draw a horizontal line where the width of the tympanogram is 100 mm daPa
- (2) Measure the height of the peak above this line (hp), as well as the total height (ht) of the tympanogram from its peak to its baseline.
- (3) Find the gradient by dividing hp/ht



- **<0.2 : abnormally Low**

Normative Values for Tympanometry Measurements at 226 Hz for Adults

Study	Gender (N)		Y_{tm} (SA) + mmho	TW + daPa	TPP daPa	V_{ea} + (cm^3)
Roup et al. (1998)	M	Mean	0.87	59.8	−26.18	1.40
20–30 yr	$N = 51$	SD	0.46	17.3	31.66	0.32
		90% Range	0.30–1.80	35.0–87.0	−110.00 to 9.0	1.00–2.10
	F	Mean	0.58	73.9	−27.75	1.18
	$N = 51$	SD	0.27	17.2	23.50	0.22
		90% Range	0.30–1.12	45.0–107.0	−80.0 to −3.0	0.80–1.60
	Overall	Mean	0.72	66.9	−29.96	1.29
	$N = 102$	SD	0.40	18.6	27.76	0.29
		90% Range	0.30–1.19	32.8–95.0	−103.50 to 4.2	0.90–1.80
Wiley et al. (1996)	M	Mean	0.72	73		1.49
48–90 yr	$N = 825$	SD				
		90% Range	0.2–1.60	35–125		1.0–2.20
	F	Mean	0.62	76		1.28
	$N = 1,322$	SD				
		90% Range	0.2–1.40	40–120		0.9–1.90
	Overall	Mean	0.66	75		1.36
	$N = 2,147$	SD				
		90% Range	0.2–1.50	35–125		0.9–2.0

Peak-compensated static admittance, Y_{tm}; tympanometric width, TW; tympanometric peak pressure, TPP; equivalent ear canal volume, V_{ea}.

Developmental and Aging Effects

- Static admittance increases, ear canal volume increases, and TW decreases from infancy up to age 6 years.
- These changes are because of the increase in ear canal and middle-ear space, which make the middle-ear system more compliant with increased age.
- These changes continue into adulthood, especially for ear canal volume.
- Young adults aged 20 to 30 years have larger ear canal volume and narrower TW relative to children.
- Older adults (48 to 90 years) have lower static admittance, higher ear canal volume, and lower TW than younger adults.

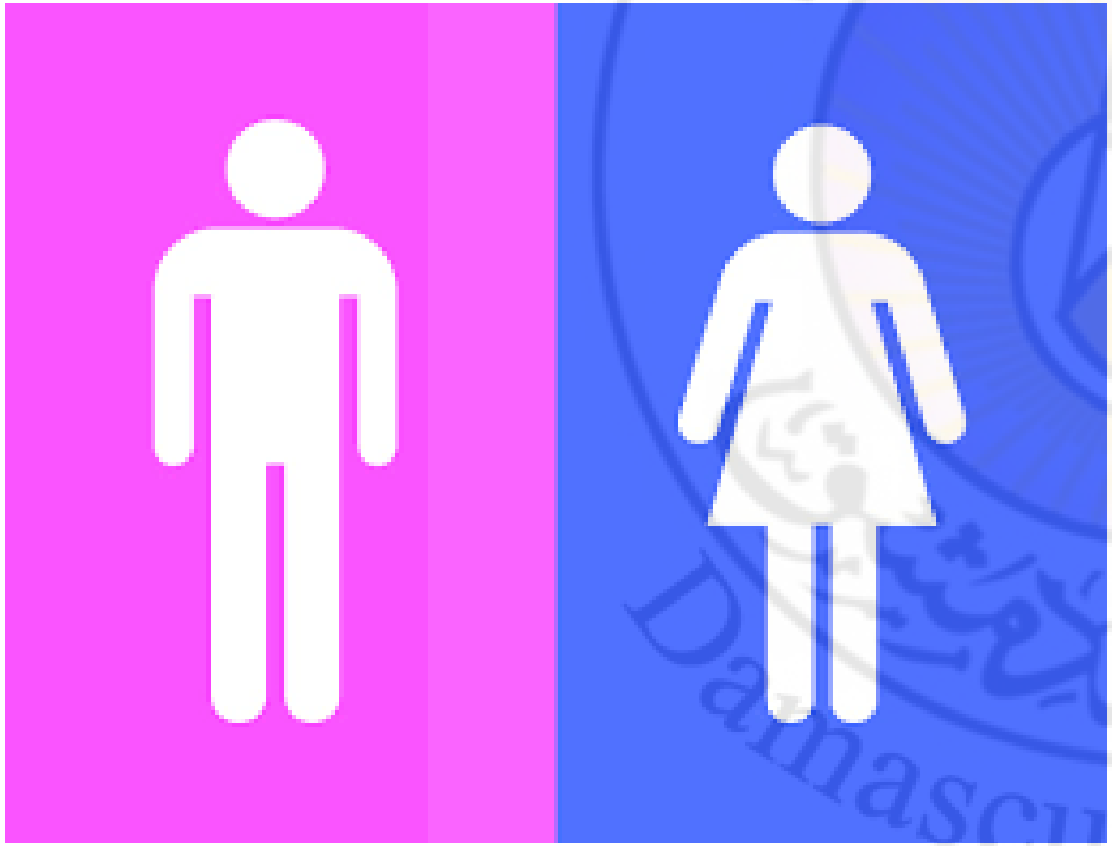
Table 7.2 Ninety percent ranges for peak static acoustic admittance (mmhos) among older adults from two large-sample studies

Age (years)	Wiley et al (2005)[a]	Golding et al (2007)
48 (49)[b]–59	0.2–1.5	0.3–2.2
60–69	0.2–1.6	0.3–2.1
70–79	0.0–1.8	0.2–2.2
≥ 80	0.0–2.0	0.2–2.5

[a]Combined across right and left ears using baseline examination data.

[b]Range: 48–59 in Wiley et al (2005), and 49–59 in Golding et al (2007).

Sex effects on tympanometric parameters



- Males have a higher static admittance and ear canal volume and narrower TW than females.

Effects of Middle-Ear Pathologies

	Y	TW	Volume	Mass	Springiness	Resonant Frequency
Middle-ear effusion	Low	Wide	Normal	↑	↓	Low
Monomer or ossicular discontinuity	High	Narrow	Normal	↑	↑	Low
Perforation	Flat or variable	–	High	–	–	–
Tympanosclerosis	Normal to low	Normal	Normal	↑	↓	Low
Cholesteatoma	Low	Wide	Normal		↓	Low
Lateral ossicular fixation	Low	Wide	Normal	–		High
Medial ossicular fixation (otosclerosis)	Normal	Normal/narrow	Normal		↓	Normal to high

Common Middle Ear Pathology and the Characteristics of Y-226 Tympanograms Frequently Associated With Them[a]

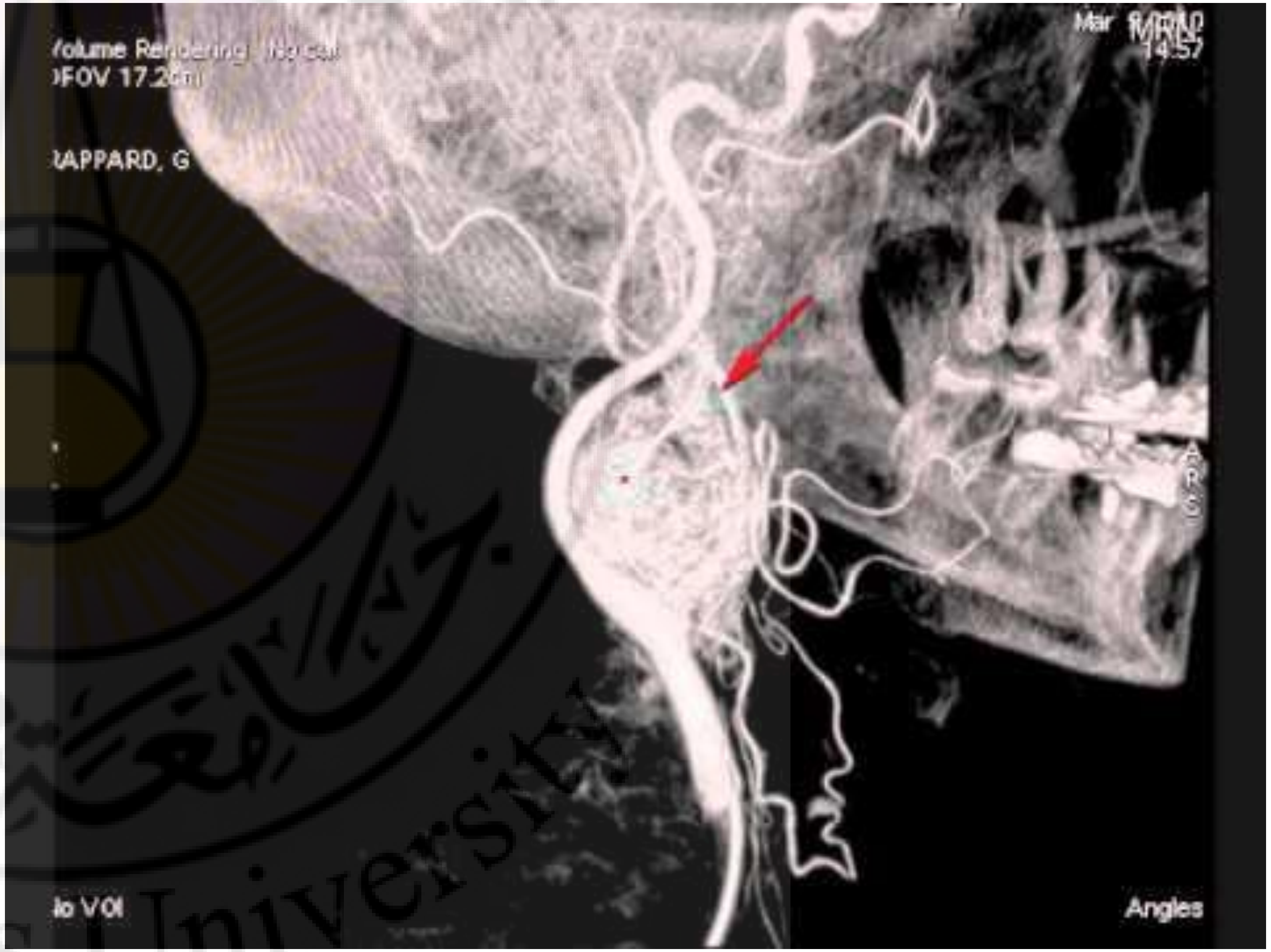
Pathology	V_{ea}	Y_{tm}	TW	TPP
Early ME effusion	Normal	Reduced	Widened	Normal/positive
ME effusion	Normal	Reduced/flat	Widened	Negative/CNT
Ossicular discontinuity	Normal	Increased	Normal	Normal
TM pathology	Normal	Increased	Normal	Normal
Otosclerosis	Normal	Normal/reduced	Normal/reduced	Normal
Malleus fixation	Normal	Reduced/flat	Increased	Normal
ET blockage	Normal	Normal	Normal	Negative
Open PE tubes	Increased	Flat	CNT	CNT
TM perforation	Increased	Flat	CNT	CNT
Cerumen blockage	Decreased	Flat	CNT	CNT

[a]V_{ea}, equivalent ear canal volume; Y_{tm}, peak compensated static acoustic admittance; TW, tympanogram width; TPP, tympanogram peak pressure; ME, middle ear; TM, tympanic membrane; ET, eustachian tube; PE, pressure equalization; CNT, cannot test.

Vascular Pulsing

Although most tympanograms are smooth, they sometimes have regular ripples or undulations that are synchronized with the patient’s pulse, which is their origin .

Medical referral is indicated when vascular pulsing is present on the tympanogram because it tends to occur in patients with glomus **jugular tumors.**



دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Acoustic Immittance Measures

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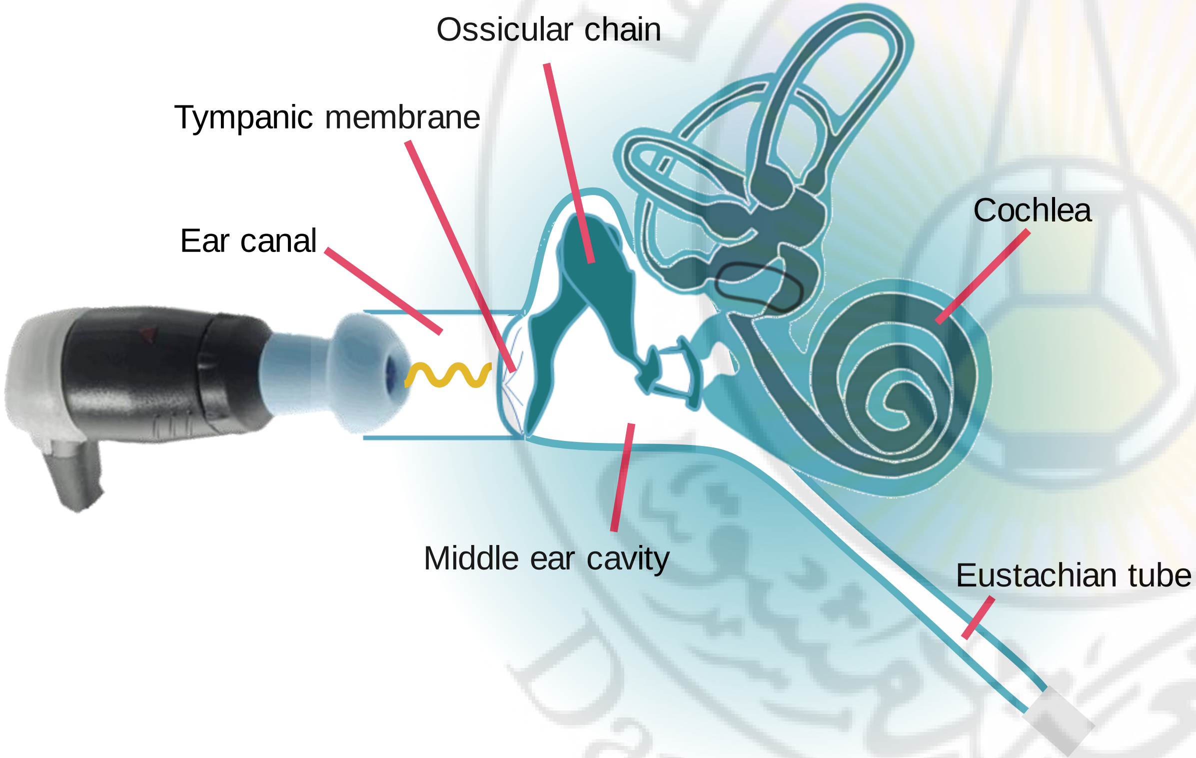
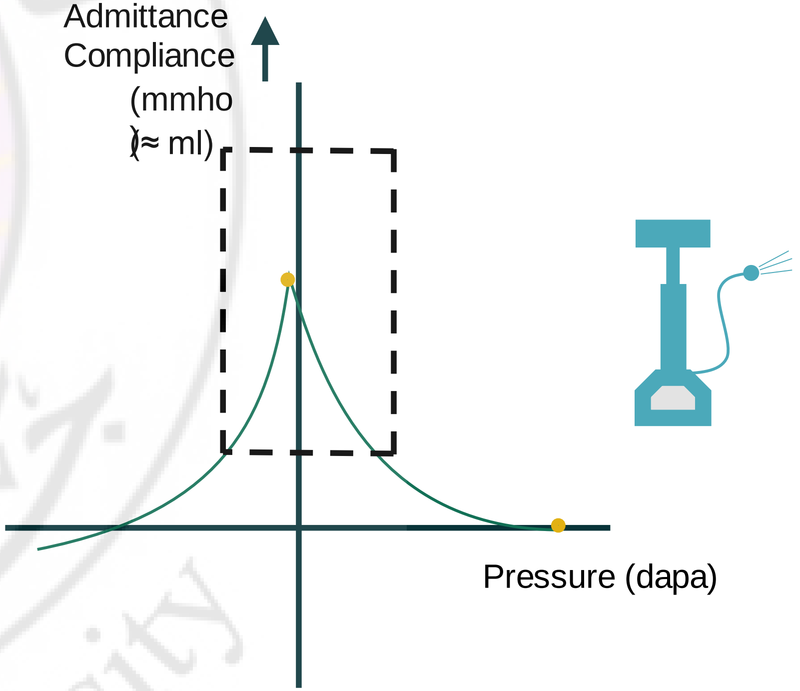
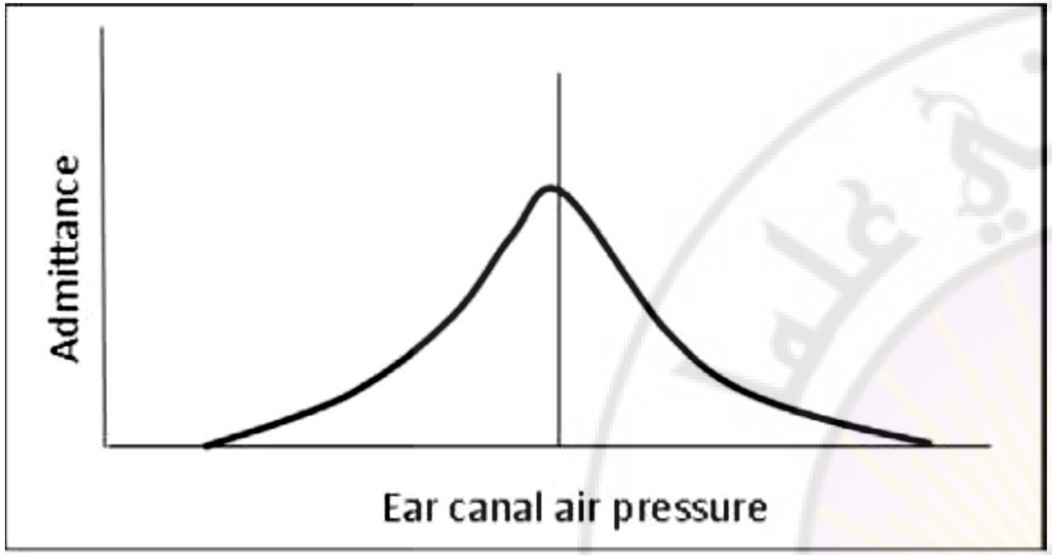
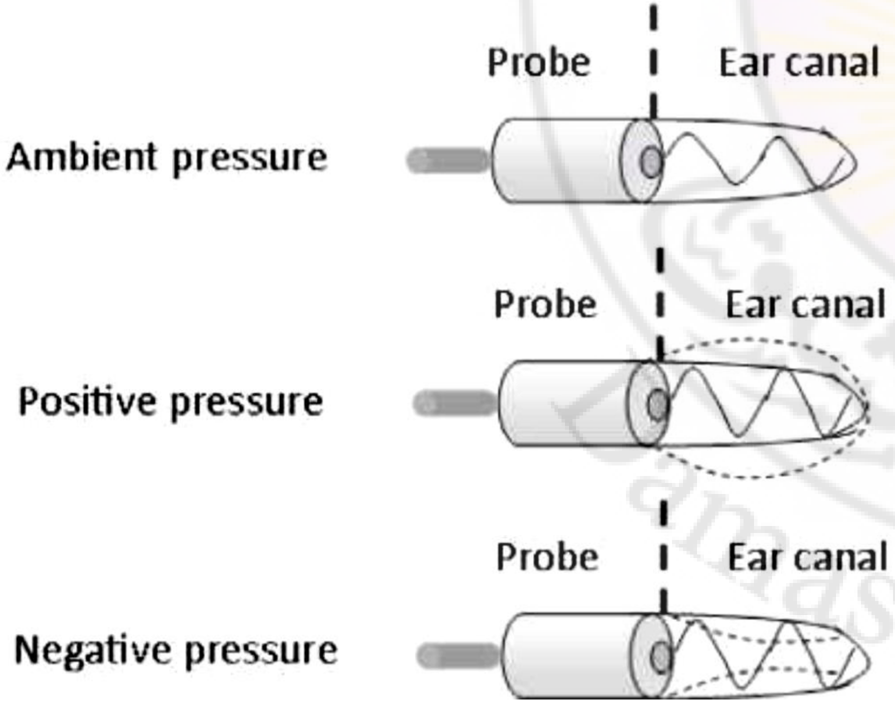
5. Multi-frequency Tympanometry & Wideband Tympanometry

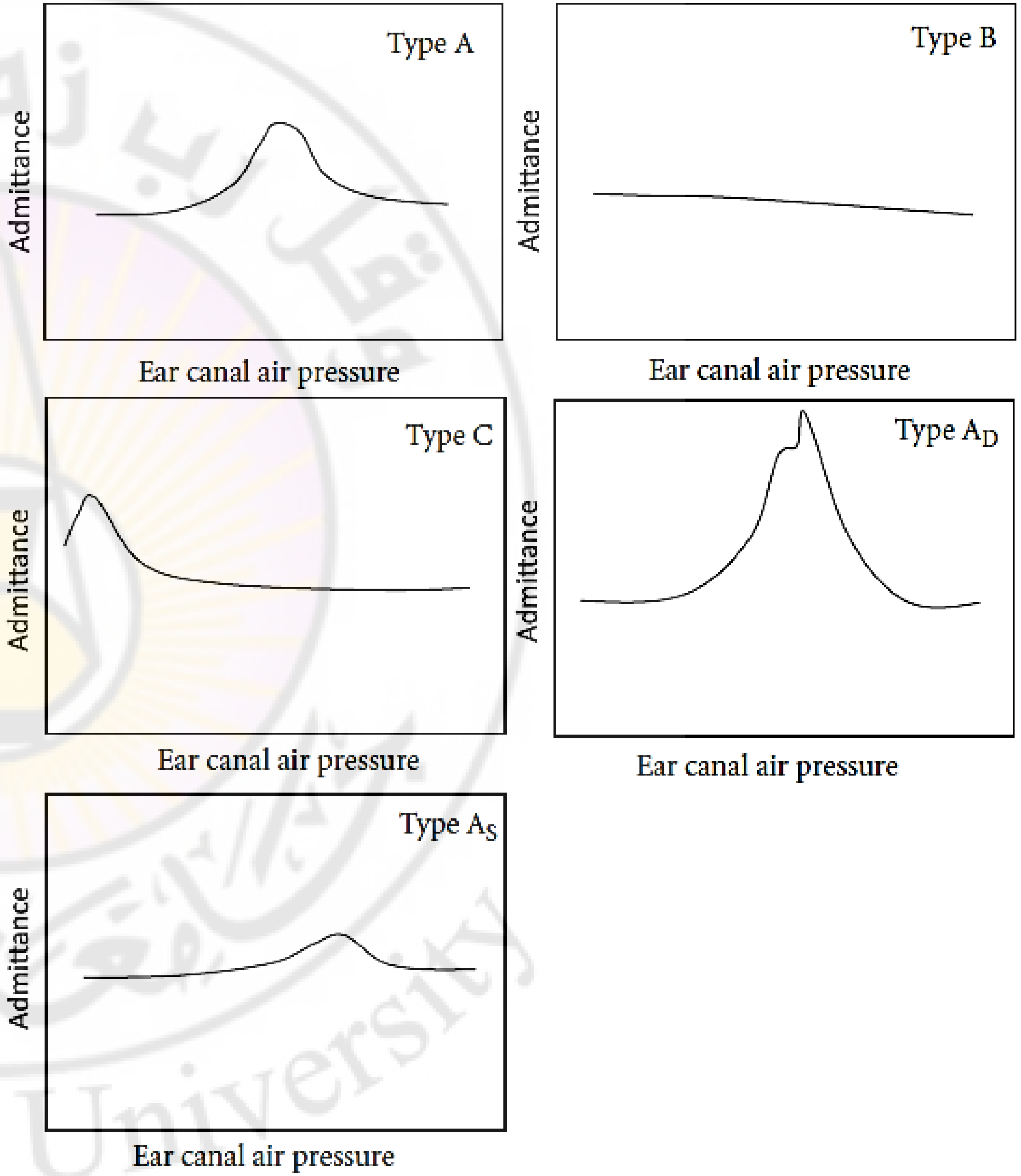
Tympanometry | A recap






Admittance
Ear canal air pressure


Probe
Ear canal
Ambient pressure
Probe
Ear canal
Positive pressure
Probe
Ear canal
Negative pressure


Type A
Admittance
Ear canal air pressure
Type B
Admittance
Ear canal air pressure
Type C
Admittance
Ear canal air pressure
Type A_D
Admittance
Ear canal air pressure
Type A_S
Admittance
Ear canal air pressure

Tympanometry

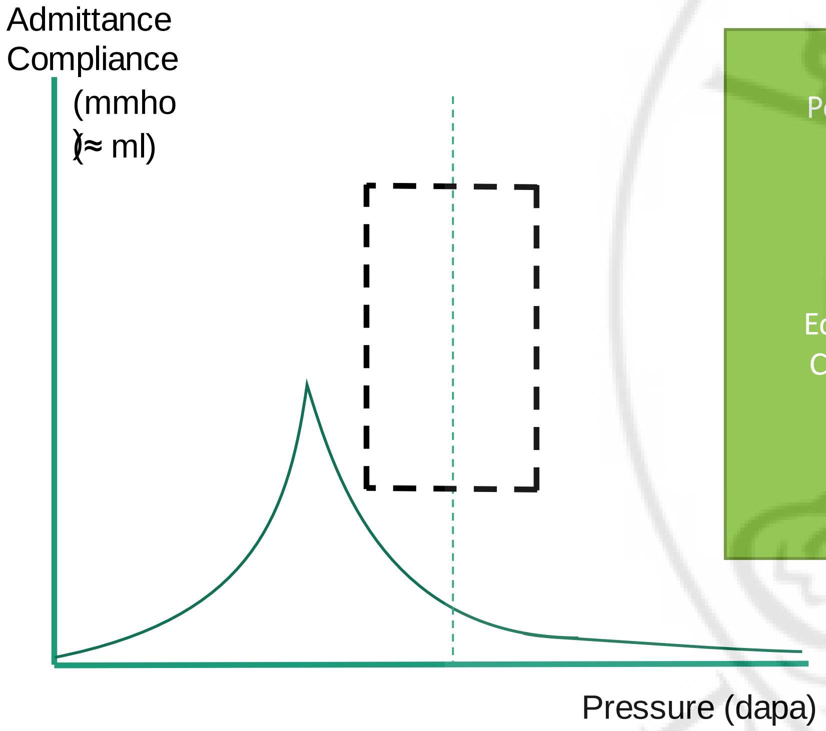
High sensitivity and low specificity

Common Middle Ear Pathology and the Characteristics of Y-226 Tympanograms Frequently Associated With Them[a]

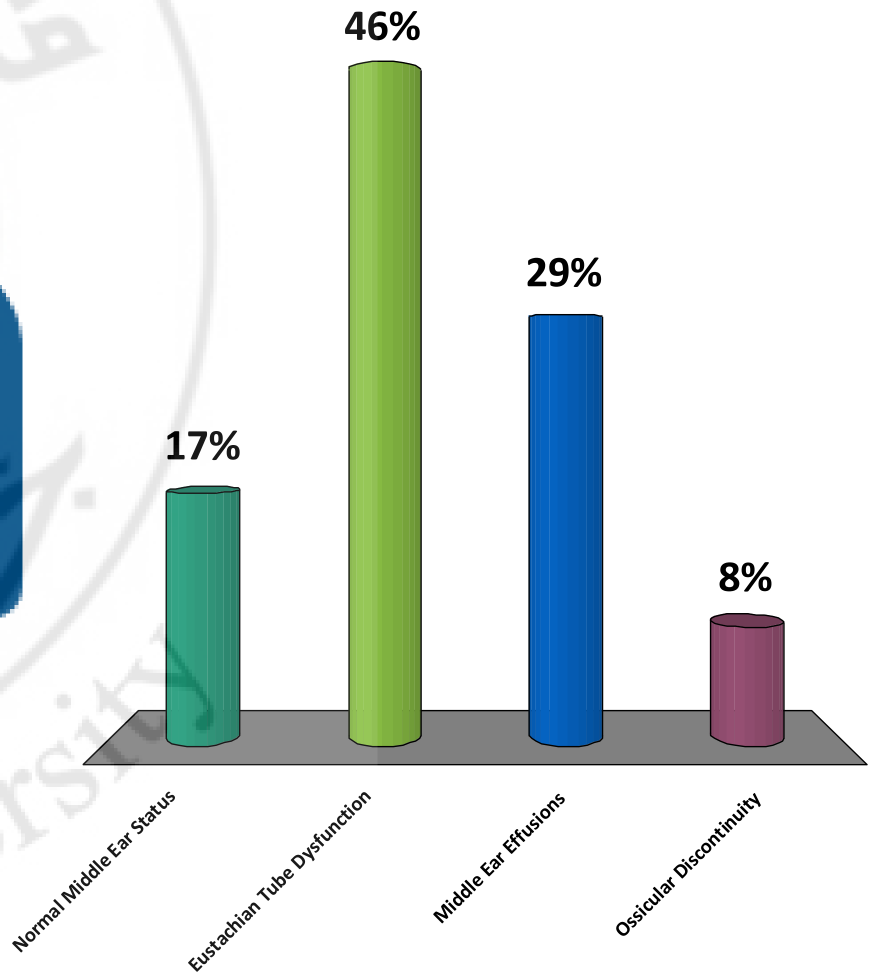
Pathology	V_{ea}	Y_{tm}	TW	TPP
Early ME effusion	Normal	Reduced	Widened	Normal/positive
ME effusion	Normal	Reduced/flat	Widened	Negative/CNT
Ossicular discontinuity	Normal	Increased	Normal	Normal
TM pathology	Normal	Increased	Normal	Normal
Otosclerosis	Normal	Normal/reduced	Normal/reduced	Normal
Malleus fixation	Normal	Reduced/flat	Increased	Normal
ET blockage	Normal	Normal	Normal	Negative
Open PE tubes	Increased	Flat	CNT	CNT
TM perforation	Increased	Flat	CNT	CNT
Cerumen blockage	Decreased	Flat	CNT	CNT

[a]V_{ea}, equivalent ear canal volume; Y_{tm}, peak compensated static acoustic admittance; TW, tympanogram width; TPP, tympanogram peak pressure; ME, middle ear; TM, tympanic membrane; ET, eustachian tube; PE, pressure equalization; CNT, cannot test.

Tympanometry

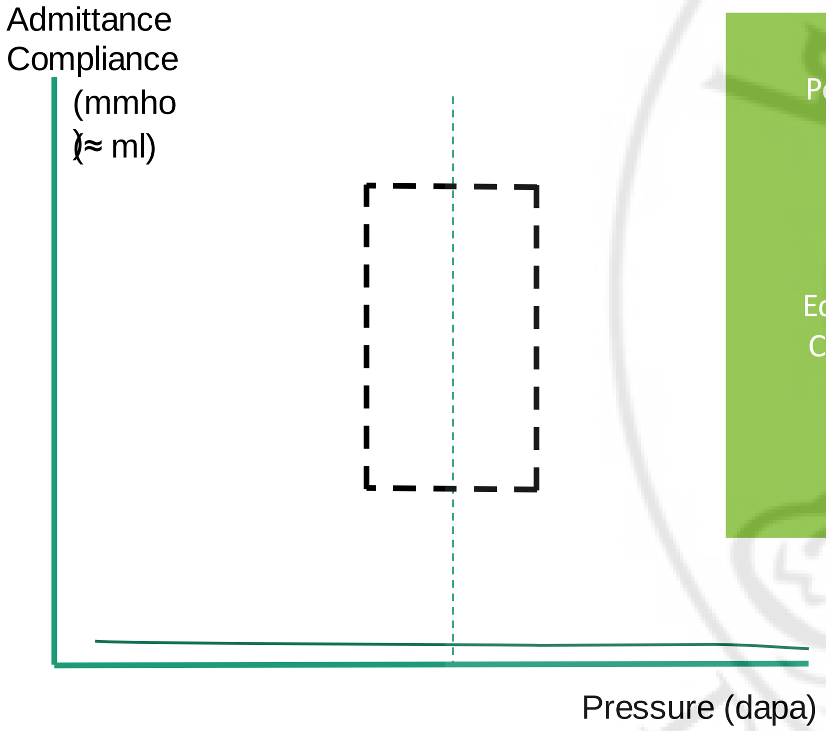


Peak Pressure	-165 dapa
Peak Compliance	1.4 ml
Equivalent Ear Canal Volume	1.2 ml
Gradient	45 dapa

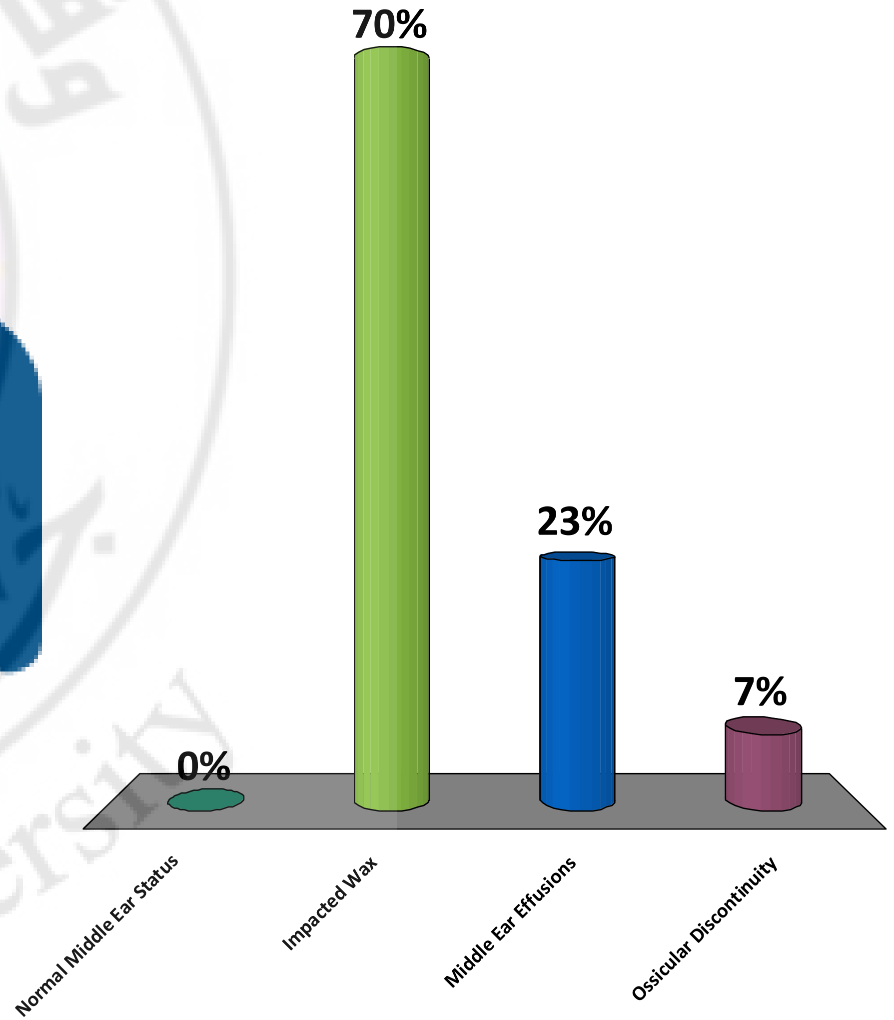


A. Normal Middle Ear Status
B. Eustachian Tube Dysfunction
C. Middle Ear Effusions
D. Ossicular Discontinuity

Tympanometry

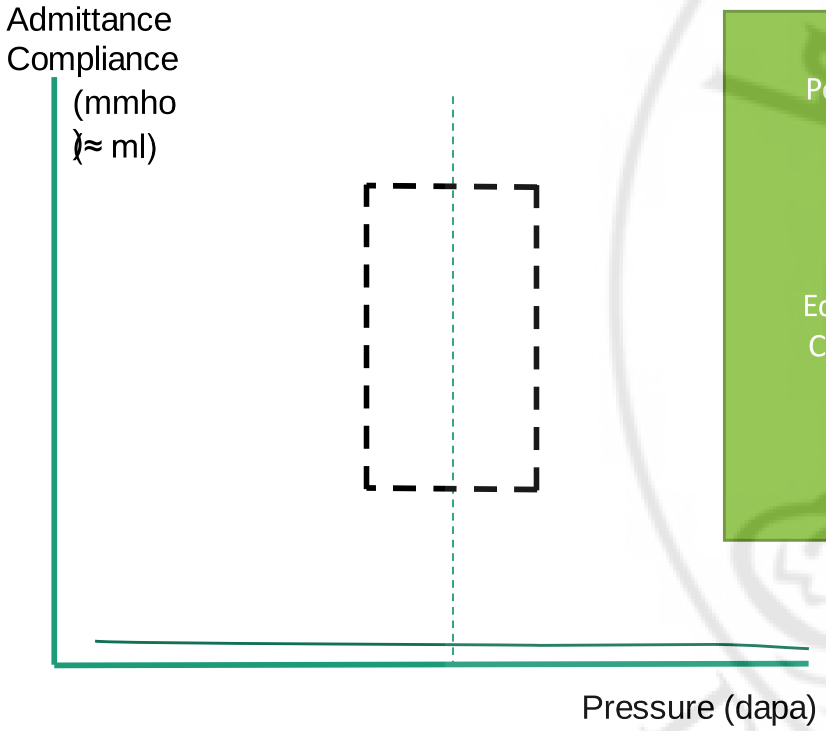


Peak Pressure	-
Peak Compliance	-
Equivalent Ear Canal Volume	0.3 ml
Gradient	-

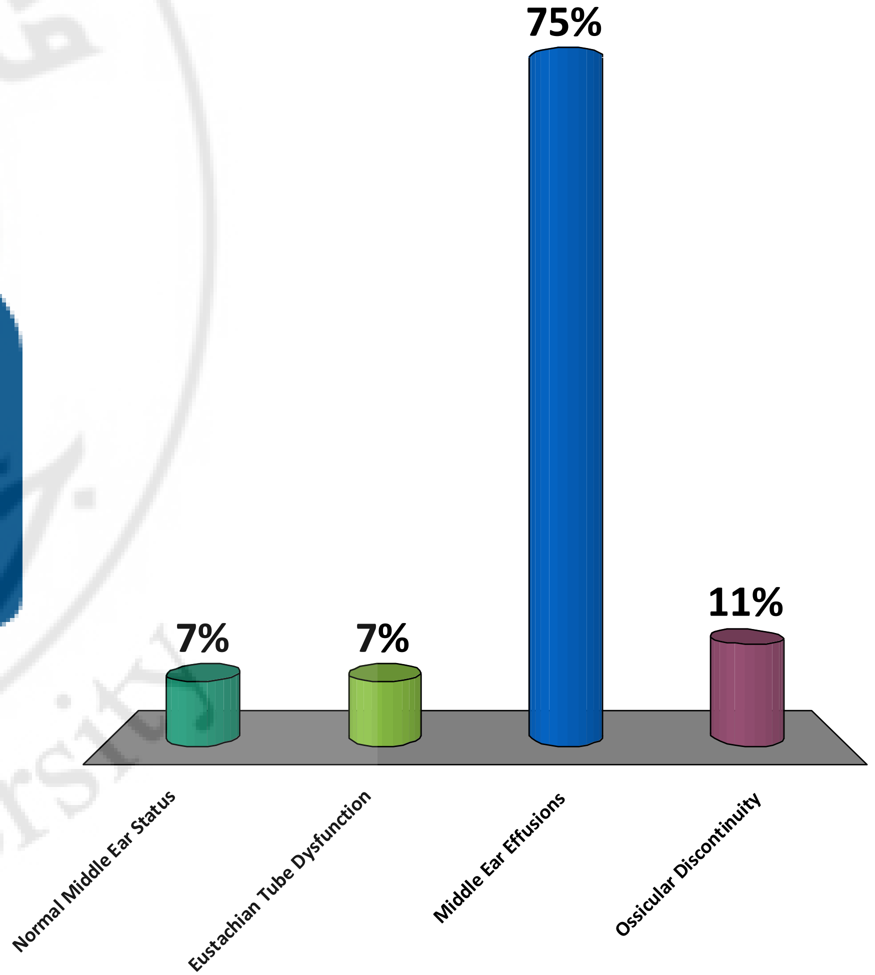


A. Normal Middle Ear Status
B. Impacted Wax
C. Middle Ear Effusions
D. Ossicular Discontinuity

Tympanometry

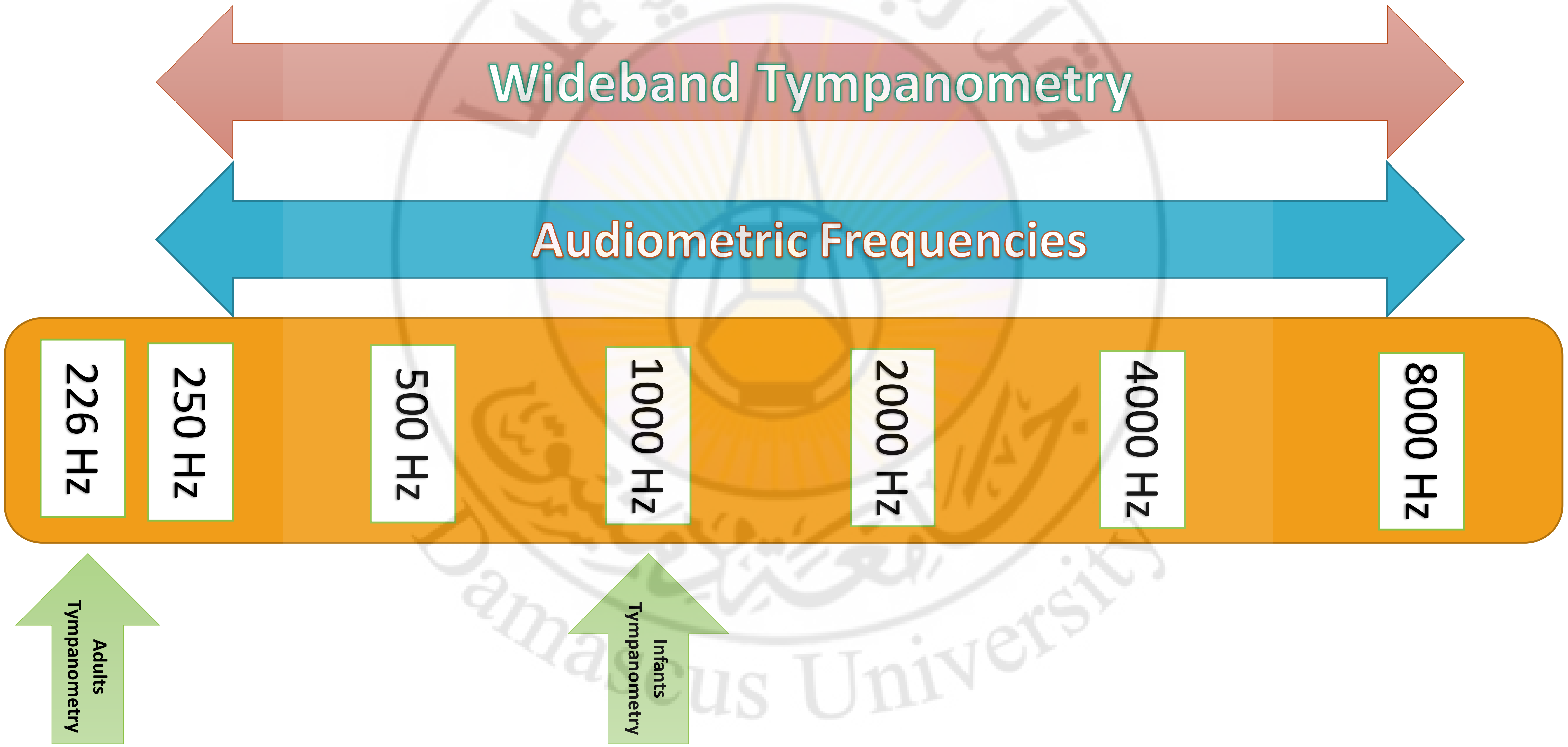


Peak Pressure	-
Peak Compliance	-
Equivalent Ear Canal Volume	1.2 ml
Gradient	-



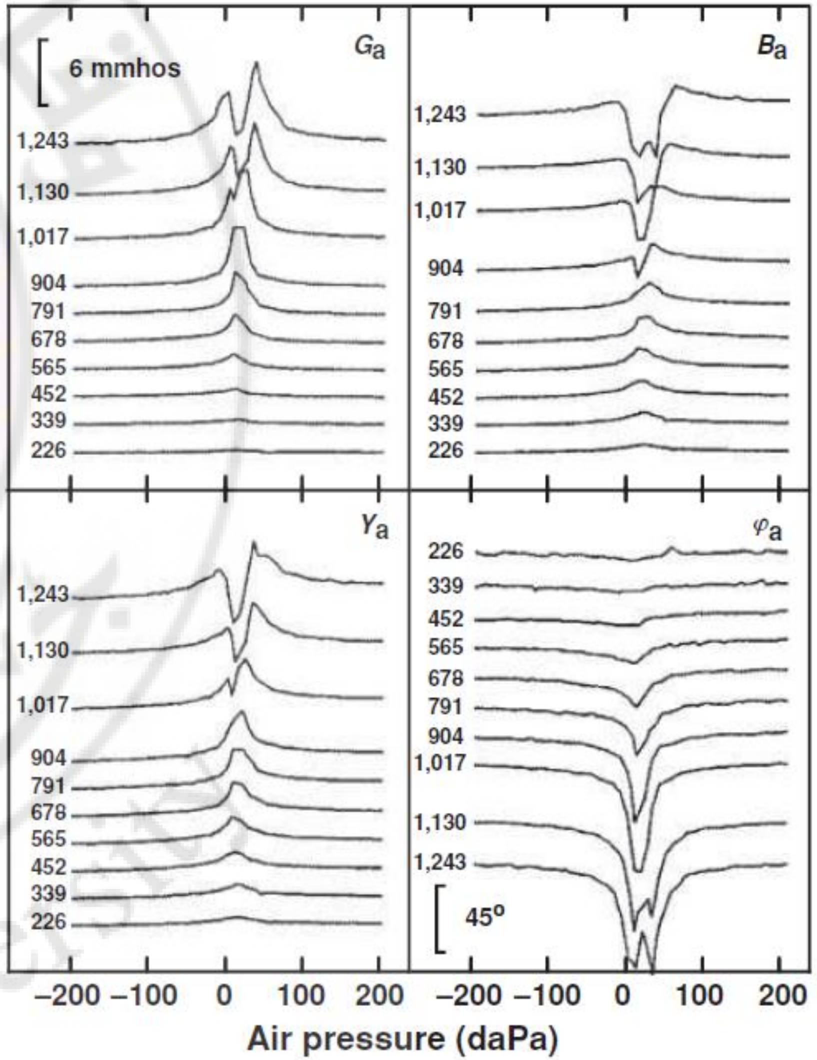
A. Normal Middle Ear Status
B. Eustachian Tube Dysfunction
C. Middle Ear Effusions
D. Ossicular Discontinuity

Frequency range of middle ear assessments

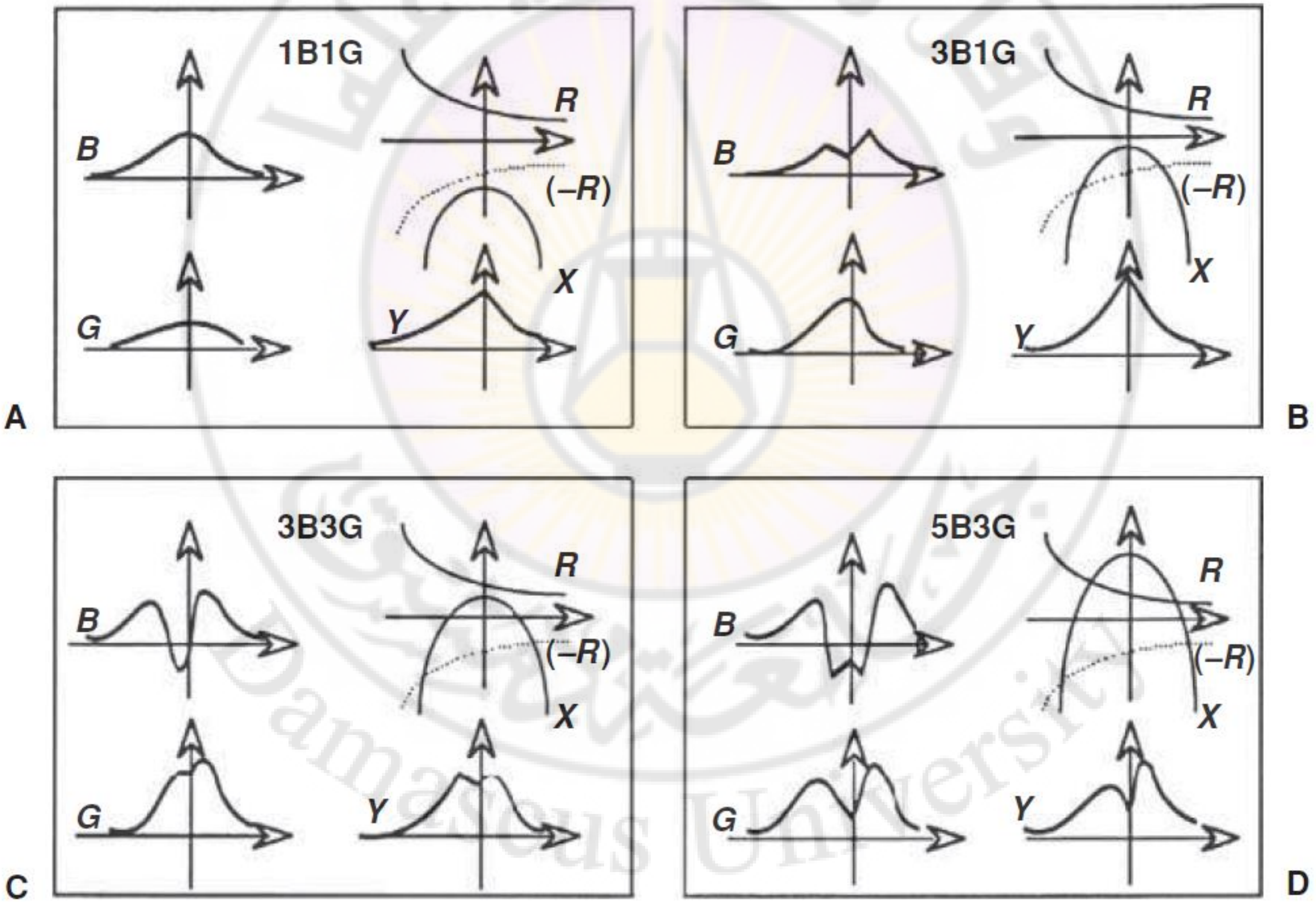


Multifrequency, Multicomponent Tympanometry

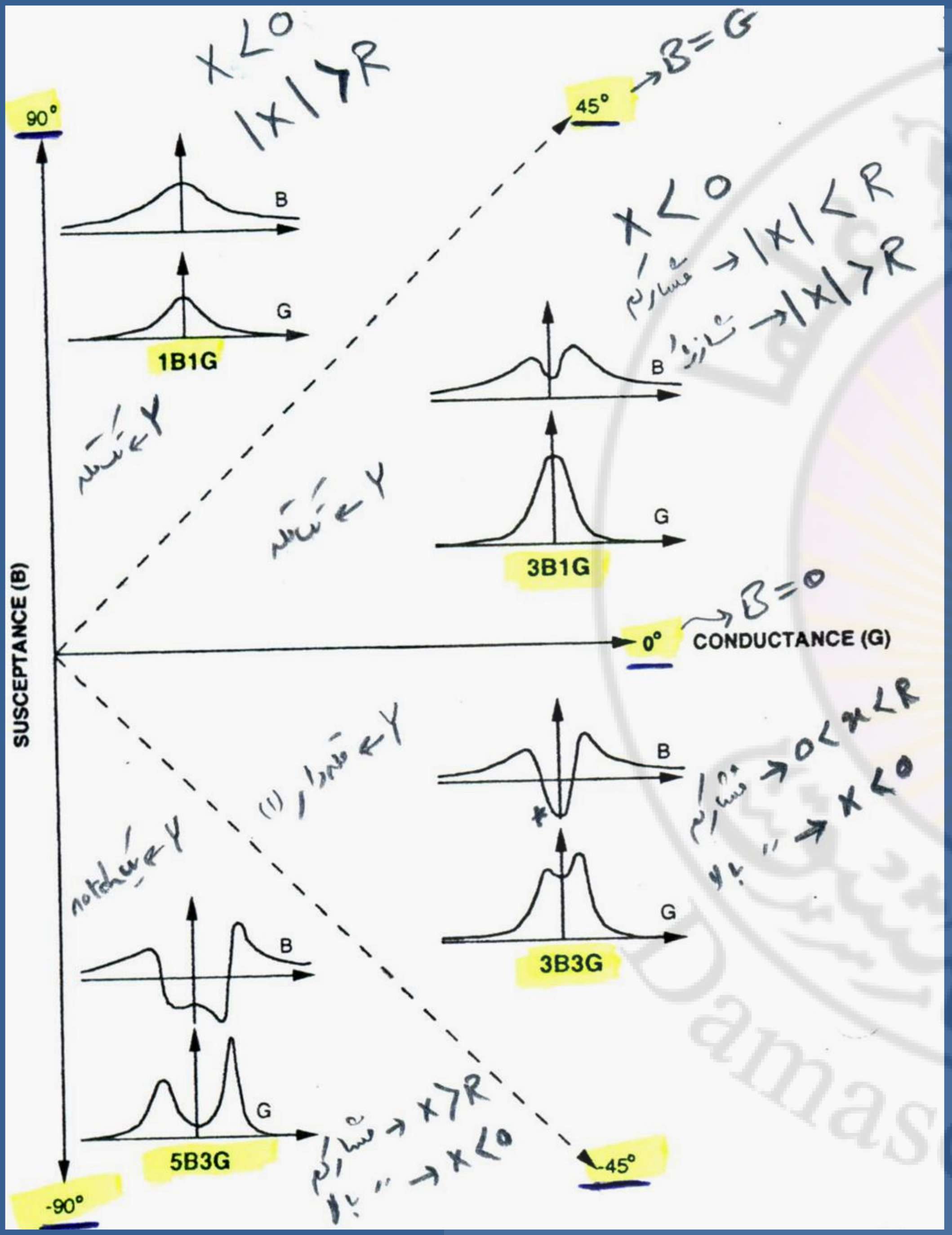
- Multifrequency, multicomponent tympanometry (MFT) expands on conventional 226-Hz tympanometry throughthe use of more than one probe tone frequency, typically ranging from 226 to 2,000 Hz, and measurement of more than one acoustic immittance component (e.g., admittance (*Y*a), conductance (*G*a), susceptance (*B*a), and phase angle φa).
- A strength o MFT is the ability to identify both quantitative and qualitative changes I immittance components across frequency to obtain a more detailed view of the admittance characteristics of the middle ear than is possible with only a single-frequency or single-immittance component.

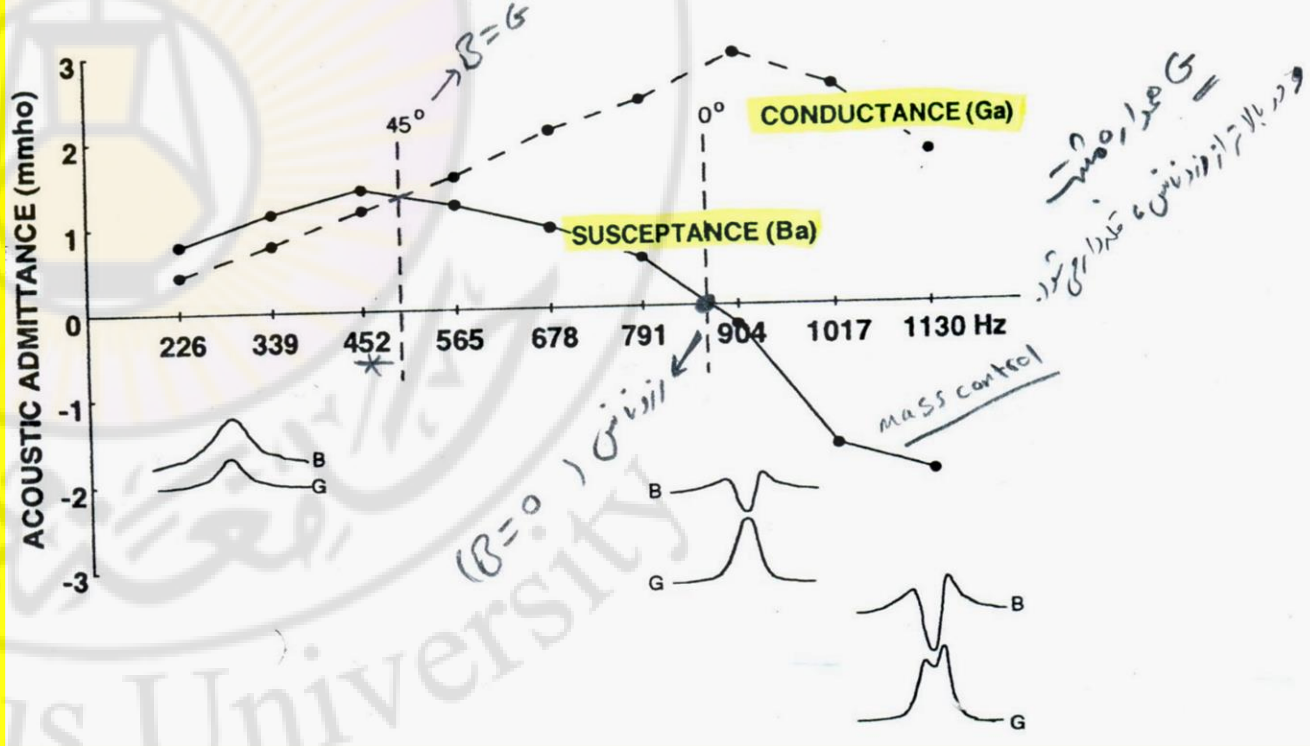


Vanhuyse Model

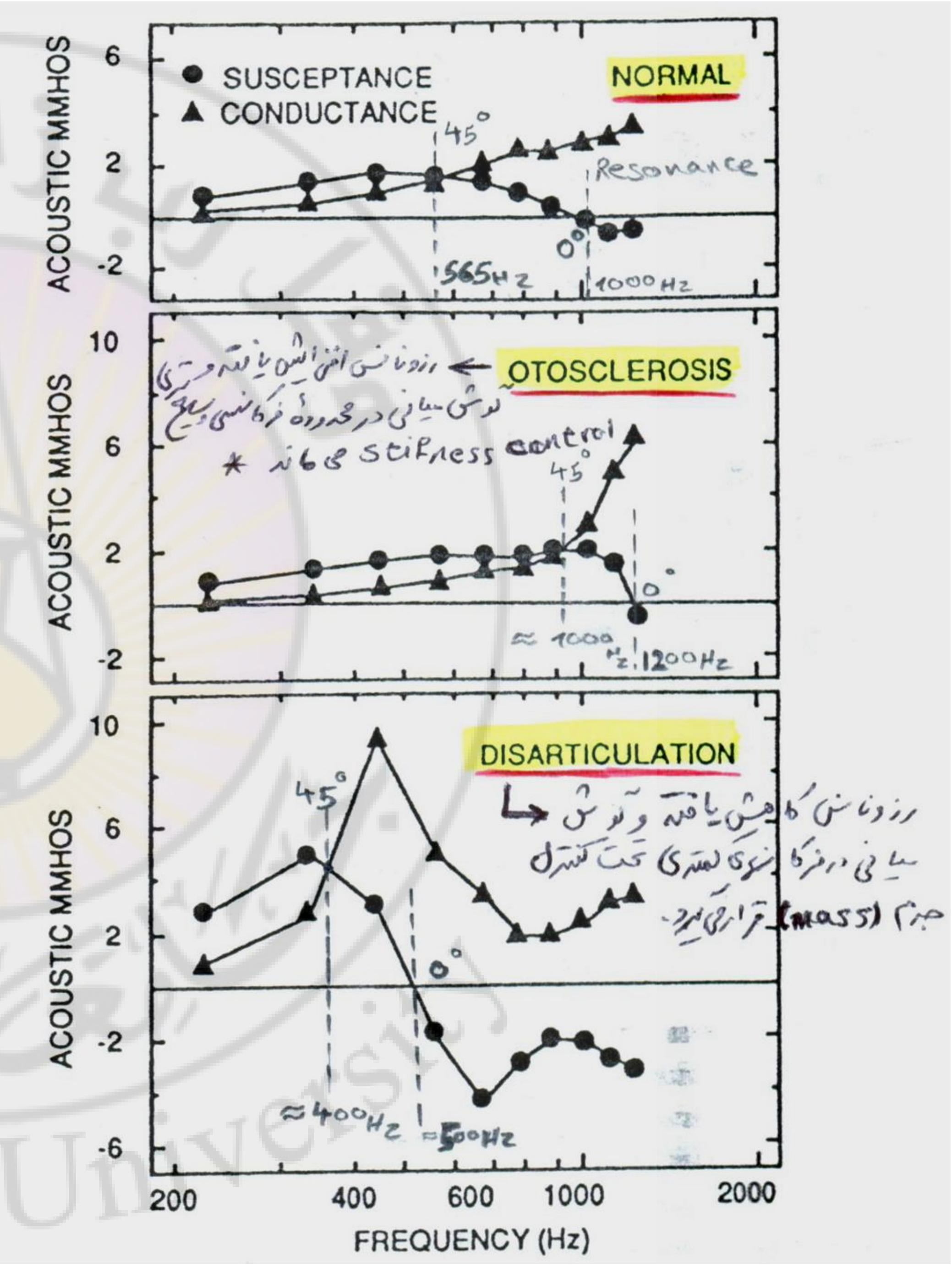


چرخش بردار ادمیتانس به عنوان تابعی از فرکانس پروب تون





Effects of Middle ear pathologies



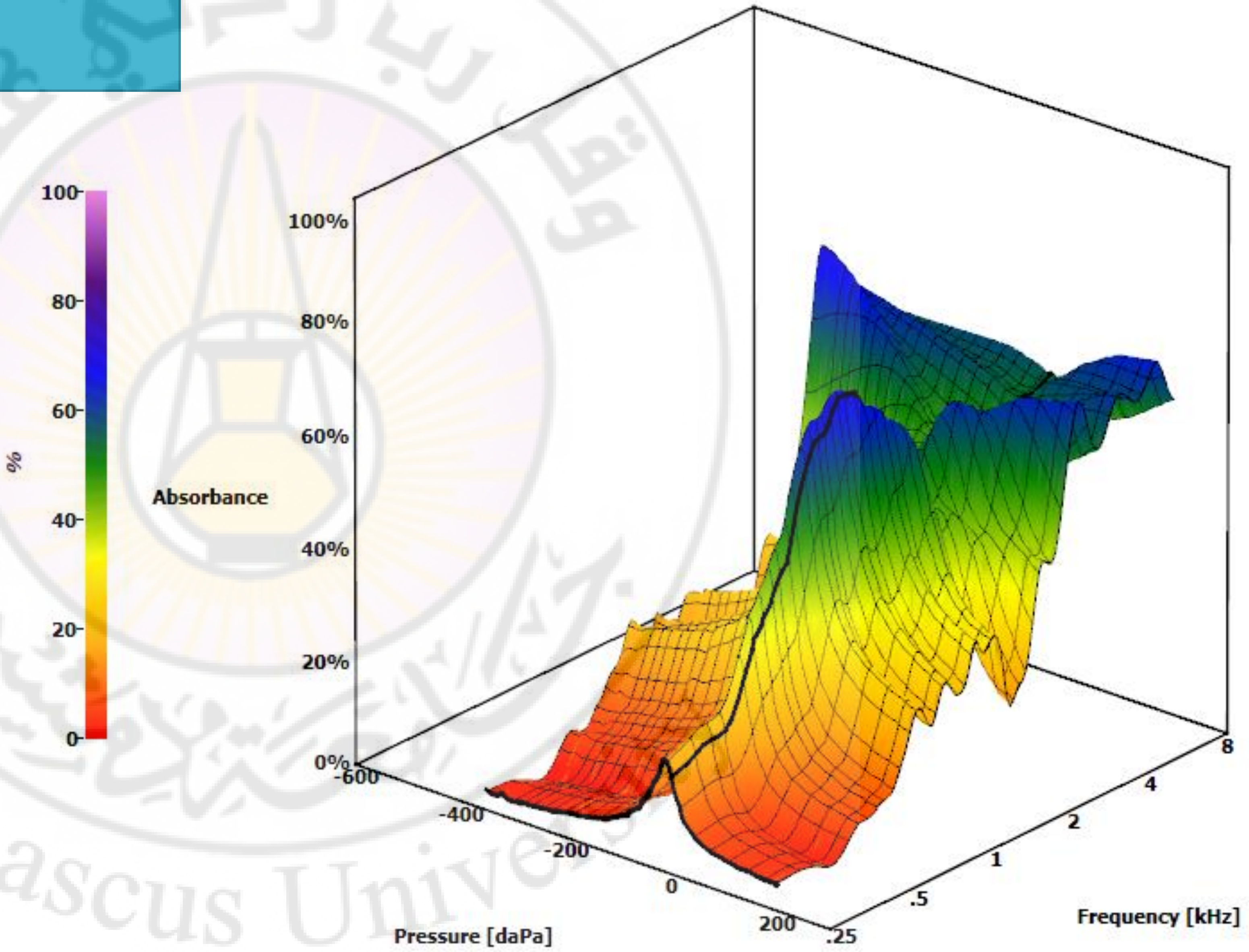
Limitation of MFT

- Restricted range of probe frequencies (<2,000 Hz), which could limit identification of RF in some cases.
- The more complicated multifrequency tympanometric response patterns are often difficult for clinicians to interpret
- The normative range of RF is fairly wide

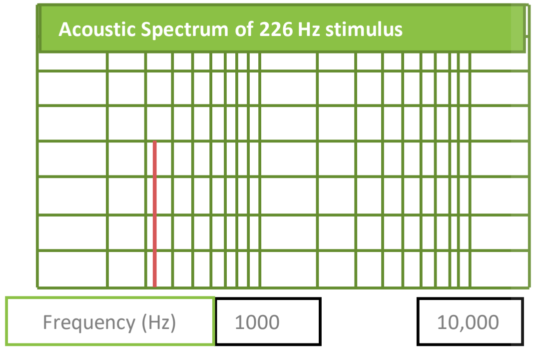
Wideband Tympanometry
A new dimension in middle ear diagnostics

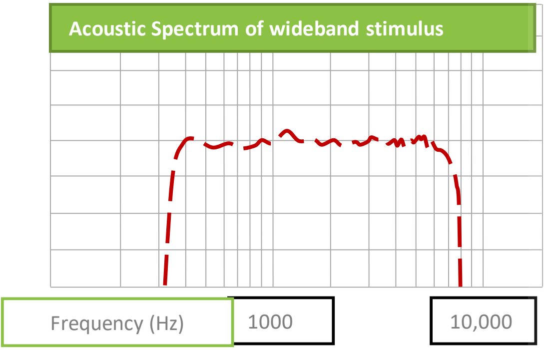
- Wideband (WB) reflectance and WB absorbance are names for an emerging type of acoustic ear-canal measurement that provides new dimensions for middle-ear assessment across a wide range of frequencies.

- Reflectance measurements are performed over a frequency range from 0.22 kHz up to approximately 8 kHz using a WB stimulus such as a click.



Wideband Tympanometry



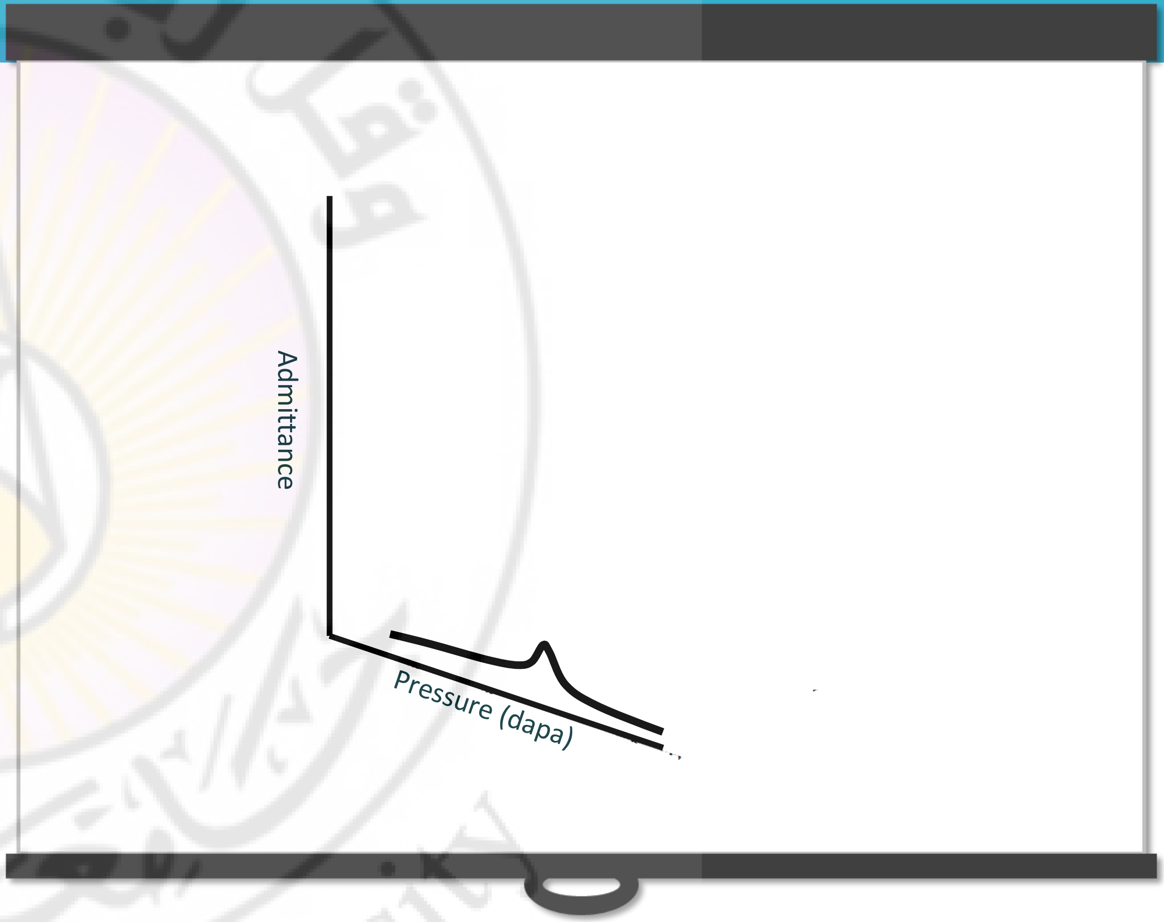


Traditional Tympanometry

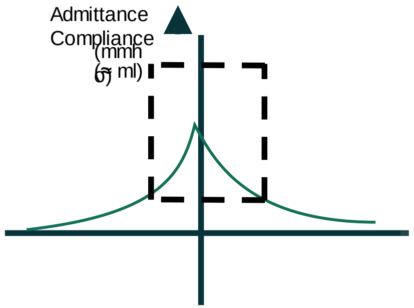
- Looks at a single probe tone frequency
- At 226 Hz the middle ear is stiffness dominated
- Detect problems with the TM and ear cavity (parts of the ear which affect the stiffness)

Wideband Tympanometry

- Uses a Wideband click Stimulus
- Measures the effects of middle ear pathologies at multiple frequencies
- Detects problems with a high degree of accuracy



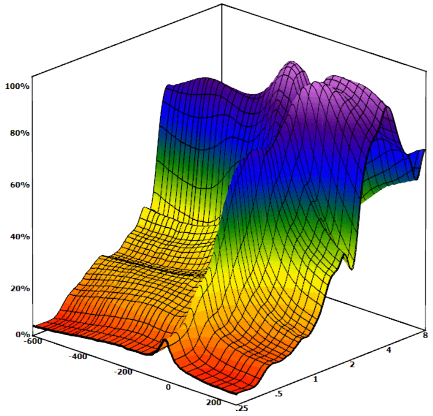
Wideband Tympanometry



Traditional Tympanometry

Measured in admittance / Compliance
Cannot test above ≈ 1500 Hz due to effect of standing waves

Admittance (Y) = Conductance (G) + total Susceptance (jBa)



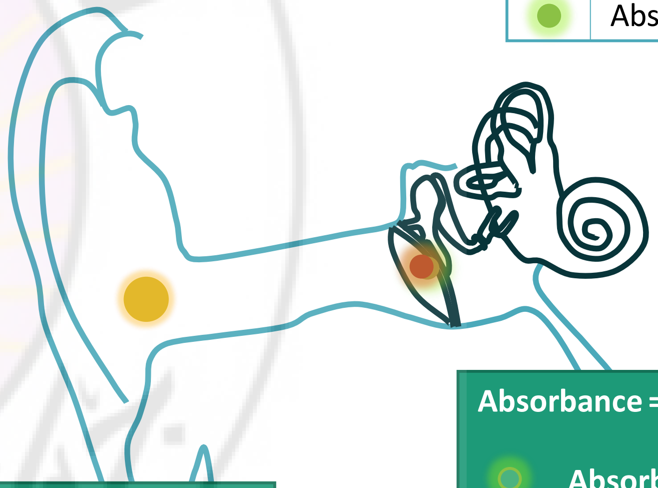
Wideband Tympanometry

Measured in Absorbance (and admittance)
Can test all the way to 8000 Hz without being contaminated by standing waves
Provides the same information as traditional tympanometry (admittance) and new information (absorbance)

Absorbance = Absorbed Power / Incident Power

Absorbance

- Incident sound
- Reflected sound
- Absorbed sound

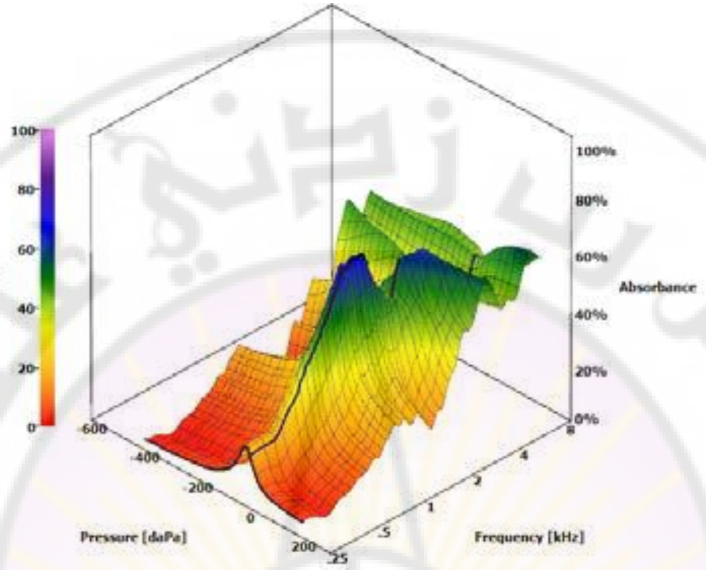


Absorbance =

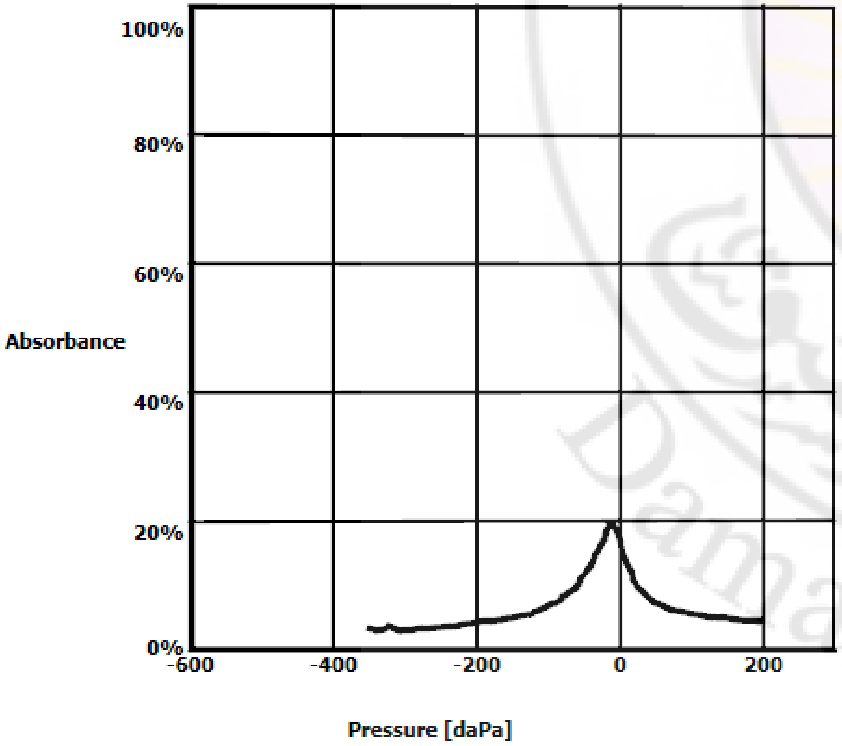
$$\frac{\text{Absorbed sound}}{\text{Incident sound}}$$

OR

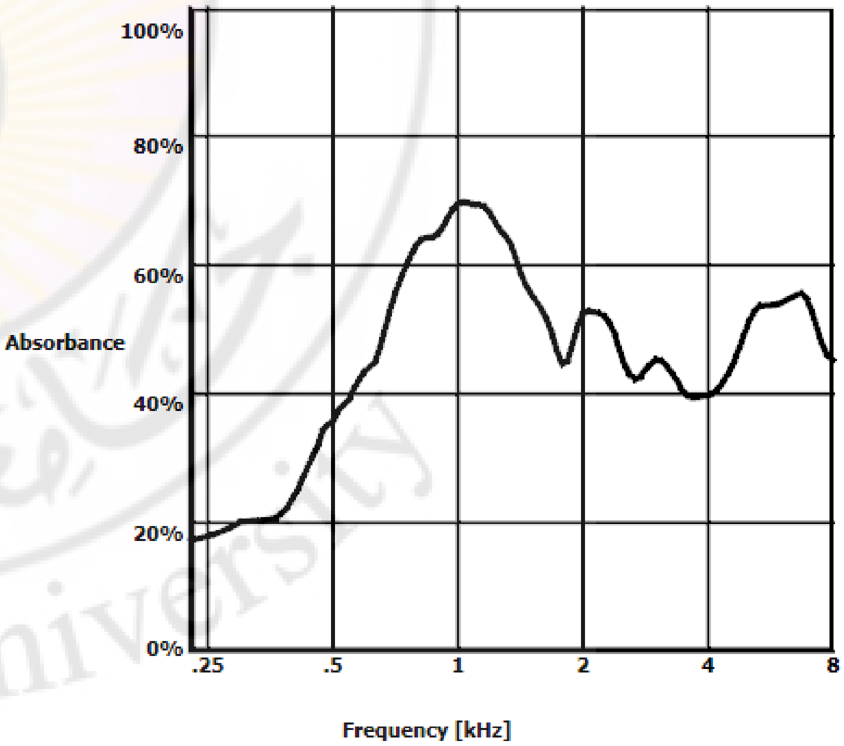
1 – Energy Reflectance



Tympanograms



Absorbance



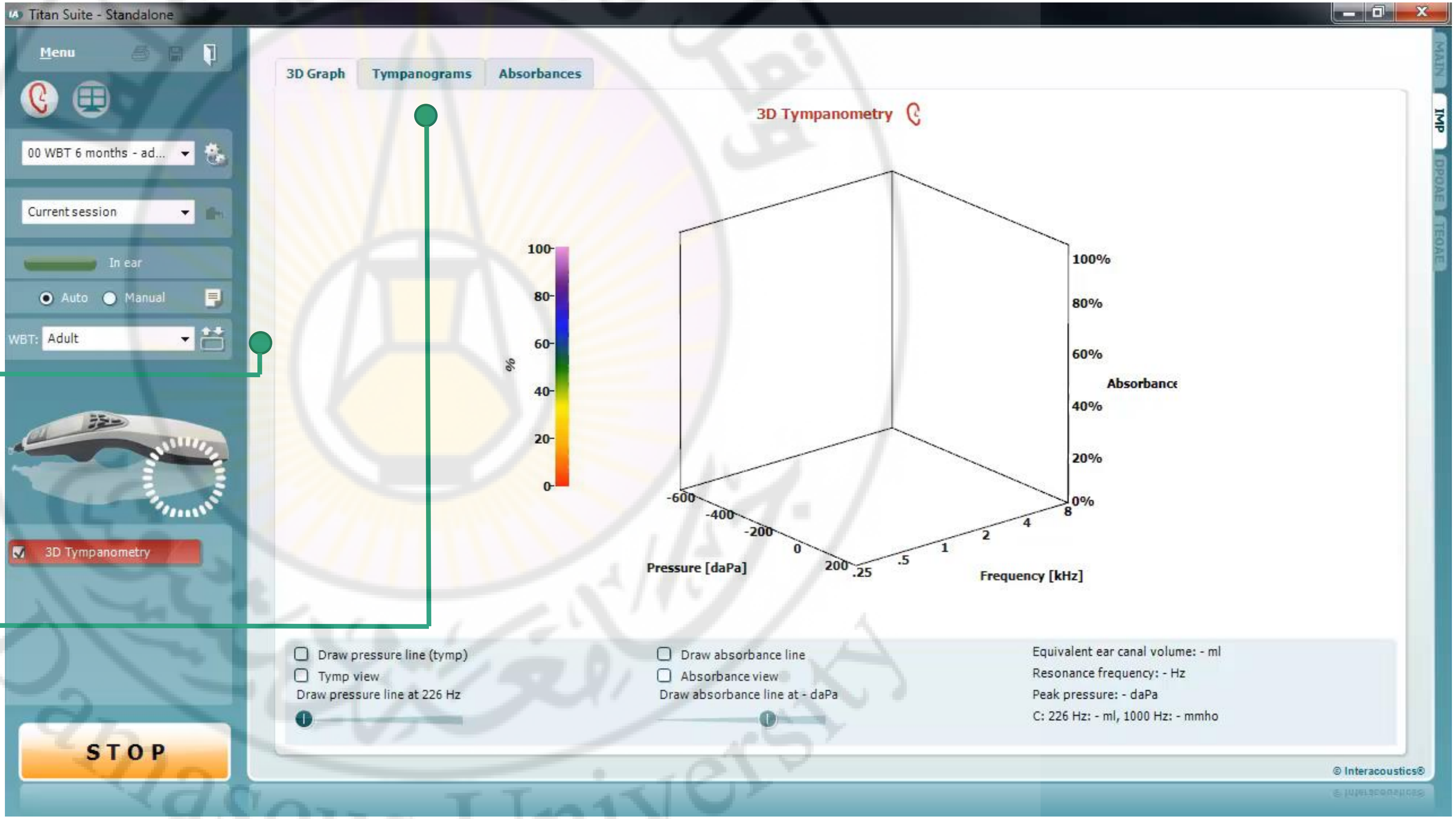
Wideband Tympanometry

A measurement in action

Time

Two calibration sets Adults and Children

Key information is extracted into tabs



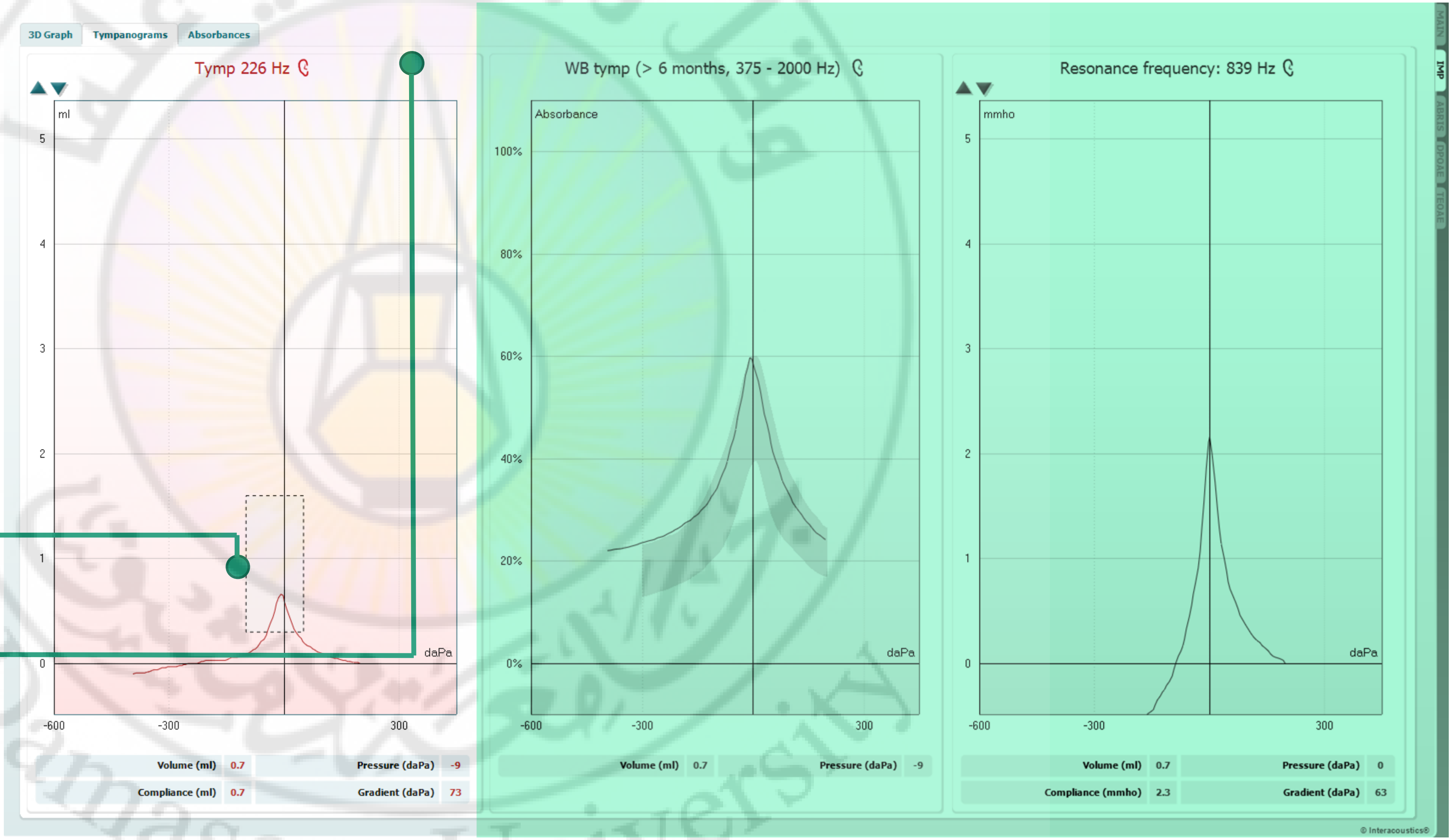
Wideband Tympanometry

Extracted Data: Tympanograms

Traditional tympanograms

Option to break down the Y component and see the susceptance (B) and conductance (G) components

Admittance tympanograms available for probe tone frequencies 226 Hz 678 Hz 800 Hz 1000 Hz



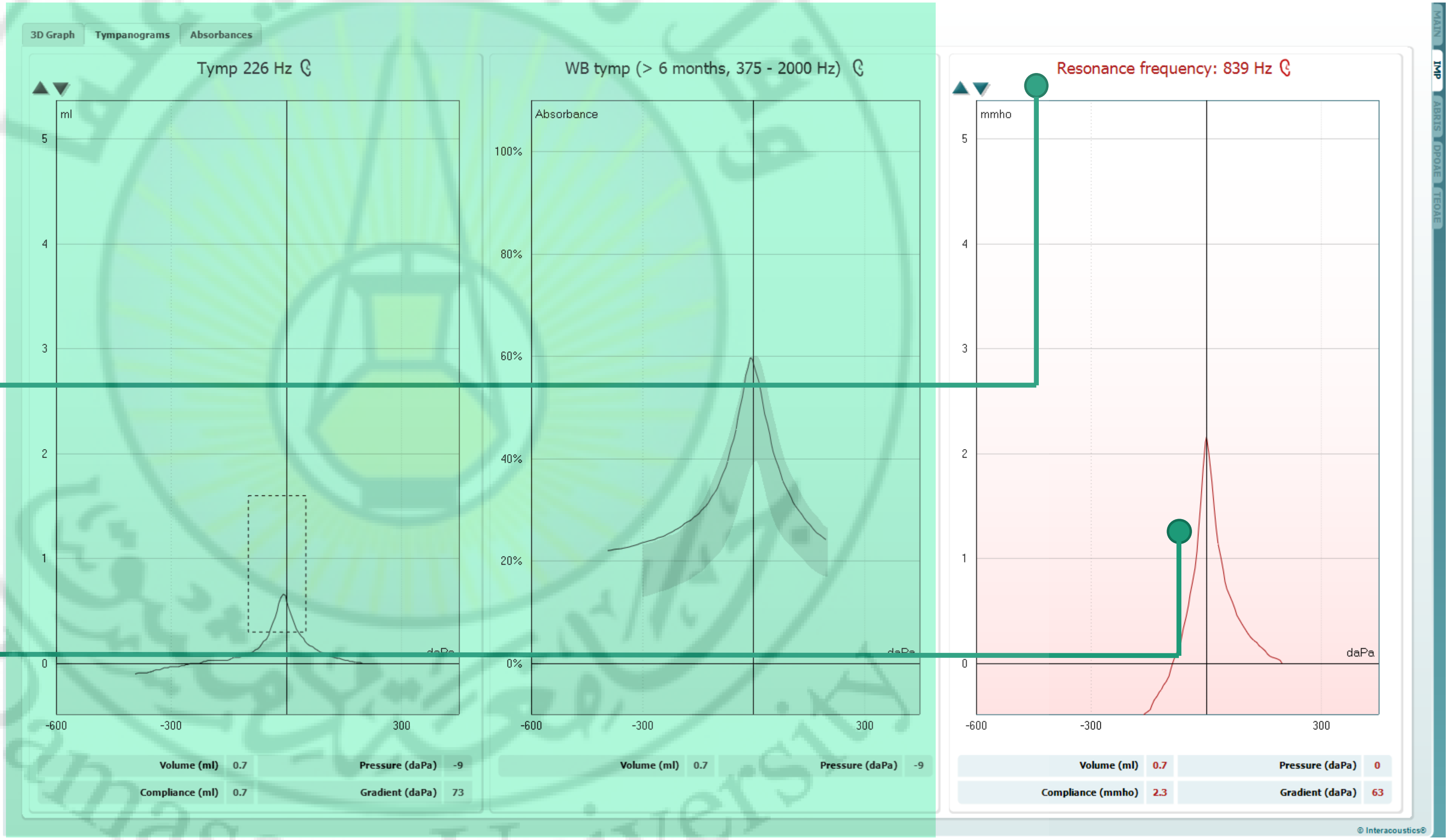
Wideband Tympanometry

Extracted Data: Tympanograms

Resonance Frequency

The frequency which allows the most energy to pass to the middle ear

Useful for looking at pathologies affecting mass

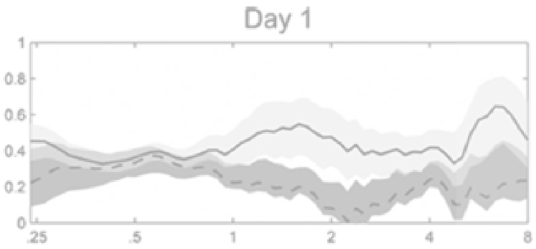


Wideband Tympanometry

Extracted Data: Tympanograms

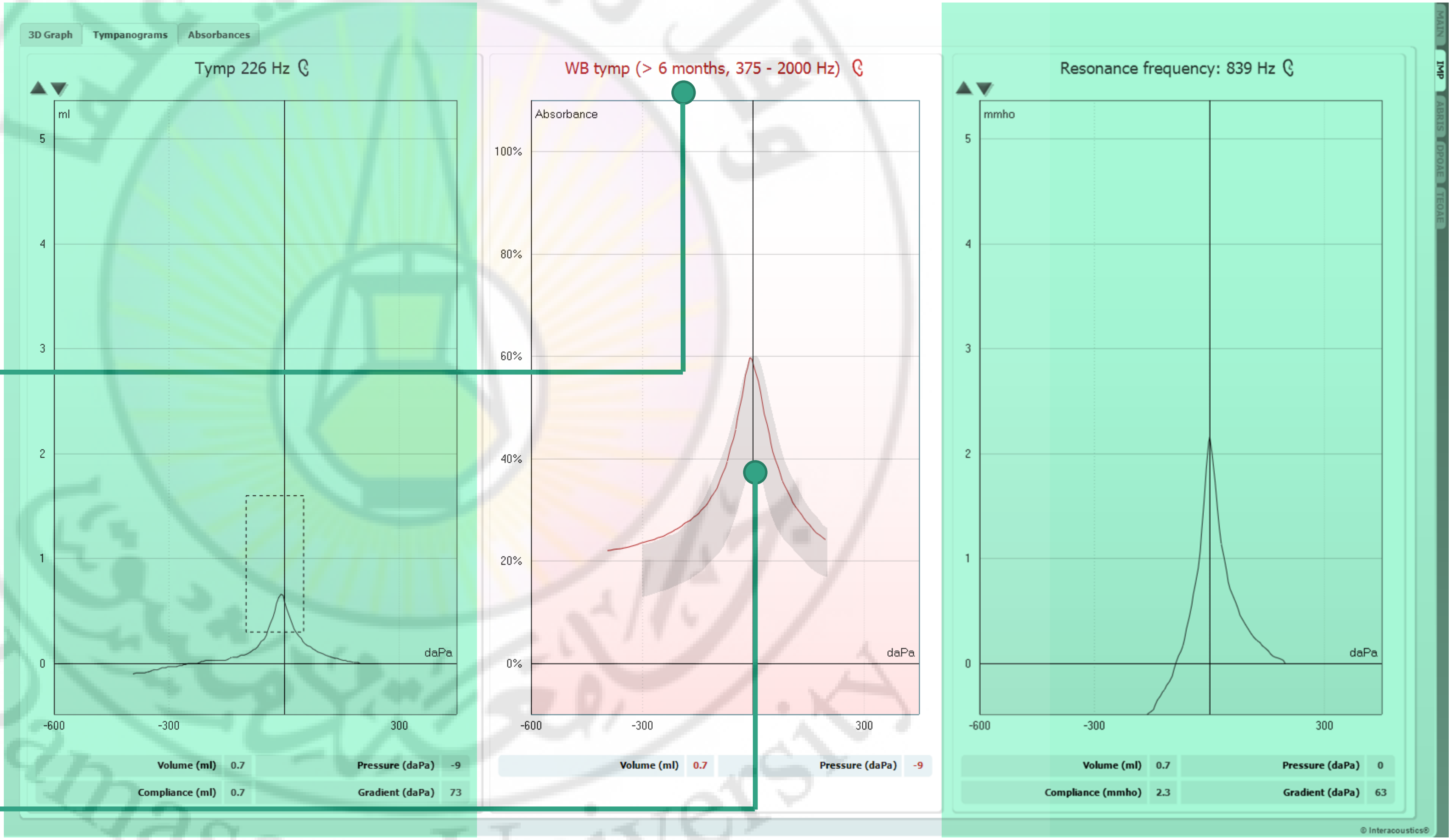
Wideband averaged tympanogram

Adults 375 and 2000 Hz
Infants 800 and 2000 Hz



Better detector of middle ear effusions

More noise robust



Wideband Tympanometry

Extracted Data: Absorbance

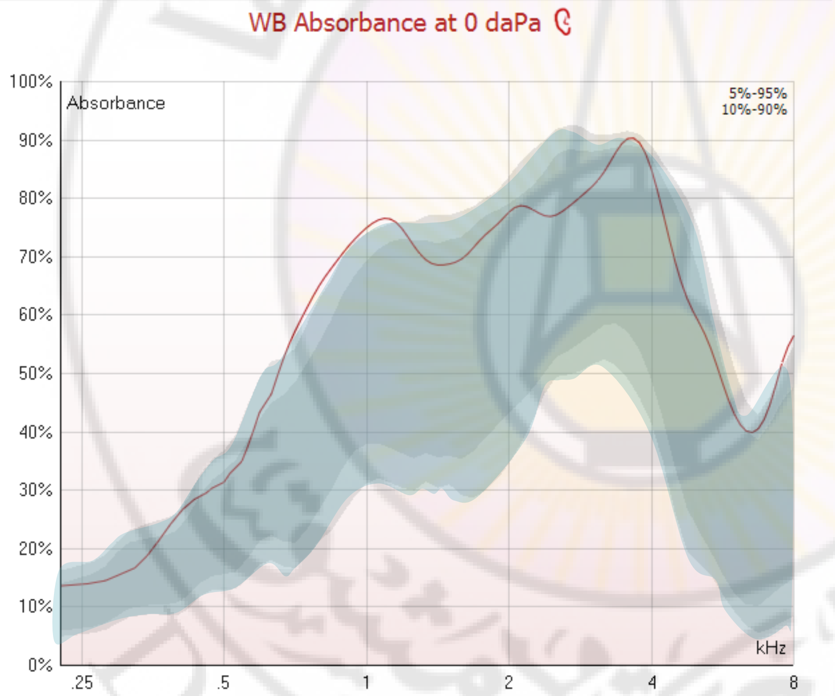
Absorbance Graph

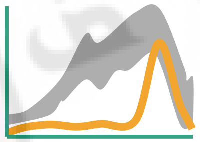
X axis shows frequency

Y axis shows absorbance

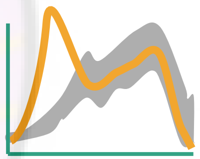
Grey area is normative data

Red line is measured absorbance

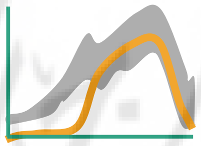




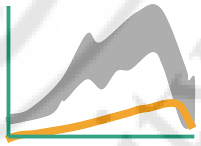
Middle Ear Effusion



Ossicular Continuity



Otoscleriosis

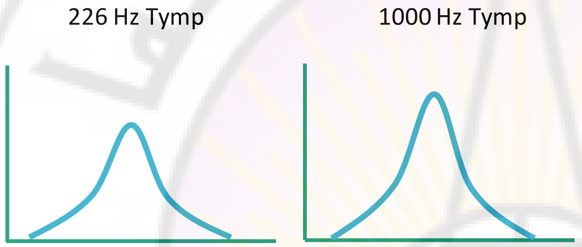


Middle Ear Effusion

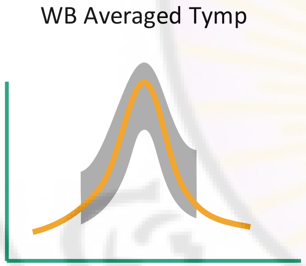
Wideband Tympanometry

Benefits for Children

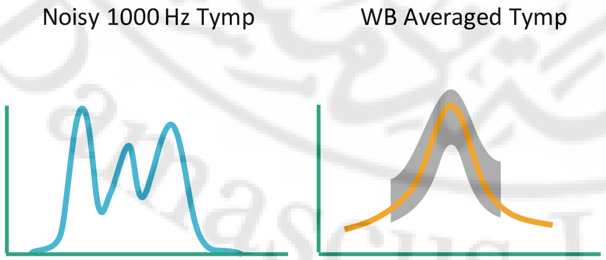
1 **Multiple Tympanograms**
Save time with fewer measurements



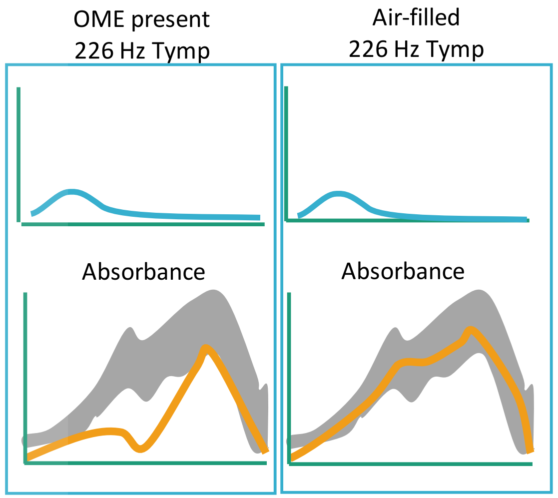
2 **Improved Sensitivity**
Improved accuracy over standard tympanometry



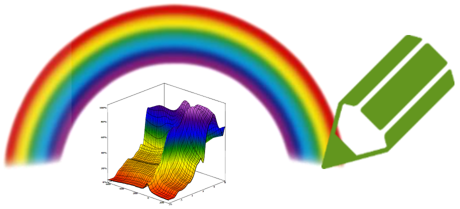
3 **Stable and robust results**
Clear results with noisy children



4 **Know your Type C Tympanogram**
Know when OME is present in the middle ear



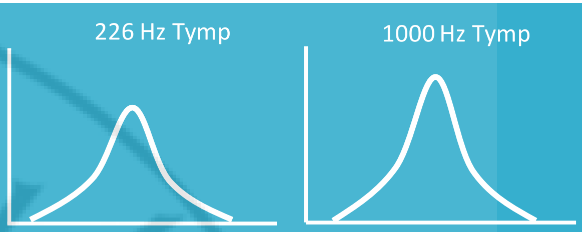
5 **Drawing Rainbows**
Child tolerates measurement

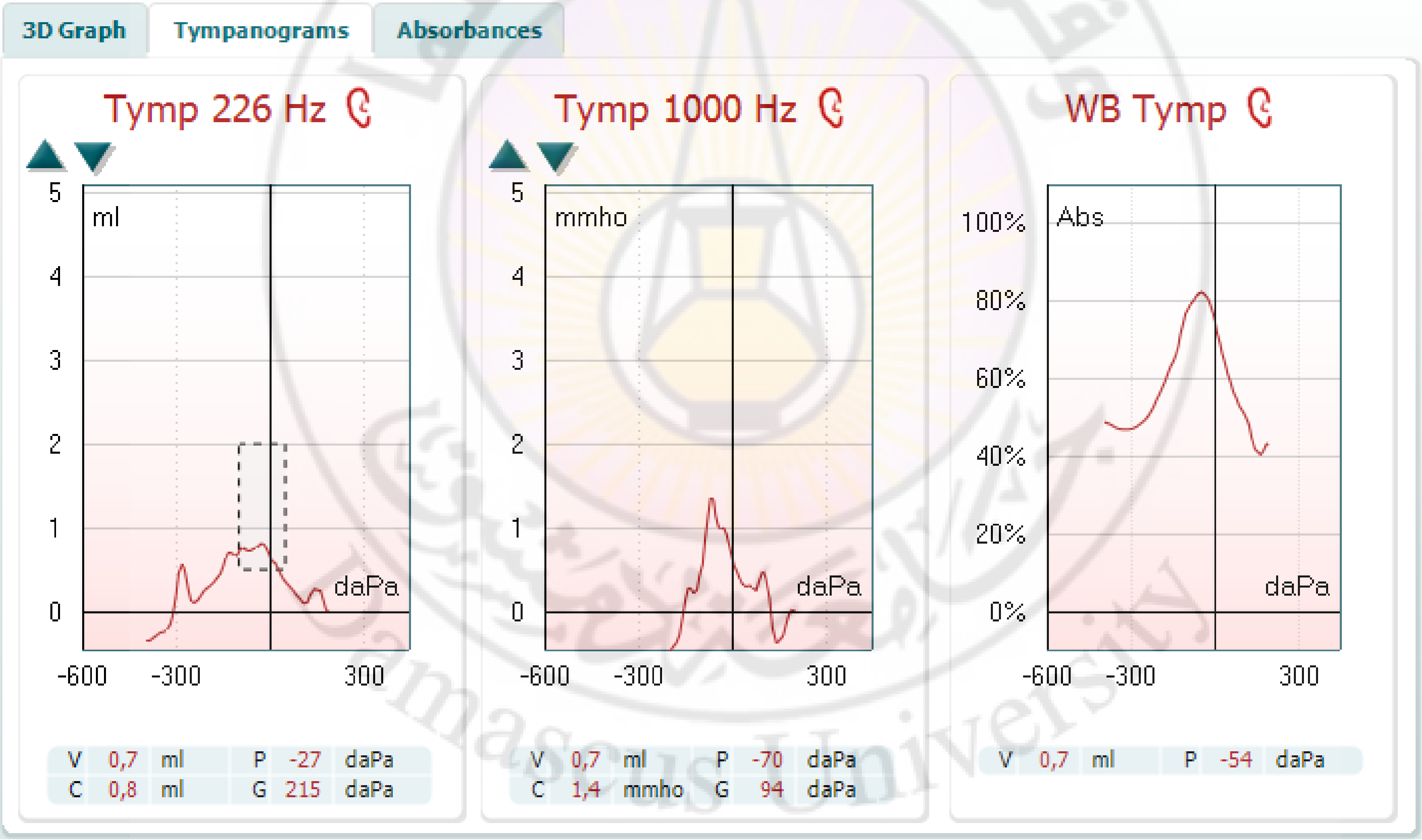


Wideband Tympanometry

1

Multiple Tympanograms
Save time with fewer measurements

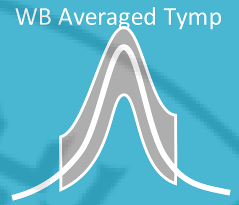


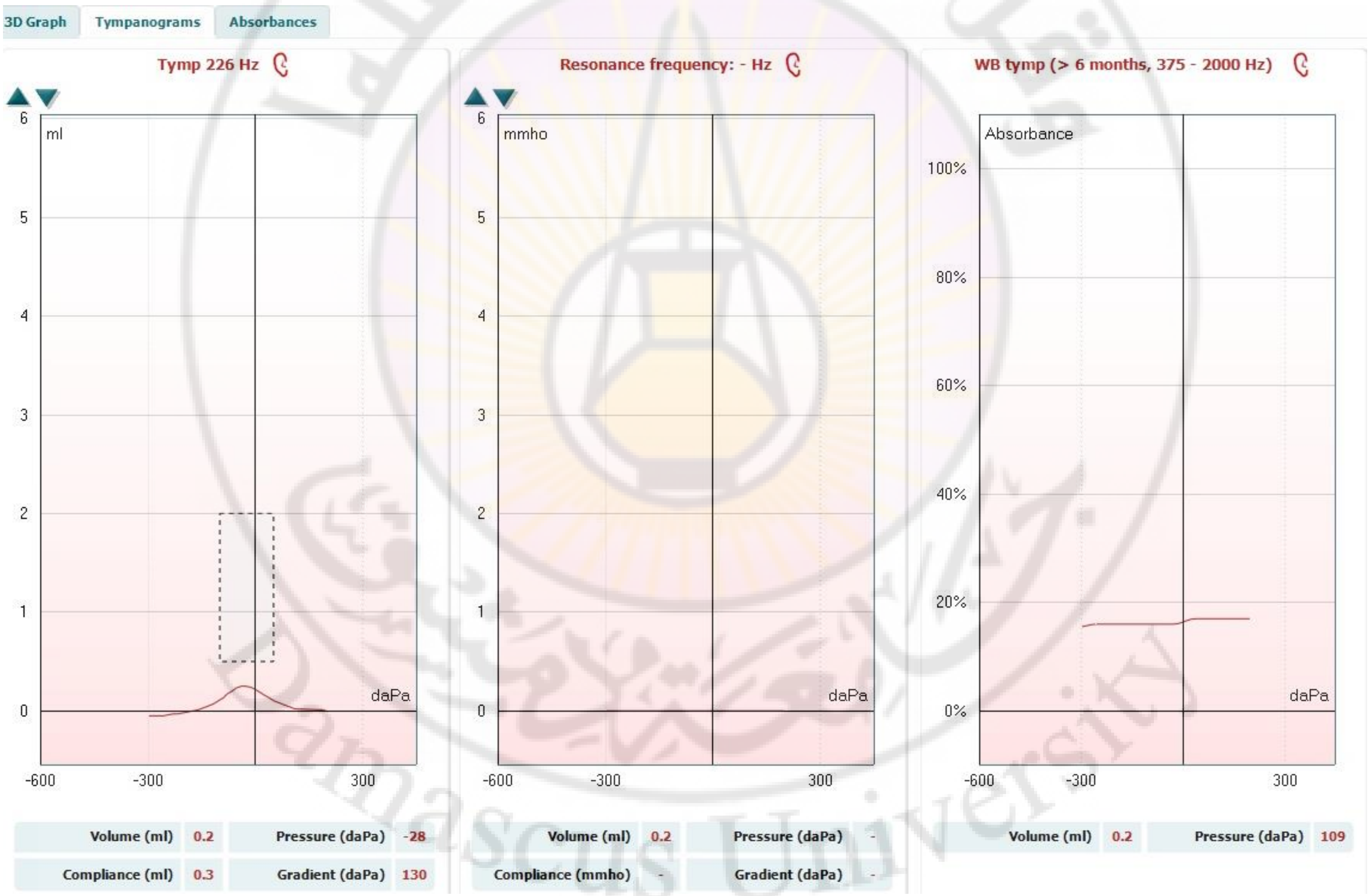


Wideband Tympanometry

2

Improved Sensitivity
Improved accuracy over standard tympanometry



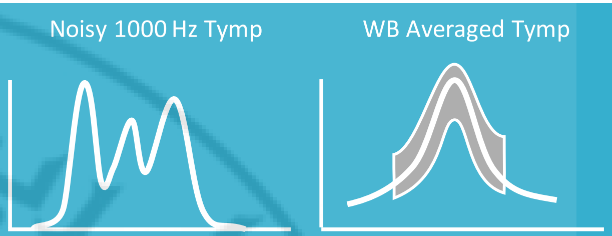


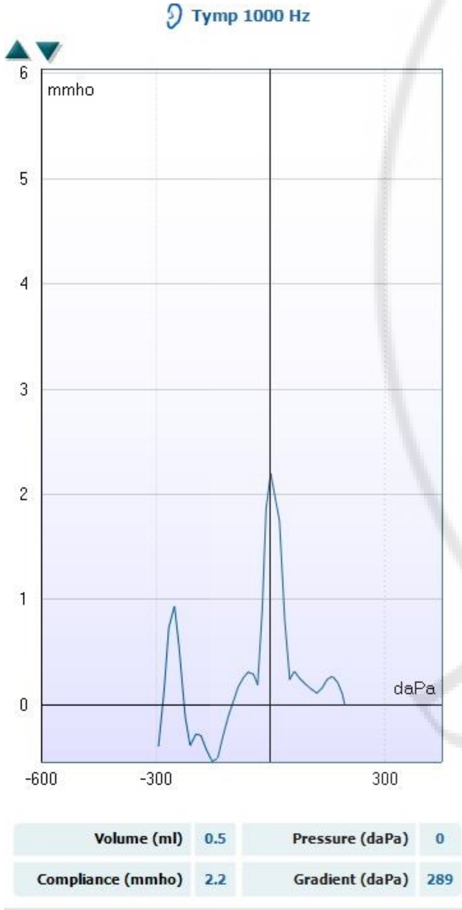
Wideband Tympanometry

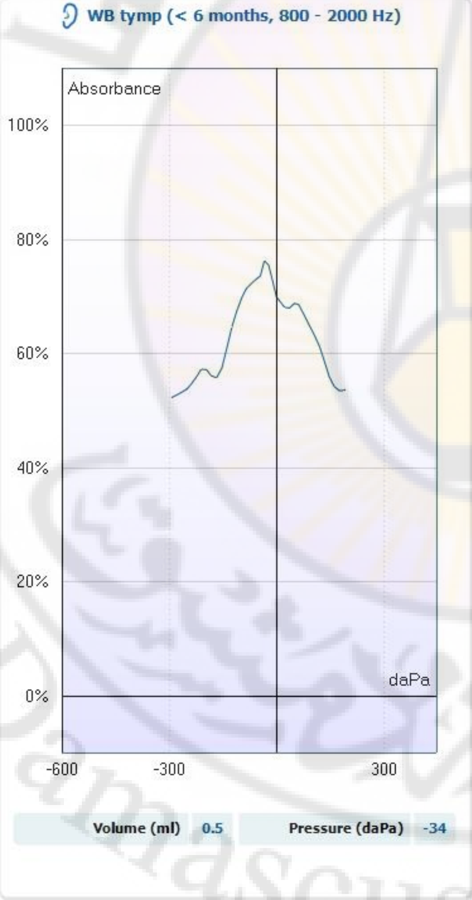
3

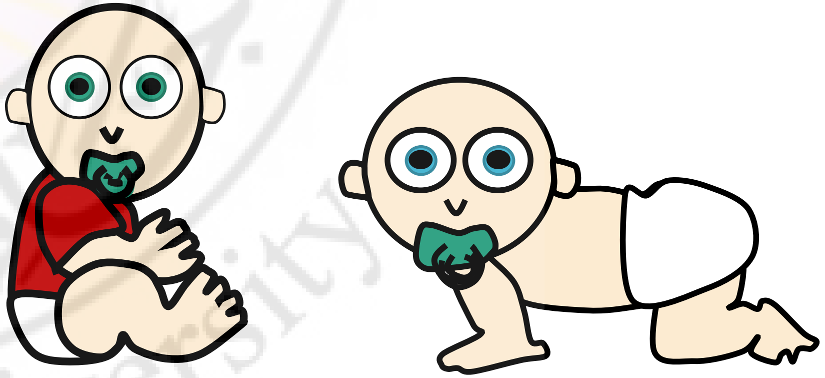
Stable and robust results

Clear results with noisy children







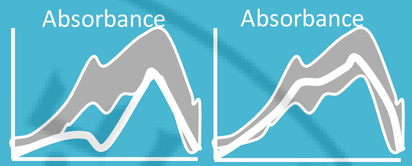


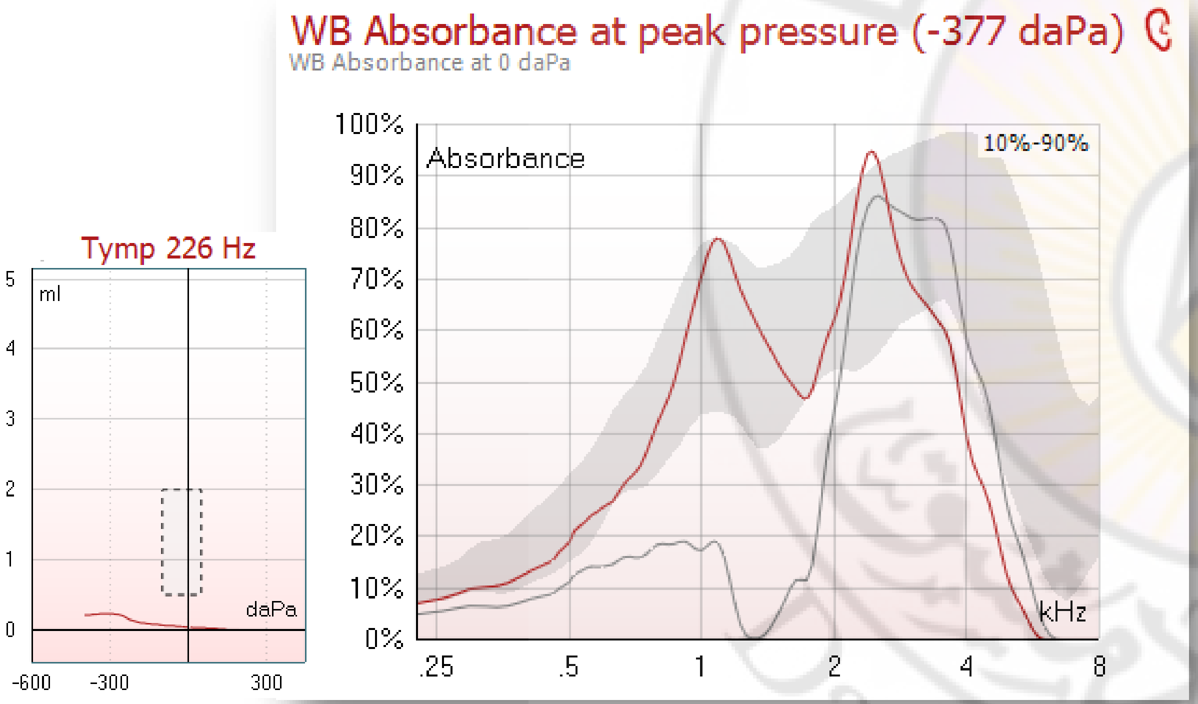
Wideband Tympanometry

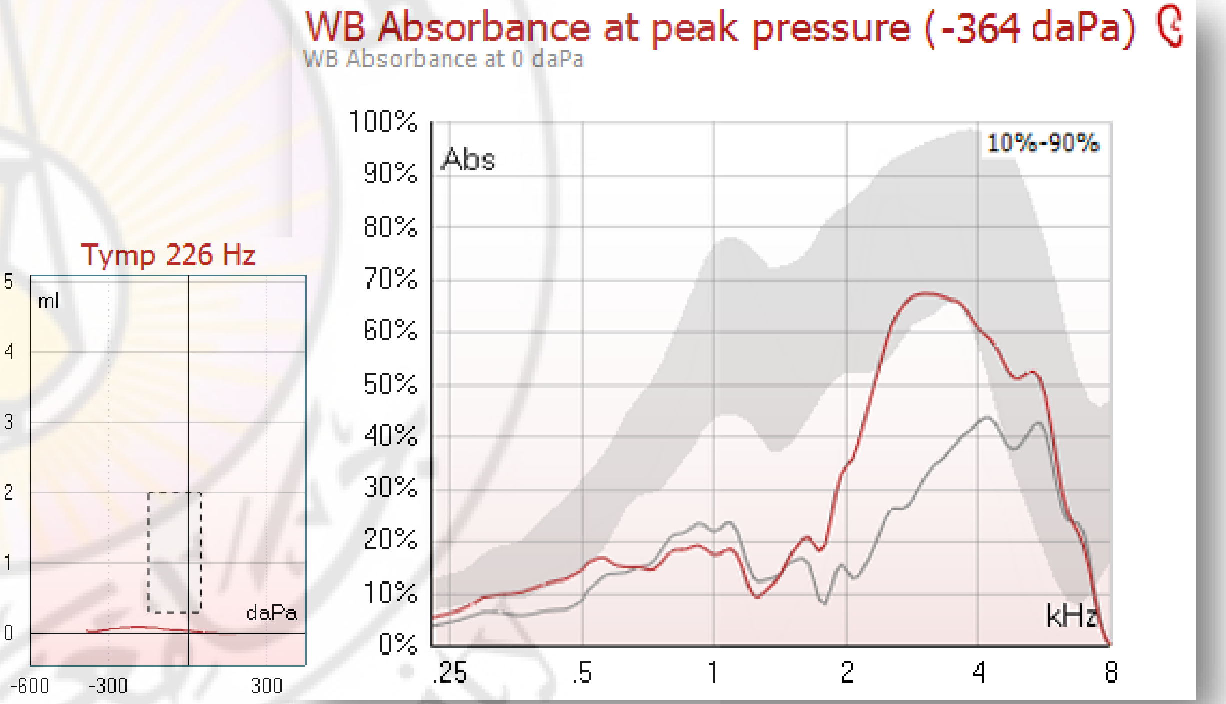
4

Know your Type C Tympanogram

Know when OME is present in the middle ear



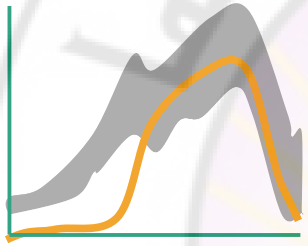




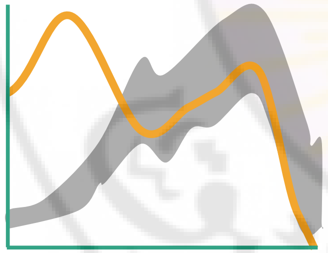
Wideband Tympanometry

Benefits for adults

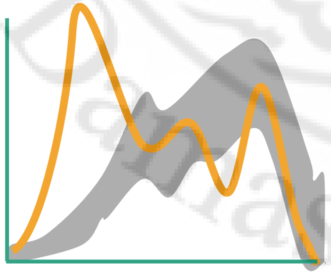
1 Detecting and monitoring Otosclerosis



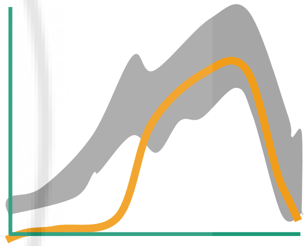
2 Seeing though perforations

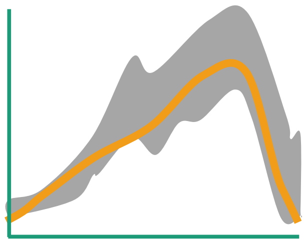


3 Detection of ossicular discontinuity

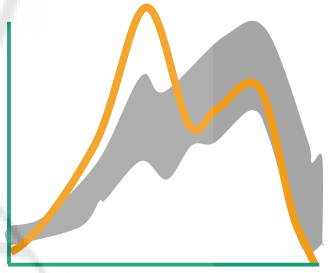


4 Pre and post operative monitoring using no pressure test



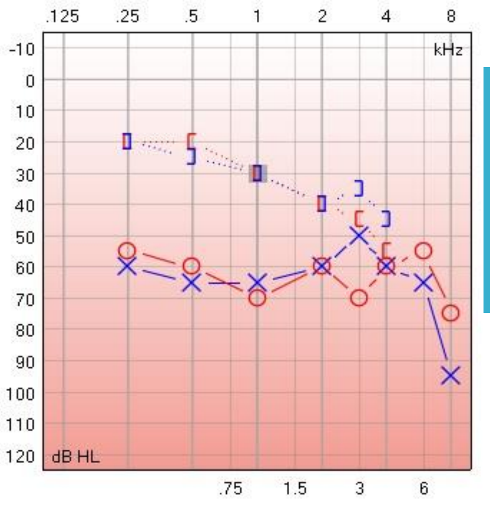


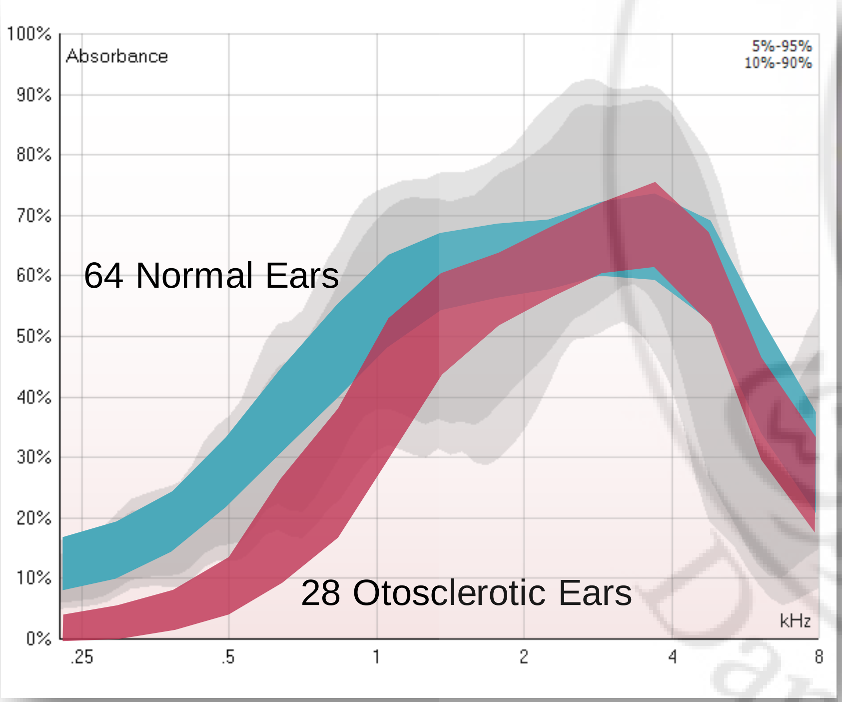
5 Detecting of SSCD

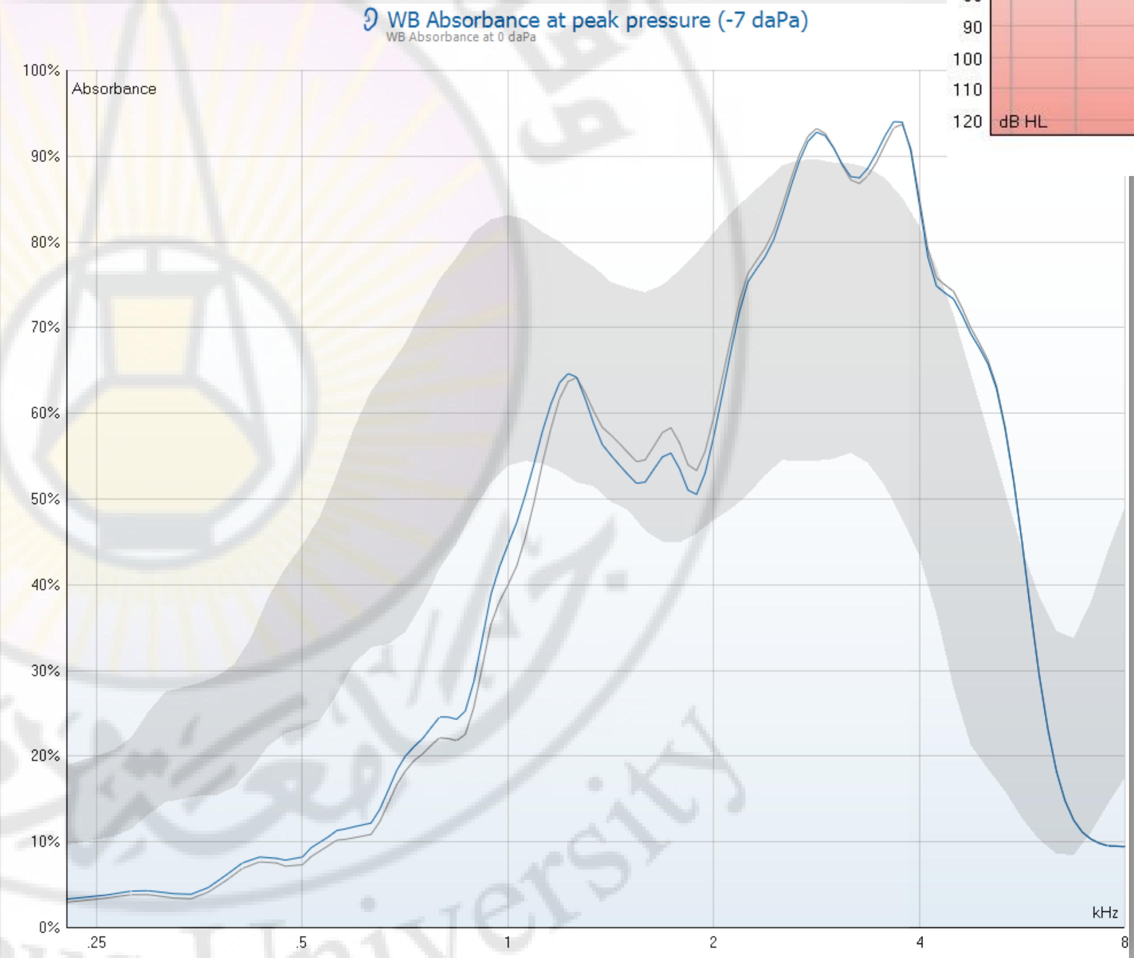


Wideband Tympanometry

1 Detecting and monitoring Otosclerosis

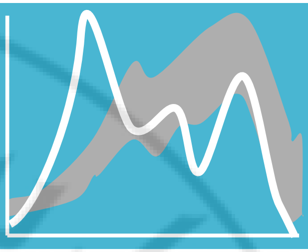


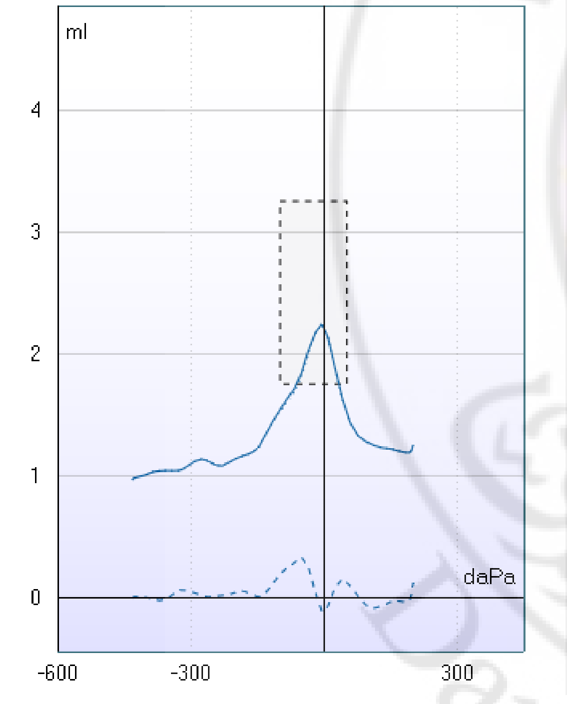


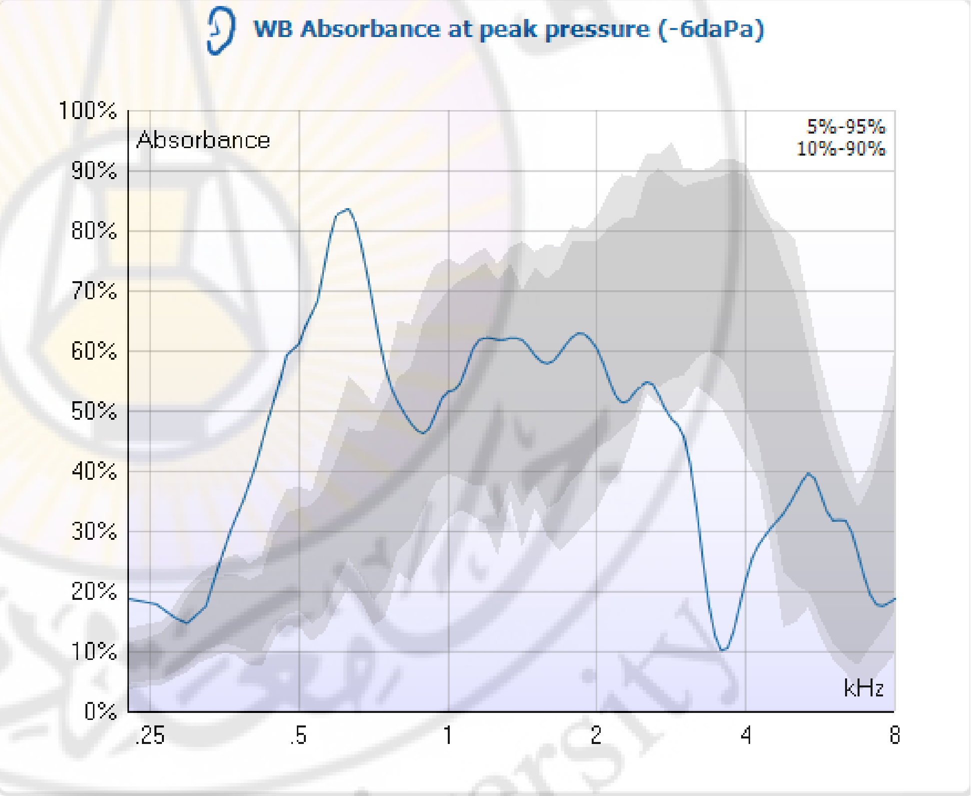


Wideband Tympanometry

2 Detection of ossicular discontinuity

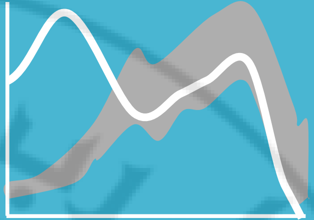


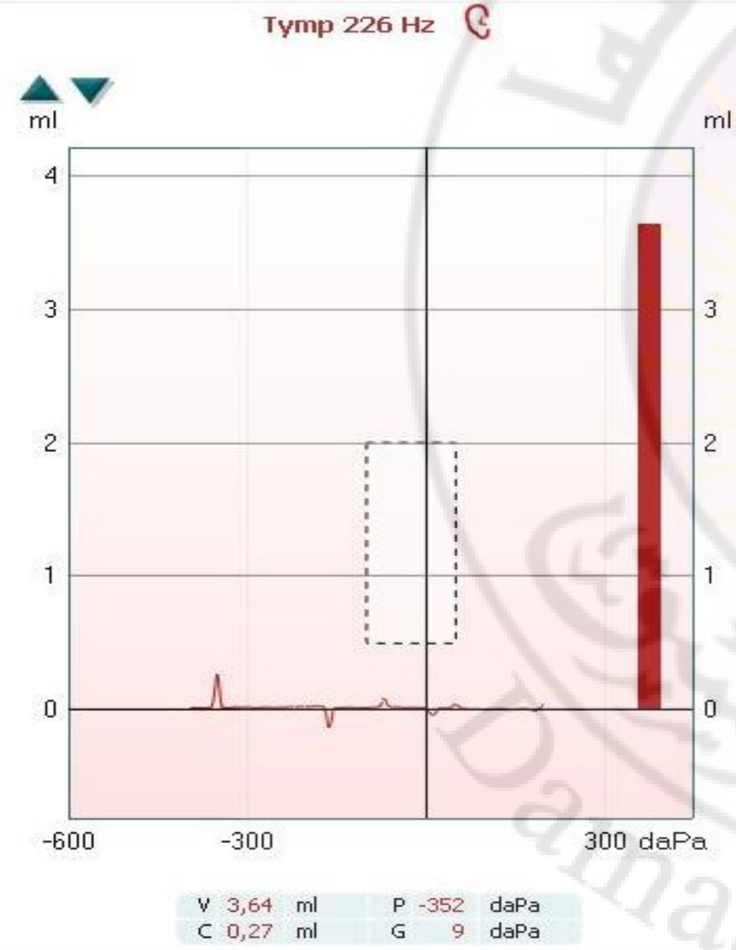


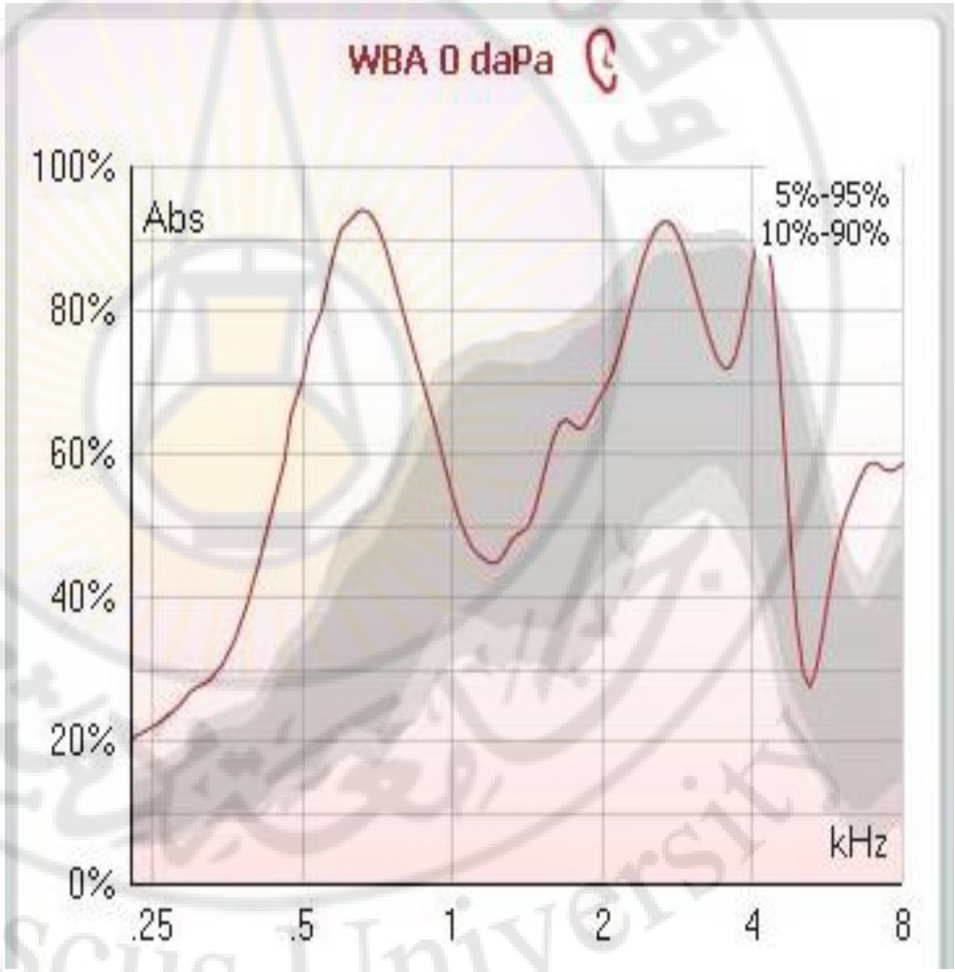


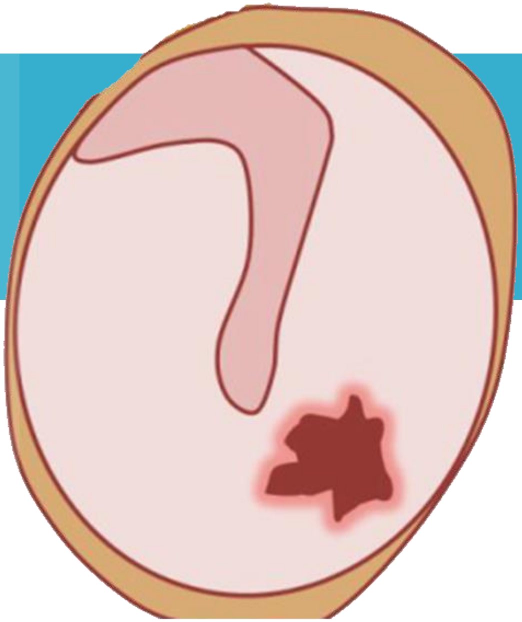
Wideband Tympanometry

3 Seeing though perforations



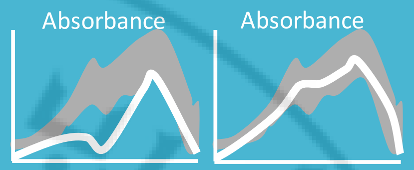


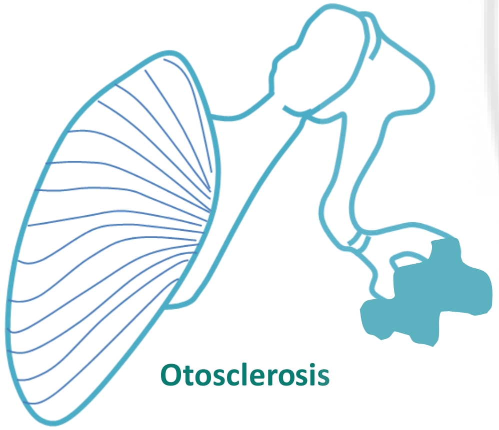




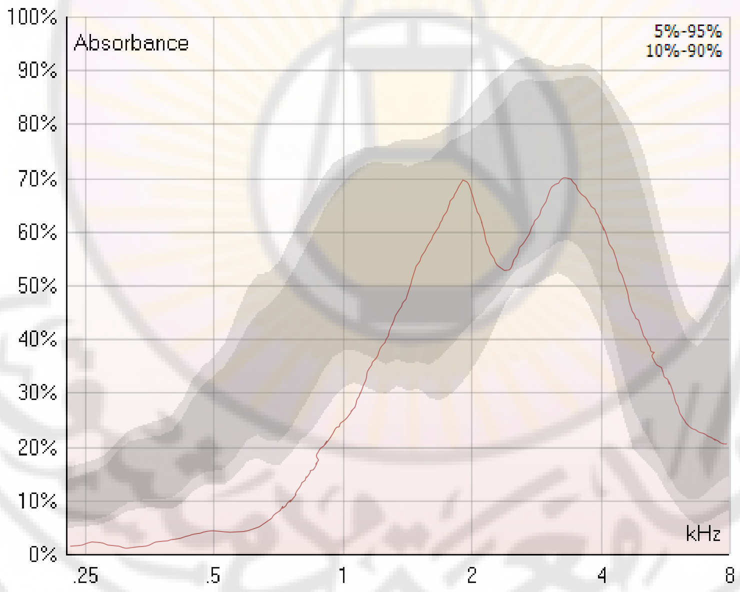
Wideband Tympanometry

4 Pre and post operative monitoring

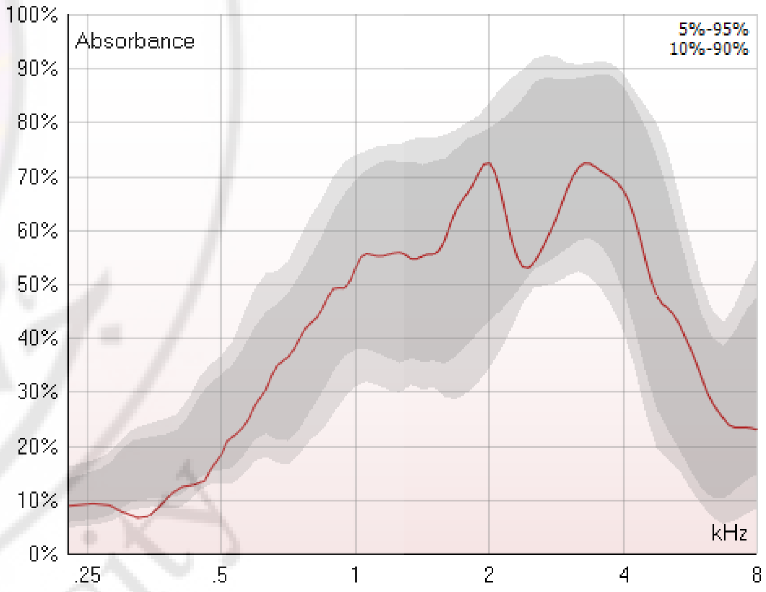




Pre-operative

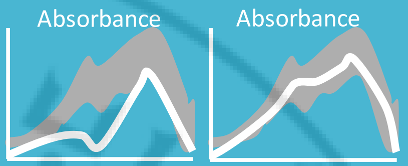


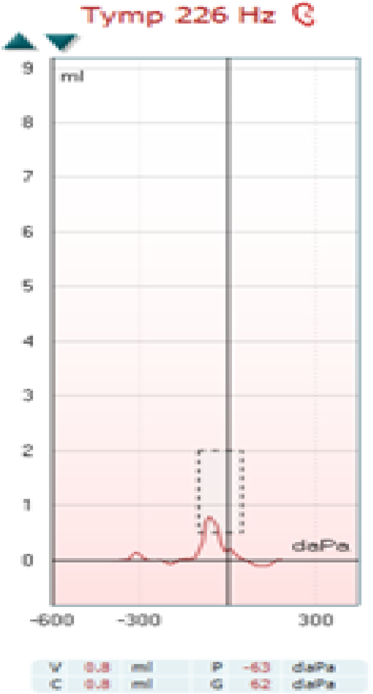
Post-operative

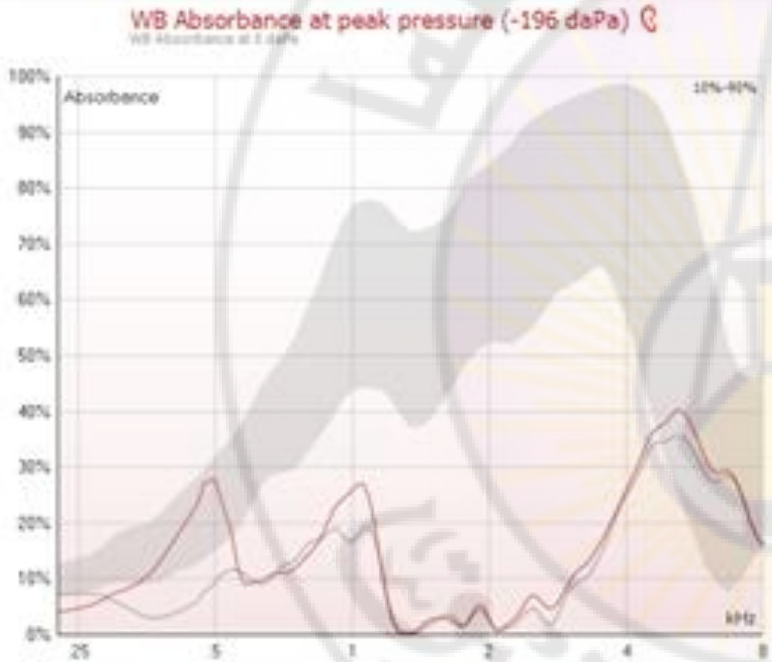


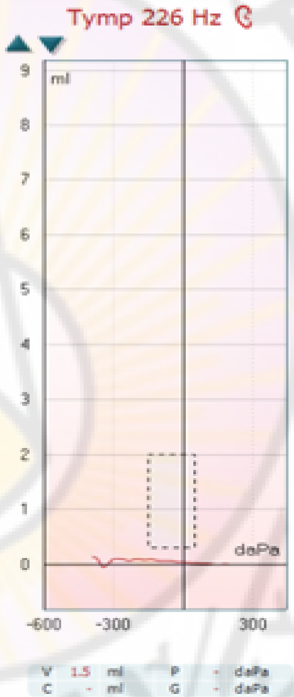
Wideband Tympanometry

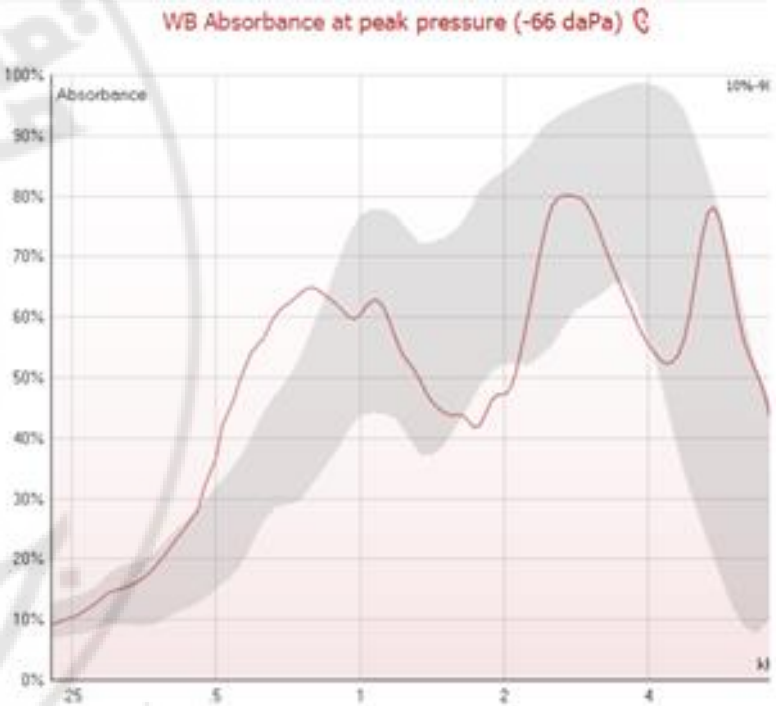
4 Pre and post operative monitoring

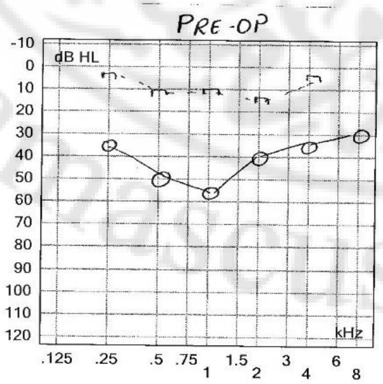


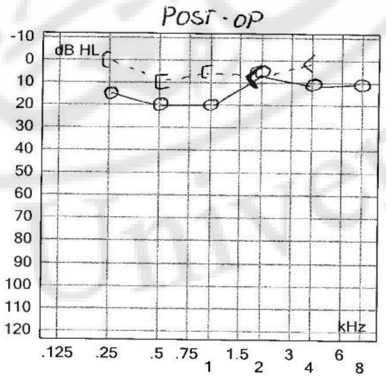


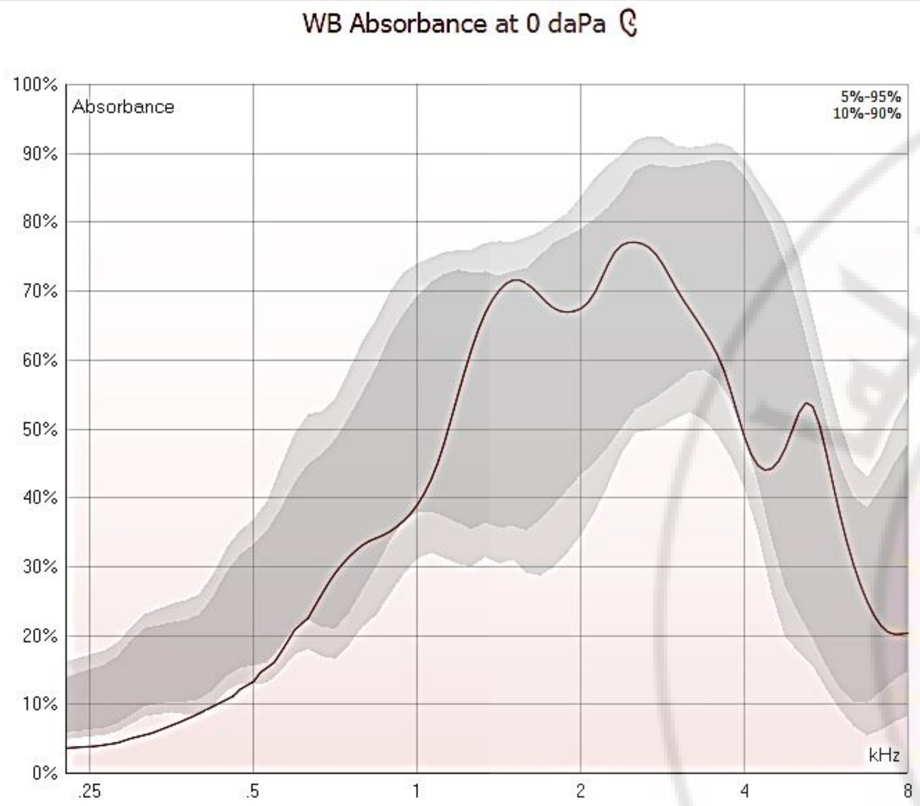


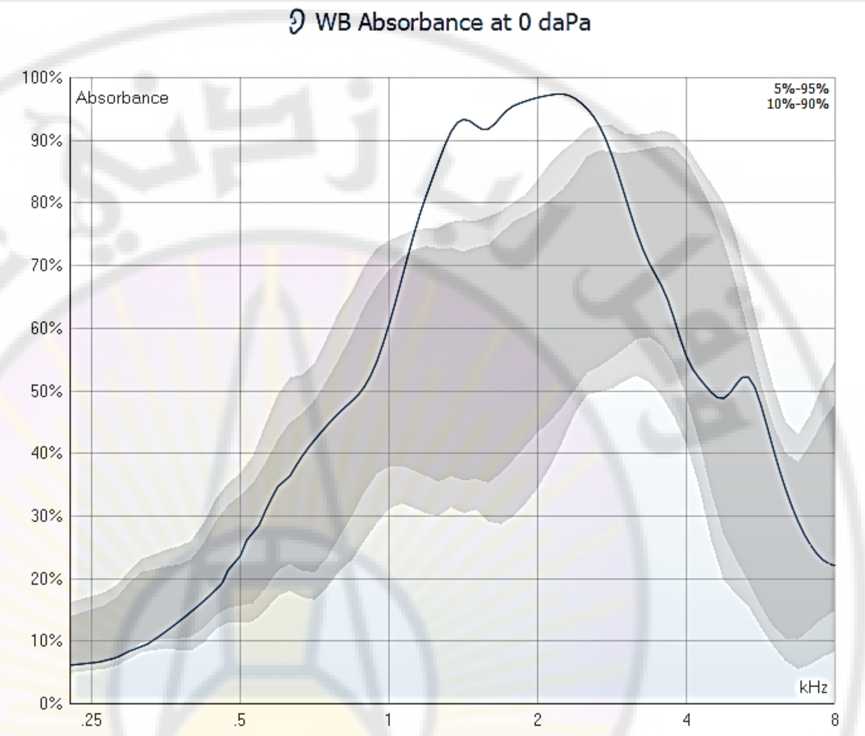


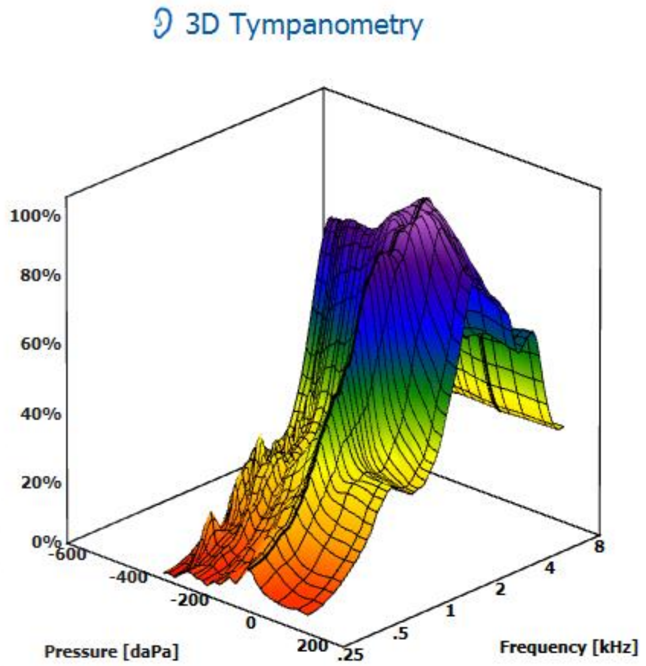




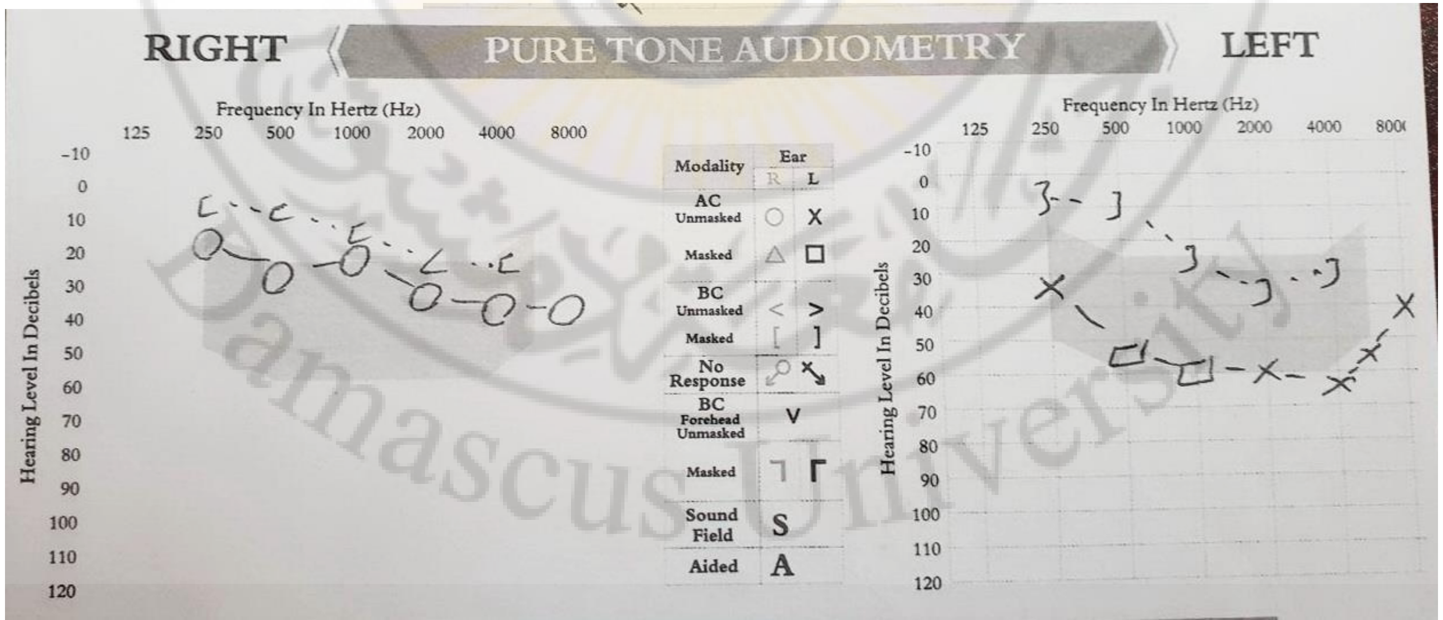








خانم ۳۲ ساله
گوش راست یک هفته
عمل شده
گوش چپ در نوبت عمل



Limitations of 226 Hz tympanometry

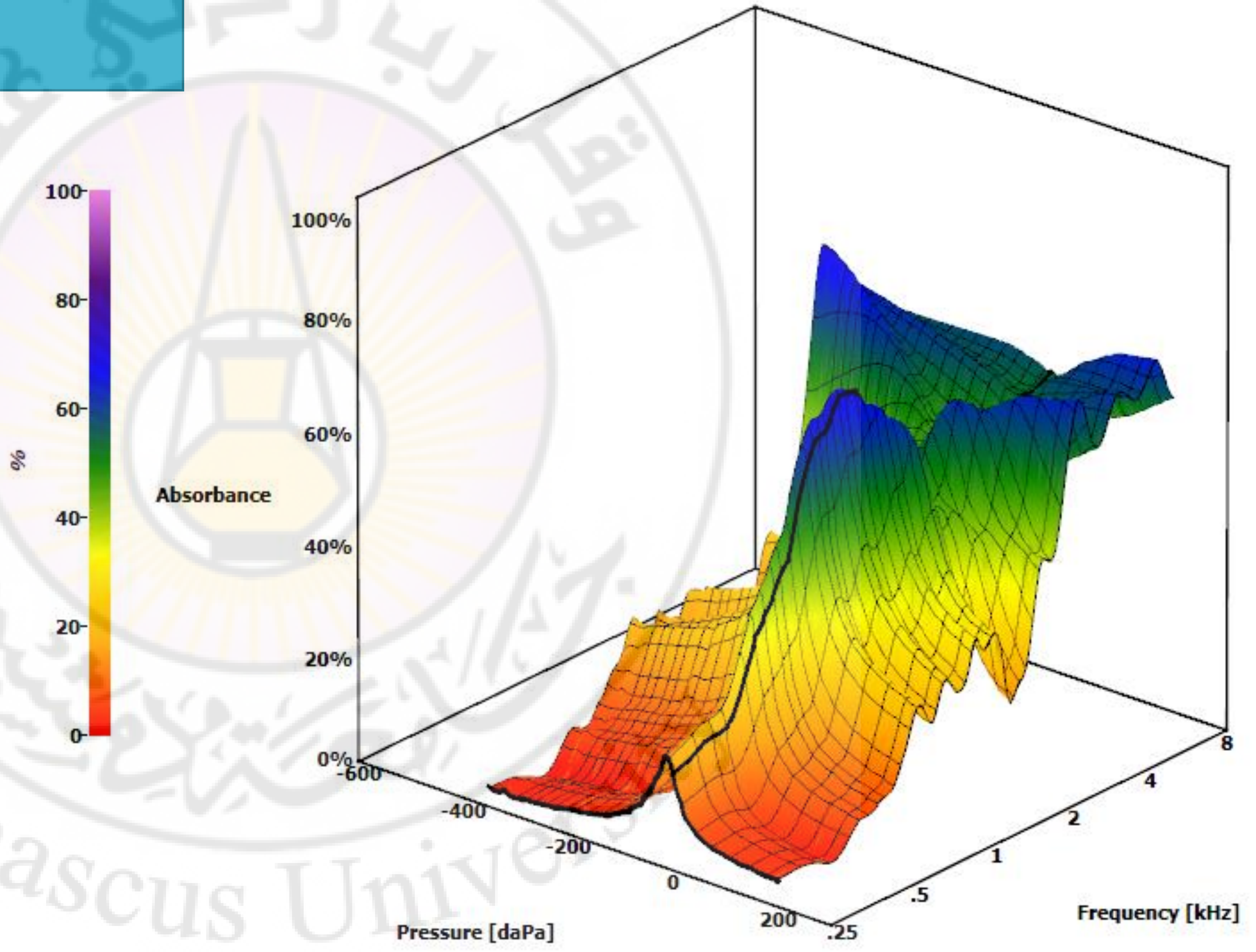
- Pattern in different pathologies
- Effects of more lateral pathologies and coexistent pathologies
- Overlapping the values
- High sensitivity and low specificity

Wideband Tympanometry

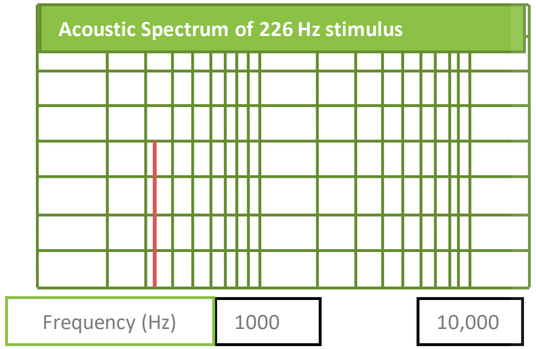
A new dimension in middle ear diagnostics

- Wideband (WB) reflectance and WB absorbance are names for an emerging type of acoustic ear-canal measurement that provides new dimensions for middle-ear assessment across a wide range of frequencies.

- Reflectance measurements are performed over a frequency range from 0.22 kHz up to approximately 8 kHz using a WB stimulus such as a click.

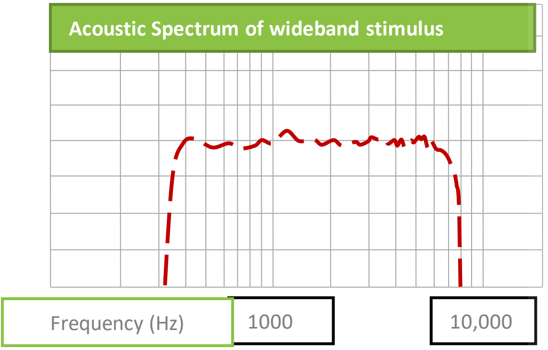


Wideband Tympanometry



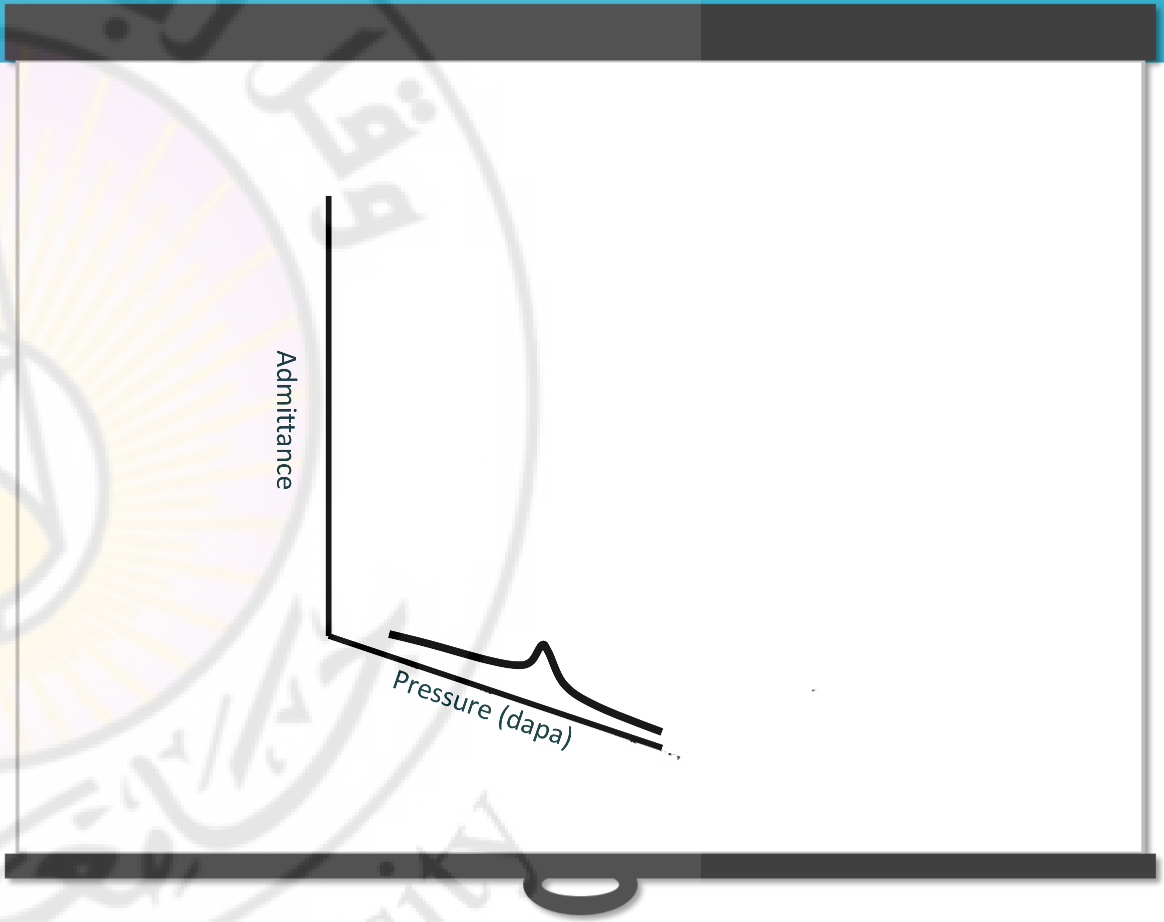
Traditional Tympanometry

- Looks at a single probe tone frequency
- At 226 Hz the middle ear is stiffness dominated
- Detect problems with the TM and ear cavity (parts of the ear which affect the stiffness)

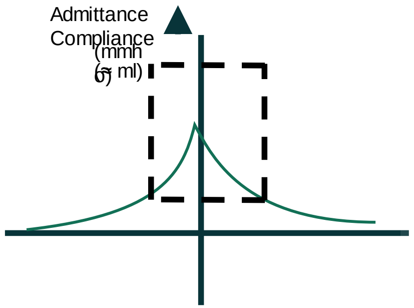


Wideband Tympanometry

- Uses a Wideband click Stimulus
- Measures the effects of middle ear pathologies at multiple frequencies
- Detects problems with a high degree of accuracy



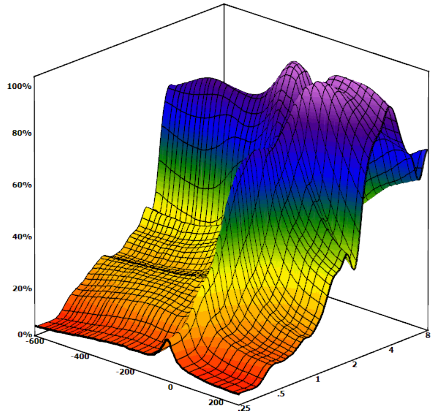
Wideband Tympanometry



Traditional Tympanometry

Measured in admittance / Compliance
Cannot test above ≈ 1500 Hz due to effect of standing waves

Admittance (Y) = Conductance (G) + total Susceptance (jBa)



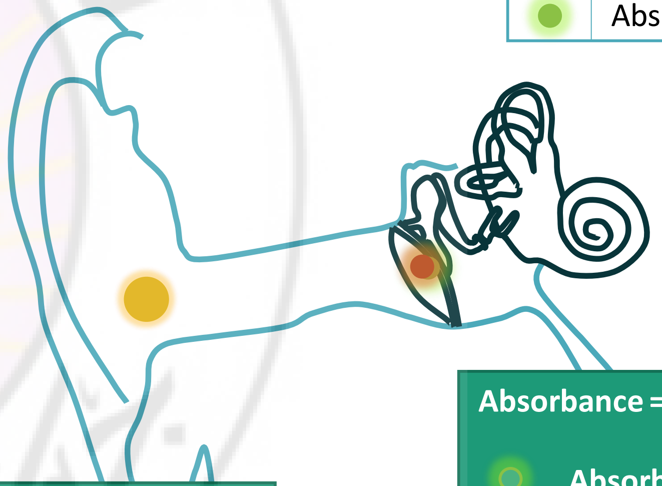
Wideband Tympanometry

Measured in Absorbance (and admittance)
Can test all the way to 8000 Hz without being contaminated by standing waves
Provides the same information as traditional tympanometry (admittance) and new information (absorbance)

Absorbance = Absorbed Power / Incident Power

Absorbance

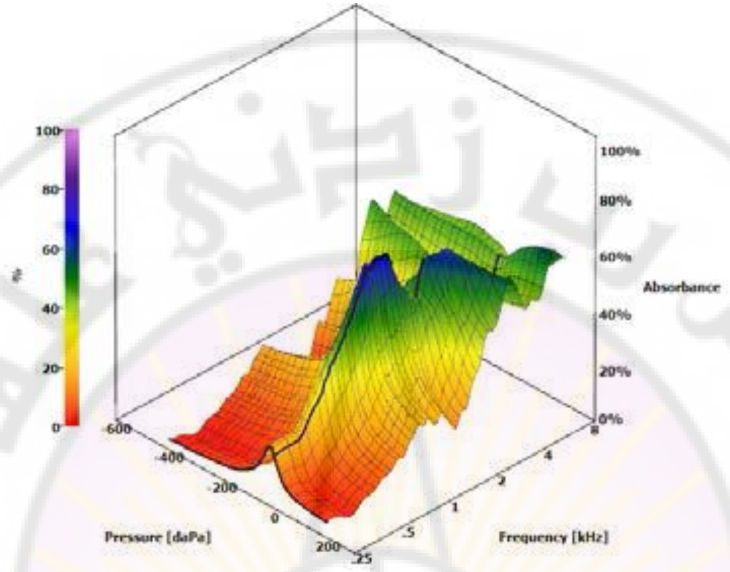
- Incident sound
- Reflected sound
- Absorbed sound



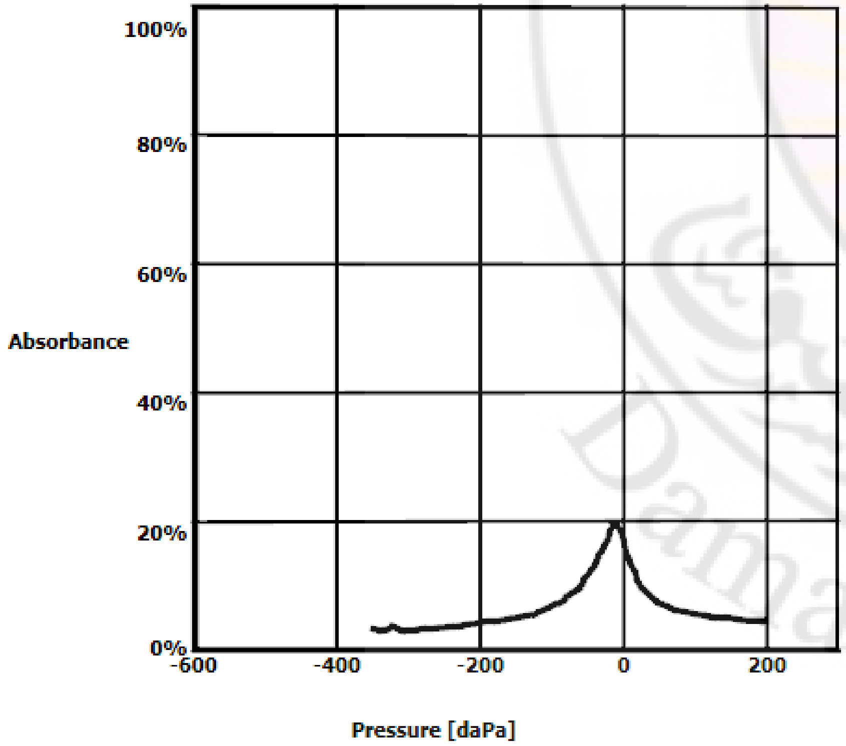
Absorbance = $\frac{\text{Absorbed sound}}{\text{Incident sound}}$

OR

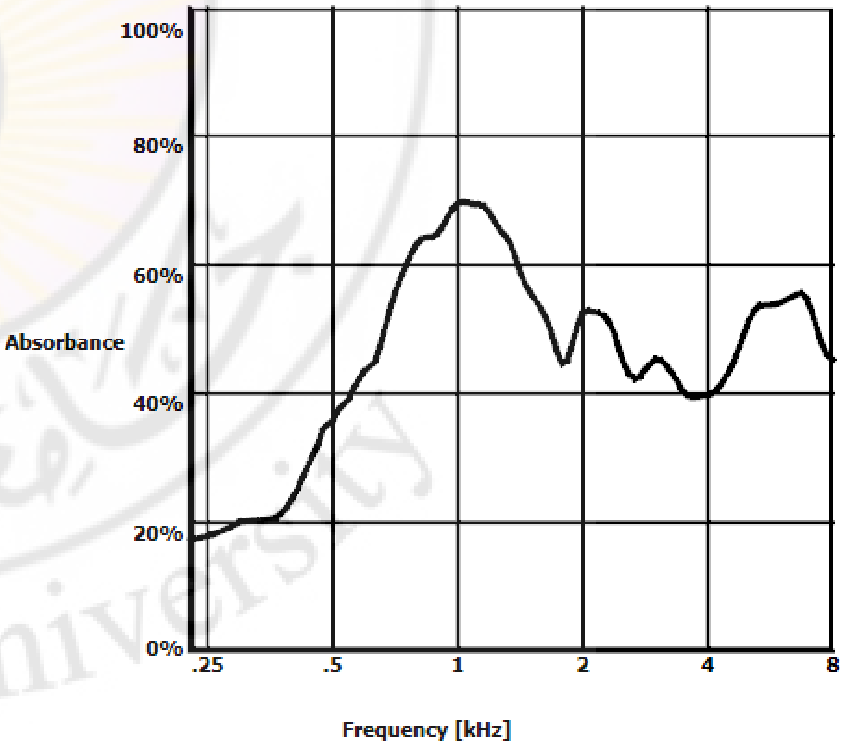
1 – Energy Reflectance



Tympanograms



Absorbance



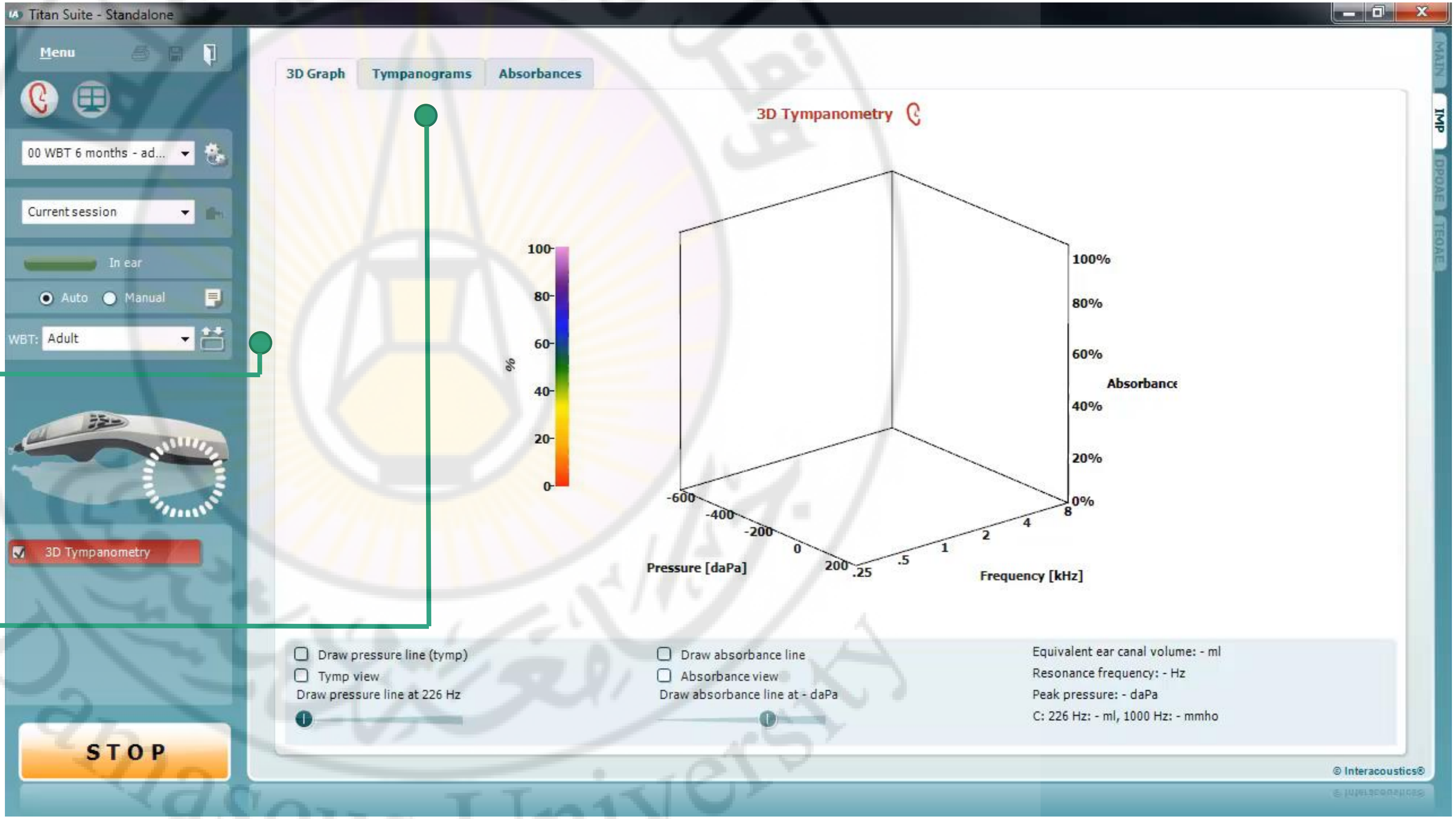
Wideband Tympanometry

A measurement in action

Time

Two calibration sets Adults and Children

Key information is extracted into tabs



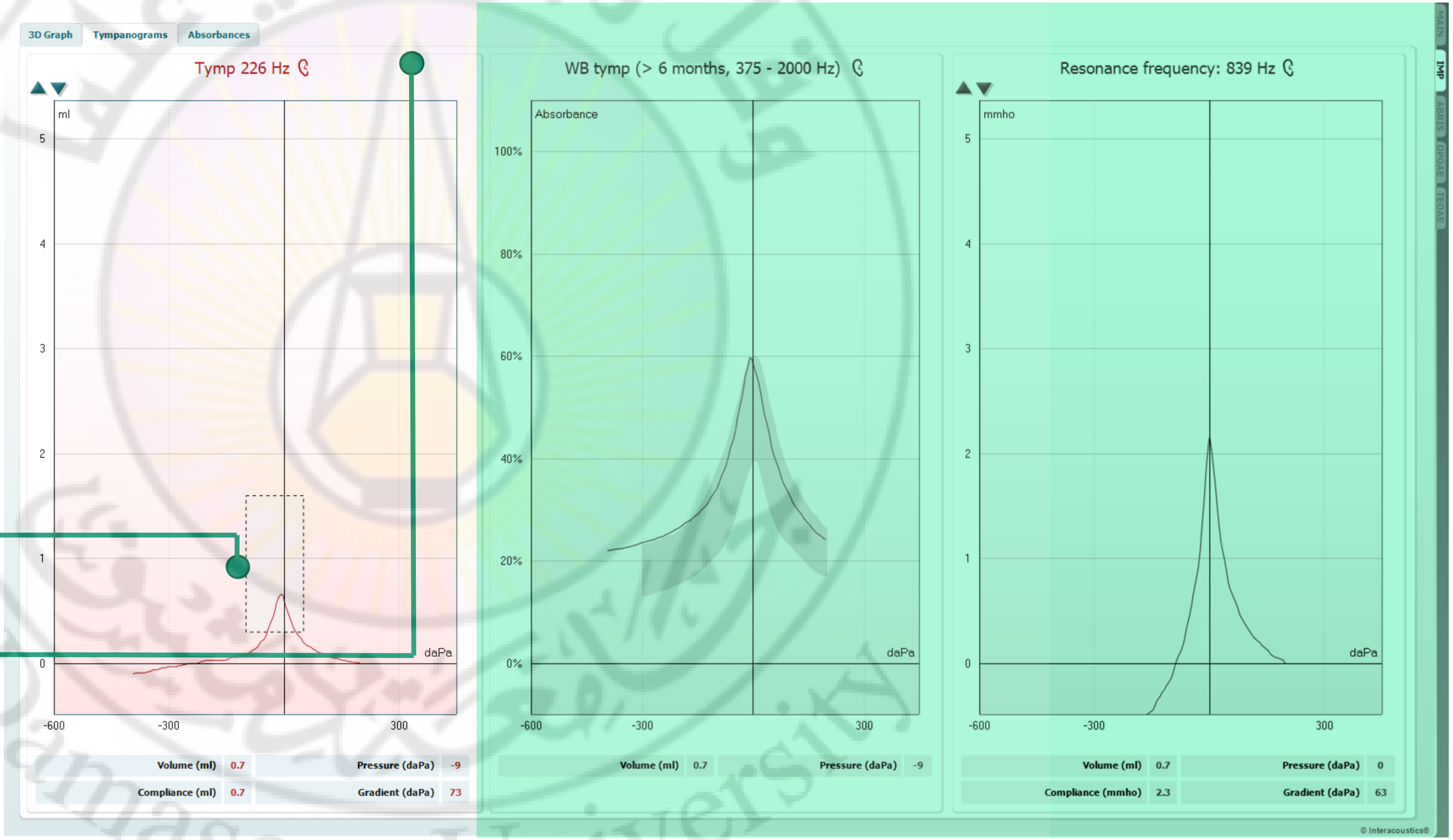
Wideband Tympanometry

Extracted Data: Tympanograms

Traditional tympanograms

Option to break down the Y component and see the susceptance (B) and conductance (G) components

Admittance tympanograms available for probe tone frequencies
226 Hz 678 Hz 800 Hz 1000 Hz



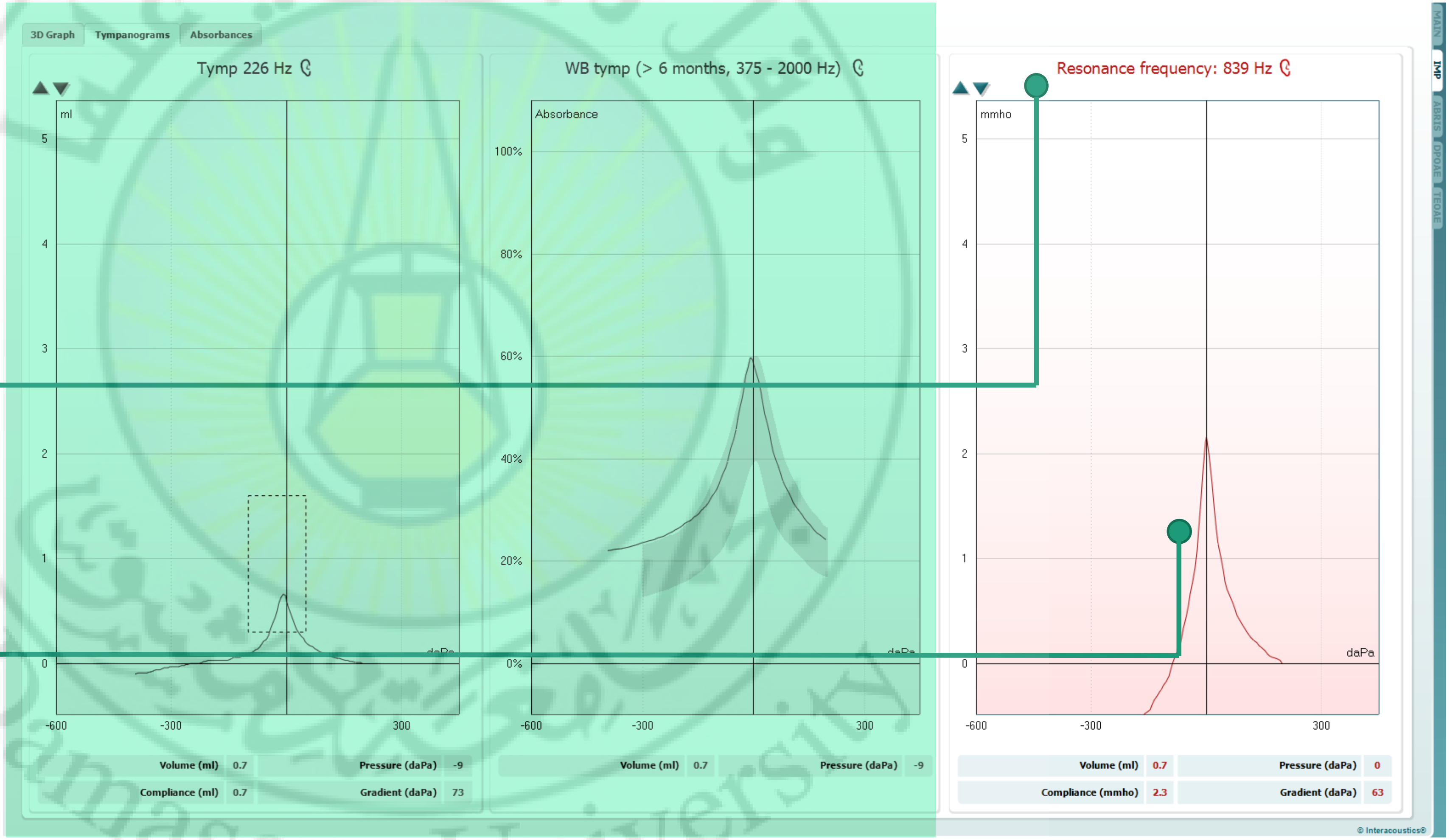
Wideband Tympanometry

Extracted Data: Tympanograms

Resonance Frequency

The frequency which allows the most energy to pass to the middle ear

Useful for looking at pathologies affecting mass

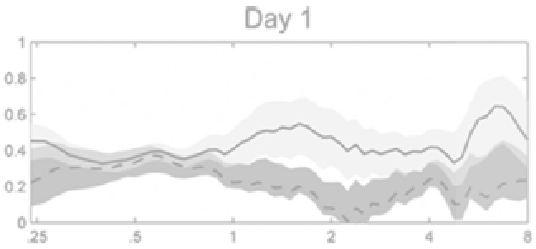


Wideband Tympanometry

Extracted Data: Tympanograms

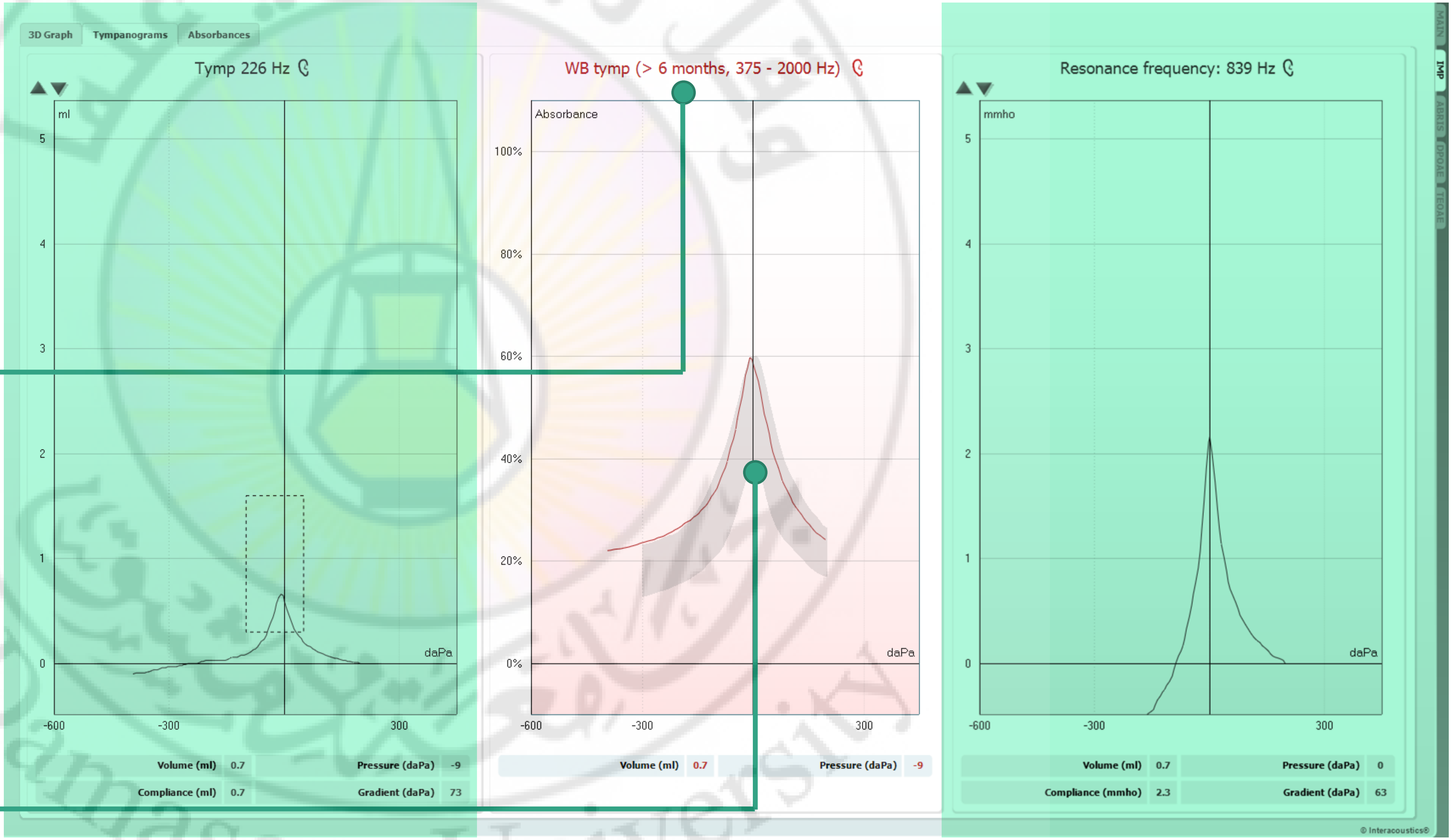
Wideband averaged tympanogram

Adults 375 and 2000 Hz
Infants 800 and 2000 Hz



Better detector of middle ear effusions

More noise robust



Extracted Data: Absorbance

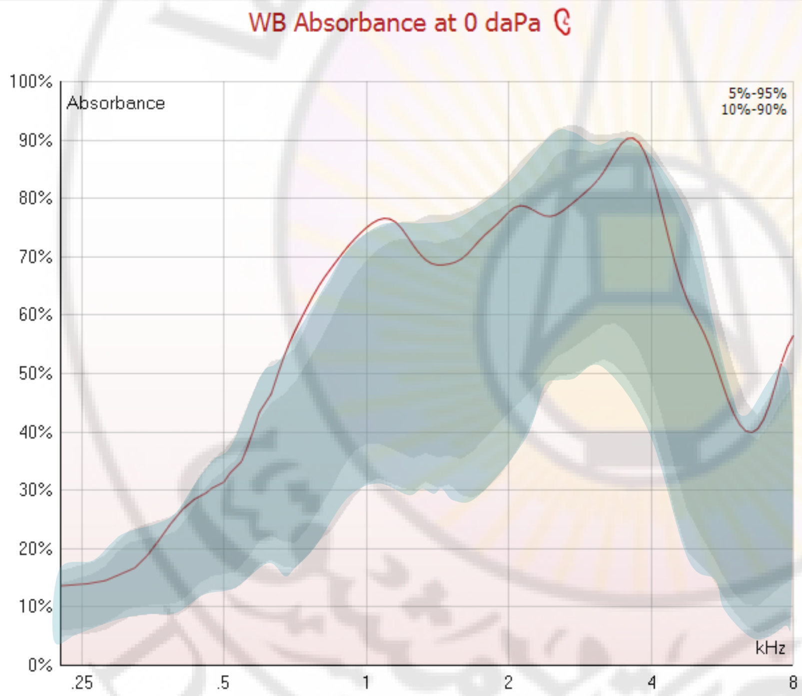
Absorbance Graph

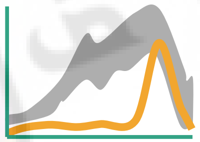
X axis shows frequency

Y axis shows absorbance

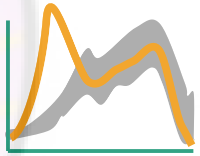
Grey area is normative data

Red line is measured absorbance

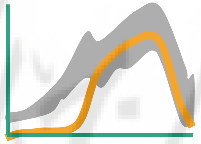




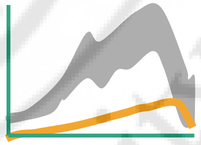
Middle Ear Effusion



Ossicular Continuity



Otoscleriosis



Middle Ear Effusion

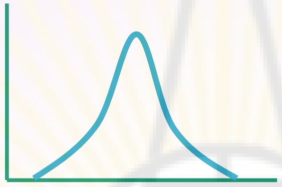
Wideband Tympanometry

Benefits for Children

1 Multiple Tympanograms
Save time with fewer measurements

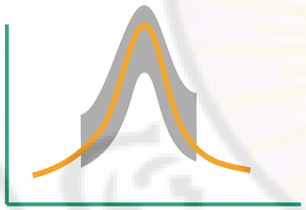
226 Hz Tymp

1000 Hz Tymp



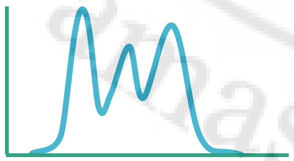
2 Improved Sensitivity
Improved accuracy over standard tympanometry

WB Averaged Tymp

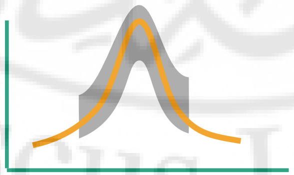


3 Stable and robust results
Clear results with noisy children

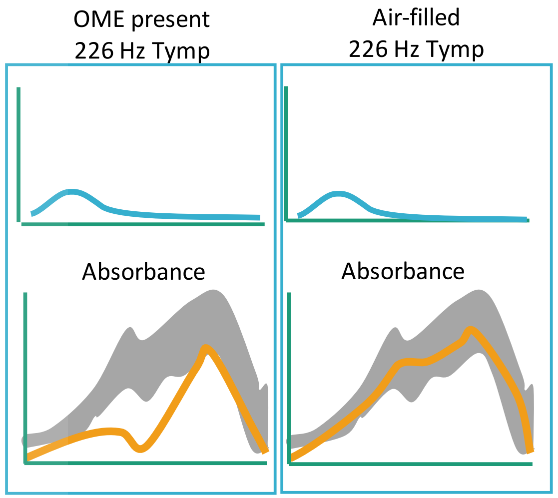
Noisy 1000 Hz Tymp



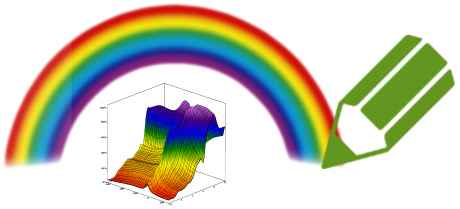
WB Averaged Tymp



4 Know your Type C Tympanogram
Know when OME is present in the middle ear



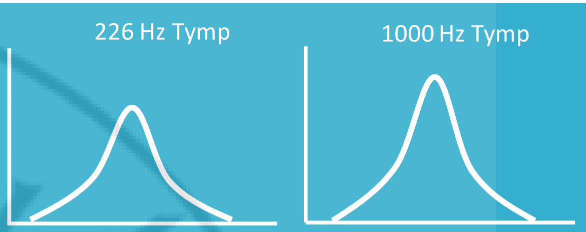
5 Drawing Rainbows
Child tolerates measurement

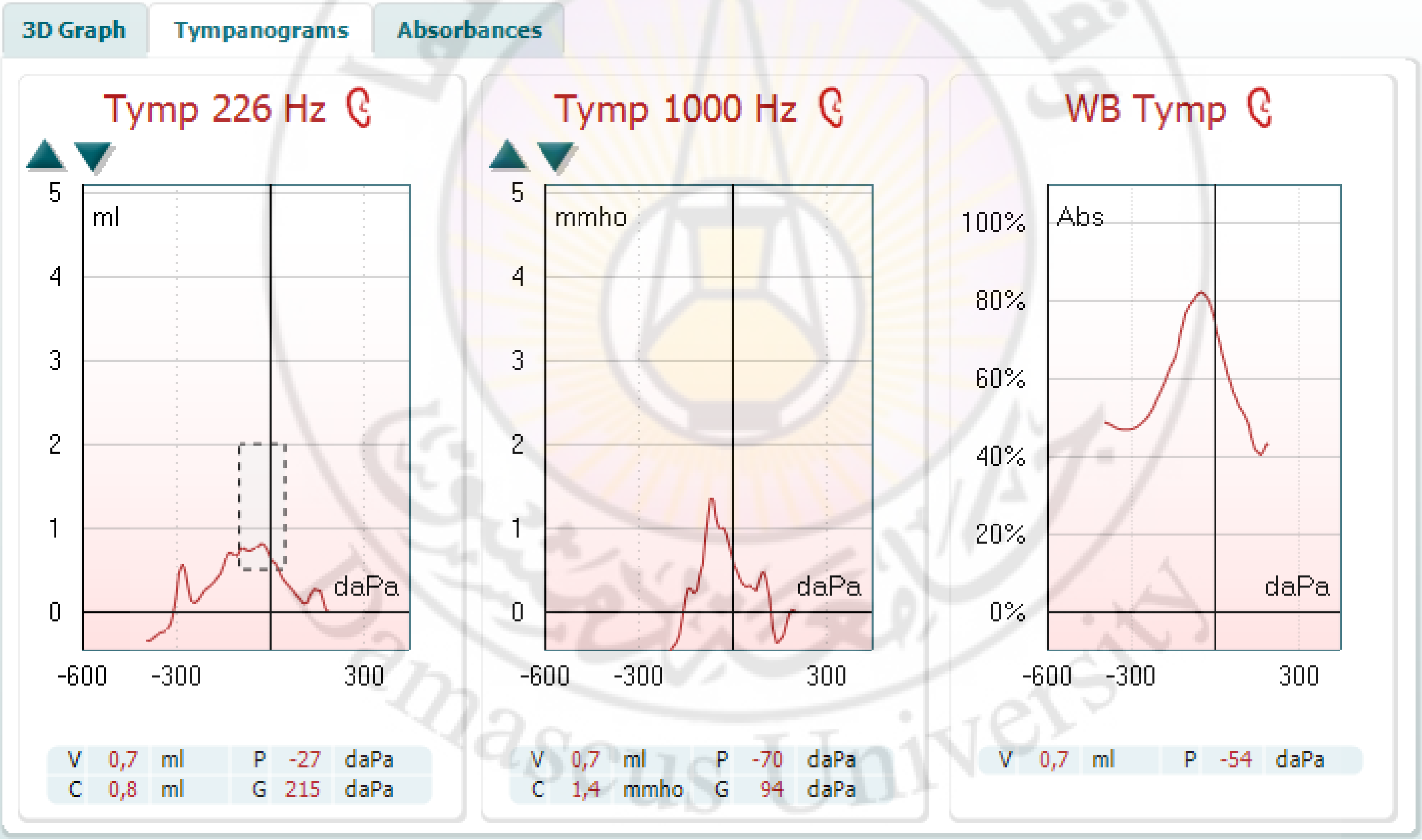


Wideband Tympanometry

1

Multiple Tympanograms
Save time with fewer measurements

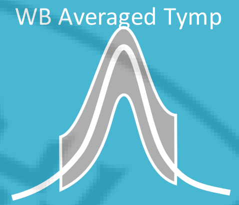


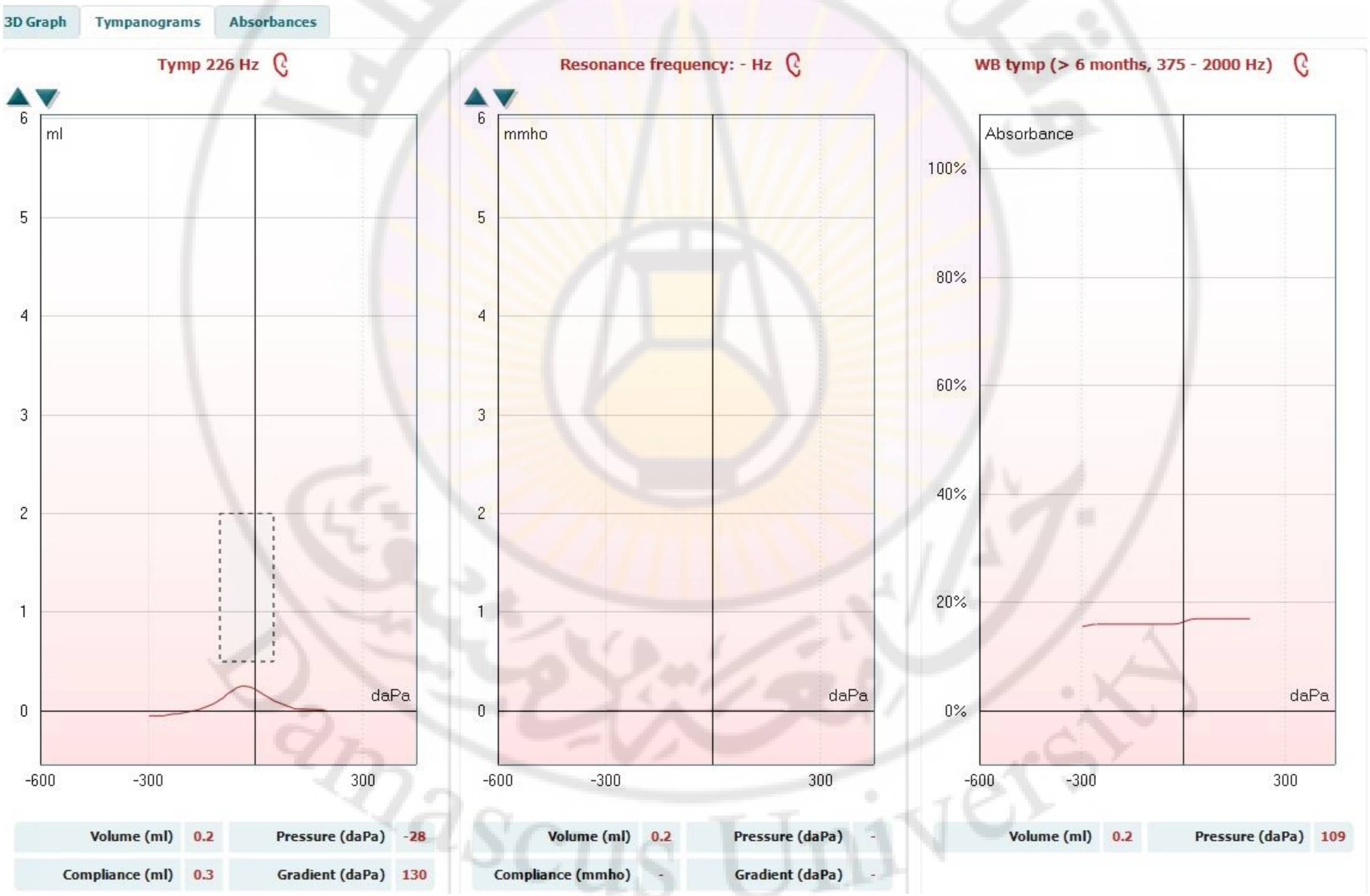


Wideband Tympanometry

2

Improved Sensitivity
Improved accuracy over standard tympanometry



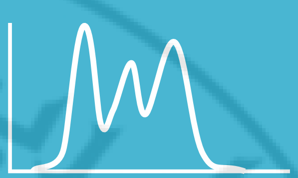


Wideband Tympanometry

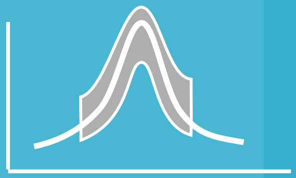
3

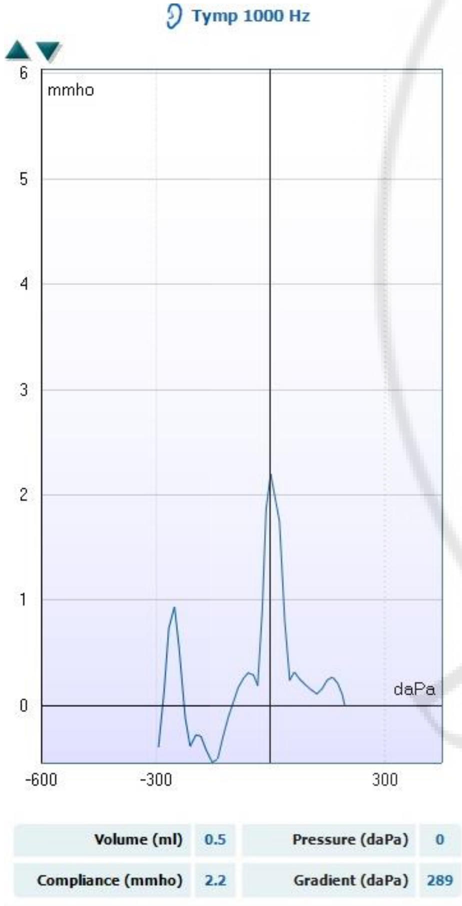
Stable and robust results
Clear results with noisy children

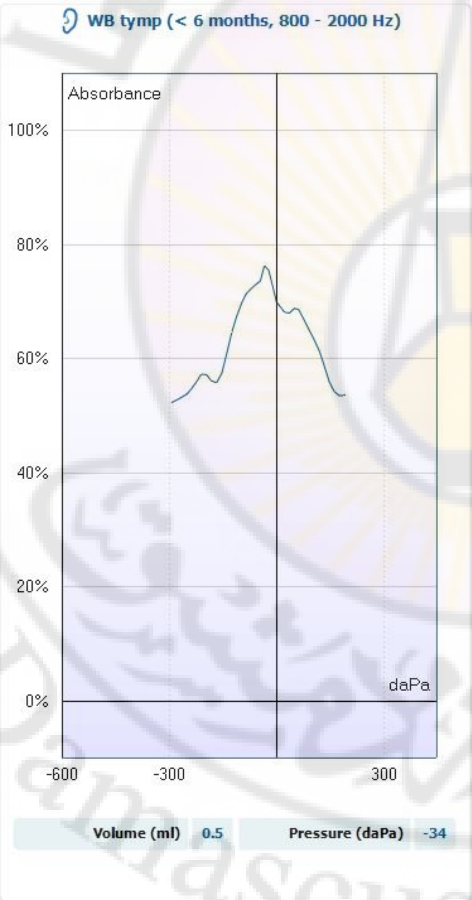
Noisy 1000 Hz Tymp

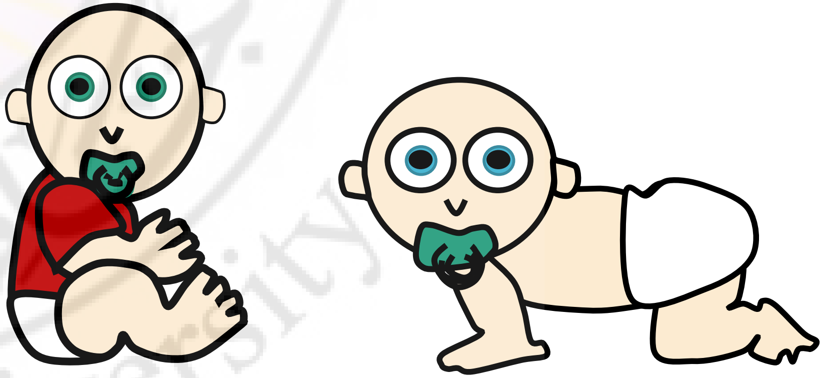


WB Averaged Tymp







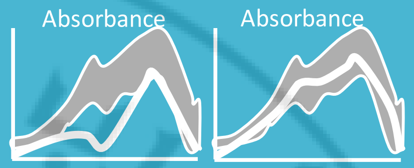


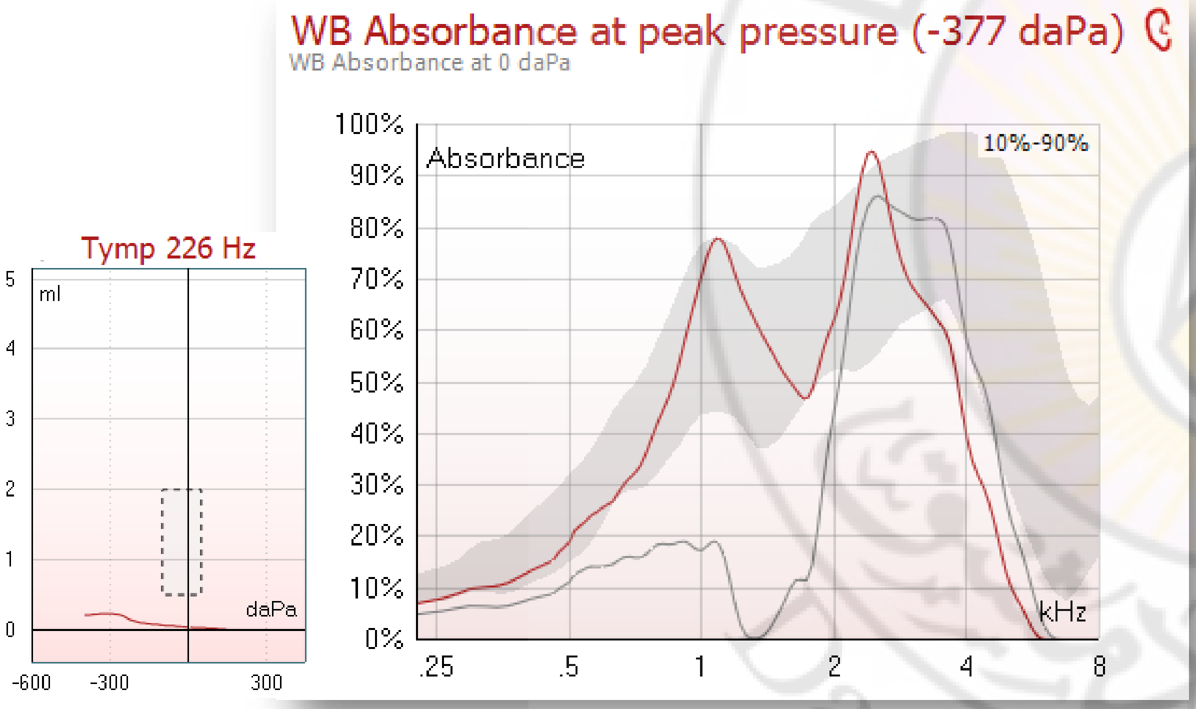
Wideband Tympanometry

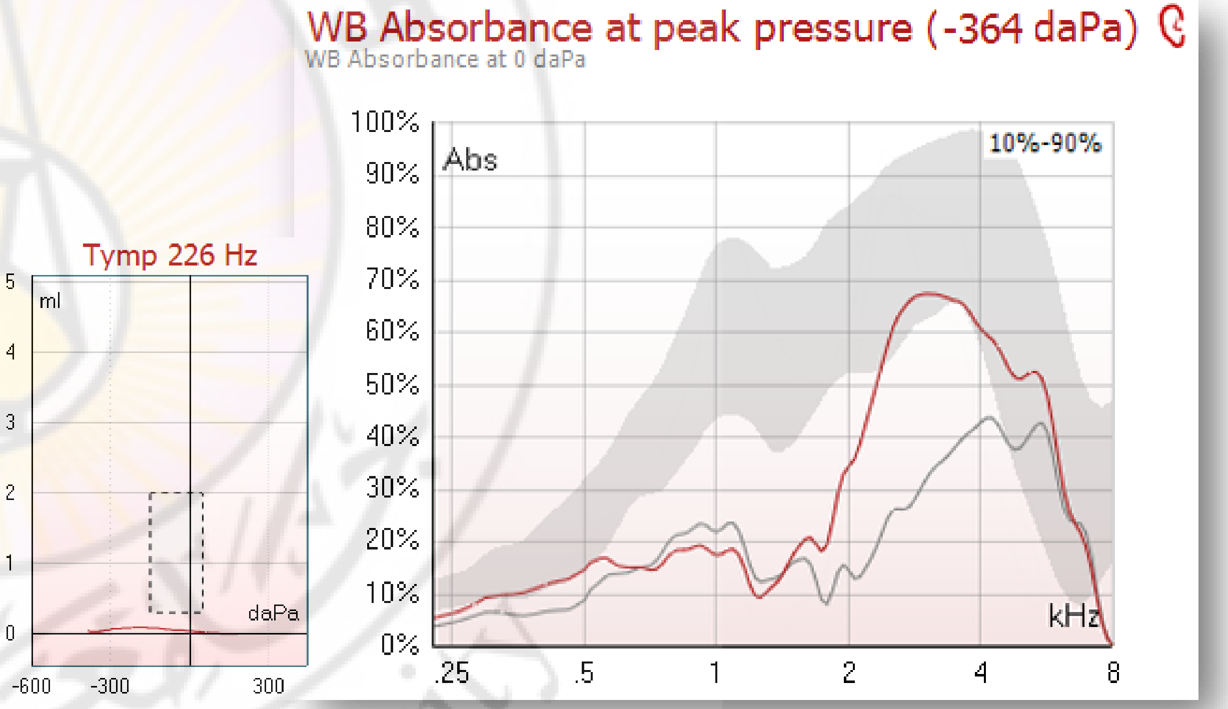
4

Know your Type C Tympanogram

Know when OME is present in the middle ear



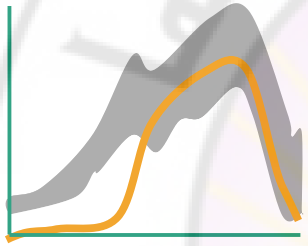




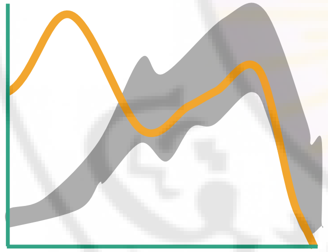
Wideband Tympanometry

Benefits for adults

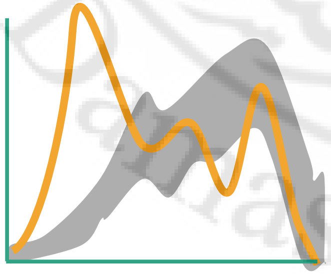
1 Detecting and monitoring Otosclerosis



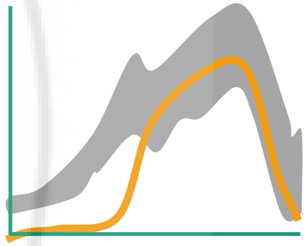
2 Seeing though perforations

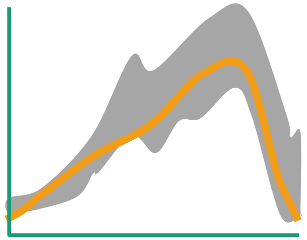


3 Detection of ossicular discontinuity

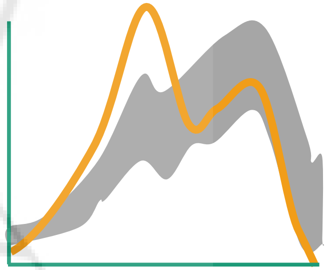


4 Pre and post operative monitoring using no pressure test



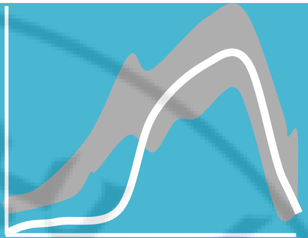


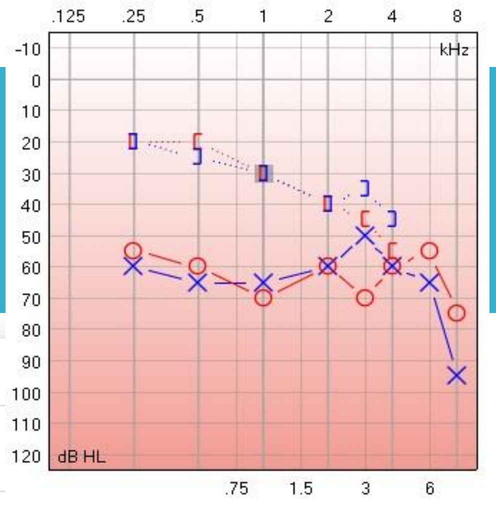
5 Detecting of SSCD

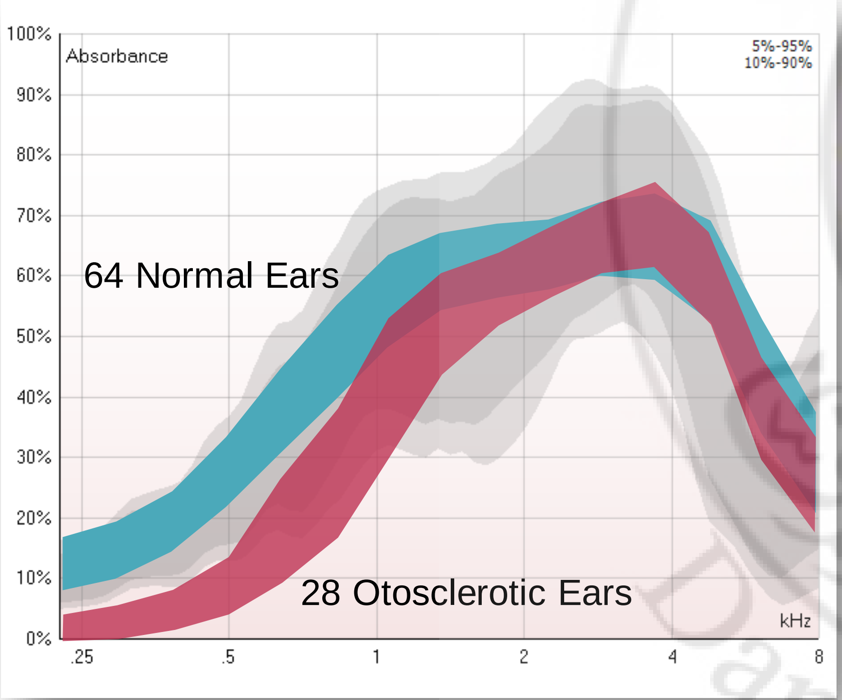


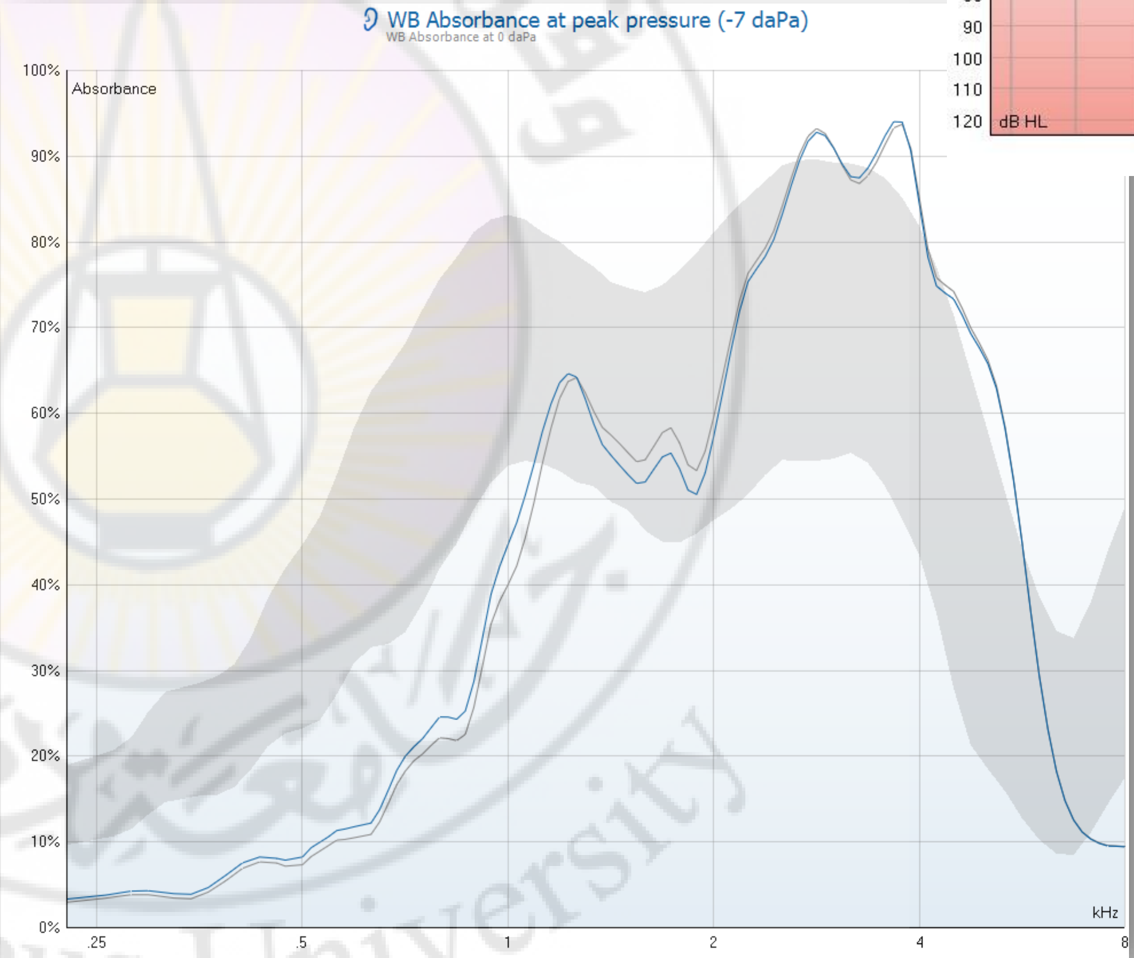
Wideband Tympanometry

1 Detecting and monitoring Otosclerosis





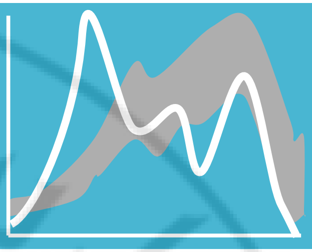


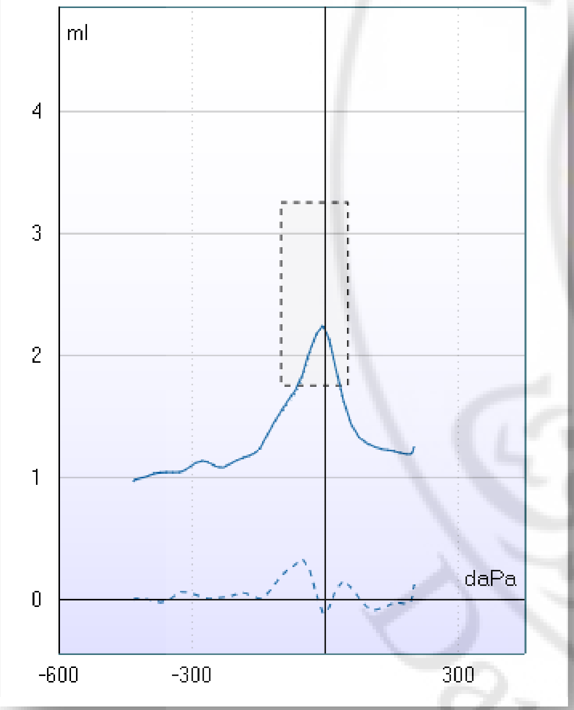


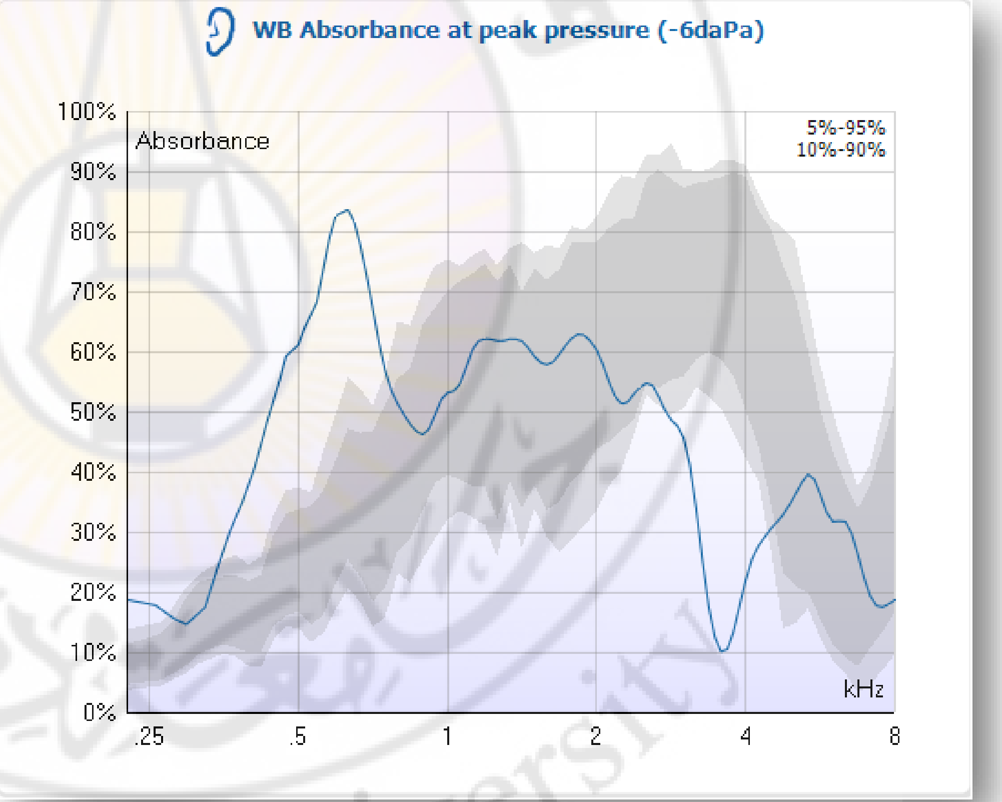
Wideband Tympanometry

2

Detection of ossicular discontinuity

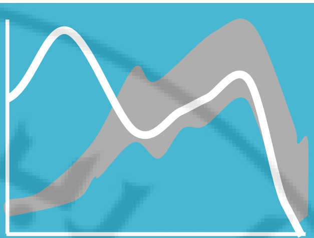


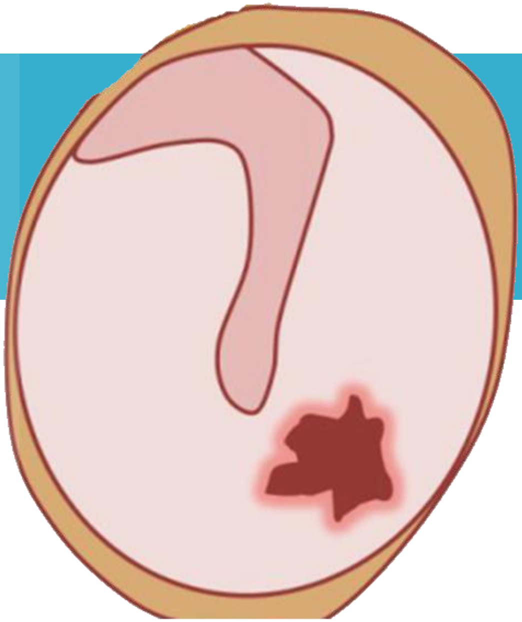


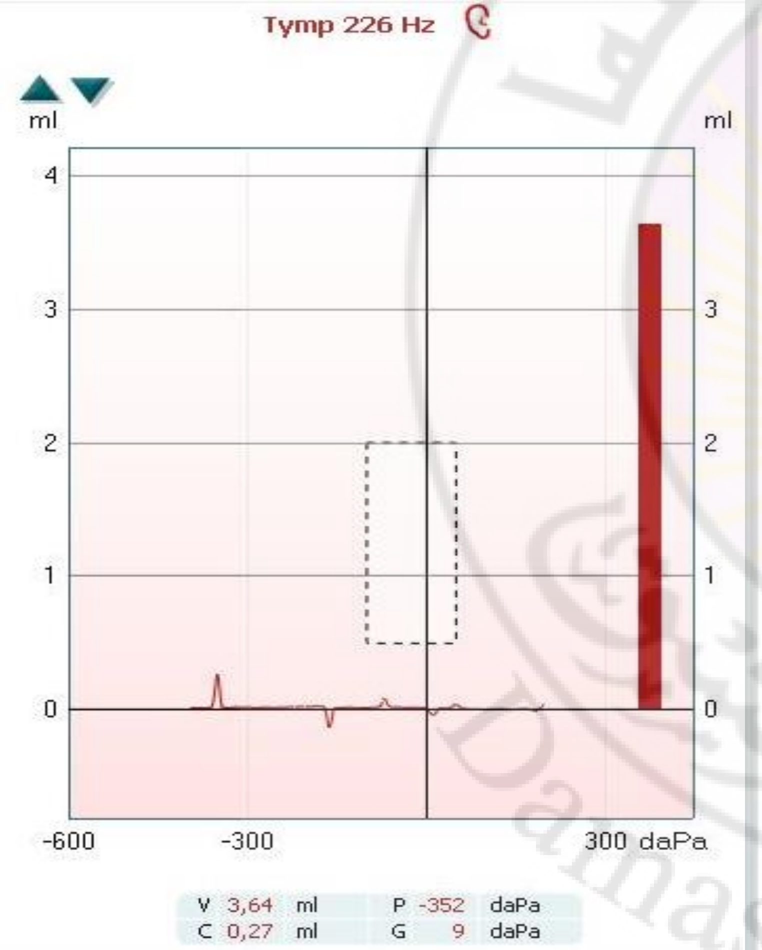


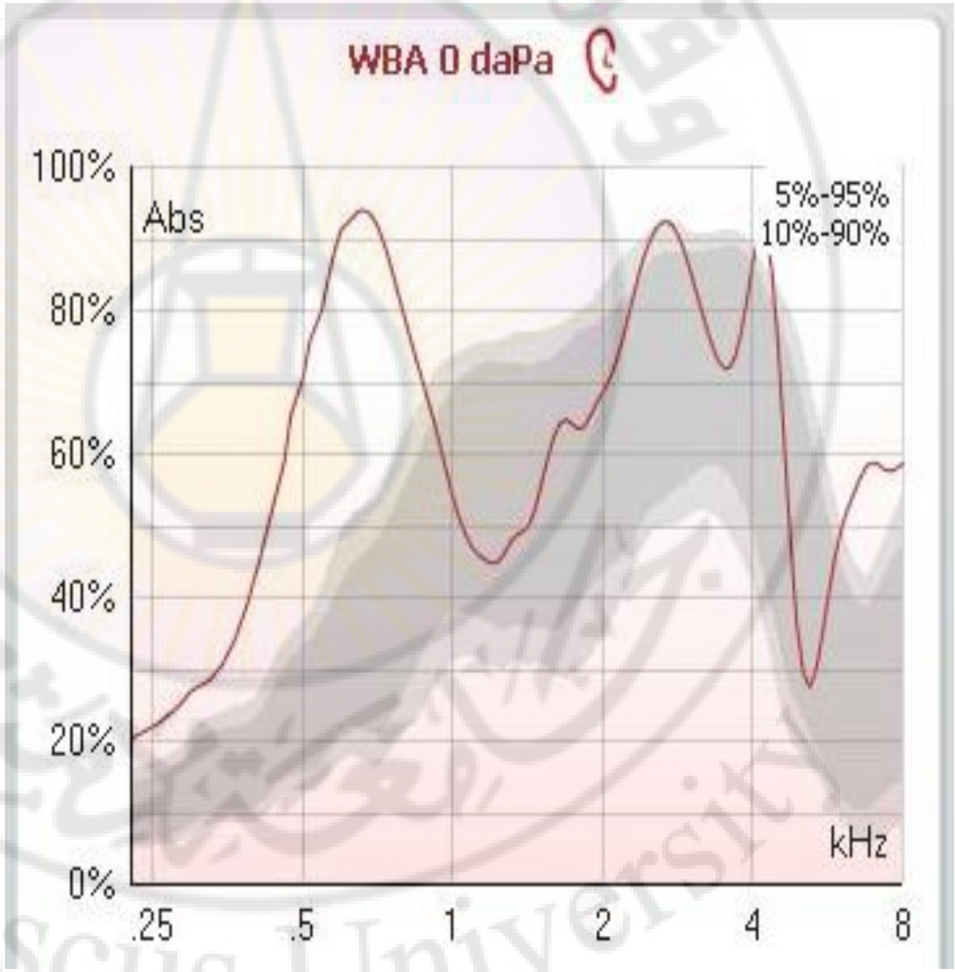
Wideband Tympanometry

3 Seeing though perforations



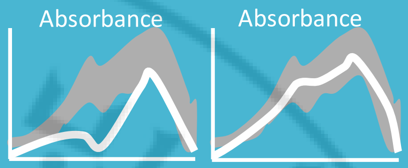


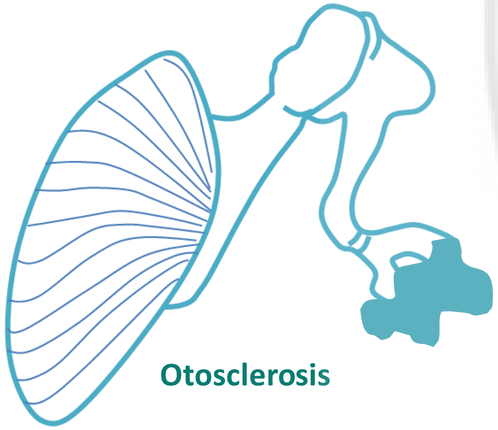




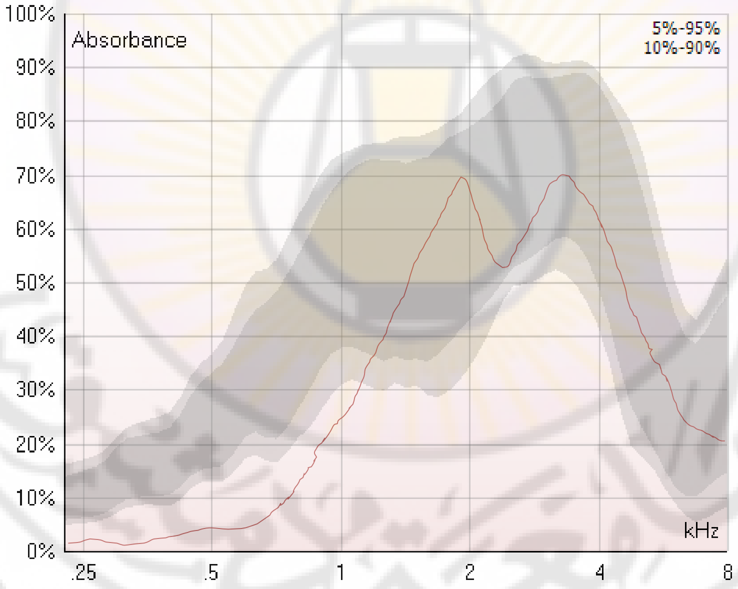
Wideband Tympanometry

4 Pre and post operative monitoring

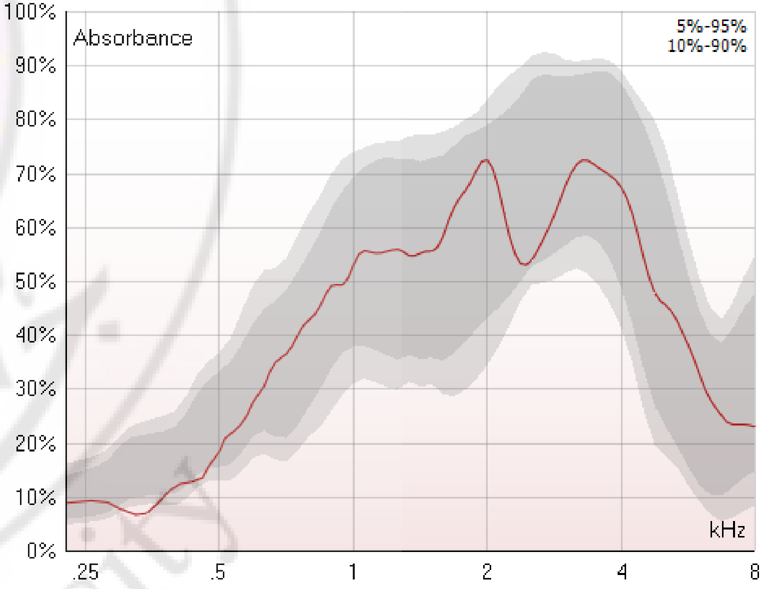




Pre-operative

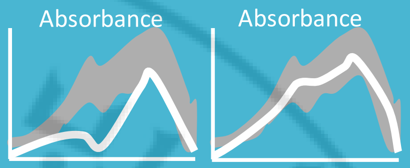


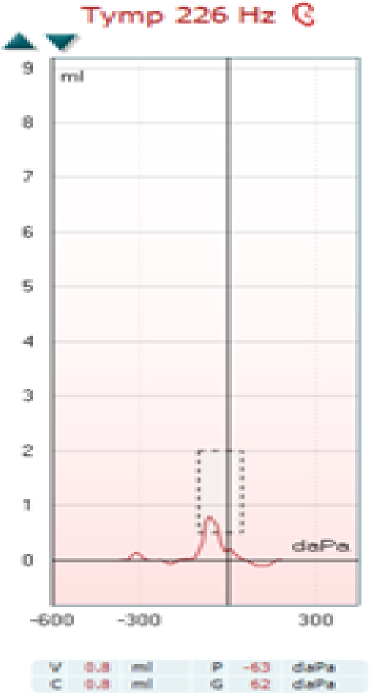
Post-operative

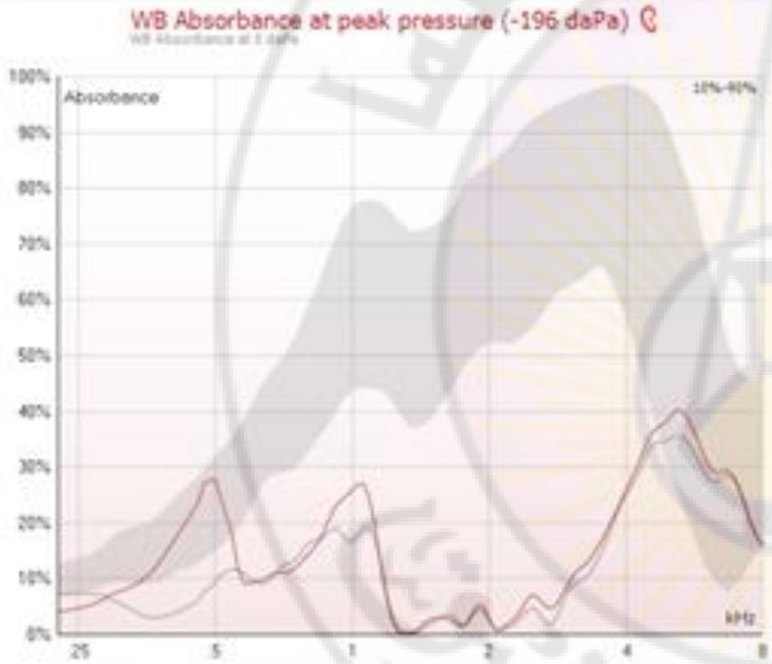


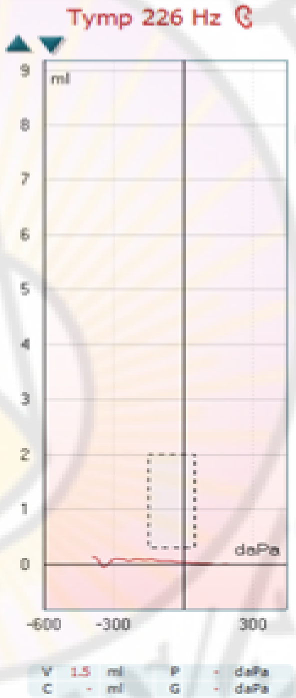
Wideband Tympanometry

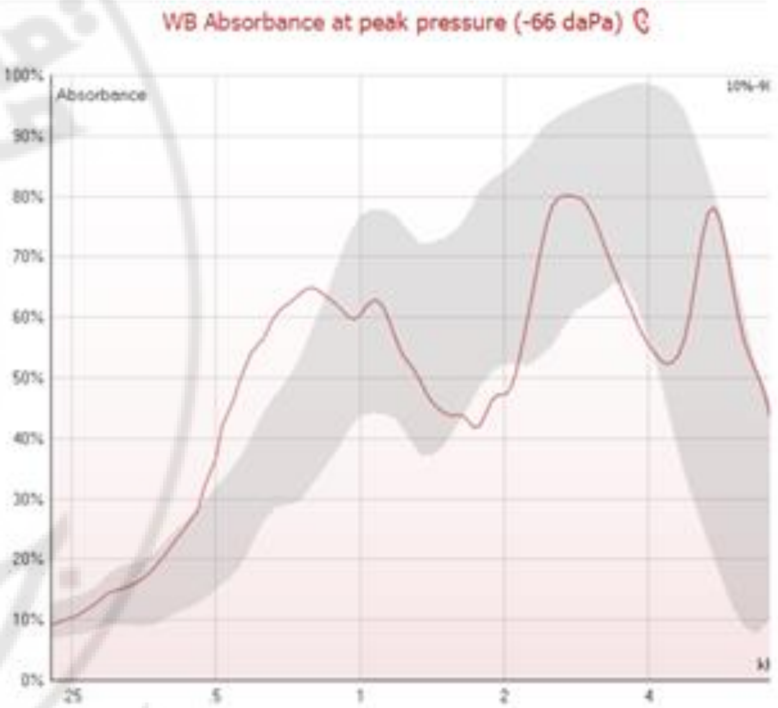
4 Pre and post operative monitoring

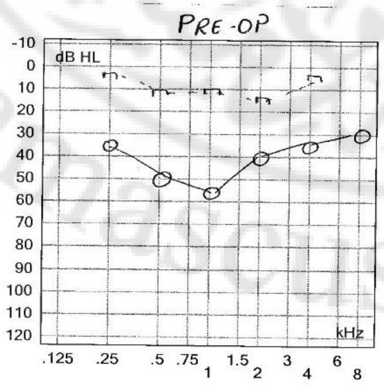


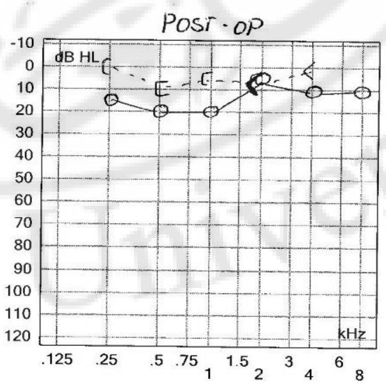


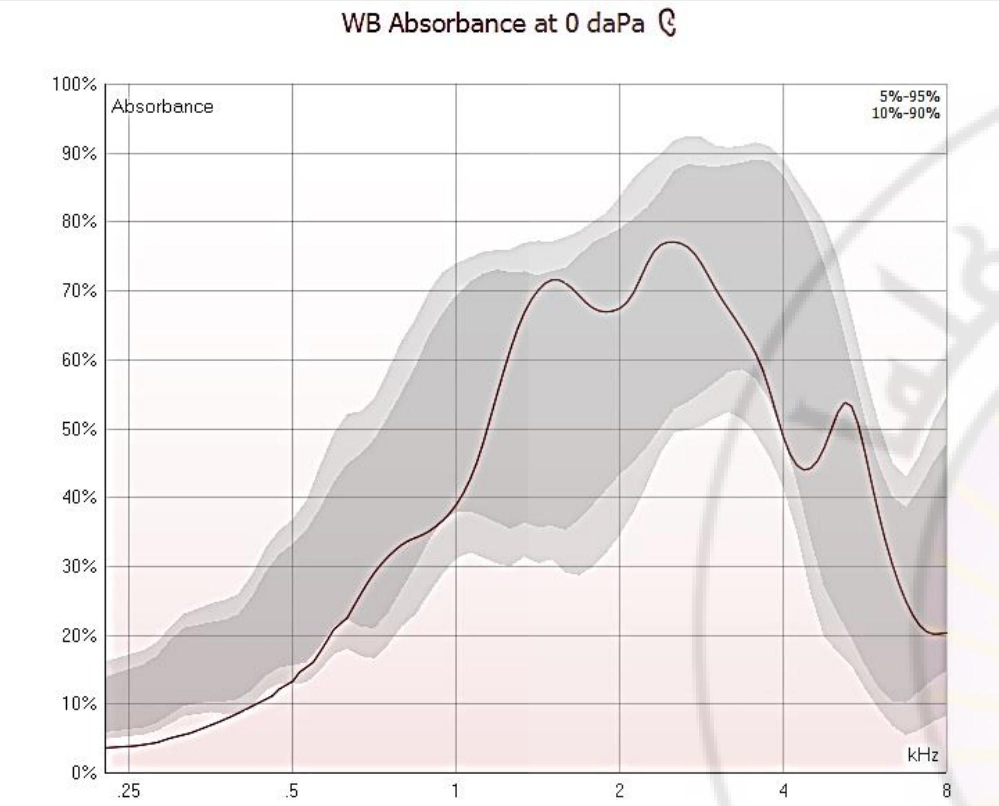


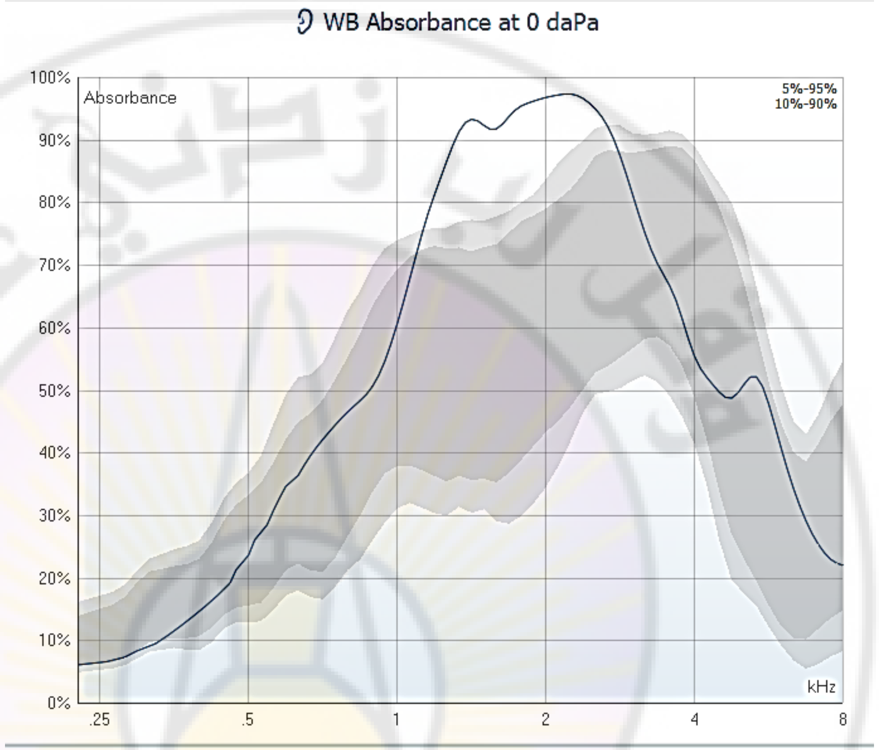


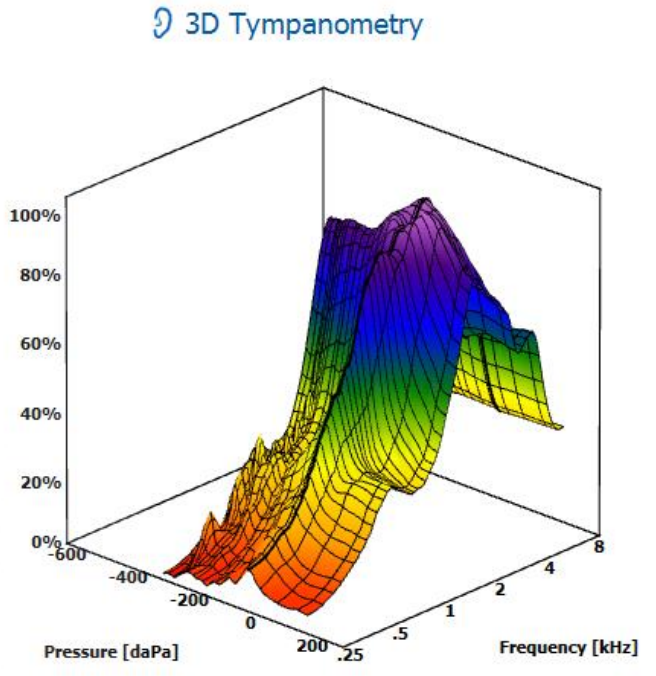




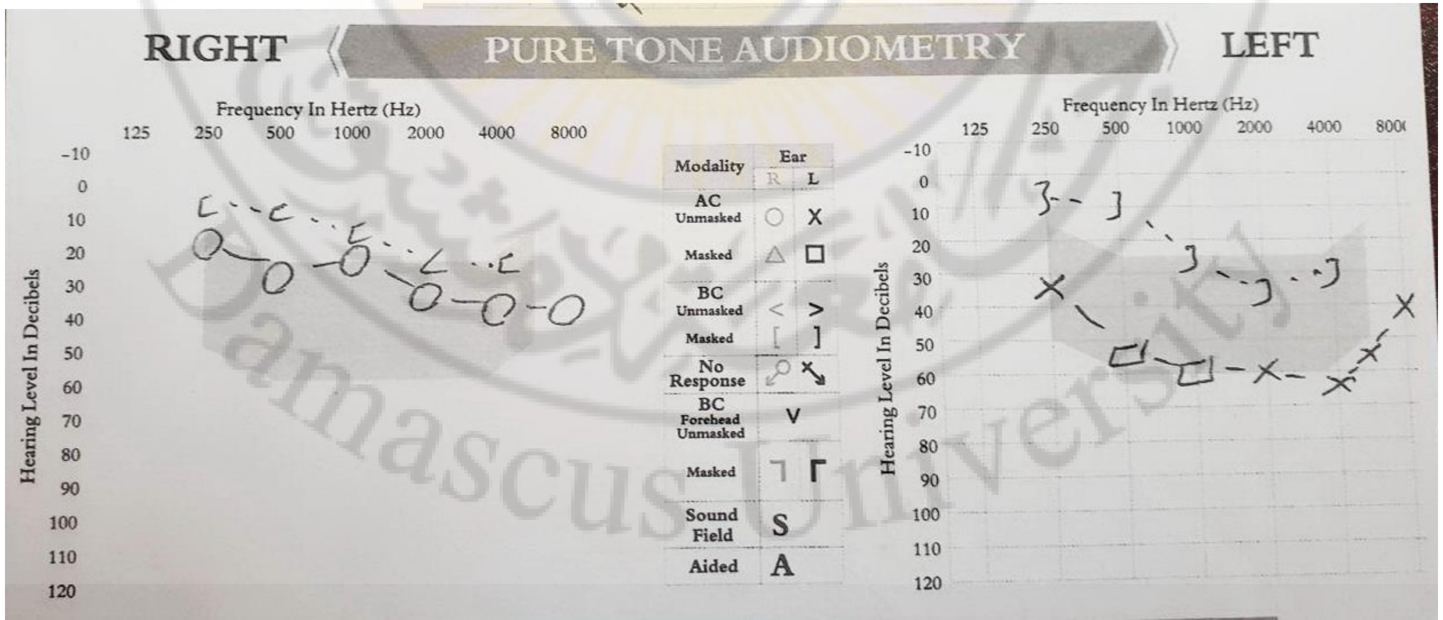




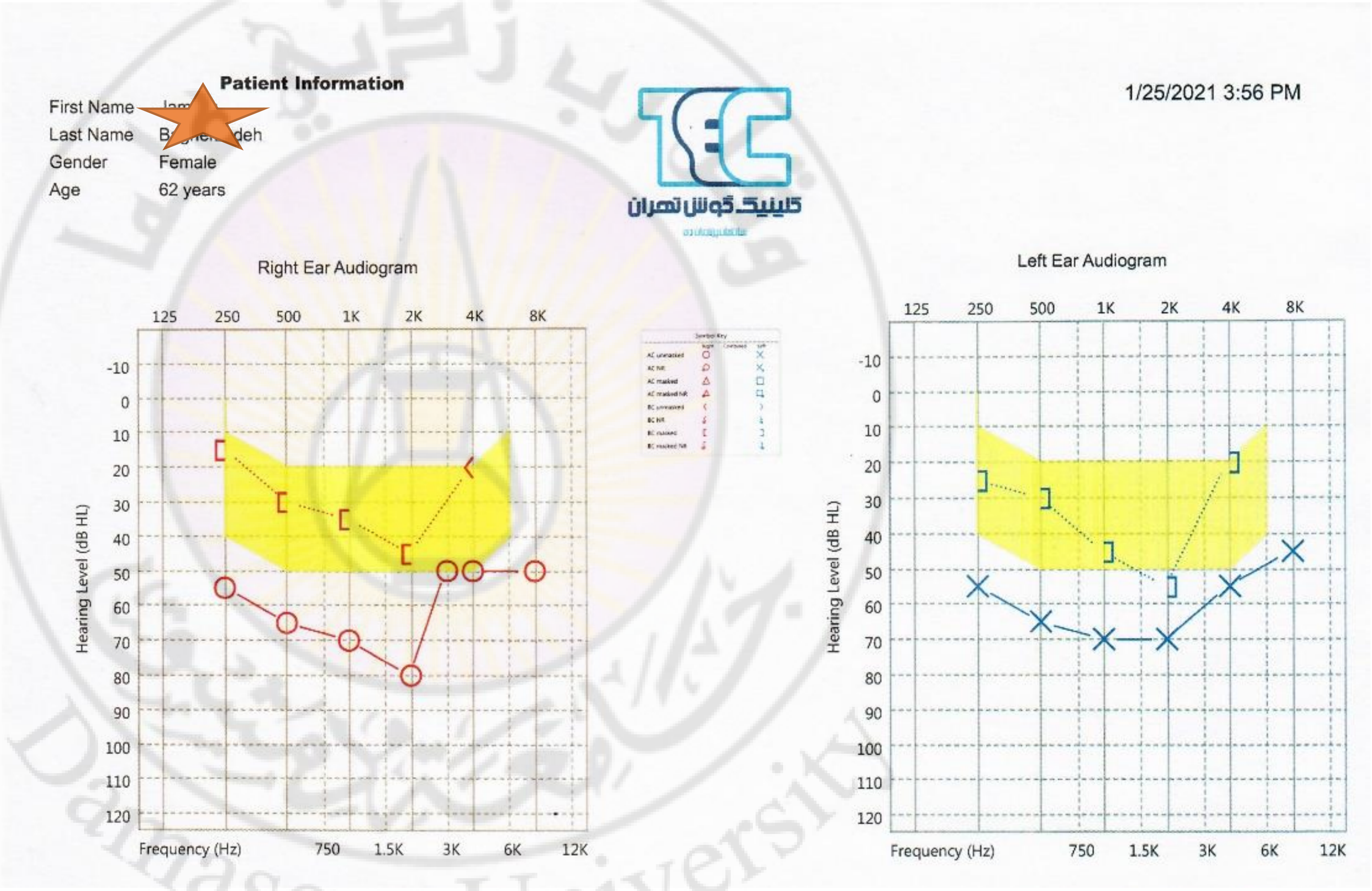




خانم ۳۲ ساله
گوش راست یک هفته
عمل شده
گوش چپ در نوبت عمل



Case study 1: Otosclerosis

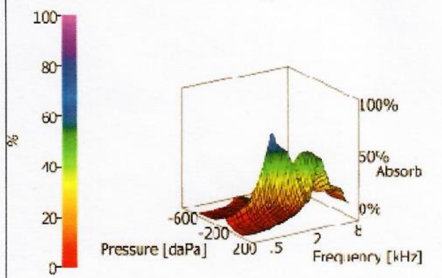


Person ID 99116
First name Ja
Last name B erzad
Birth date 2/9/1960
Gender Female

کلینیک گوش تهران

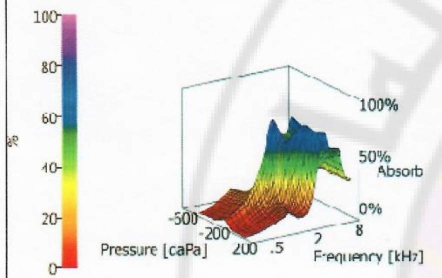
Tehran Ear Clinic (Audiology Unit)
Day Medical Tower
Unit C, 9th Floor
Tehran
021-88205806

3DT - Right



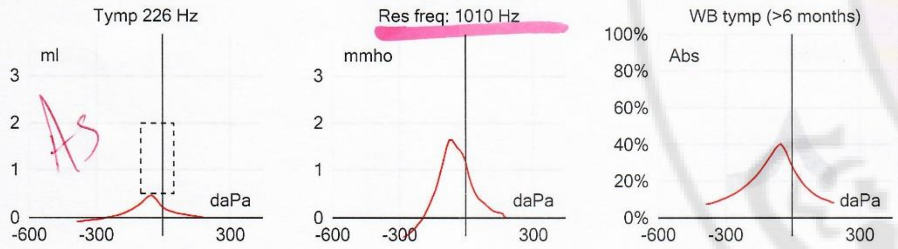
V: 1.1 Peak: -49 daPa
Res freq: 1010 Hz C at 226 Hz: 0.5, 1000 Hz: 1.8 mmho

3DT - Left



V: 1.2 Peak: -64 daPa
Res freq: 1051 Hz C at 226 Hz: 0.5, 1000 Hz: 3.0 mmho

3DT - tymps Right

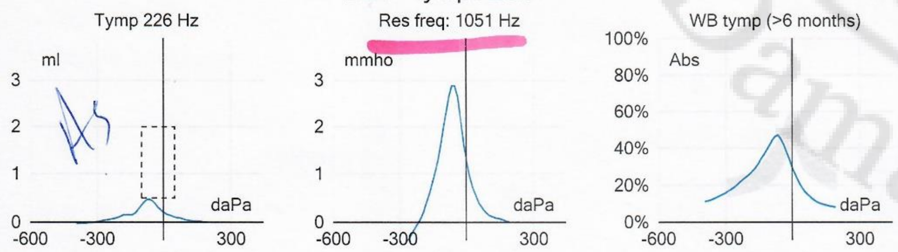


Volume: 1.13 ml Pressure: -49.0 daPa
Compliance: 0.46 ml Gradient: 113.0 daPa

Volume: 1.13 ml Pressure: -60.0 daPa
Compliance: 1.63 m Gradient: 139.0 daPa

Volume: 1.13 ml Pressure: -49.0 daPa

3DT - tymps Left

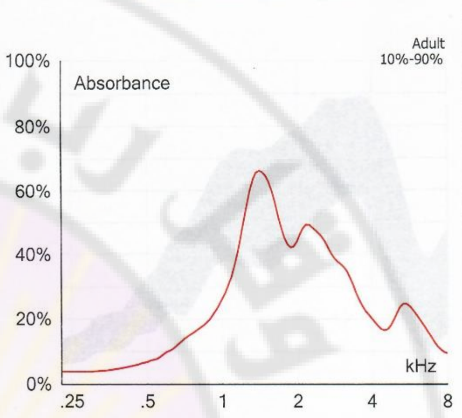


Volume: 1.15 ml Pressure: -64.0 daPa
Compliance: 0.48 ml Gradient: 103.0 daPa

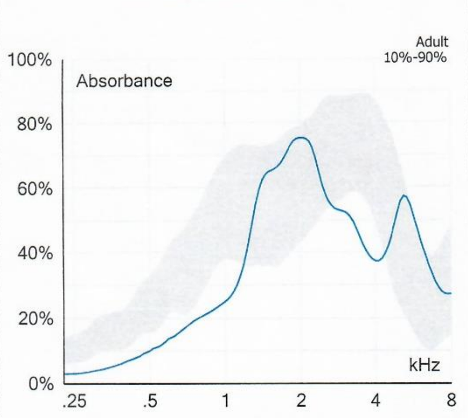
Volume: 1.15 ml Pressure: -52.0 daPa
Compliance: 2.92 m Gradient: 128.0 daPa

Volume: 1.15 ml Pressure: -64.0 daPa

WB absorbance Right



WB absorbance Left



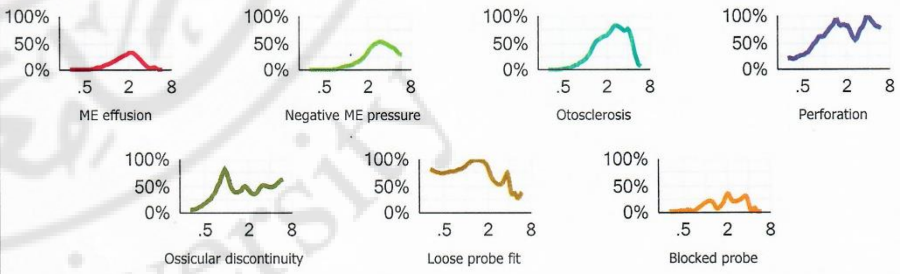
Reflex Right F:226 Hz P:-47 daPa

500 Hz I	0.00	0.00	0.00	0.00	0.00	
1 kHz I		0.00	0.00	0.00	0.00	0.00
2 kHz I		0.00	0.00	0.00	0.00	0.00
4 kHz I		0.00	0.00	0.00	0.00	
500Hz C						
1 kHz C						
2 kHz C						
4 kHz C						

Reflex Left F:226 Hz P:-67 daPa

500 Hz I	0.00	0.00	0.00	0.00	0.00	
1 kHz I		0.00	0.00	0.00	0.00	0.00
2 kHz I		0.00	0.00	0.00	0.00	0.00
4 kHz I		0.00	0.00	0.00	0.00	
500Hz C						
1 kHz C						
2 kHz C						
4 kHz C						

WB Absorbance Examples



کلینیک گوش تهران

Patient Name: [redacted]
Date of Service: [redacted]

Age: 60
Referring Physician: Dr. Yazdani

Audiologic Report:
The patient referred to this center with a chief complaint of hearing loss.

Objective (Test Results):
Audiometry revealed a mild to moderate to severe mixed hearing loss in both ears.

Wide Band Tympanometry (WBT) using click stimulus performed to assess the status of middle ear function in the range of 250 through 8000 Hz in both ears. Results showed a very limited Absorbance by the middle ear at low frequencies, and increased Resonance Frequency (High RF) at both ears, compared to normative values.
Ear canal volume were within normal limits in both sides.

Acoustic reflexes were also absent in both sides.

Assessment:
Ossicular chain fixation is indicated in both ears.

Plan:
1. ENT intervention

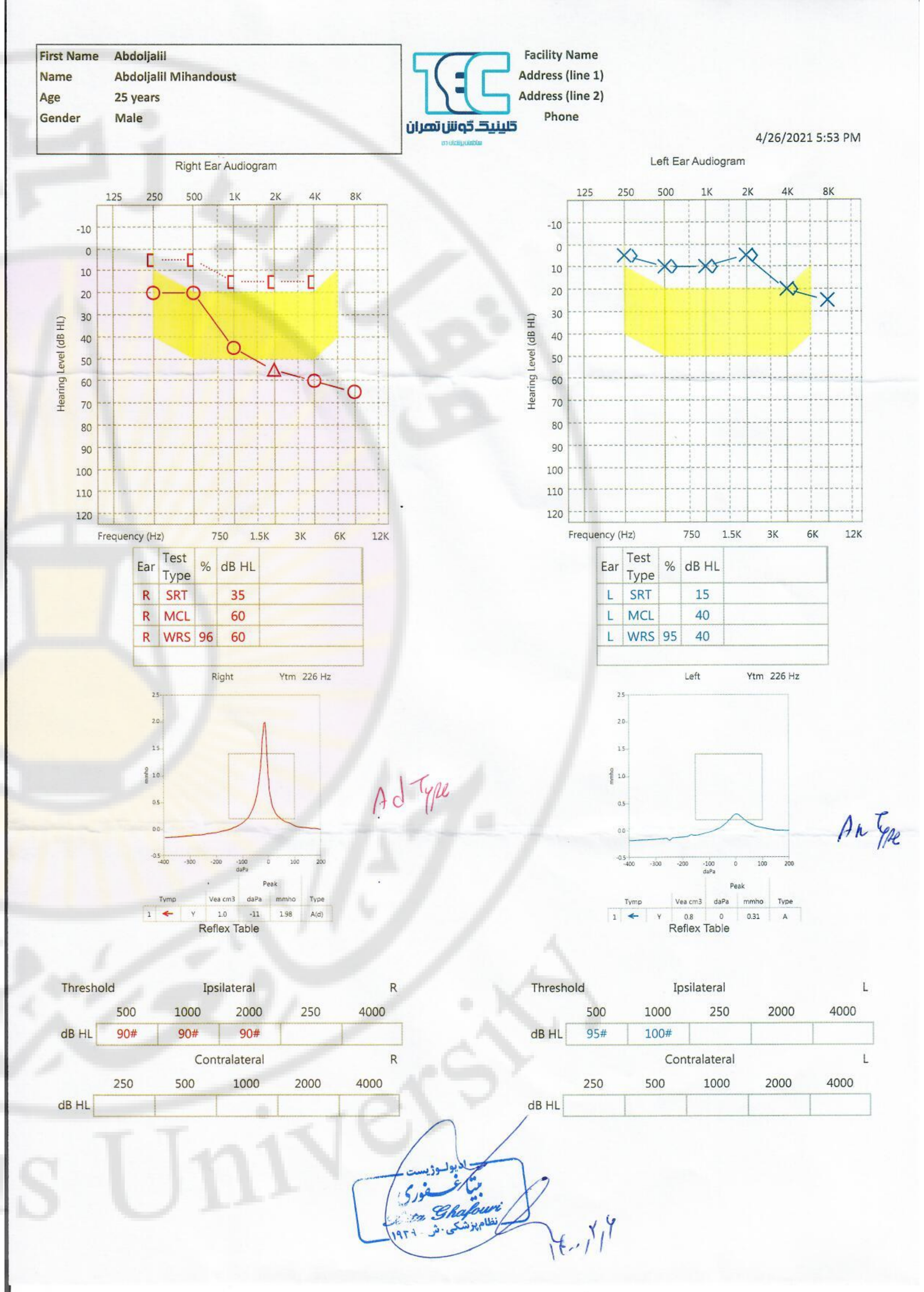
Best Regards;
Mohsen Ahadi, Ph.D.
Audiologist

دکتر محسن احدی
(Ph.D.) ادیولوژیست
نظام پزشکی ش-۵۶۵

tehranearclinic

تهران، خیابان ولیعصر، روبروی بیمارستان دی، ساختمان پزشکان دی (پلاک ۱۲)، طبقه نهم، واحد تخصصی بیماری‌های گوش و جراحی (9e)، واحد ادیولوژی (شنوایی‌شناسی) (9c)
واحد تخصصی بیماری‌های گوش و جراحی: ۸۸۸۷۰۹۱۱ ۰۹۱۲۱۲۷۱۹۸۷
واحد تخصصی ارزیابی‌های شنوایی و تعادل: ۸۸۲۰۵۸۰۶ - ۸۸۲۰۲۹۳۴

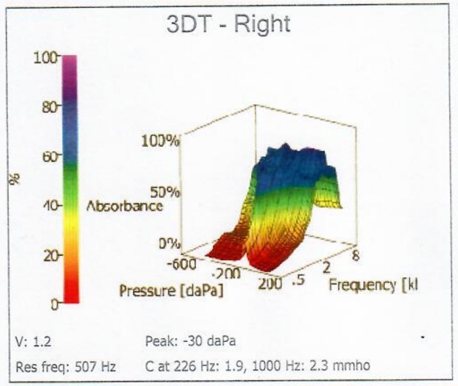
Case study 2:
Ossicular chain disruption

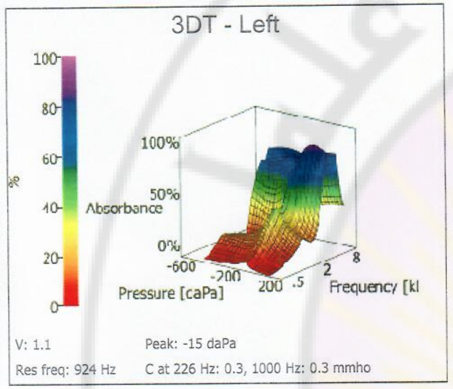


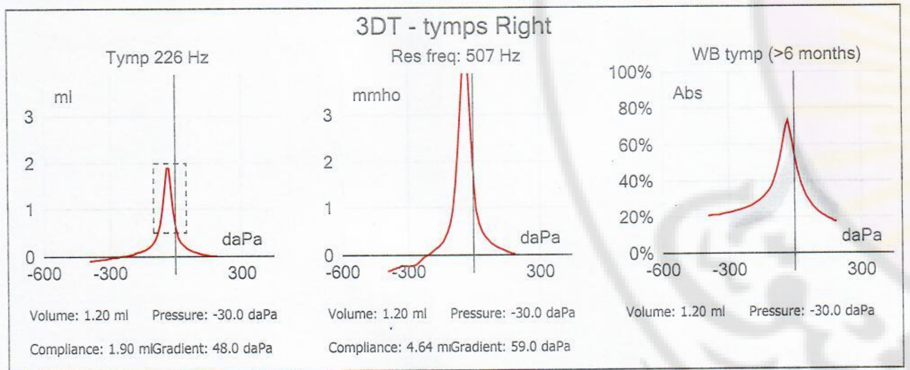
Person ID 4000225
First name Abdoljalil
Last name Mihandoust
Birth date 7/13/1994
Gender Male

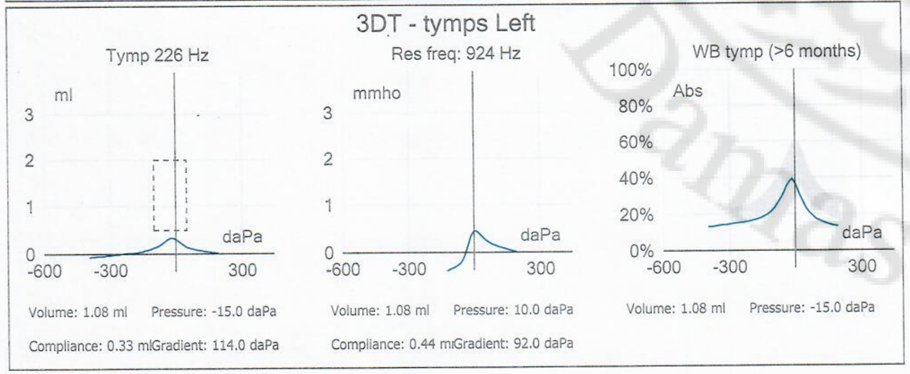
کلینیک گوش تهران
ساختمان پزشکان دی

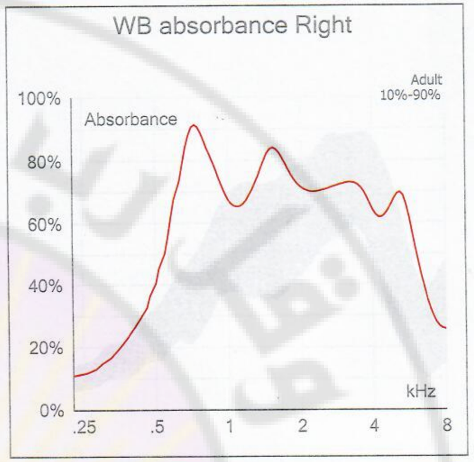
Tehran Ear Clinic (Audiology Unit)
Day Medical Tower
Unit C, 9th Floor
Tehran
021-88205806

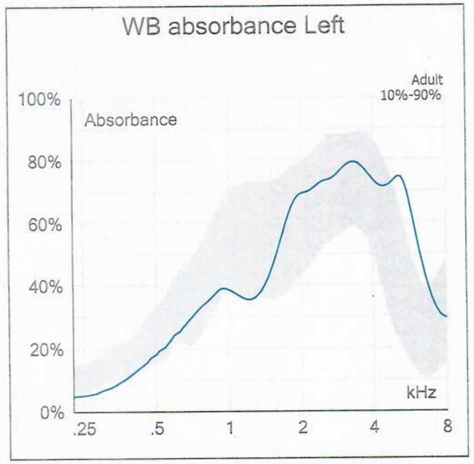


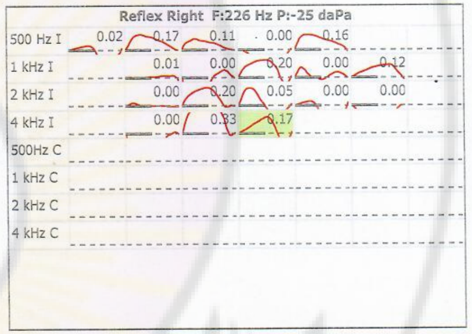


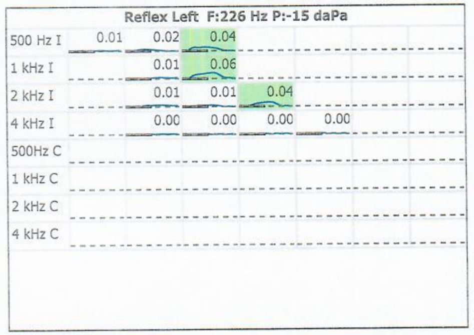


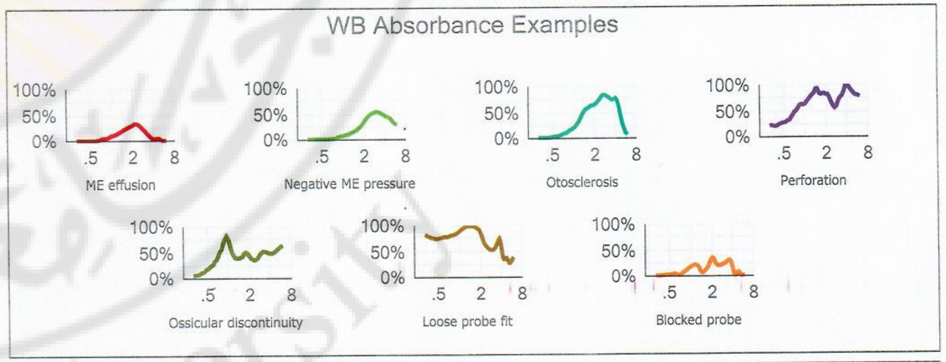












Patient Name: Abdoljalil Mihandoost
Date of Service: 06.02.1400

Age: 25
Referring Physician: Dr. Yazdani

Audiologic Report:

The patient referred to this center with a chief complaint of hearing loss.

Objective (Test Results):

Wide Band Tympanometry (WBT) using click stimulus performed to assess the status of middle ear function in the range of 250 through 8000 Hz in both ears. Results showed a very limited Absorbance by the middle ear at high frequencies, and decreased Resonance Frequency (Low RF) at right ear, compared to normative values.
Ear canal volume were within normal limits in both sides.

Acoustic reflexes were also absent in right side.

Assessment:

Ossicular chain discontinuity is suspected in right side.

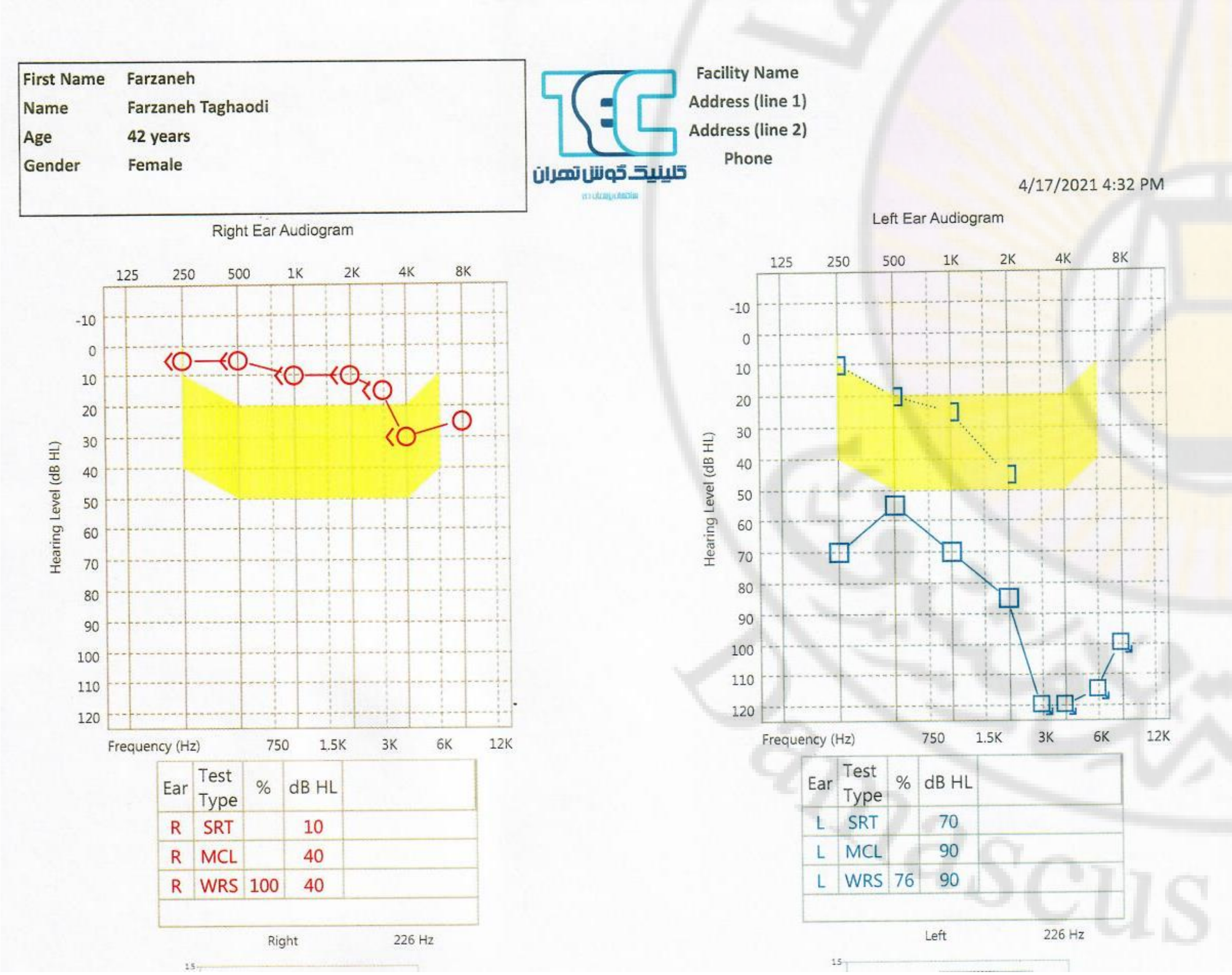
Plan:

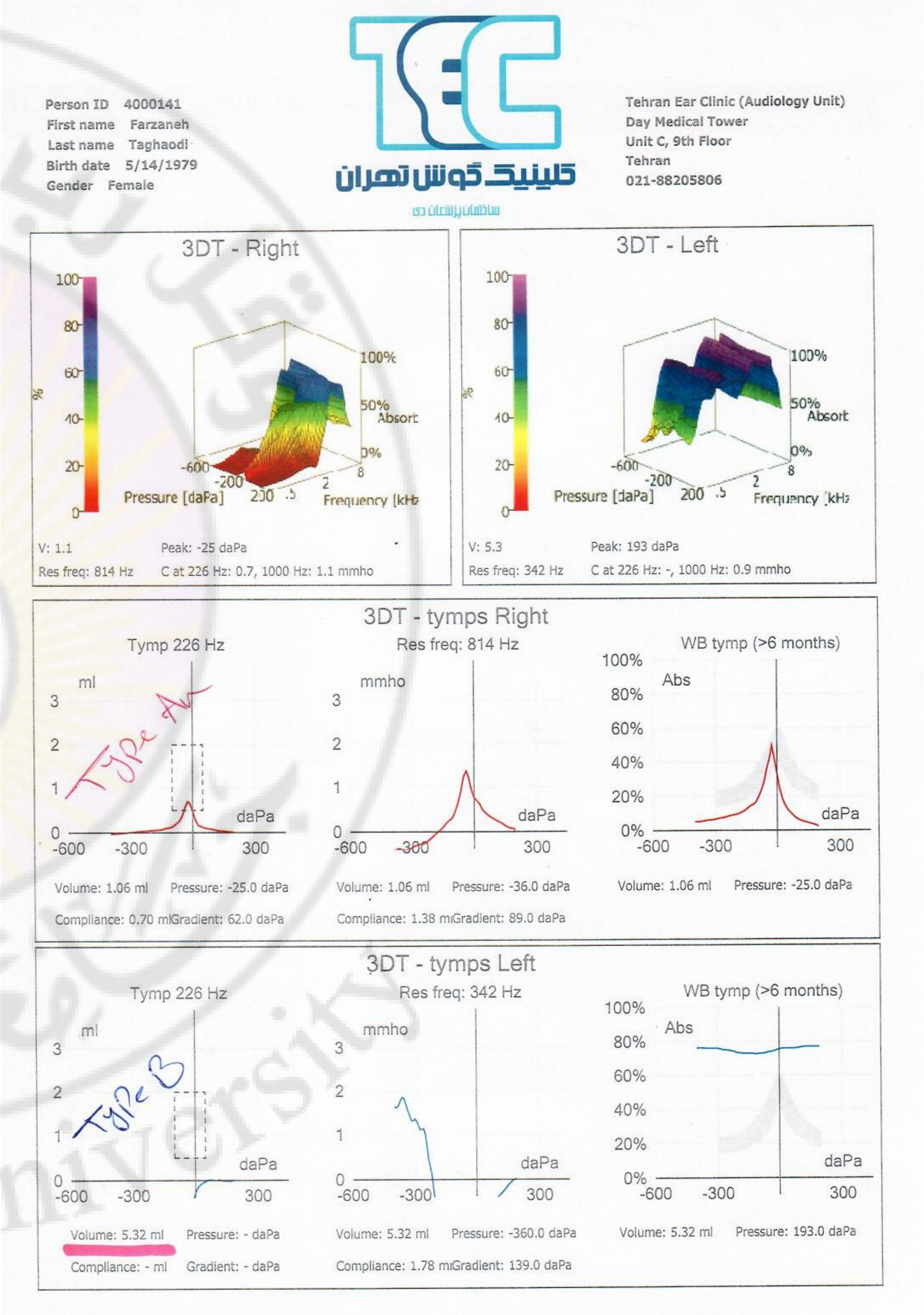
1. ENT intervention

Best Regards;
Mohsen Ahadi, Ph.D.
Audiologist

دکتر محسن احدی
ادیولوژیست (Ph.D.)
نظام پزشکی ش-۵۶۵

Case study 3: TM Perforation





Tympanometry in Newborns and Infants

- In neonate ears with confirmed middle-ear disease, 226-Hz tympanograms may not provide accurate diagnostic information.
- tympanometry using a higher probe tone frequency (e.g., 1,000 Hz) is more sensitive to middle-ear status, compared with 226-Hz tympanometry, in infants less than 4 to 6 months old.
- These effects are probably related to developmental differences between infant ear canals and middle ears relative to those of older children and adults. Anatomical and physical differences in the infant ear, ear canal wall flaccidity (Holte et al., 1991), smaller ear canal and middle-ear space, TM thickening, presence of middle-ear fluid and mesenchyme in some ears, and a more horizontal orientation of the TM with respect to the axis of the ear canal, are the most likely contributors.

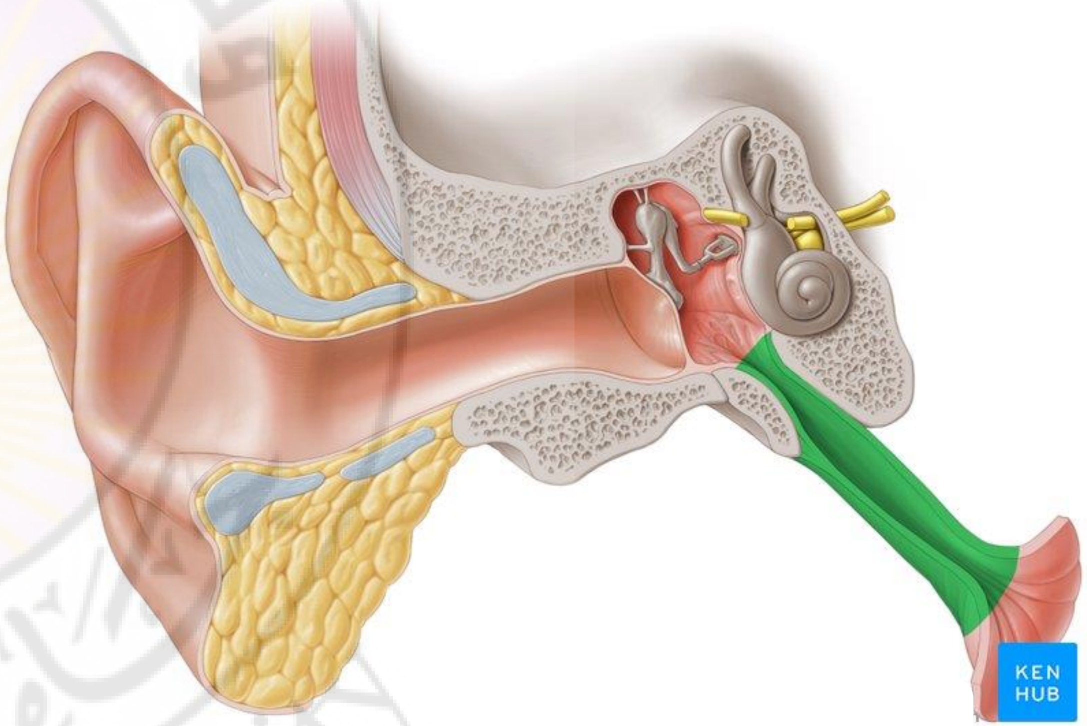
Normative Data for Tympanometry (226- and 1,000-Hz Probe Tones) in Infants and Children

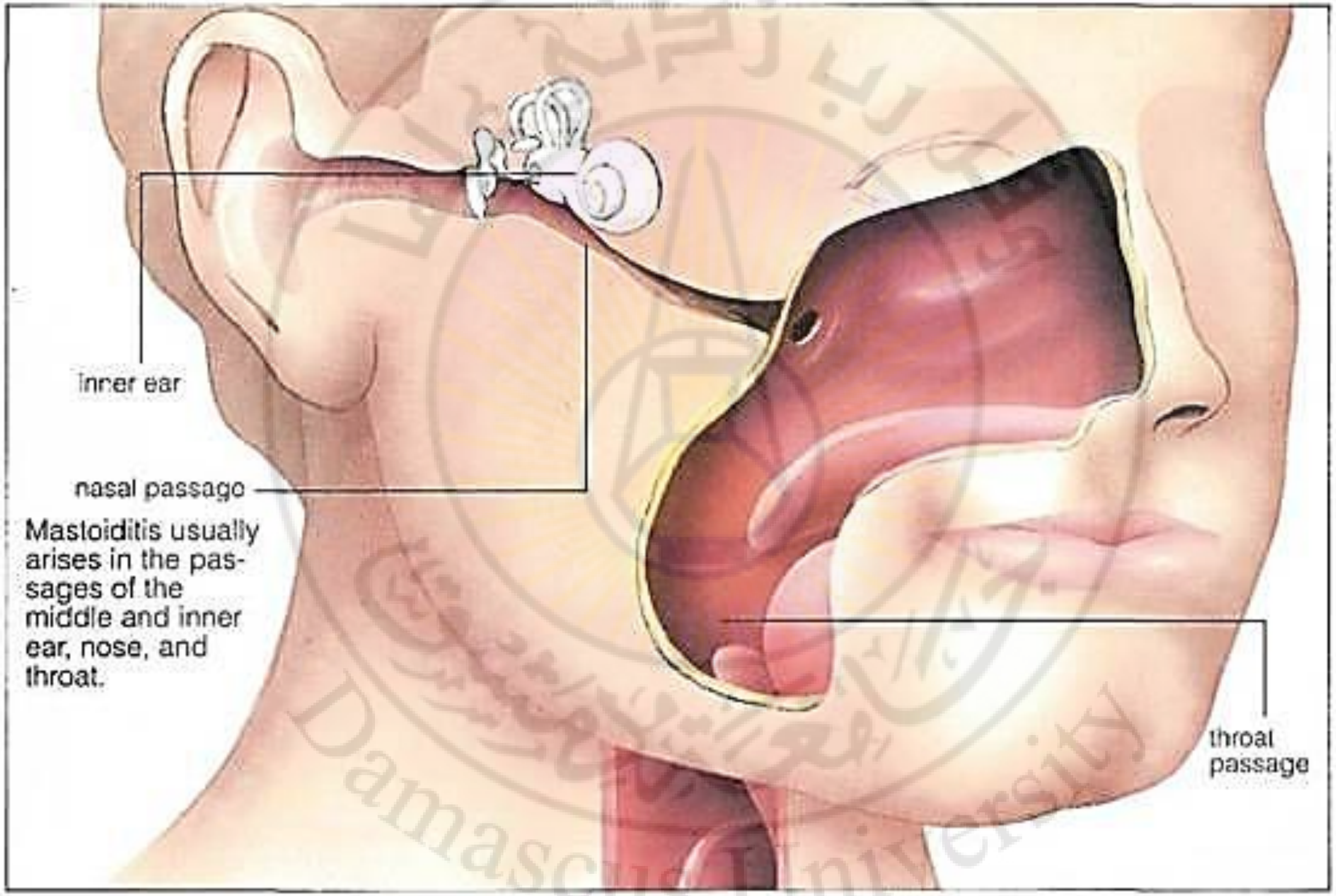
Study	Age	Probe Frequency (Hz)	Y_{tm} 5–95 Percentiles (mmho)	Tympanic Width (daPa)
Margolis et al. (2003)	Birth to 4 wks	1,000	0.60–4.3 (–400 tail)	NA
Shahnaz et al. (2008)	32 wks gestational age	1,000	0.10–1.50 (+250 tail) 0.53–2.31 (–400 tail)	NA
Kei et al. (2003)	1–6 days	1,000	Right ears 0.39–2.28 (+200 tail)	Right ears 56.6–154
	1–6 days	1,000	Left ears 0.39–1.95 (+200 tail)	Left ears 46.1–144.2
Roush et al. (1995)	6–12 mos	226	0.20–0.50 (+200 tail)	102–234
	12–18 mos	226	0.20–0.60 (+200 tail)	102–204
	18–24 mos	226	0.30–0.70 (+200 tail)	102–204

6. Eustachian tube function tests

Eustachian tube Anatomy

- The Eustachian tube is also known as the pharyngotympanic tube or auditory tube.
- The Eustachian tube is about 31–38 mm (1.2–1.5 inches) long in humans and lined with mucous membrane.
- It is directed downward and inward from the middle ear to the nasopharynx.
- The upper end of the eustachian tube is narrow and surrounded by bone. As it nears the pharynx, the tube becomes wider and cartilaginous.
- The mucous lining is continuous with that of the middle ear.
- Cilia (small hairlike projections) cover it to aid the drainage of mucous secretions from the middle ear to the pharynx.

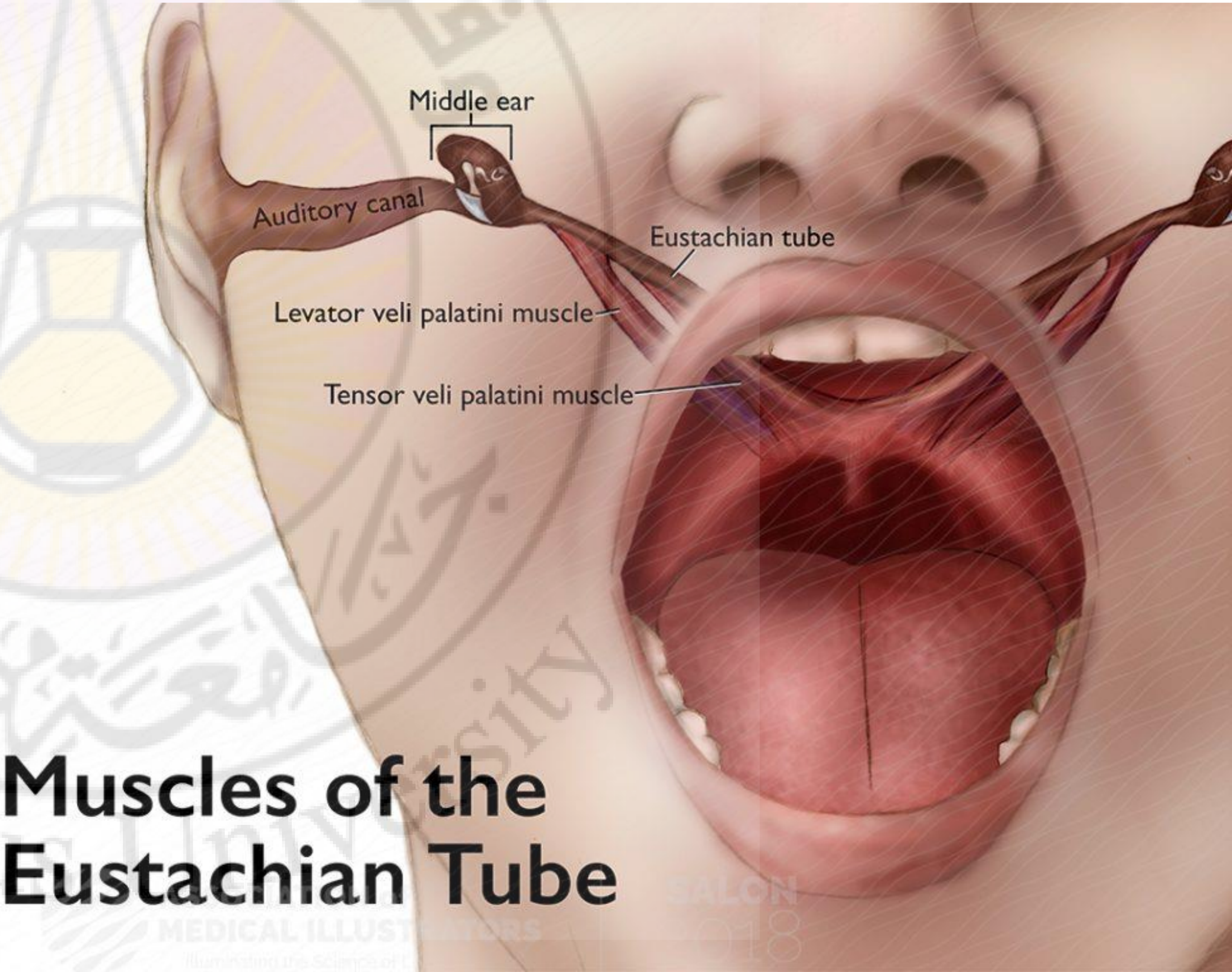



Inner ear
nasal passage
Mastoiditis usually arises in the passages of the middle and inner ear, nose, and throat.
throat passage

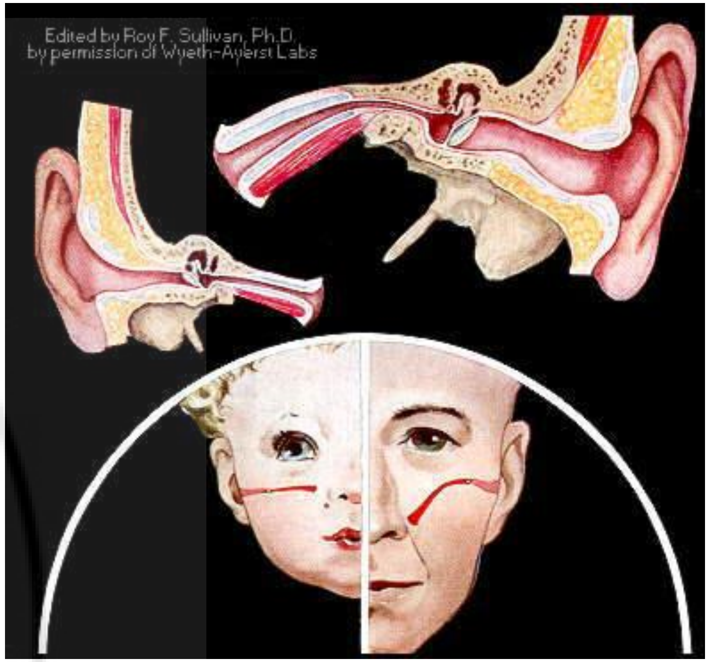
Muscles

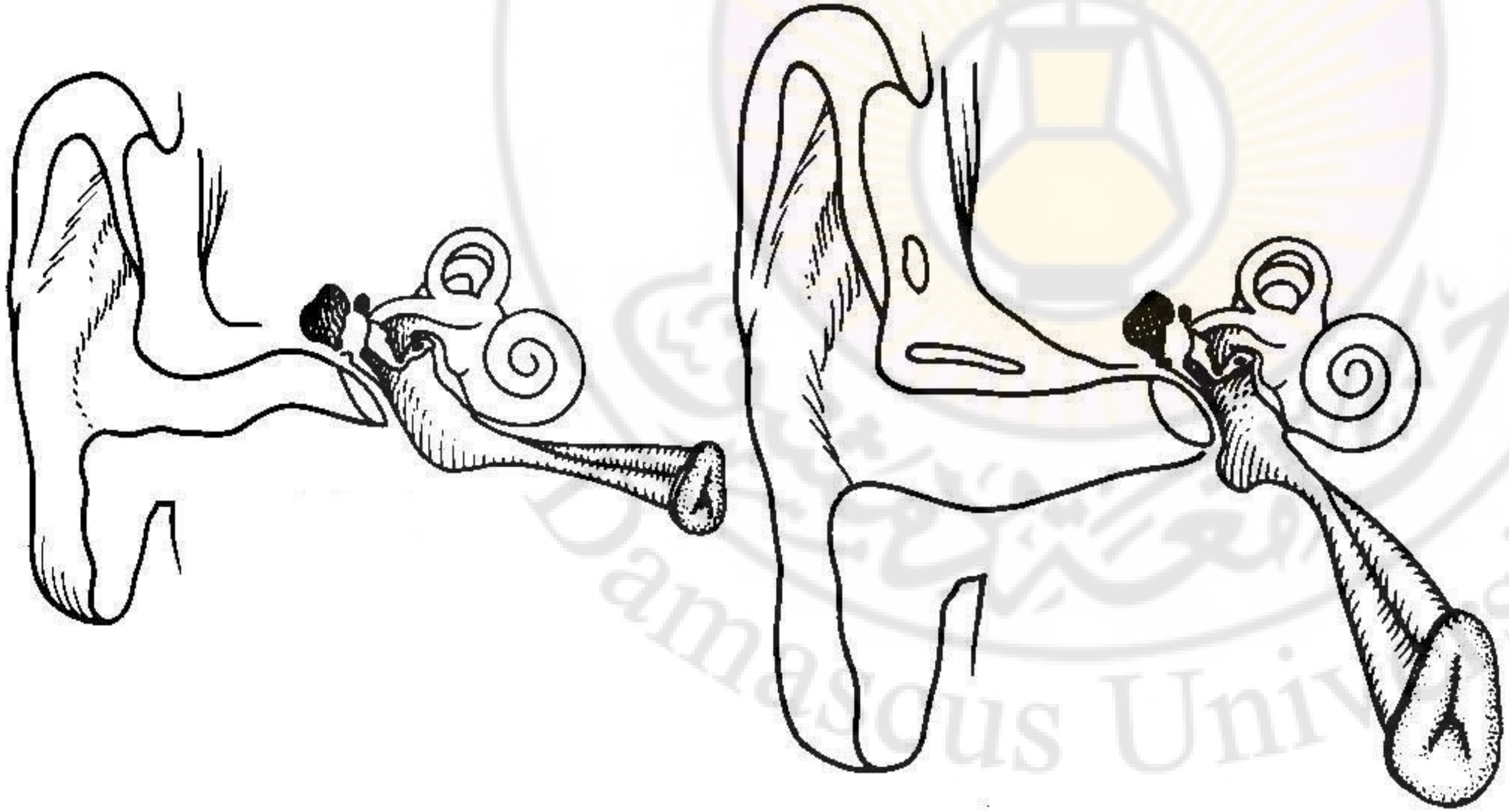
- The Eustachian tube is normally collapsed, i.e. closed, to protect the middle ear, but it opens during actions such as chewing, swallowing, and yawning.

- There are muscles that are responsible for Eustachian tube functioning. The **tensor and levator veli palatini muscles** open the tube, by contracting the muscles of the soft palate.



In **children**, the ET is shorter and straighter, as well as having poorer muscular control, which make them susceptible to otitis media, and leading to reflux of nasopharyngeal secretions into the middle ear.



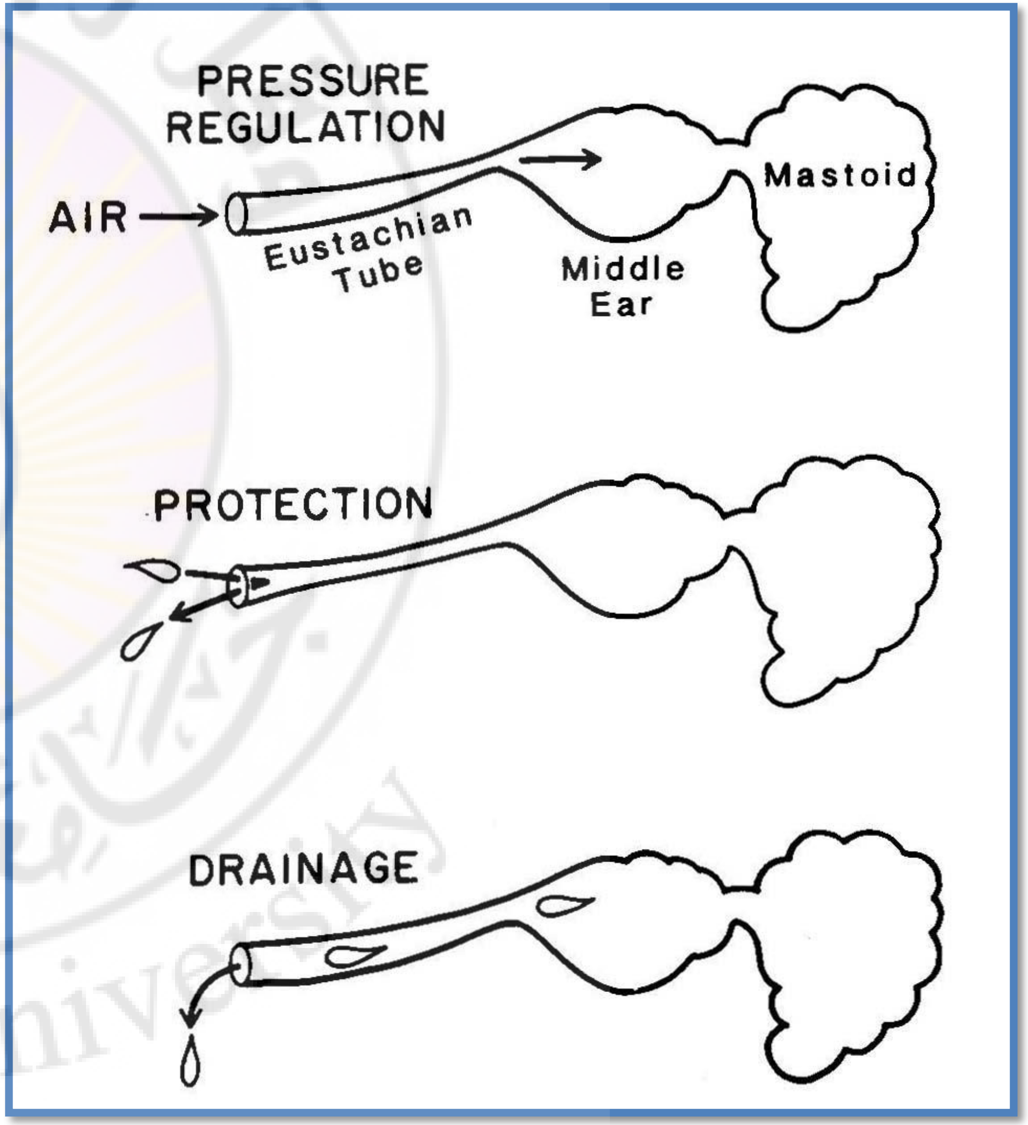


ET Function

1. When there are changes in atmospheric pressure, the Eustachian tube is required to equalize pressure in the middle ear.

2. Normally, ET is closed to protect the middle ear

3. The tube also drains mucus from the middle ear because of its ciliated epithelium and aerates the middle ear.

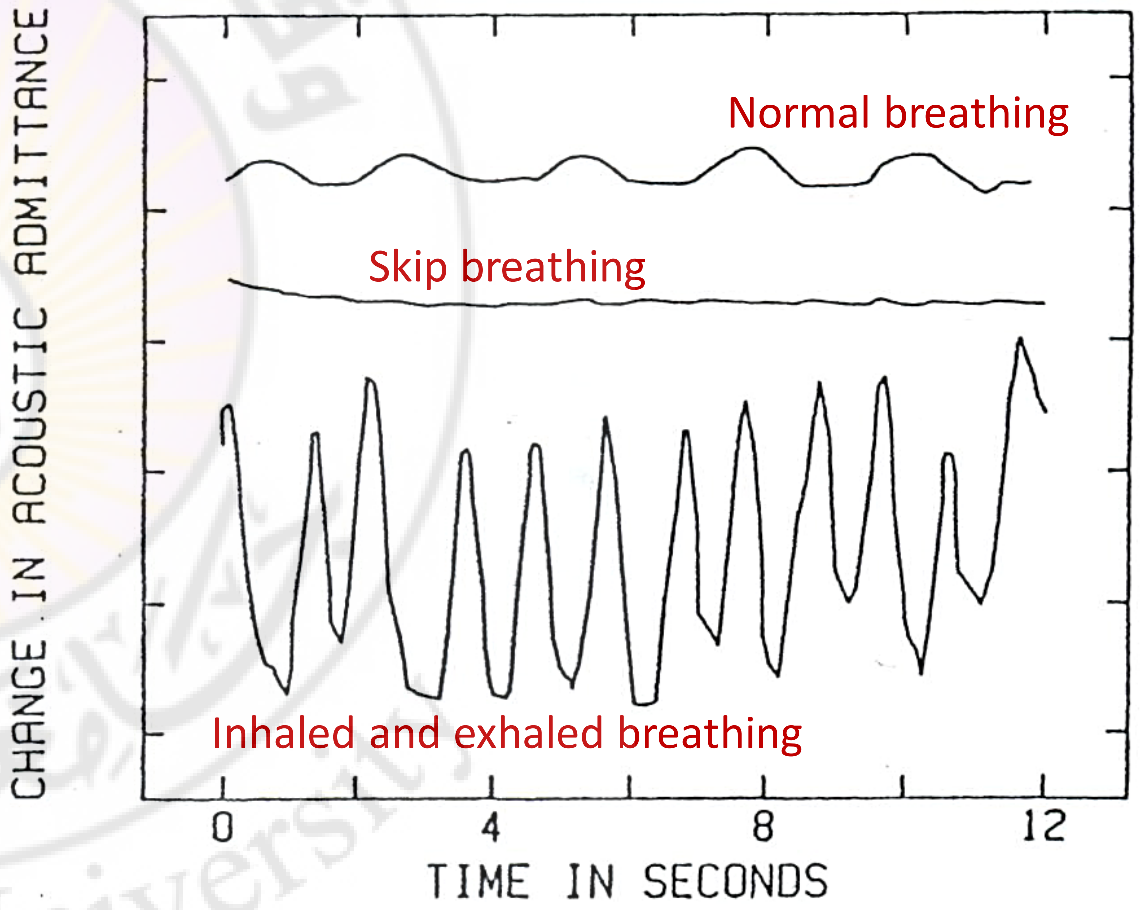


Eustachian tube dysfunction

- Patulous Eustachian Tube
- Blocked (Obstructive)Eustachian Tube

Patulous Eustachian Tube

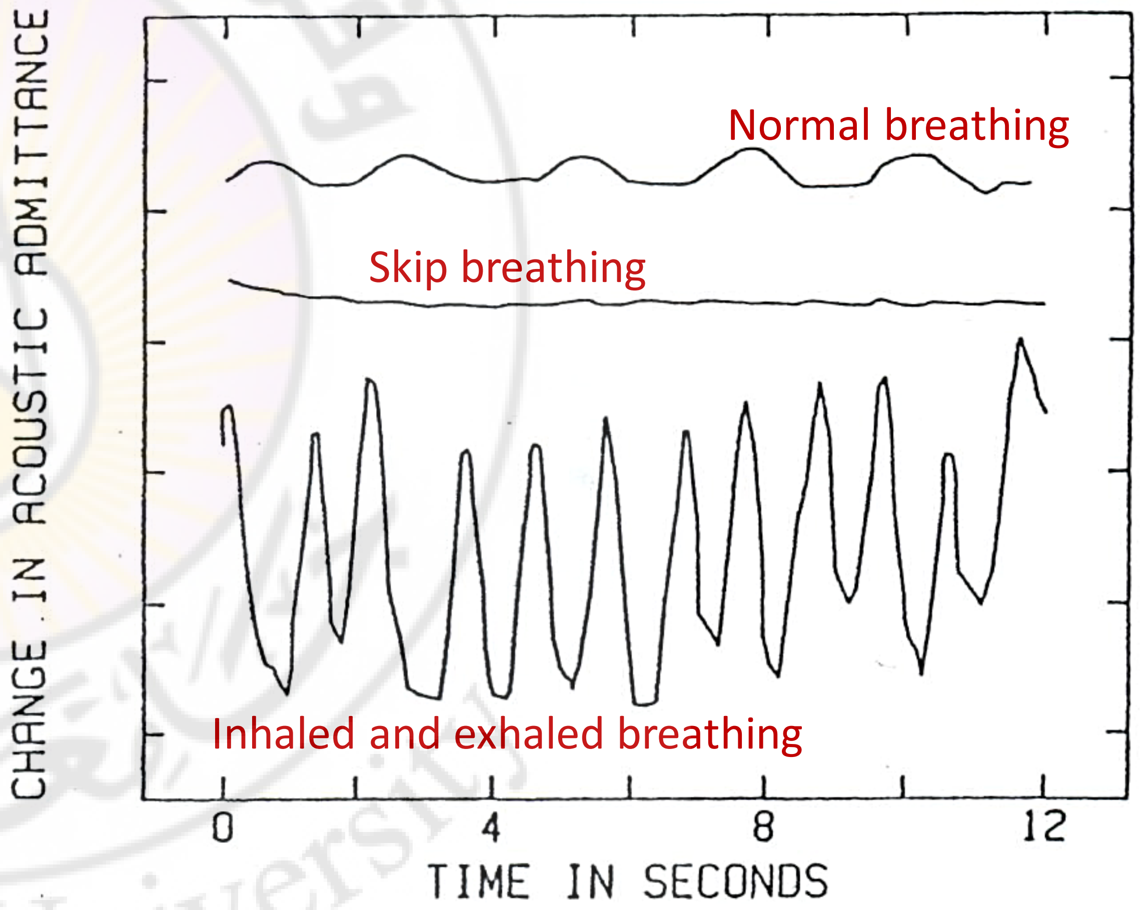
- A patulous ET is abnormally open at rest, which can cause discomfort because of **autophony** (hearing one's own voice and breathing) that coincides with breathing.
- When patients present with complaints about discomfort because of hearing their own voice, breathing, or chewing, a patulous ET should be suspected.
- Patulous ET can be evaluated using immittance tests performed during breathing tasks.
- patulous Eustachian tubes is identify by > 0.07 ml immittance changes.

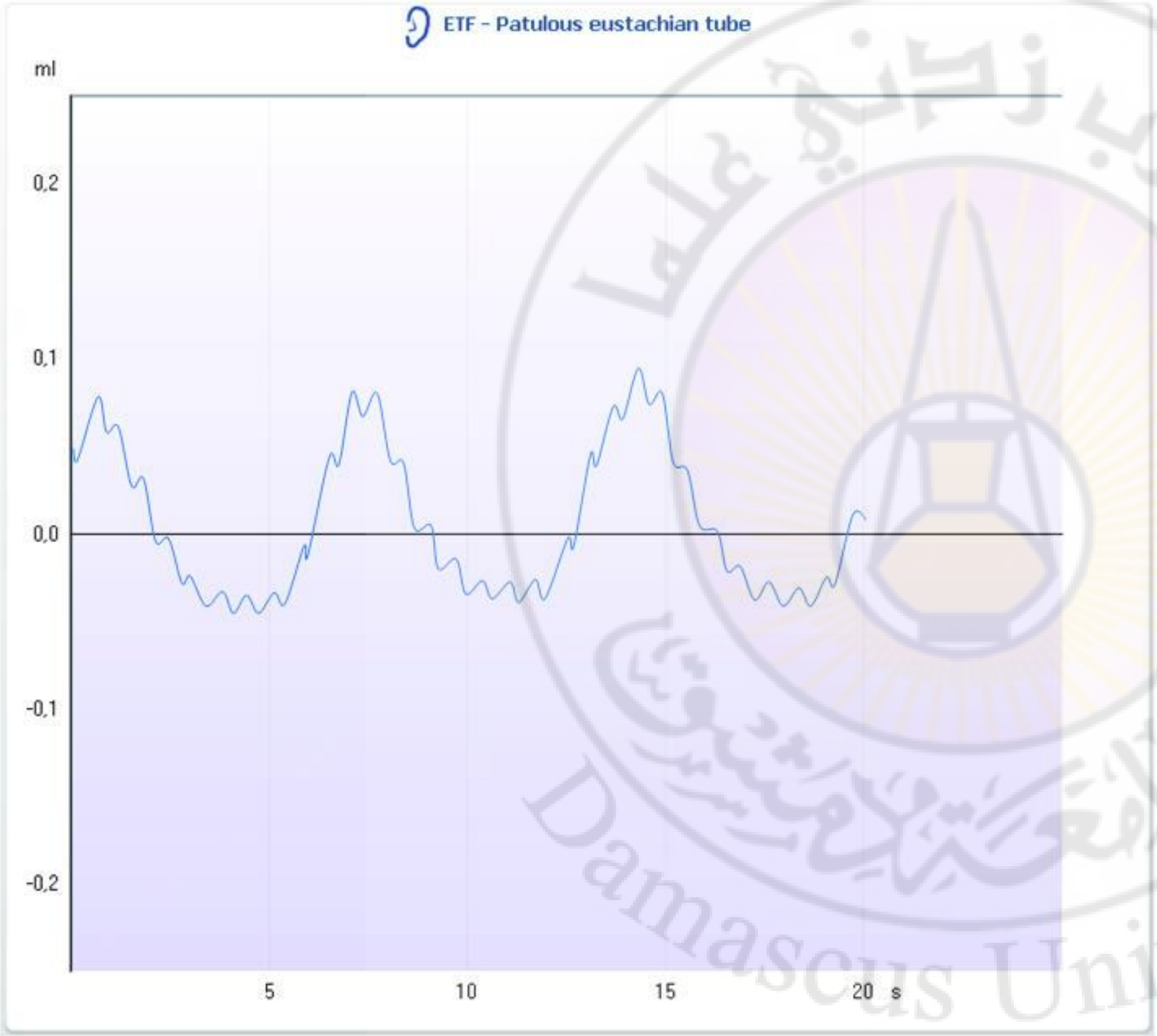


Patulous Eustachian Tube

- Vibration of TM during otoscopy
- Feeling of pressure

- In most cases, the cause of patulous eustachian tube is unknown. Weight loss and pregnancy may be predisposing factors. Neurologic disorders that cause muscle atrophy such as stroke, multiple sclerosis, and motor neuron disease have been implicated in some cases of patulous eustachian tube.

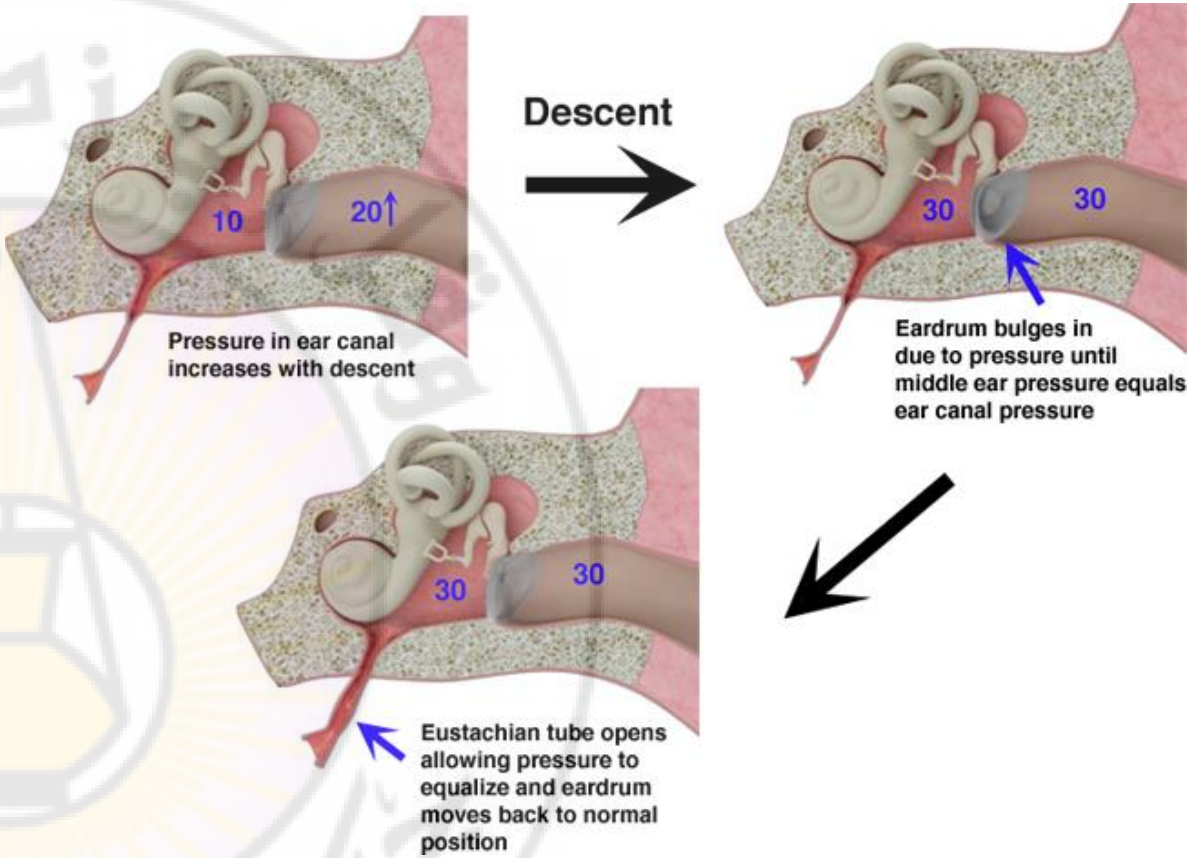


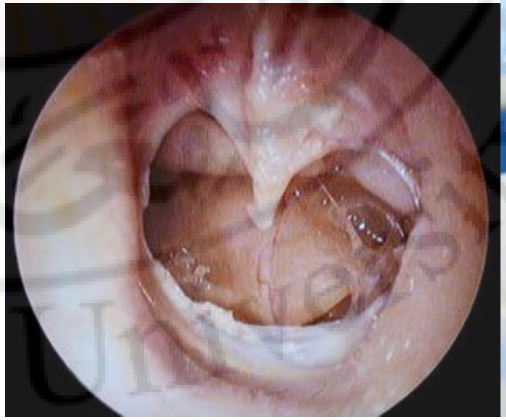


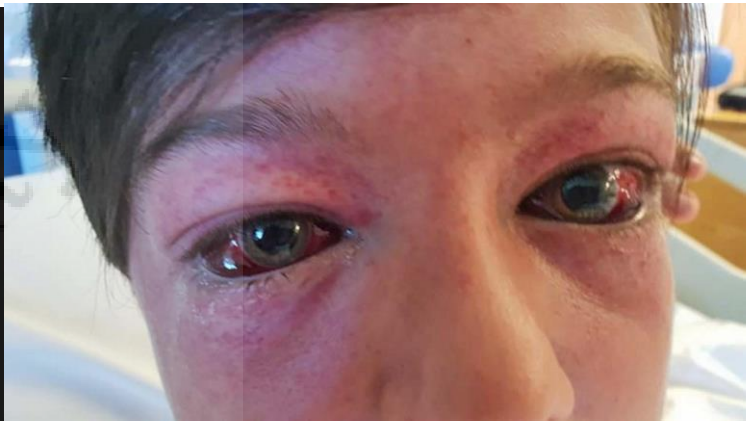
Patulous Eustachian Tube test is an impedance baseline test.

Obstructive Eustachian Tube

- The nonpatency of the Eustachian tube will cause the air to be trapped within the middle ear cavity and prevents ventilation of the middle ear that would re-equalize the pressure and “unclog” the ear.
- If this problem is caused by an abrupt pressure change, it is called **aerotitis** or **barotrauma.**
- **barotrauma** is usually caused by the abrupt air pressure increase of an airplane descent, which causes the tympanic membrane to retract and prevents the Eustachian tube from opening.
- Barotrauma can cause TM perforation, CHL, and, in rare cases, a fistula of the oval window.







Eustachian Tube Function test

- Non-Perforated TM
    - Valsalva Test
    - Toynbee Test
    - Inflation / Deflation test

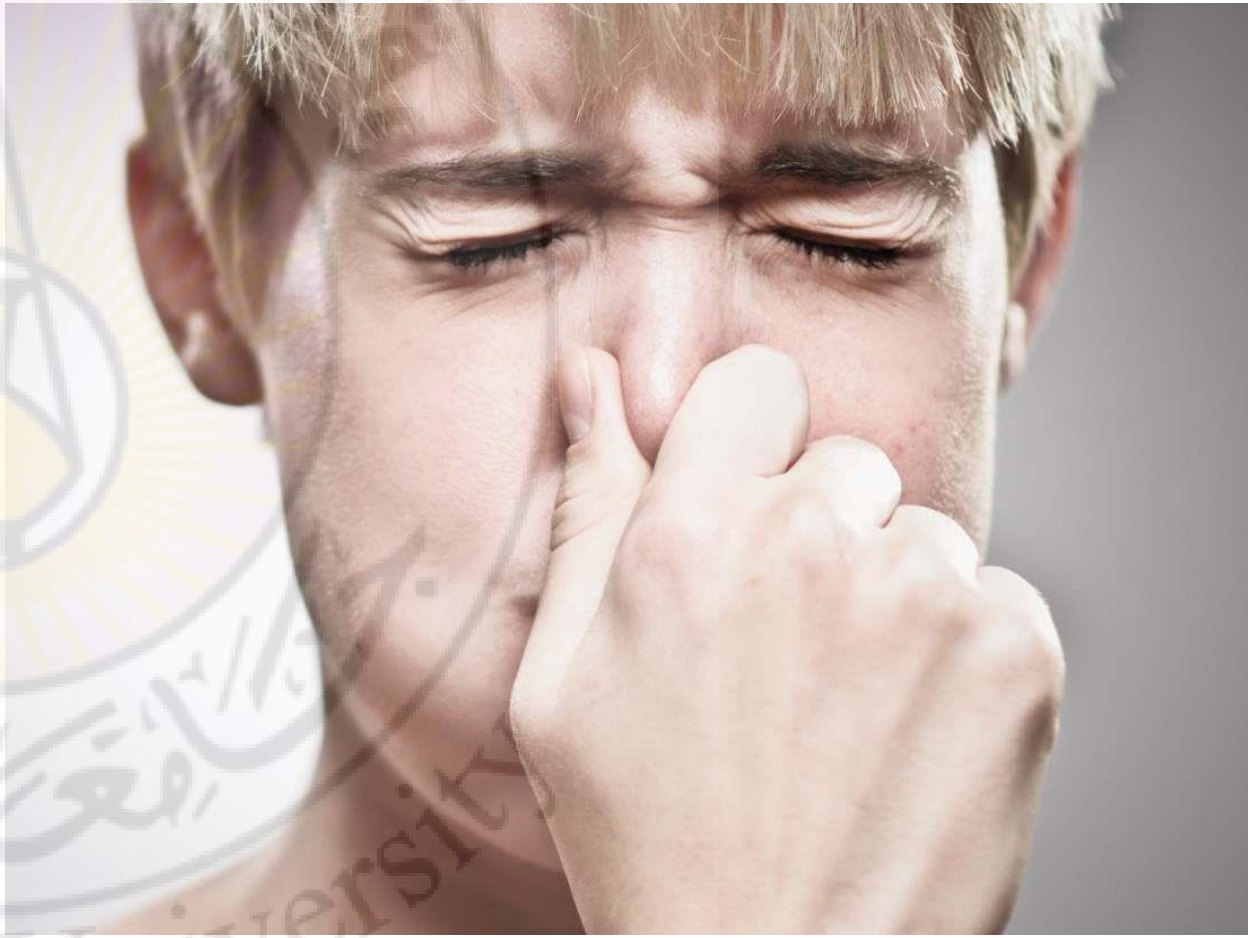
- Perforated TM
    - Inflation Test

Valsalva Test

- The Valsalva test (Bluestone, 1975) introduces positive pressure into the middle ear via the ET using the classic Valsalva maneuver.

1. *A pretest tympanogram is recorded,*
2. *the patient is instructed to perform the Valsalva maneuver by holding the nose and gently blowing air into the posterior nasopharynx.*
3. *Then, a posttest tympanogram is recorded.*

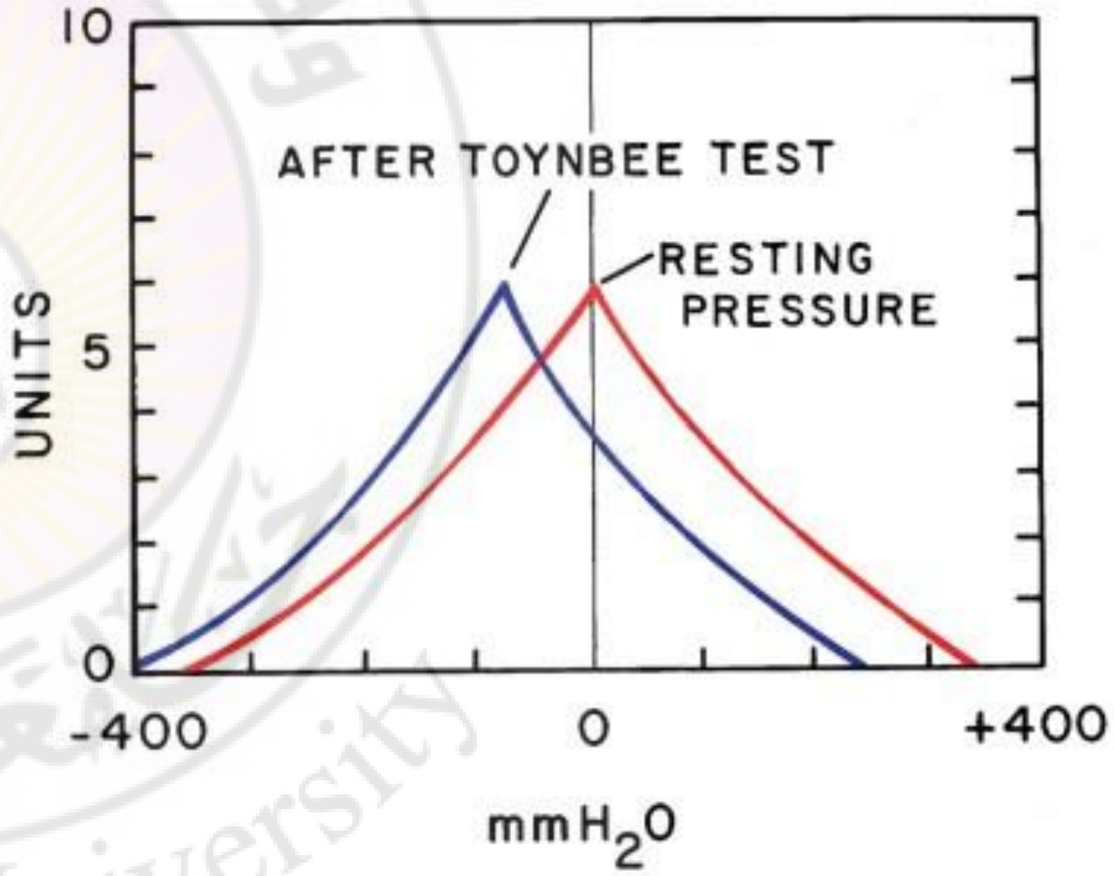
- Tubal opening is indicated by a **positive shift in TPP.**




Valsalva Maneuver
To equalise your ears,
Singapore
General Hospital
SingHealth
Valsalva - Ear Equalisation Techniques

Toynbee Test

- In the Toynbee maneuver the patient is instructed to swallow while holding his nose closed (by pinching his nostrils).
- The Toynbee maneuver is typically expected to make the middle ear pressure more **negative**, but it actually causes *either* a positive *or* negative shift in middle ear pressure.
- The Toynbee test follows the same procedures used for the Valsalva test, except that the Toynbee maneuver is used.

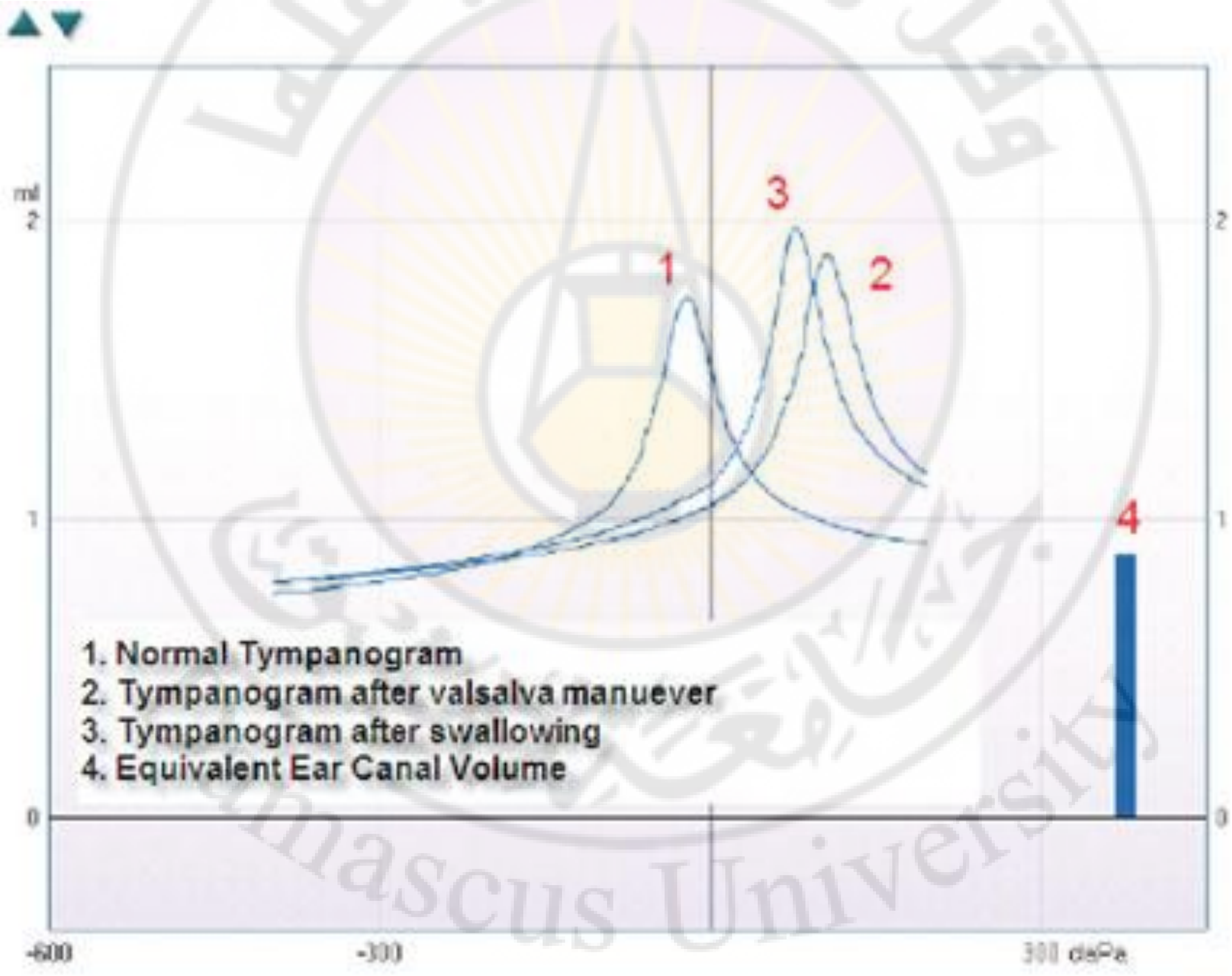


Toynbee Maneuver

Singapore General Hospital
SingHealth

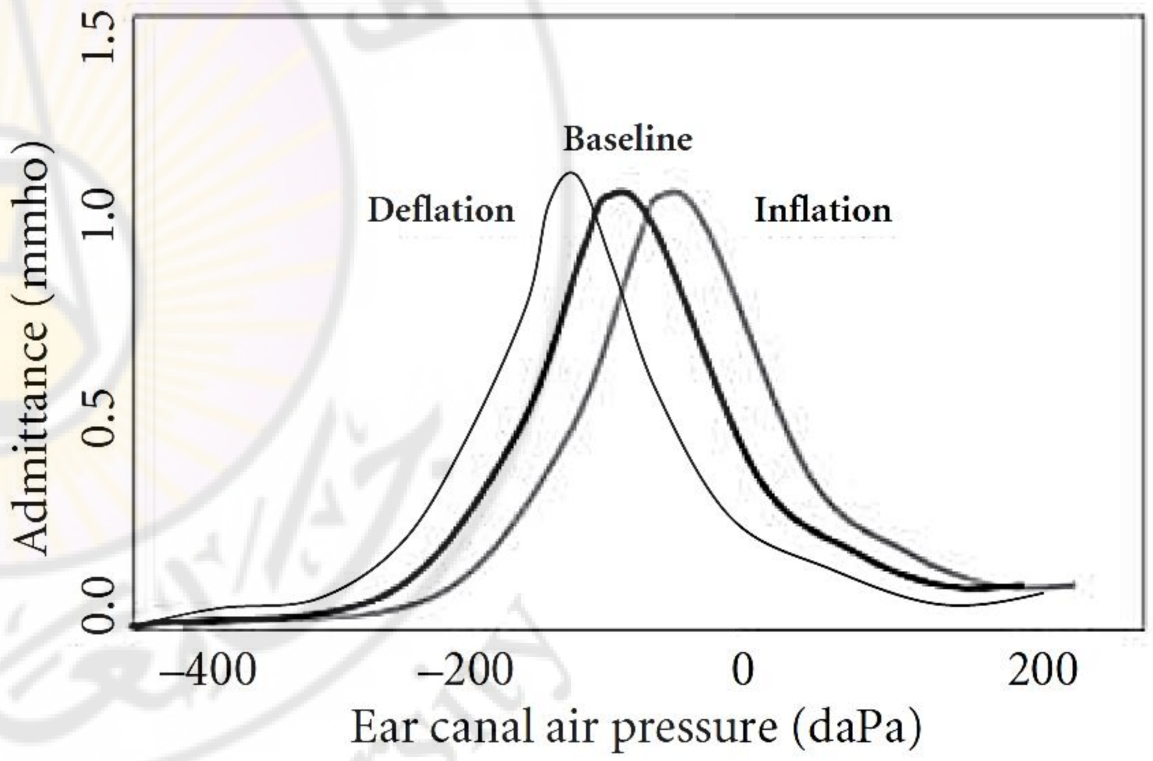
Valsalva - Ear Equalisation Techniques

Suggested 3-stage ETF testing



Inflation / Deflation test

- The inflation–deflation test uses high positive pressure (inflation) or negative pressure (deflation) introduced into the ear canal using the tympanometers (±400 dapa) while the patient is asked to swallow several times.
- Pre- and posttest tympanograms are recorded.
- Tubal opening is indicated by a shift in the pressure peak in the opposite direction of applied pressure.



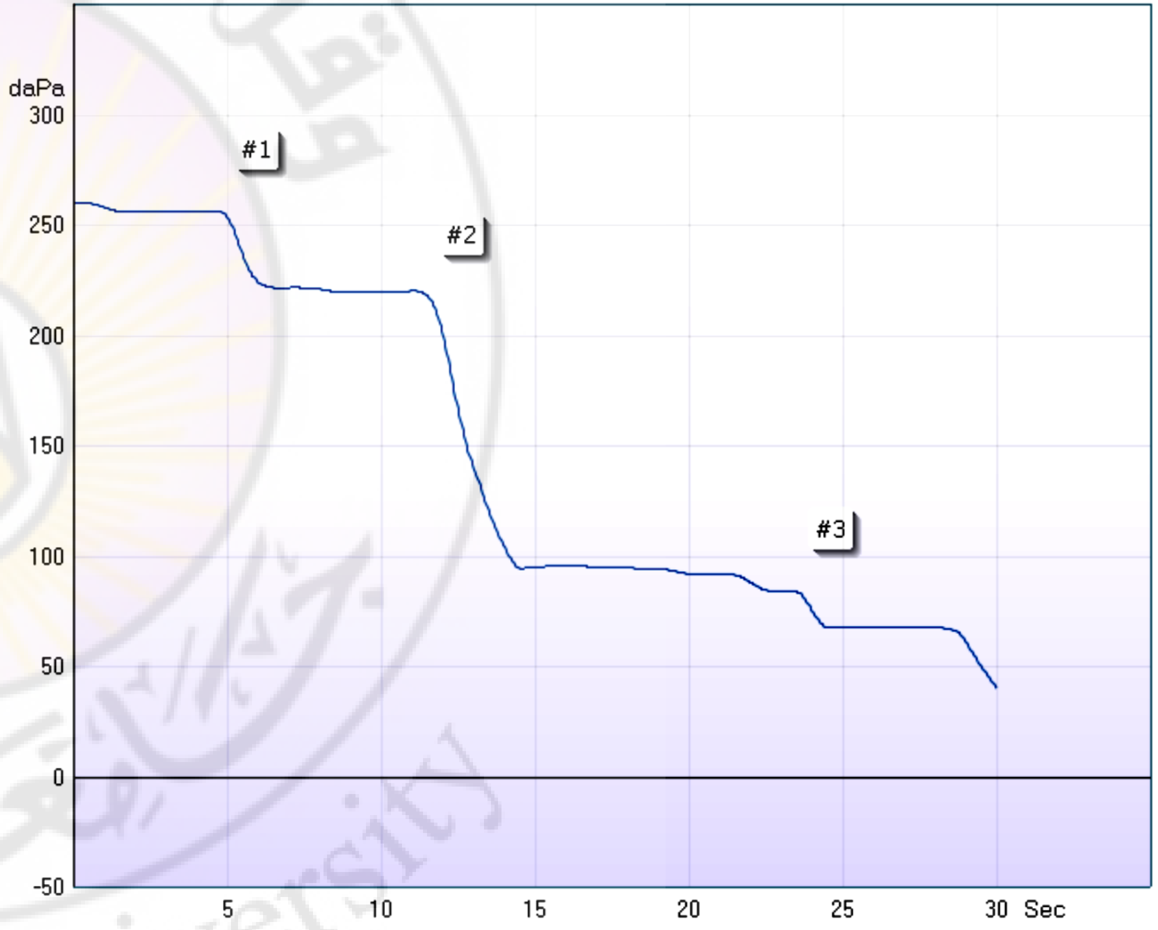
وقل رب زدني علما

جامعة دمشق

Damascus University

Inflation test for Perforated TM

- Put the positive pressure in the ear canal, with sealing of the probe tip.
- Patient swallow several times and decreasing the pressure is an indicator of normal ET function.



# 1	255 daPa	222 daPa
# 2	216 daPa	95 daPa
# 3	83 daPa	68 daPa

وقل رب زدني علما

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Damascus University

Table 4–5. Normative Values (in daPa) for Eustachian Tube Function Tests for 24 Adults with Normal Middle Ear Function

Test	*Mean*	*Standard Error*	*95% Confidence Interval*
Valsalva			
Baseline	9	1	7–11
Posttest	72	8	55–87
Shift	63	8	47–79
Toynbee			
Baseline	9	1	7–11
Posttest	−6	5	−17–5
Shift	−15	5	−26 to −4
Inflation			
Baseline	8	1	6–10
Posttest	−3	1	−6–0
Shift	−11	1	−13 to −8
Deflation			
Baseline	8	1	6–10
Posttest	23	2	20–26
Shift	15	2	12–18

دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Acoustic Immittance Measures

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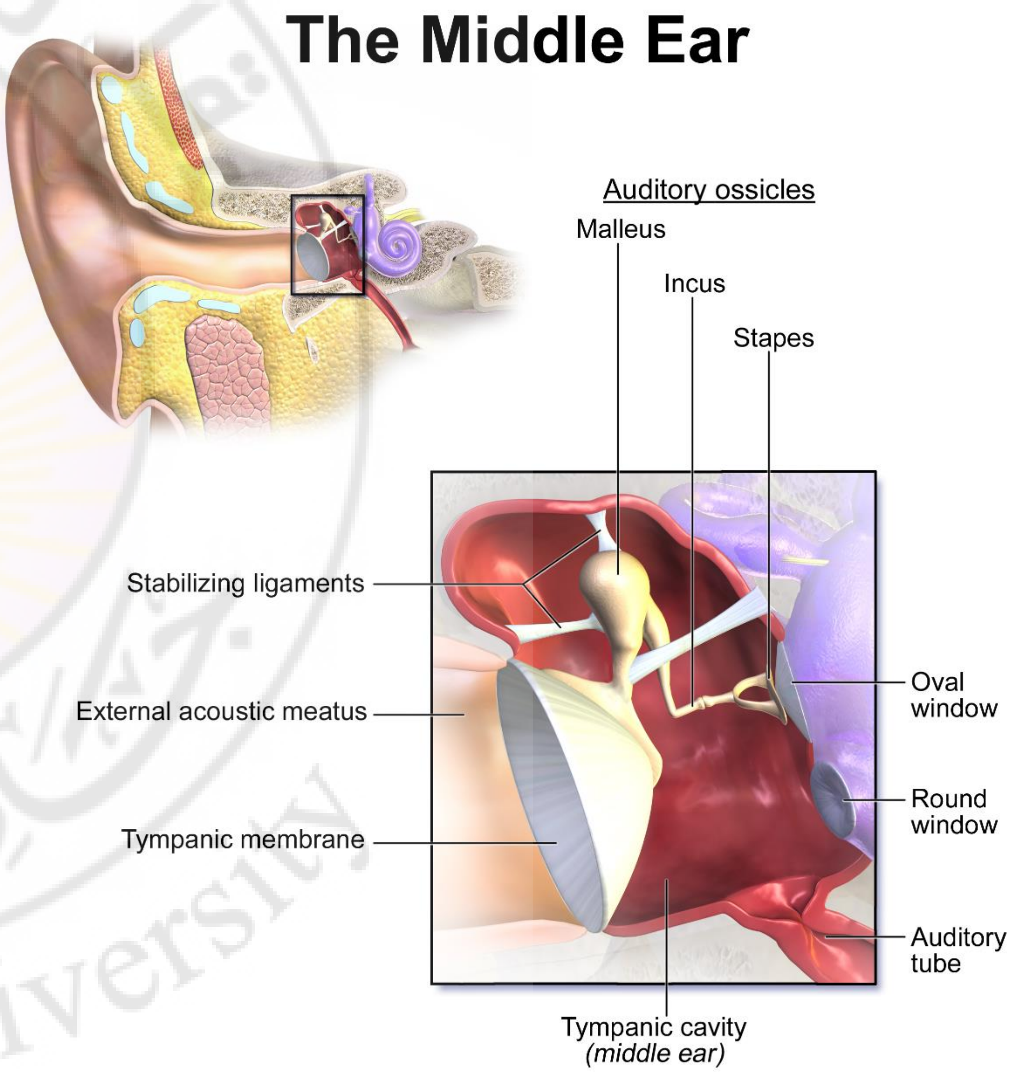
7. Acoustic stapedial reflexometry

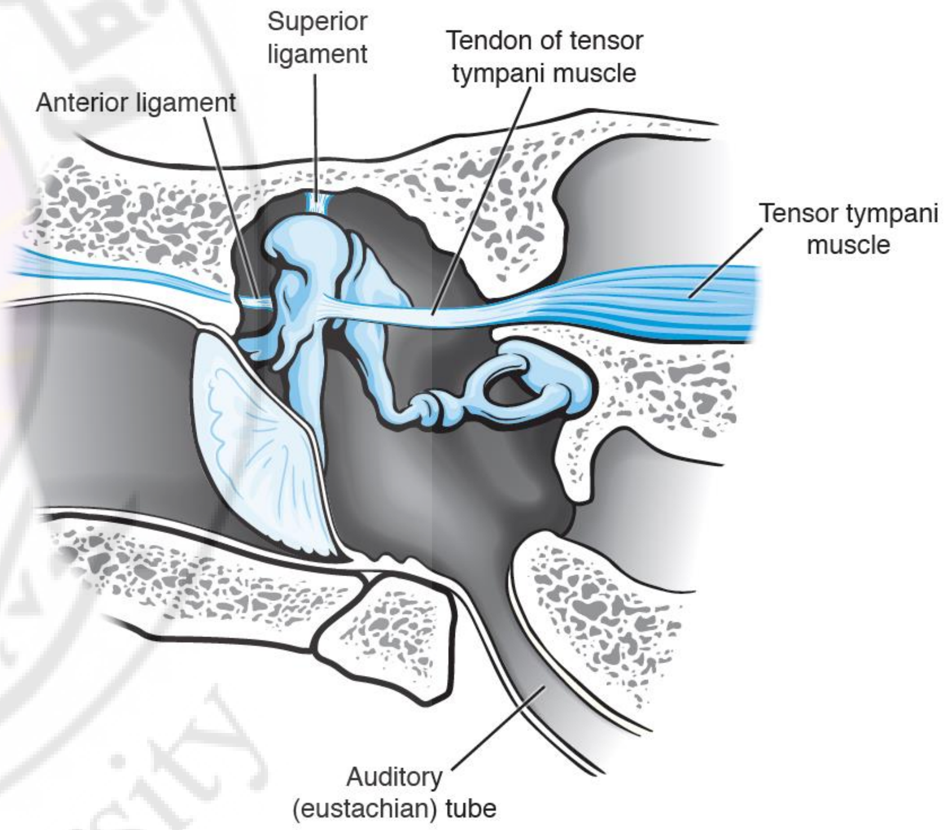
Acoustic Stapedius Reflex

- Presenting a sufficiently intense sound to either ear results in the contraction of the stapedius muscle in both ears; and is called the **acoustic** or **stapedius reflex**.
- This reflexive muscle contraction stiffens the conductive mechanism via the stapedius tendon, and therefore changes the ear's immittance.
- The acoustic reflex is easily measured because the immittance change is picked up by the probe tip and displayed on the immittance device meter.



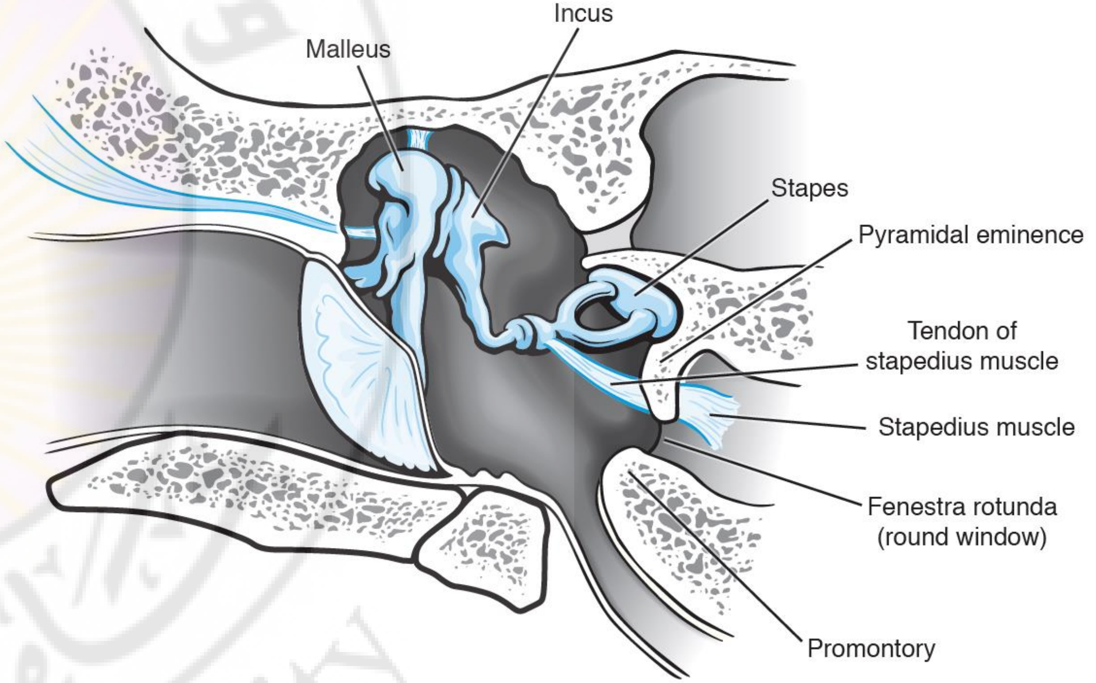
Middle ear muscles: Tensor Tympani

- The body of the tensor tympani muscle is located in a canal above the Eustachian tube in the anterior-medial wall of the middle ear.
- The tendon stretches from the body of the tensor tympani muscle to the manubrium of the malleus.
- When the muscle contracts, the tendon pulls the malleus anteriorly and medially, which stiffens the ossicular chain and tympanic membrane (TM).
- This muscle is innervated by **cranial nerve V** which is also called the **trigeminal nerve**.
- The tensor tympani may contract in response to *tactile stimulation* or as a *startle response* to loud unexpected sounds.
- However, the tensor tympani does not typically contribute to the MEMR measured clinically in humans.



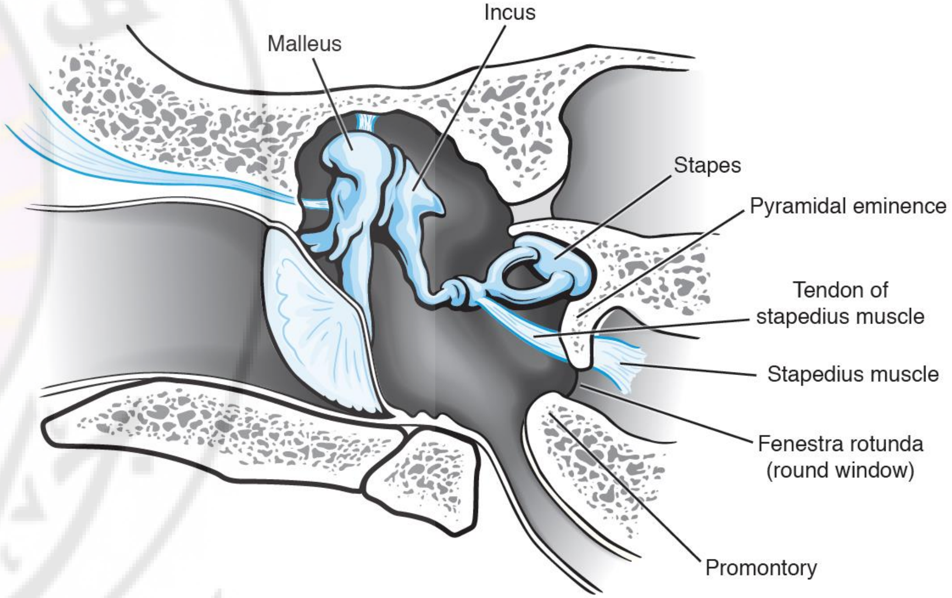
Middle ear muscles: Stapedius muscle

- The stapedius muscle is the smallest skeletal muscle in the human body, and it is the main contributor to the MEMR measured clinically in humans.
- The body of the stapedius muscle is located in the pyramidal eminence, or small bony protrusion, on the posterior wall of the middle ear.
- The tendon stretches anteriorly from the body of the stapedius muscle to the posterior surface of the neck of the stapes.
- The stapedius muscle is innervated by the motor branch of **cranial nerve VII** which is also called the **facial nerve**.

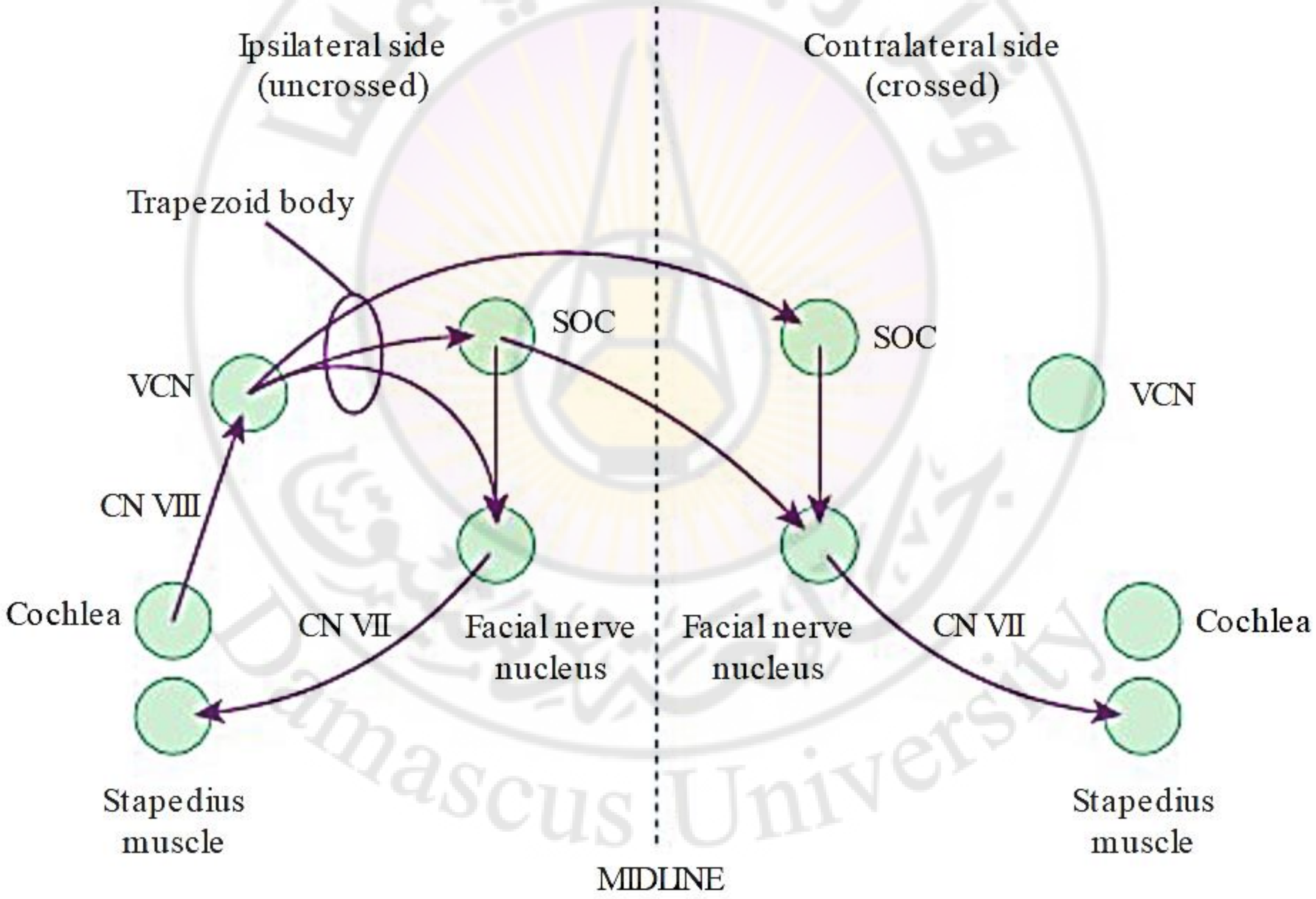


Middle ear muscles: Stapedius muscle

- When an intense sound is presented to the ear, the stapedius muscle contracts and pulls the head of the stapes posteriorly toward the muscle body, which causes an increase in stiffness of the ossicular chain and the TM.
- The stiffening causes a *decrease in admittance* of sound into the middle ear that can be measured by a probe in the ear canal, and this is the basis of clinical ASR measurements.
- The stapedius reflex also can be activated by vocalizations, chewing, yawning, and tactile stimulation.
- The ASR is a **bilateral response** which means that when an activating stimulus is presented to one ear the stapedius muscle contracts in both ears (Ipsilateral or Contralateral conditions).

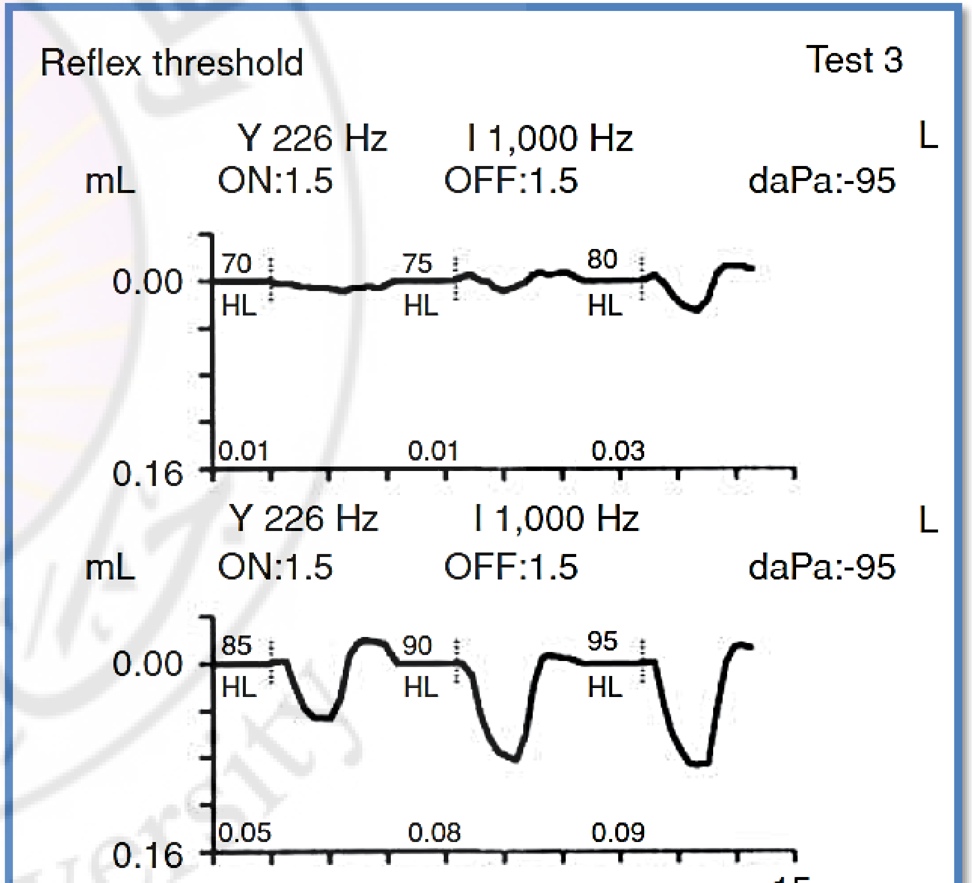


Acoustic reflex arc



Acoustic stapedius reflex (ASR) response example

- As the intensity of the eliciting stimulus increases, the amplitude of the ASR response increases.
- In this example; Acoustic stapedius reflex (ASR) response growth in an adult human ear with normal middle ear function and hearing in the left ipsilateral condition elicited by a 1,000-Hz activator (226-Hz probe tone) at levels of 70 to 95 dB HL.
- Response amplitude is plotted in mmho as a function of time in seconds.
- ASR is not elicited by 70- or 75-dB HL activators. However, from 80 to 95 dB HL the ASR is present and the amplitude increases as the activator level increases.



Functional Significance of Acoustic reflex

- **Protection theory (intensity control theory):**
  - the ASR reduces the amount of sound pressure that reaches the cochlea, and therefore it has a protective effect from high-level sounds.

- **Perceptual theory:**
  - the ASR provides humans with an advantage for understanding speech in noise because lower frequencies are attenuated relative to higher frequencies when the stapedius muscle contracts

Relevance to Clinical Practice

- ASR threshold and decay tests can be included in a **test battery**, along with tympanometry, otoacoustic emissions (OAEs), and behavioral puretone and speech tests, to differentiate among middle ear, cochlear, and retrocochlear sites of lesion.

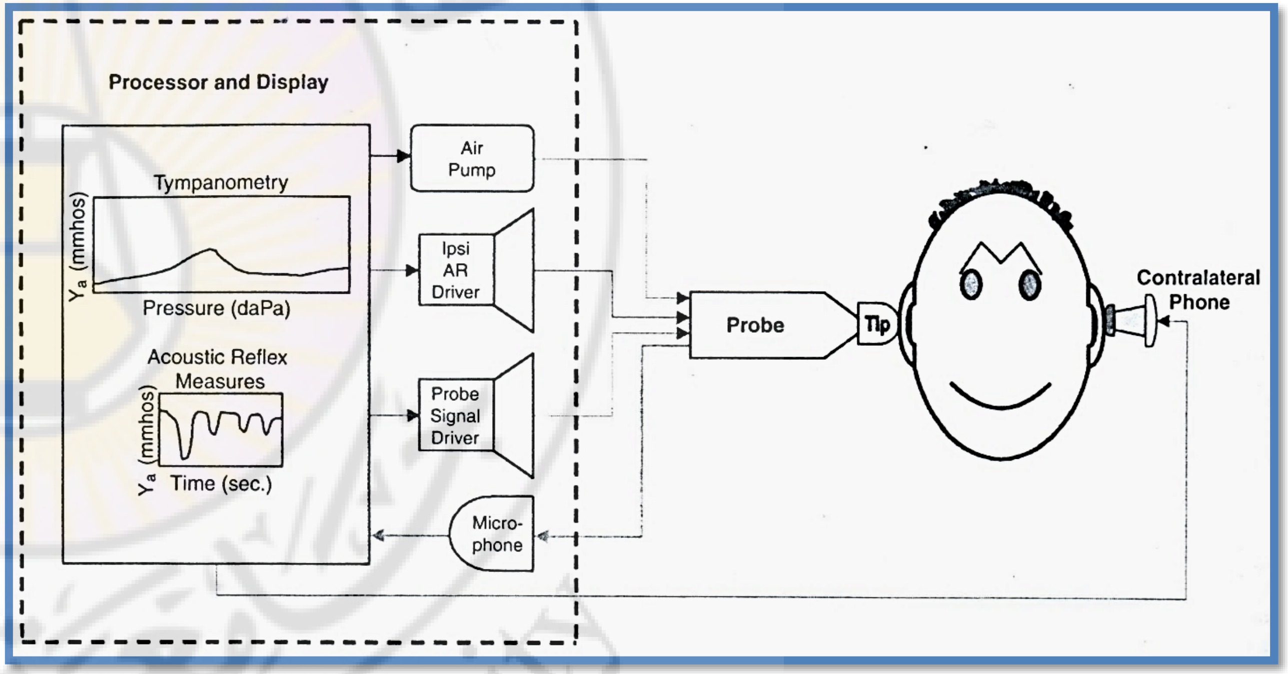
- ASR threshold also can be used as a **cross-check** with the behavioral audiogram to increase confidence in the diagnosis of hearing loss in young children with whom behavioral results may be questionable, and in older children and adults who may present with false or exaggerated hearing loss.

- Finally, the ASR thresholds can be used in **cochlear implant assessments** to verify function of the device and to set minimum or maximum stimulation levels in young children who cannot provide reliable threshold and loudness information.

Terminology

- ## Probe

- 226 Hz presented at 85 dB SPL (70 dB HL)
- Higher probe tone frequencies are required in newborns and infants



- ## Activator

- high-level acoustic stimulus that elicits the ASR.
- Activators include 500-, 1,000-, 2,000-, and 4,000-Hz puretones and broadband noise (BBN) of 1 to 2 seconds in duration.
- 4,000-Hz activators has relatively less diagnostic value because it is often elevated or absent in ears with normal hearing.
- Activator levels are typically available in 5-dB steps and should be limited in level, particularly for ASR decay tests, due to potential for temporary or permanent threshold shift.

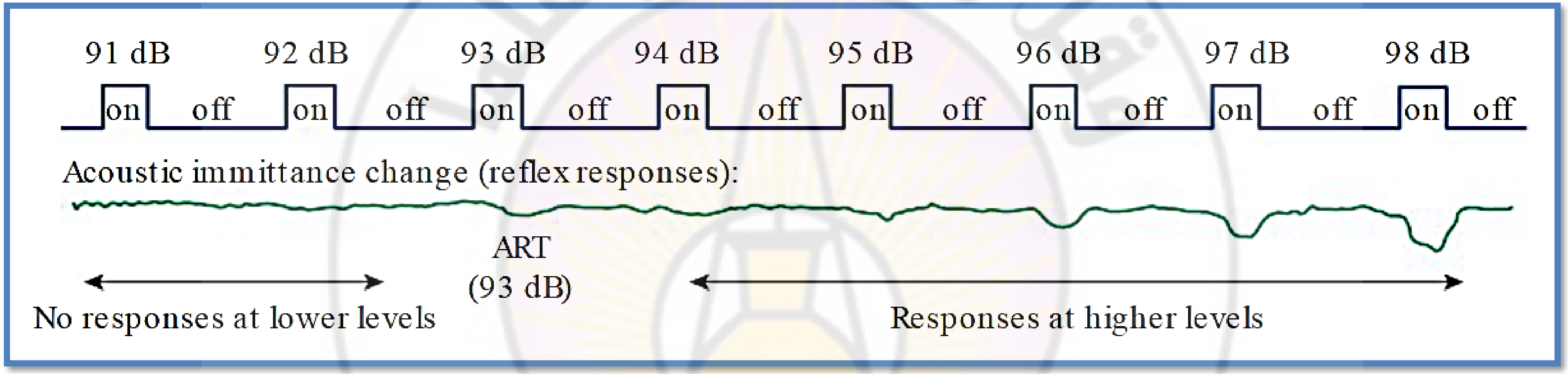
TABLE 10.1

Contralateral and Ipsilateral ASR Thresholds in dB HL for Puretone and BBN Activators in Young Adults with Normal Hearing (Wiley et al., 1987)

	Contralateral		Ipsilateral	
	Mean	SD	Mean	SD
500 Hz	84.6	6.3	79.9	5.0
1,000 Hz	85.9	5.2	82.0	5.2
2,000 Hz	84.4	5.7	86.2	5.9
4,000 Hz	89.8	8.9	87.5	3.5
BBN	66.3	8.8	64.6	6.9

SD, standard deviation.

Acoustic Reflex Threshold



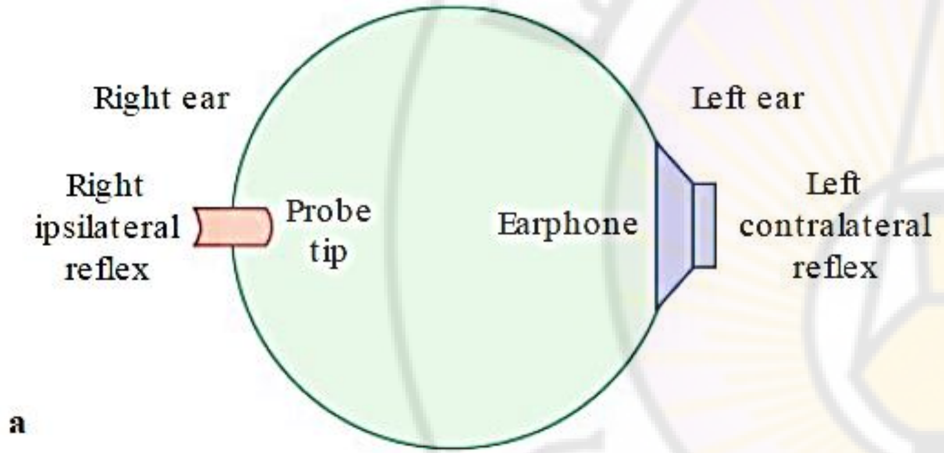
- Acoustic reflex threshold (ART) testing involves finding the lowest level of a stimulus (activator) that causes a measurable change in acoustic admittance.
- During an ASR test, the *admittance* (Ya) of the 226-Hz probe tone is continuously monitored. Admittance is the ease with which acoustic energy is admitted into the middle ear as estimated at the lateral plane of the TM.
- When the activator is presented, the stapedius muscle contracts, which stiffens the ossicular chain and TM, which creates a reduction in admittance of the probe tone at the TM.
- **Therefore, the ASR is measured as a decrease in admittance of the probe tone at the TM when the activator is presented.**

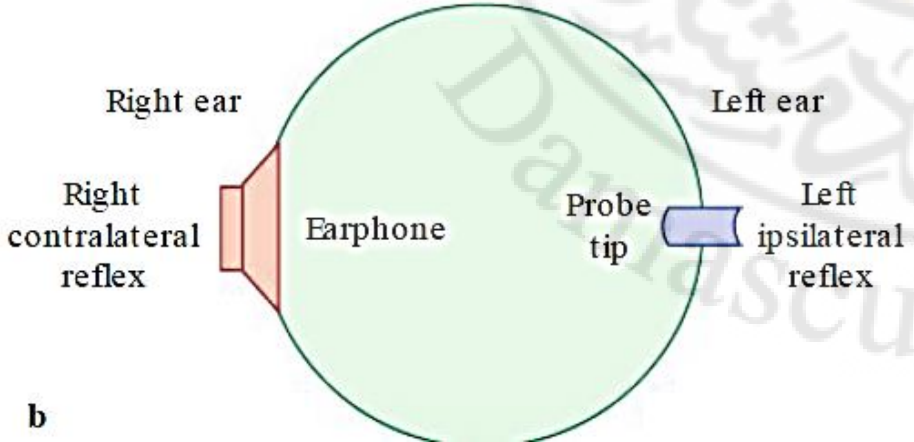
Instrumentation

- The equipment is the same as used for tympanometry.
- The instrument should have a manometer to monitor pressurization of the ear canal with an air pump, two speakers (one for the probe and one for the activator) and a microphone to measure the sound pressure level of the probe tone stimulus in the ear canal.
- **Diagnostic immittance equipment** may have multiple activators, probe frequencies, and ipsilateral and contralateral selections.
- **Screening immittance equipment** may only have the ability to present an ipsilateral activator at a single frequency and level.

Acoustic Reflex test conditions

The ASR test conditions are described based on the ear to which the activator is presented (ANSI, 2012).





a Arrangement in terms of stimulus and probe

TEST CONDITION	STIMULUS	PROBE
Right contralateral (crossed)	Right ear	Left ear
Left contralateral (crossed)	Left ear	Right ear
Right ipsilateral (uncrossed)	Right ear	Right ear
Left ipsilateral (uncrossed)	Left ear	Left ear

b Arrangement in terms of right ear and left ear

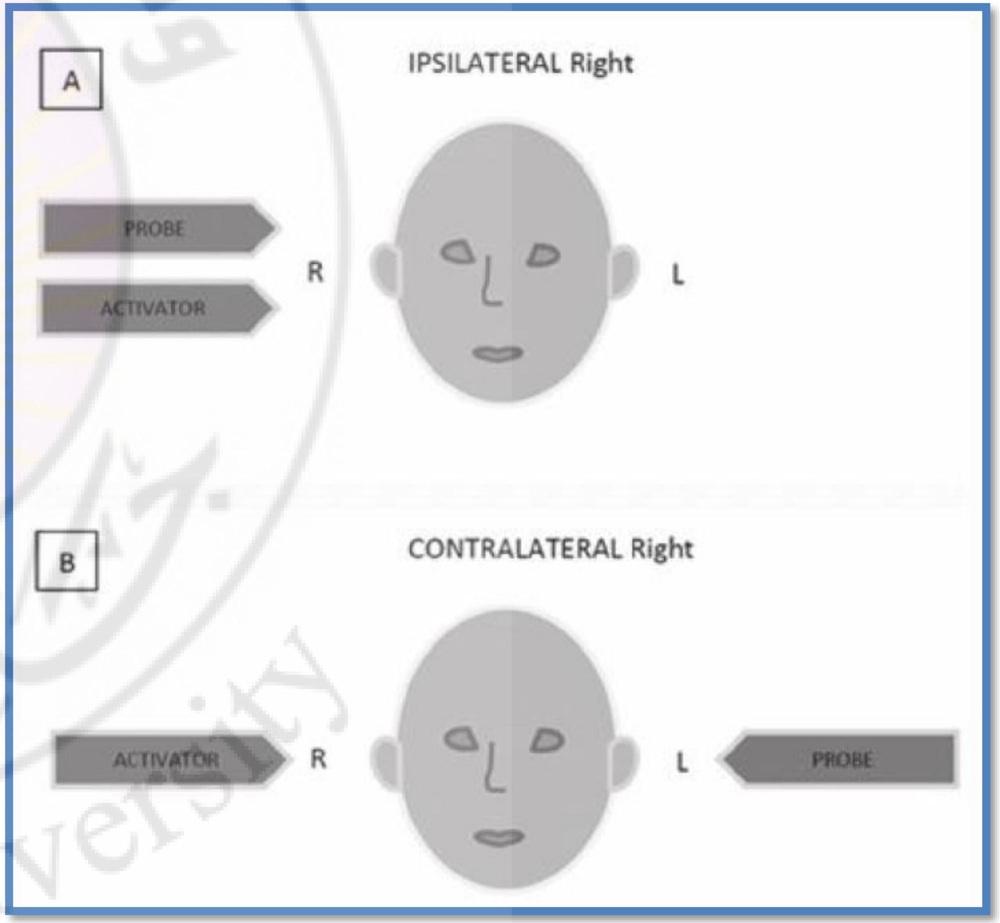
TEST CONDITION	RIGHT EAR	LEFT EAR
Right contralateral (crossed)	Stimulus	Probe
Left contralateral (crossed)	Probe	Stimulus
Right ipsilateral (uncrossed)	Stimulus & probe	
Left ipsilateral (uncrossed)		Stimulus & probe

Acoustic Reflex test conditions

The ASR test conditions are described based on the ear to which the activator is presented (ANSI, 2012).

Description of Stimulus Presentation Conditions for Ipsilateral and Contralateral ASR Measurements

Condition	Activator Ear	Probe Ear	Ear in Which ASR is Measured
Right contra-lateral	Right	Left	Left
Left ipsilateral	Left	Left	Left
Left contralateral	Left	Right	Right
Right ipsilateral	Right	Right	Right



Ipsilateral and Contralateral conditions advantages

- **Ipsilateral Reflex**

- Sensitive to middle ear effects because the probe and activator are presented to the same ear
- Ease of use in young children and other individuals who are difficult to test because it requires only one ear at a time
- No concern for collapsed ear canals (for systems in which a supra-aural earphone is used to present a contralateral activator).

- **Contralateral reflex**

- Sensitive to crossed pathways, and therefore mid-brainstem pathologies
- Less susceptible to artifact because the activator and probe stimuli are presented through separate transducers to the two ears
- More normative data available

Manual threshold estimation

- the probe tone is presented continuously and the activator is manually presented in 5-dB steps either from higher to lower levels or from lower to higher levels.
- The lowest level at which an activator elicits a **criterion change in admittance** is the ASR threshold for that activator.
- In a typical threshold search, the criterion change in admittance in the presence of the activator is **0.02 or 0.03 mmho**, depending on the selected normative data, and the response should be **time-locked** to the onset of the stimulus (e.g., not associated with patient movement, swallowing).
- The response should be **repeatable** at the level defined as threshold with at least two presentations of the activator.
- Moreover, a response should be present (with possible growth of the admittance change) for an **activator 5 dB above threshold** as long as that does not exceed 105 dB HL.s

Automated threshold estimation

- **Screening**
  - the ASR test may be limited to ipsilateral, single-frequency (usually 1,000 Hz), single-level (90 or 95 dB HL), single presentation tests and the outcome is either ***pass or fail***.

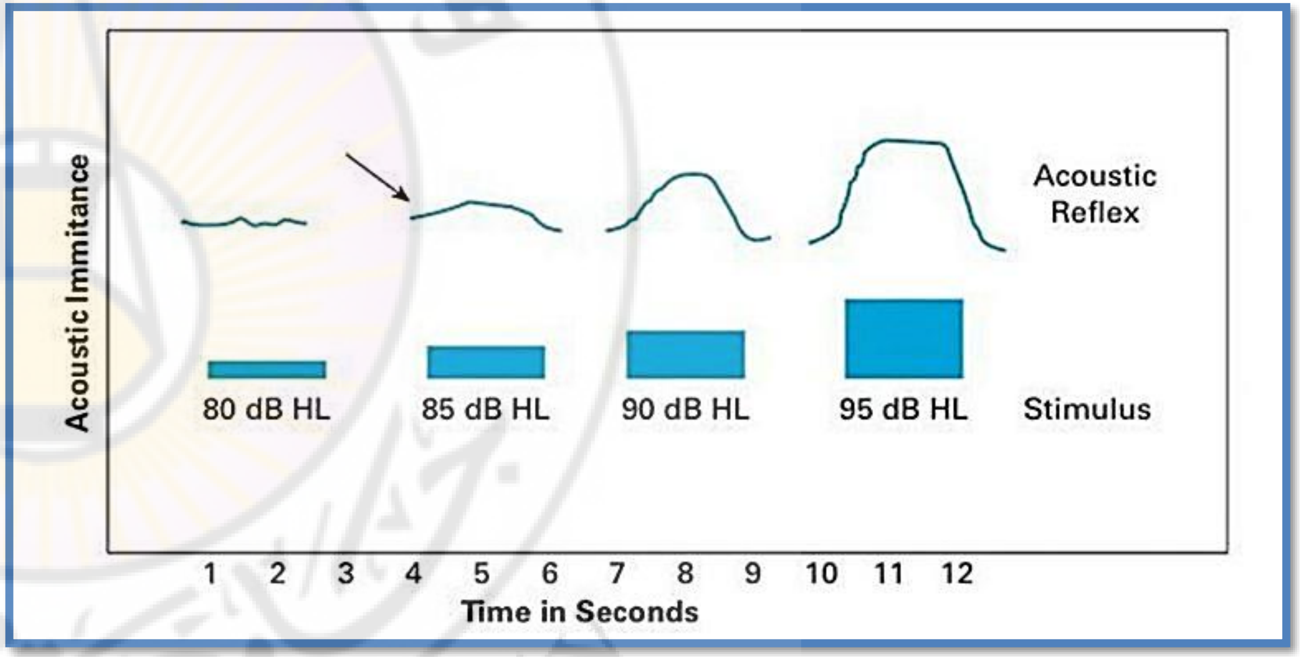
- **Diagnostic**
  - Diagnostic equipment may have the same type of screening procedure, and in addition, they may have the ability to store user defined threshold estimation procedures.

Point: inclusion of an ASR test in hearing screening is not recommended (ASHA, 1990) due to contribution of absent ASRs to high false-positive and medical over-referral rates.

Normative Data

- ASR thresholds should be about **70 to 90 dB** above behavioral air conduction thresholds at corresponding activator frequencies in ears with normal hearing.

- These general guidelines are predicated on the assumption that the ear canal is clear and middle ear function is normal.

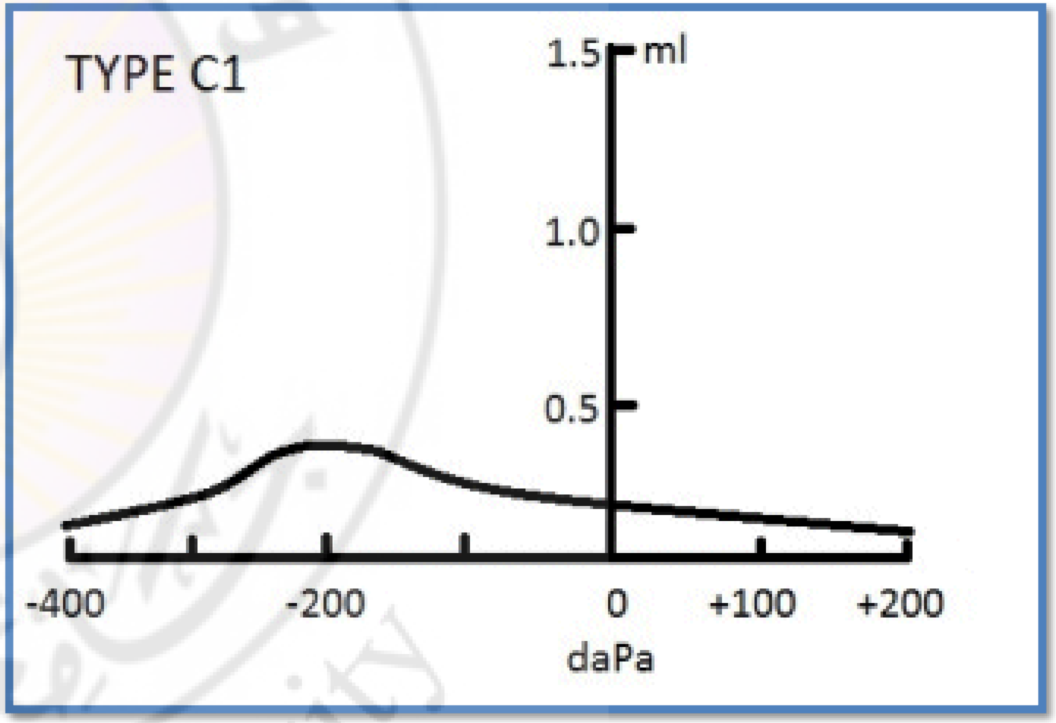


Clinical Considerations

Hermetic Seal and Ear Canal Pressure

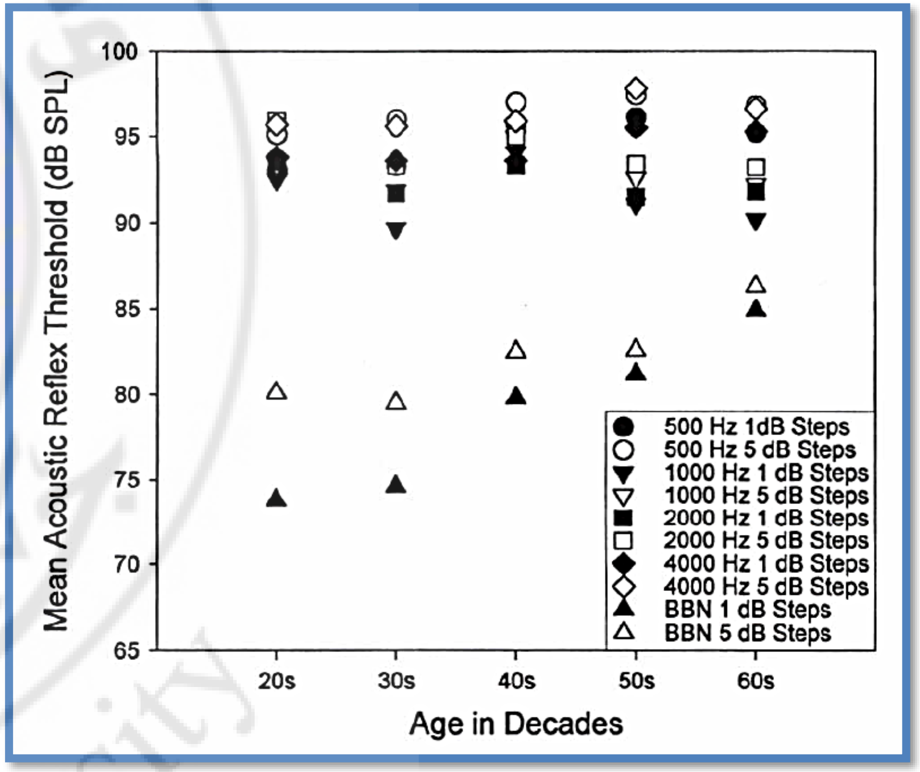
- Acoustic reflexes should be obtained at the point of **tympanometric peak pressure (TPP)**, which usually requires the probe tip to be inserted so that it provides an airtight seal for the ear canal.

- Hermetic seal is critical in conductive disorders, as reflexes would be absent without a seal.



Gender And Age Effects

- There are no significant effects of **gender**.
- However, there are two effects of **age** on ASR thresholds:
  - First, ASR thresholds in adults increase with age for BBN activators beginning around 44 years of age, and increase with age above 50 years for puretone activators above 2,000 Hz.
  - Second, higher probe tone frequencies must be used to increase the probability of observing an ASR in newborns and young infants. By 6 months of age, a 226-Hz probe tone can be used for tympanometry and ASR measurement.

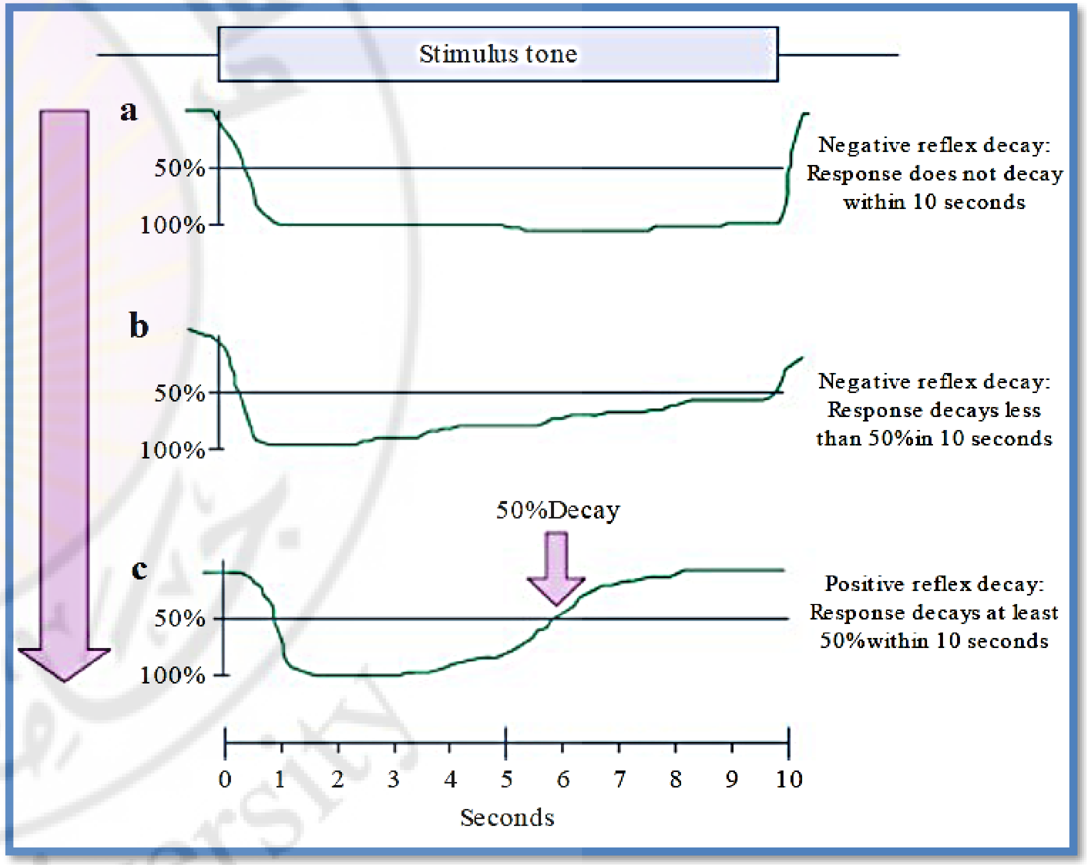


Pharmacological Effects

- Elevated ASR thresholds have been reported with **alcohol**, **barbiturates** and **chlorpromazine**, an antipsychotic drug.
- **Barbiturates** have been reported to produce elevated ARTs, with a greater effect contralaterally than ipsilaterally, as well as increases in acoustic reflex latency.
- **Ethyl alcohol** results in elevated ARTs. This effect is similar for both contralateral and ipsilateral reflexes, but is larger for broadband noise than for puretone stimuli.
- Acoustic reflex magnitudes are reduced and ARTs are elevated by **curare**.
- ARTs are elevated by **chlorpromazine**.

Reflex Decay

- The 226-Hz probe tone is used with a 500- or 1,000-Hz activator for the standard ASR decay test.
- The ipsilateral or contralateral activator is presented for 10 seconds at 10 dB above the ASR threshold for the activator (Should not exceed 105 dB HL).
- The activator should elicit a reflex and a decrease in admittance should be observed that is essentially constant for the entire 10 seconds.
- In ears with **8th nerve disorders**, "abnormal" or "positive" decay is observed, meaning the amplitude of the reflex decreases by half its initial magnitude in less than 10 seconds.

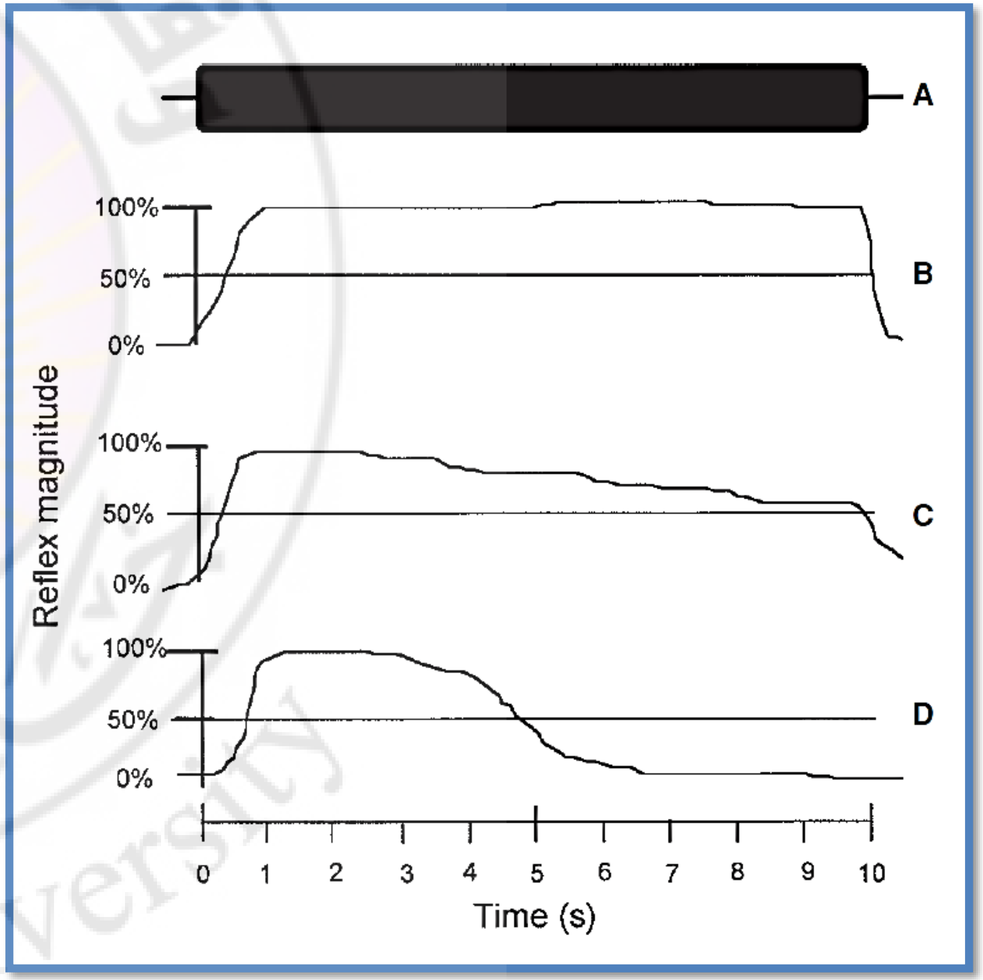


Disadvantages of Reflex Decay

1. The test often cannot be completed because ASR is absent or elevated to the point that 10 dB sensation level (SL) re: ASR threshold cannot be presented for the decay test.

2. It has poorer sensitivity/specificity than the ABR for retrocochlear disorders.

3. Temporary and permanent threshold shifts have been reported with high-level activators.



Reflex Latency

- The latency of the acoustic reflex varies by activator, but in general it is around **100 ms** which reflects the travel time of the signal from the cochlea through the pathway to the stapedius muscle.
- When the response is being clinically measured, the latency includes the inherent delay of the measurement system.
- ASR increased latencies have been reported in ears with **retrocochlear disorders** such as vestibular schwannomas, and it has been suggested that latency may be useful in separating cochlear from retrocochlear sites of lesion.
- However, ASR latency is not routinely measured clinically

Means and 95% Normal Ranges of Acoustic Reflex Latencies[a] (in Milliseconds) of Normal-Hearing Individuals for Tonal, BBN, and Click Stimuli Presented at 10 dB Above the ART

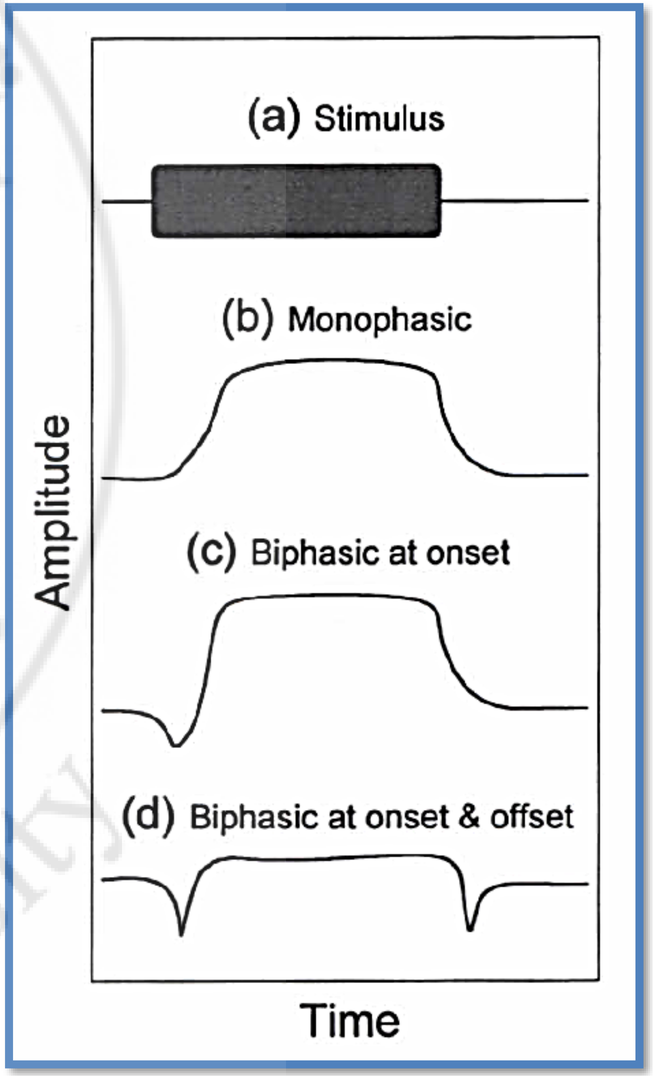
Stimulus	500 Hz	1000 Hz	2000 Hz	4000 Hz	BBN	Clicks (50/sec)
Contralateral						
Mean	102.8	101.9	127.7	147.3	132.3	156.7
95% range	56.0–149.6	51.7–152.1	66.5–188.9	77.9–216.7	59.7–204.9	107.0–206.3
Ipsilateral						
Mean	104.4	102.0	115.2	144.2		
95% range	59.2–149.6	51.4–152.0	70.6–159.8	74.8–213.6		

Data were obtained by using the Grason-Stadler GSI-33 Middle Ear Analyzer, with latencies defined as the point at which the acoustic reflex response magnitude achieves 10% of its eventual maximum value. Based on findings by Qiu & Stucker (1997).

[a] Measured for the admittance (Y) component with a 226-Hz probe tone.

Biphasic Responses

- The acoustic reflex response is generally conceptualized as an increase in impedance (or a decrease in admittance) over its entire duration.
- However, many normal reflex responses are actually biphasic, with a brief drop in impedance at the onset of the response, followed by increased impedance for the remainder of its duration.
- A different kind of biphasic pattern involves impedance drops at both the onset and offset of the reflex response. This abnormal pattern of biphasic response is associated with otosclerosis, especially in its earlier stages.
- It has also been reported to occur in **Cogan's syndrome, congenital stapes fixation, and osteogenesis imperfecta**.
- Whereas biphasic responses at both onset and offset occur in normal ears when the probe-ton frequency is in the 600- to 700-Hz range, the abnormal biphasic response associated with otosclerosis occurs *at all frequencies*.



Acoustic Reflexes And Disorders

Prerequisites for recording AR

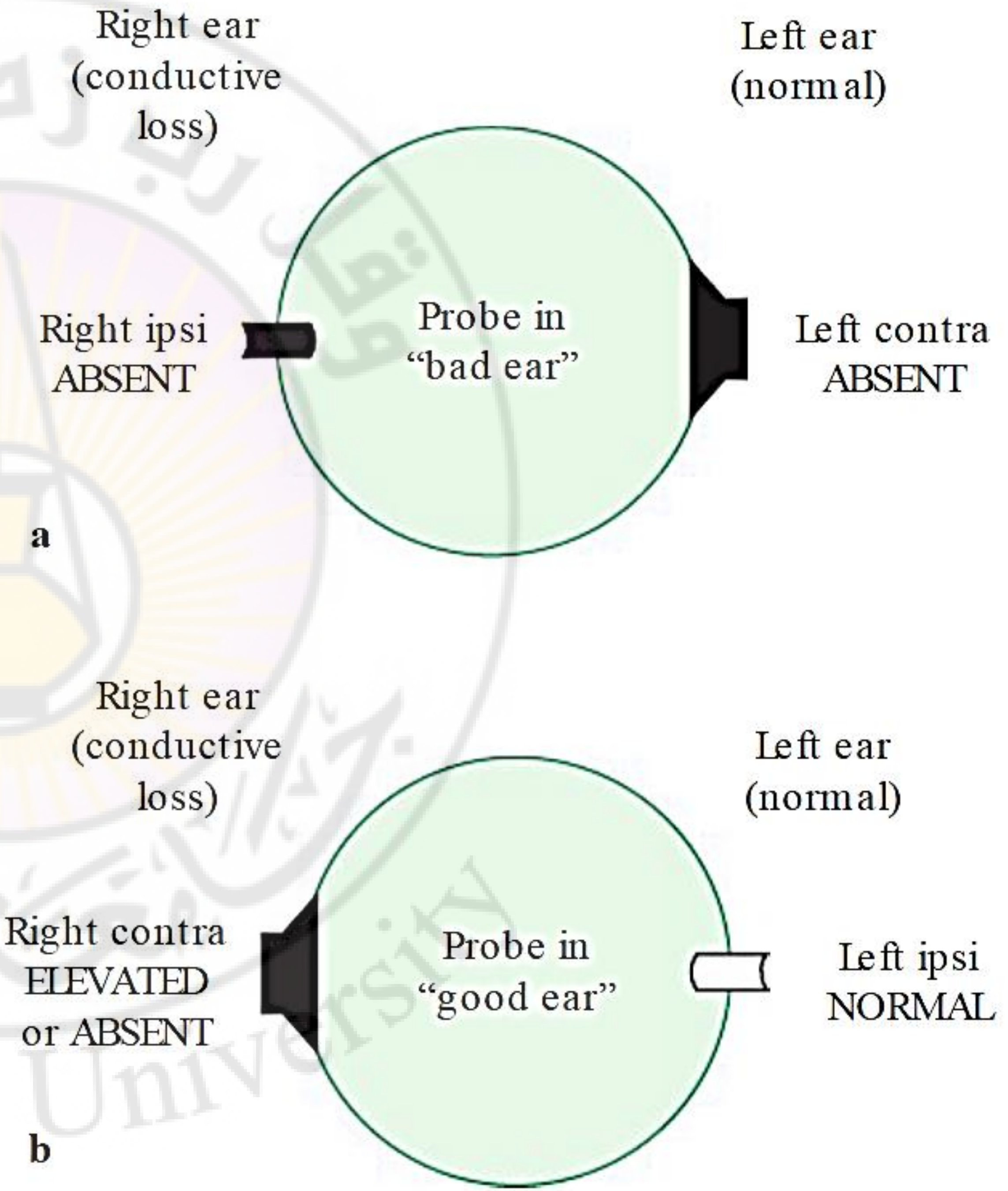
- **Normal conductive system**
- **Normal acoustic reflex neuronal arc**
- **Normal hearing sensitivity**

- Conductive hearing loss
- Sensory neural hearing loss
- Retrocochlear disorders
- Facial nerve disorders

Case 1:

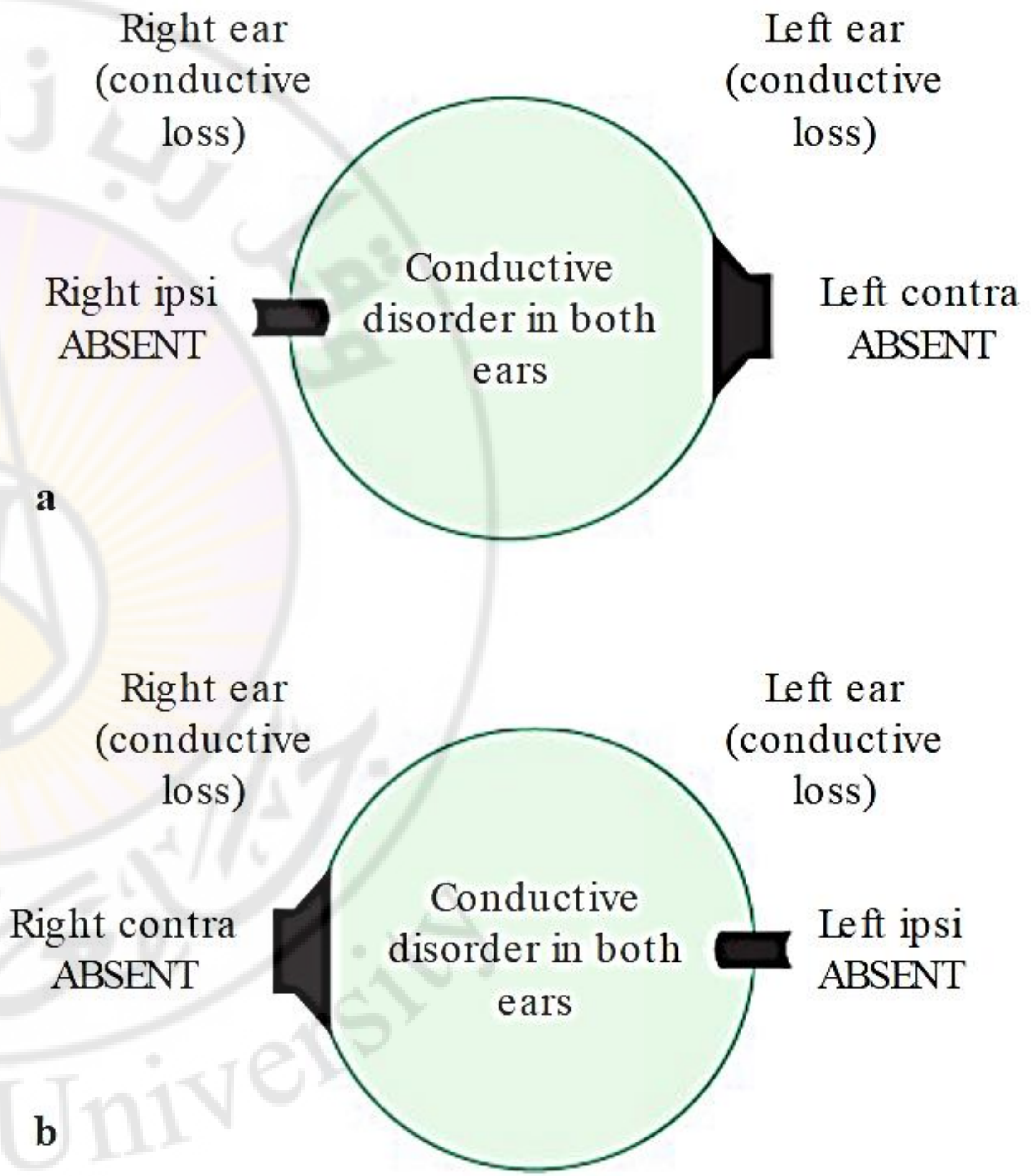
Unilateral Conductive Hearing Loss

Only 10 dB air-bone-gap would be enough to eliminate the AR.



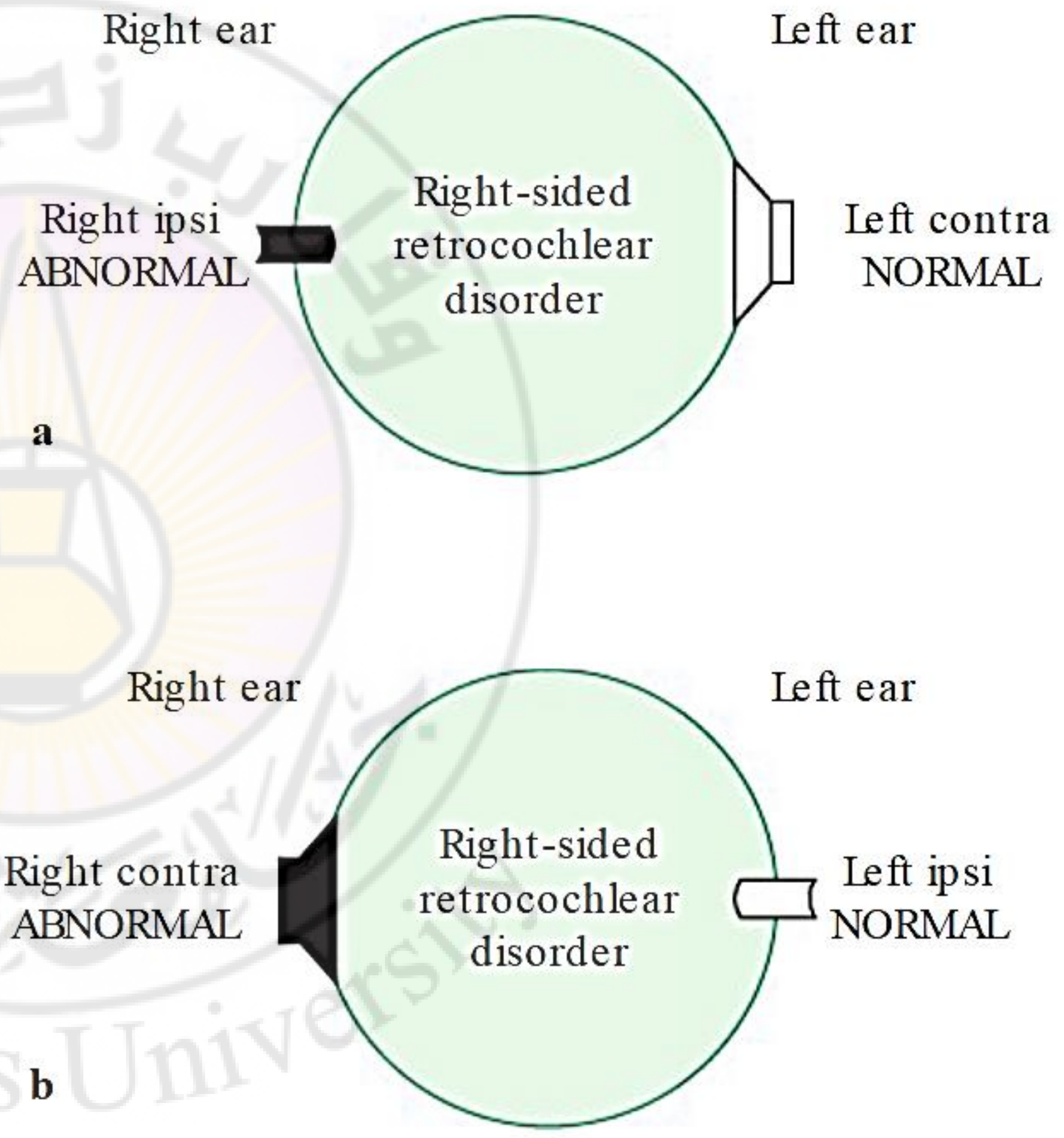
Case 2:

Bilateral Conductive Hearing Loss



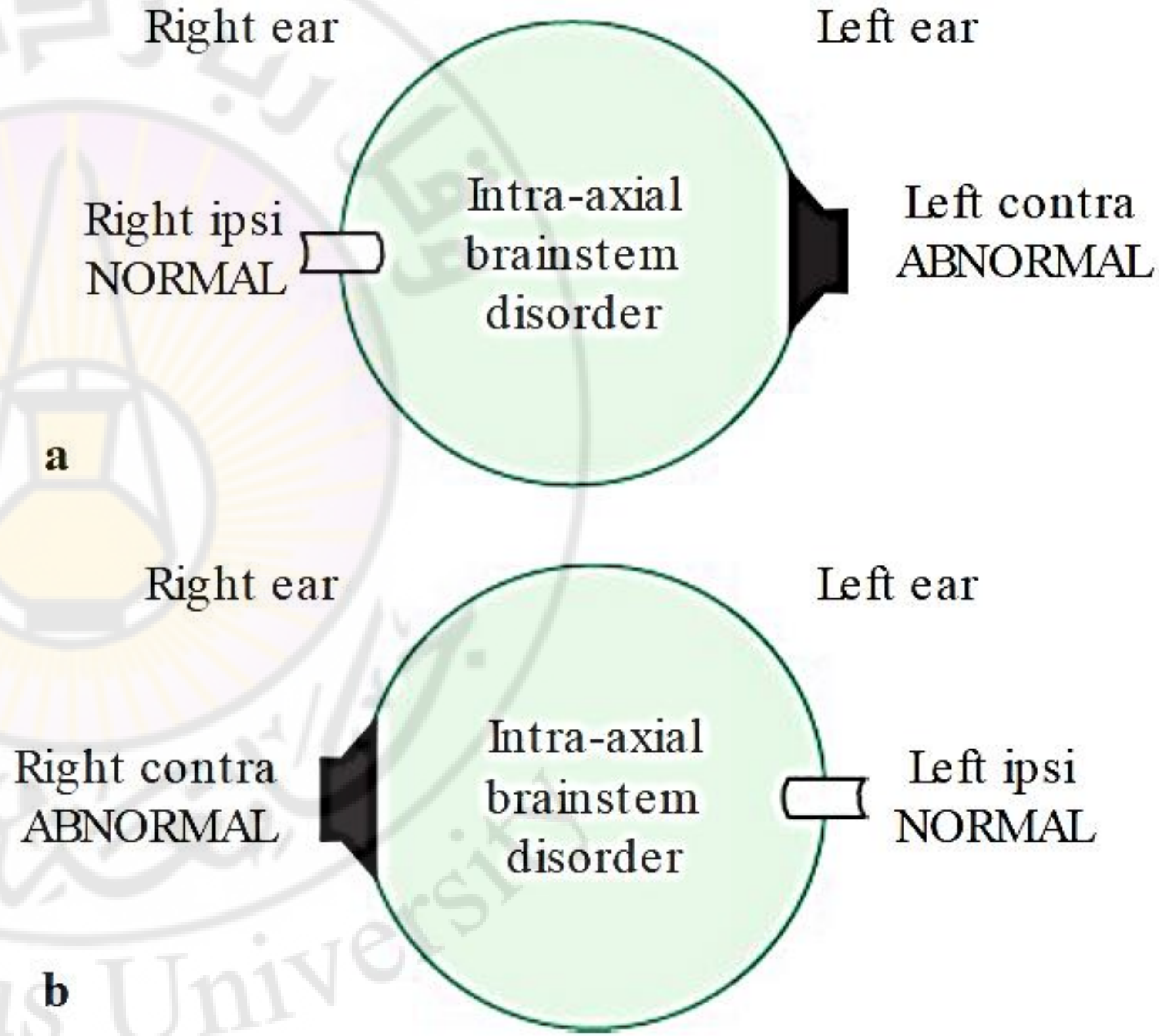
Case 3:

Unilateral SNHL (Retrocochlear origin)



Case 4:

Intra-axial Brainstem disorder



Case 5:

Unilateral facial nerve disorder

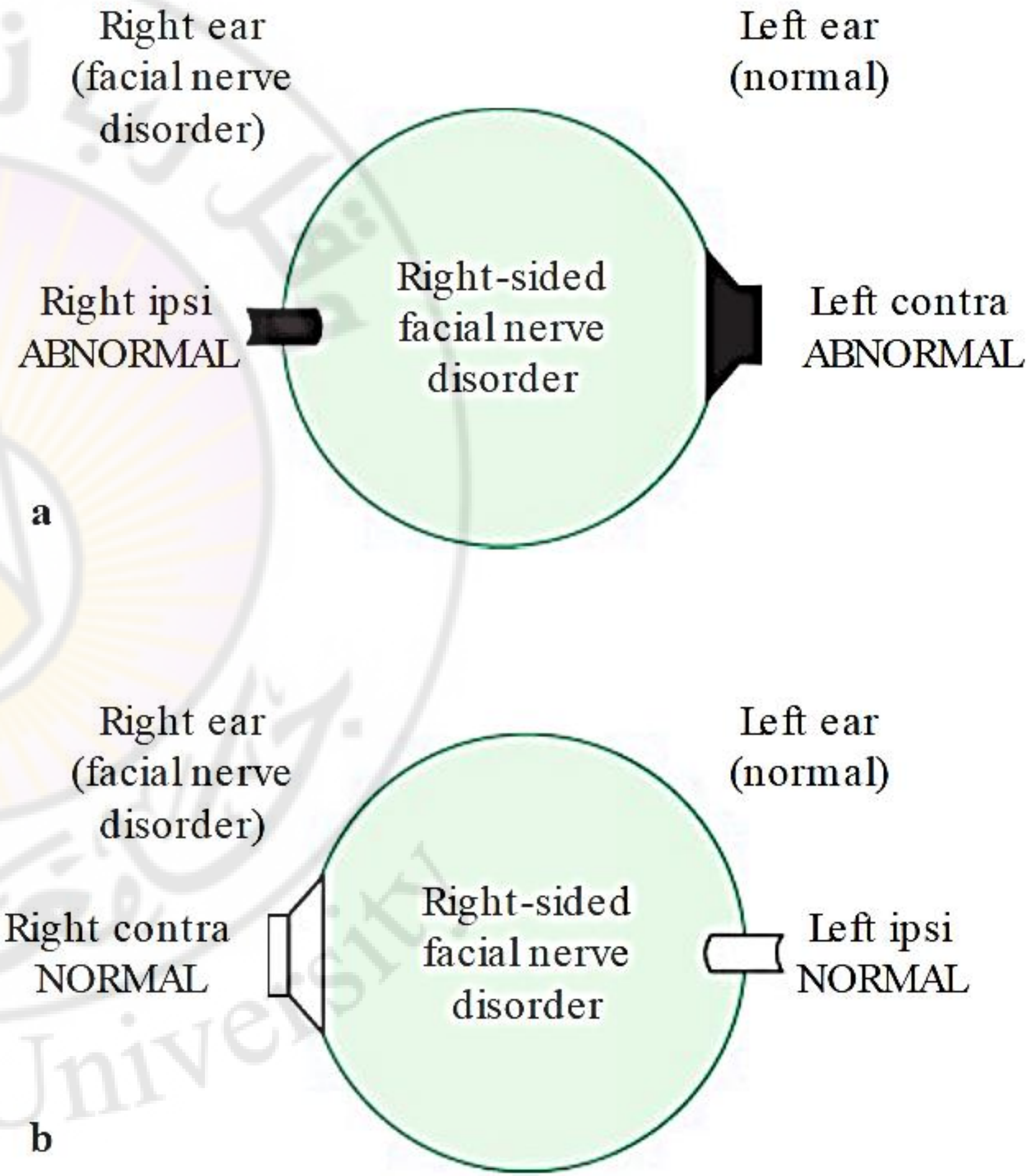


Table 6–1. Patterns of Acoustic Reflex Effects for Various Pathologies for the Affected and Unaffected Ear

Site of Lesion and Laterality	*Ipsi— affected ear*	*Contra— affected ear*	*Ipsi— unaffected ear*	*Contra— unaffected ear*
Middle ear, unilateral	A	A or E depending on severity of the loss	N	A
Middle ear, bilateral	A	A	A	A
Cochlea, unilateral (see Table 6–4)	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss	N	N
Cochlea, bilateral (see Table 6–4)	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss
Eighth cranial nerve, unilateral	E, A, D	E, A, D	N	N
Eighth cranial nerve, bilateral	E, A, D	E, A, D	E, A, D	E, A, D
Seventh cranial nerve, unilateral[a]	A	N	N	A
Seventh cranial nerve, bilateral[a]	A	A	A	A
Brainstem, unilateral, extra-axial	E, A, D	E, A, D	N	A, N
Brainstem, midline/ intra-axial	N	A	N	A

For abnormal elevation for any given hearing loss, consult Table 6–4.
[a]Proximal to the stapedial branch.
A, absent; *E,* elevated; *N,* present at normal intensity; *D,* decay.

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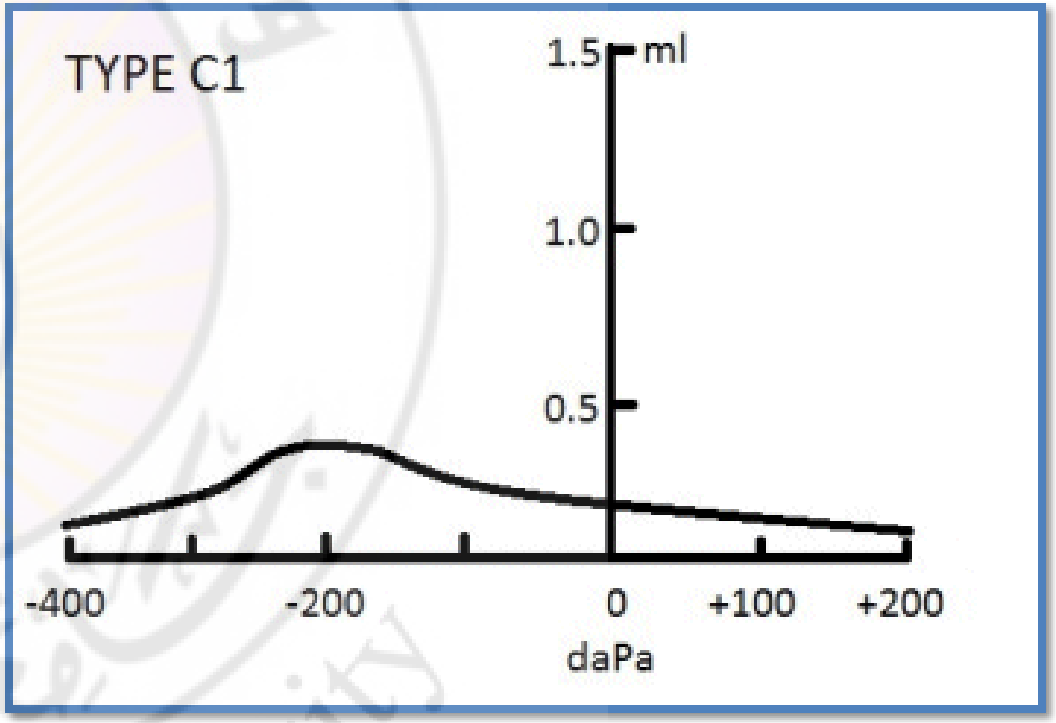

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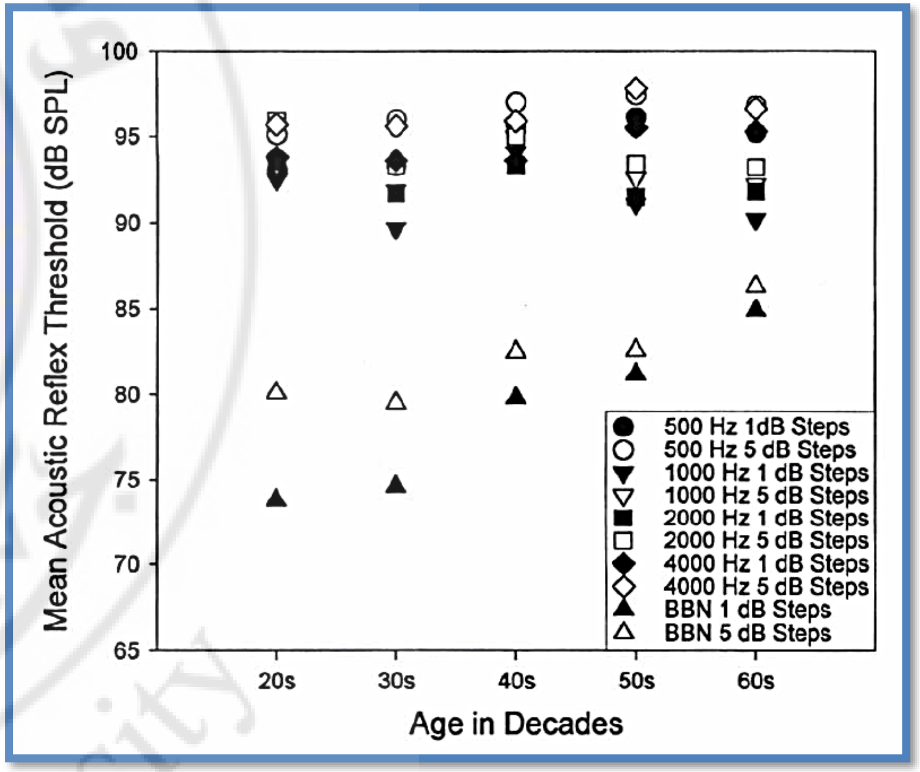

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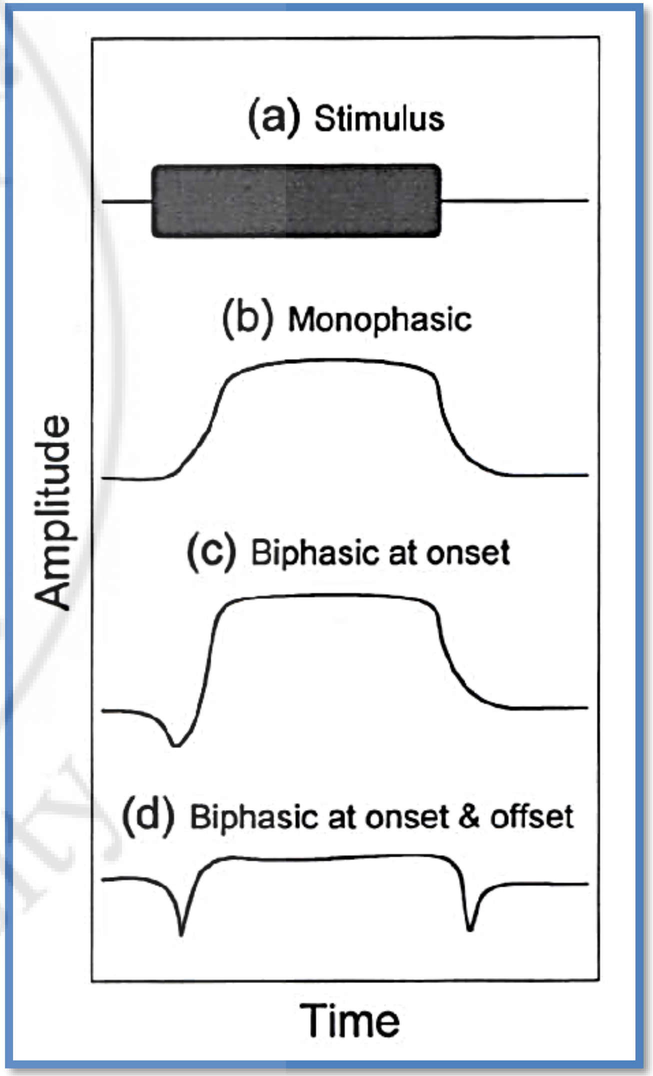


Acoustic Reflexes And Disorders

Prerequisites for recording AR

- **Normal conductive system**
- **Normal acoustic reflex neuronal arc (No abnormal adaptation to stimulus)**
- **Normal hearing sensitivity (Loud enough stimulus to elicit the response)**

- Conductive hearing loss
- Sensory neural hearing loss
- Retrocochlear disorders
- Facial nerve disorders

About 5% of the adult population have absent acoustic reflexes!

Recording Acoustic Reflex

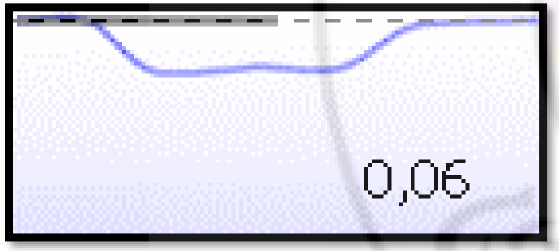
- The pure tone intensity range to elicit an acoustic reflex is 70 to 100dBHL (median = 85 dBHL).
- **Ipsilateral ARTs** in patients with normal hearing are usually 70-80dB above their pure tone thresholds, and about 5dB greater for their contralateral threshold (i.e., if pure tone thresholds were at 10dBHL, you would expect ipsilateral ARTs between 80 – 90dBHL and contralateral ARTs between 85-95dBHL as an approximation).
- Generally, **noise stimuli** elicit reflexes at lower levels than pure tones do; approximately 20dB lower.
- It is not recommended to go above 105dBHL unless you suspect a conductive loss. Acoustic reflex testing can cause permanent hearing damage and tinnitus and while there are no standards for **safe presentation levels**, most of the literature recommends testing no higher than 105-110dBHL.
- Generally a 226Hz probe tone is used unless neonates are being tested. In this case a high frequency probe tone is used (1000Hz).

Contra-indicators for reflex testing

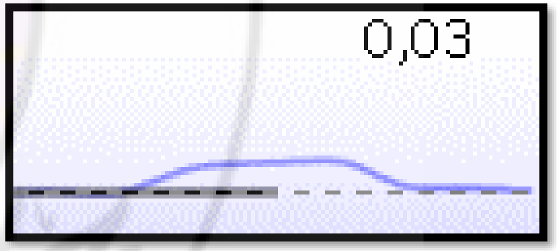
- Tinnitus
- Outer ear infection
- Severe recruitment
- Hyperacusis

Positive or negative reflex display

- Reflexes will either be displayed positively and negatively, depending on your setup of it.



A negatively displayed reflex



A positively displayed reflex

Acoustic reflex testing procedure

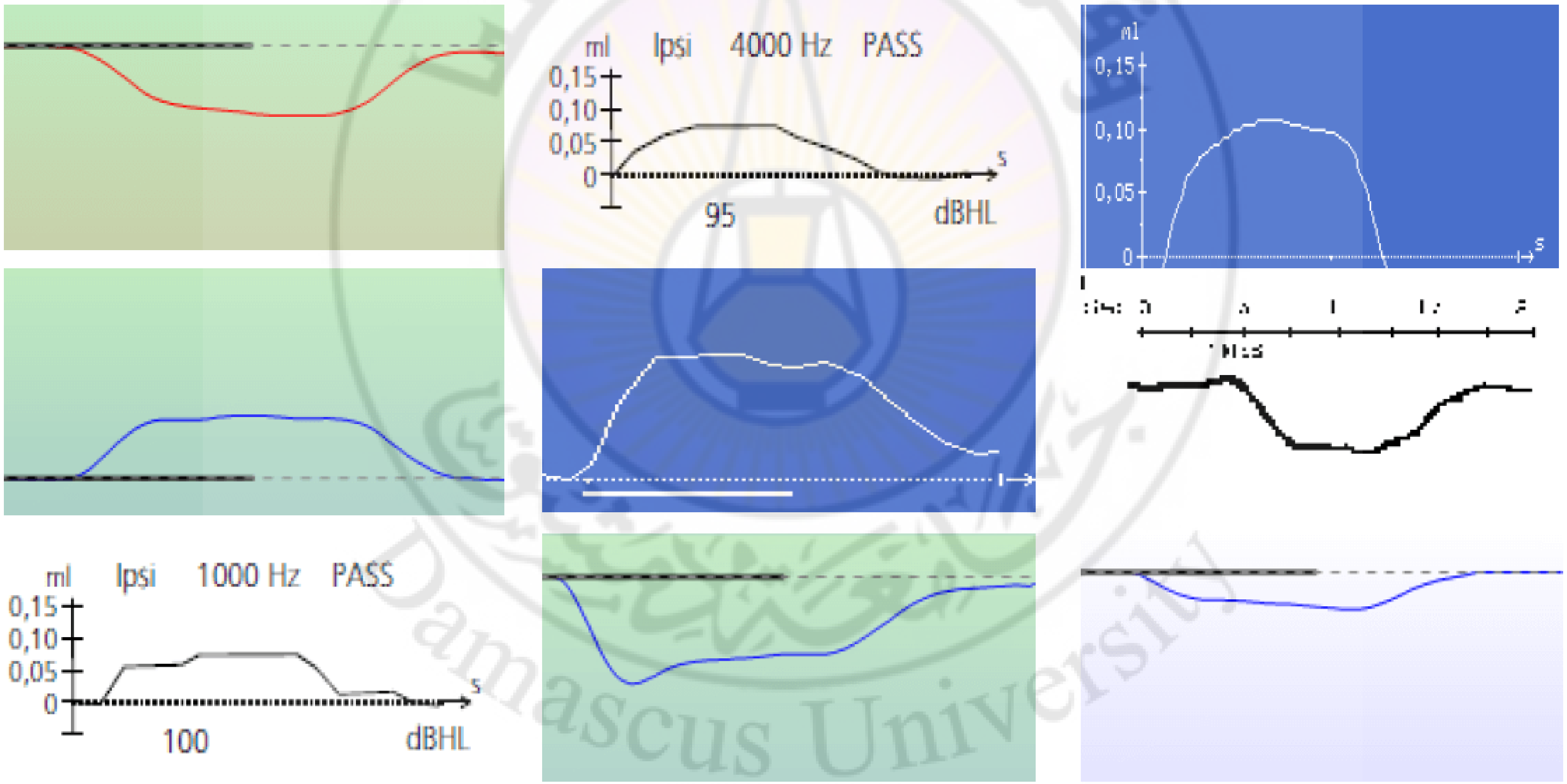
1. Alert the client that they will hear some loud sounds in either ear.
2. Ask them to sit still and quiet.
3. Place the immittance probe (probe used for tympanometry) into the ear you want to test. Place the contralateral probe into the other.
4. Perform tympanometry first. Acoustic reflexes should be measured with the ear canal pressure set to obtain maximum compliance in the presence of the 226Hz probe tone (i.e., after tympanometry).
5. Press Start. The measure will then run a reflex growth and stop automatically when a reflex is present with the defined threshold criteria. If the tone is loud enough and a contraction of the stapedius muscle occurs, the immittance probe will record that an acoustic reflex is present.
6. You can confirm the presence of a reflex by running the measure twice at the same intensity to confirm that the found threshold is reproducible. Alternatively, the measure can be repeated manually 5dB above the ART obtained to ensure it is a true.

Reasons for repeating reflex measurements

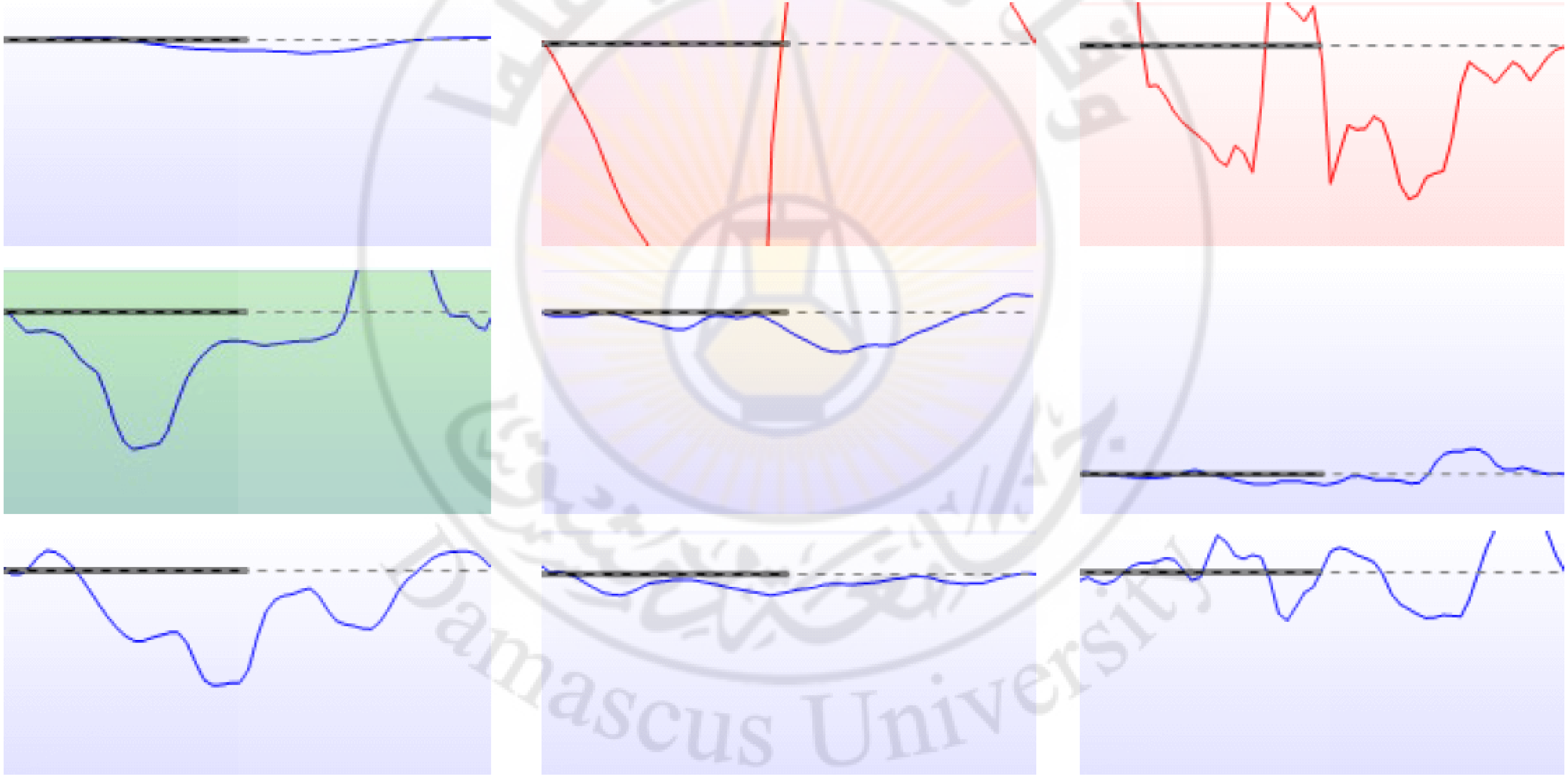
- If any of the following occur during testing, it is wise to retest to confirm your results are true:

1. Client swallows, talks, laughs, coughs during the test.
2. You get an **odd result** that does not look correct or does not match audiogram findings.
3. **Collapsed canals** can lead to false results, particularly if a headphone is used on the contralateral Recheck results if they look suspicious or do not fit with the other test battery of results.

Examples of acoustic reflexes



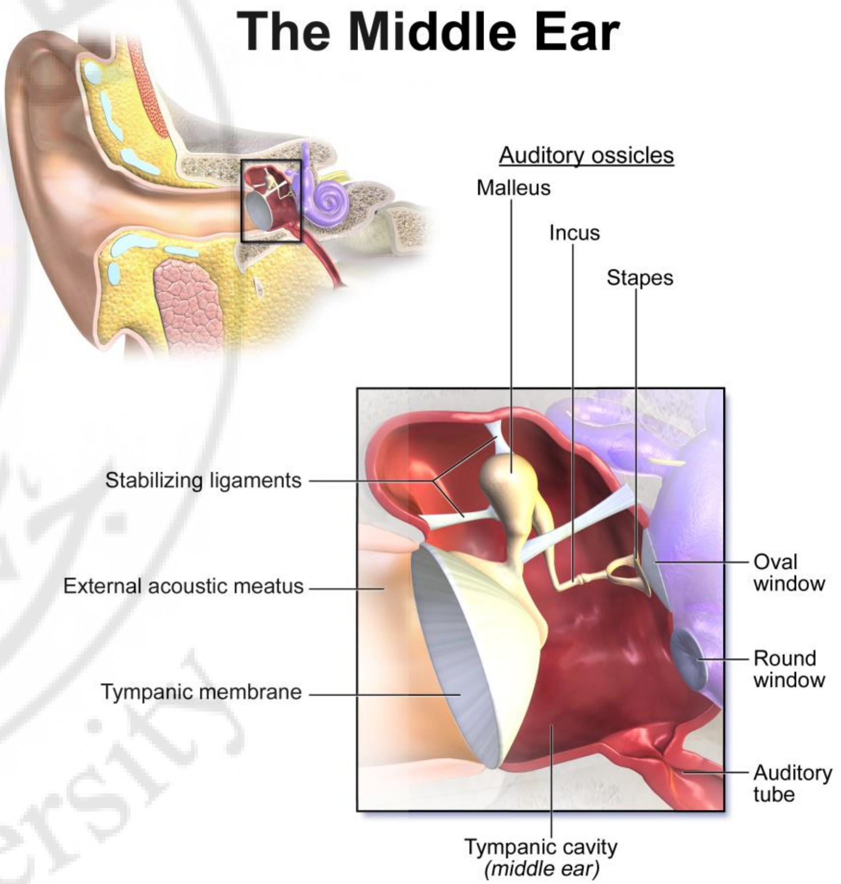
Examples of non-reflexes



ACOUSTIC REFLEX PATTERNS

Acoustic reflex patterns

- There are **nine examples** of reflex patterns you may come across during testing. However, you should be aware that these are not the results or patterns that you will see every time you test and real life clinical interpretations are much more complex.
- Different authors publish patterns or record results in different ways and therefore these examples are a guide only.
- Note that reflexes at **4000Hz** may or may not be present due to variability at this frequency. You may wish to use a BBN as an alternative to testing at 4000Hz.



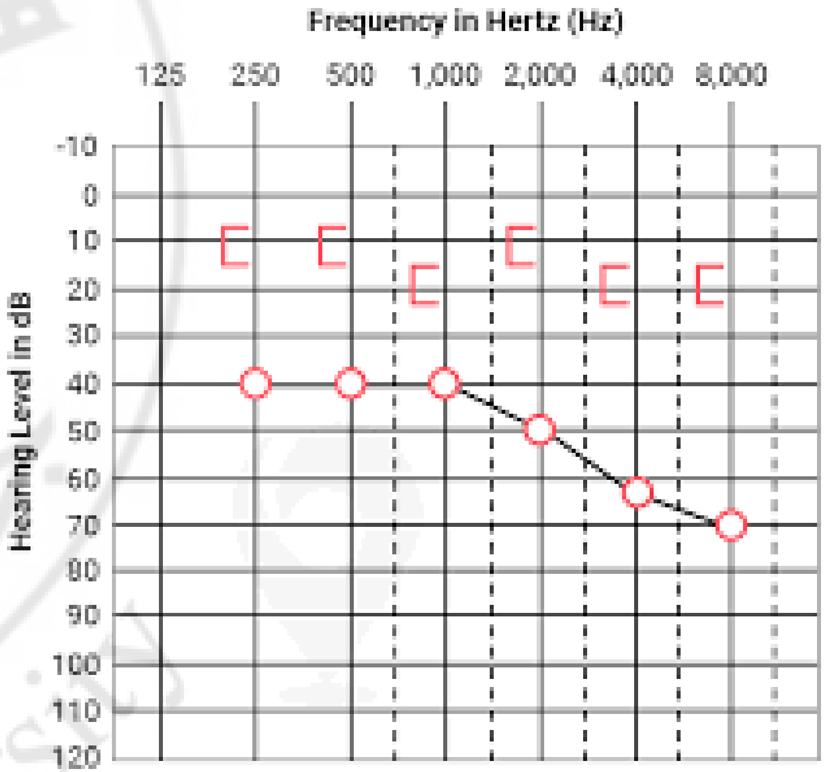
Normal hearing and middle ear function

- Generally for clients with normal hearing and normal middle ear function, both ipsilateral and contralateral reflexes will be present at all frequencies.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	85	85	85	85
	Stim L (contra)	90	90	90	90
Probe L	Stim L (ispi)	80	80	80	80
	Stim R (contra)	85	85	85	85

Conductive hearing loss

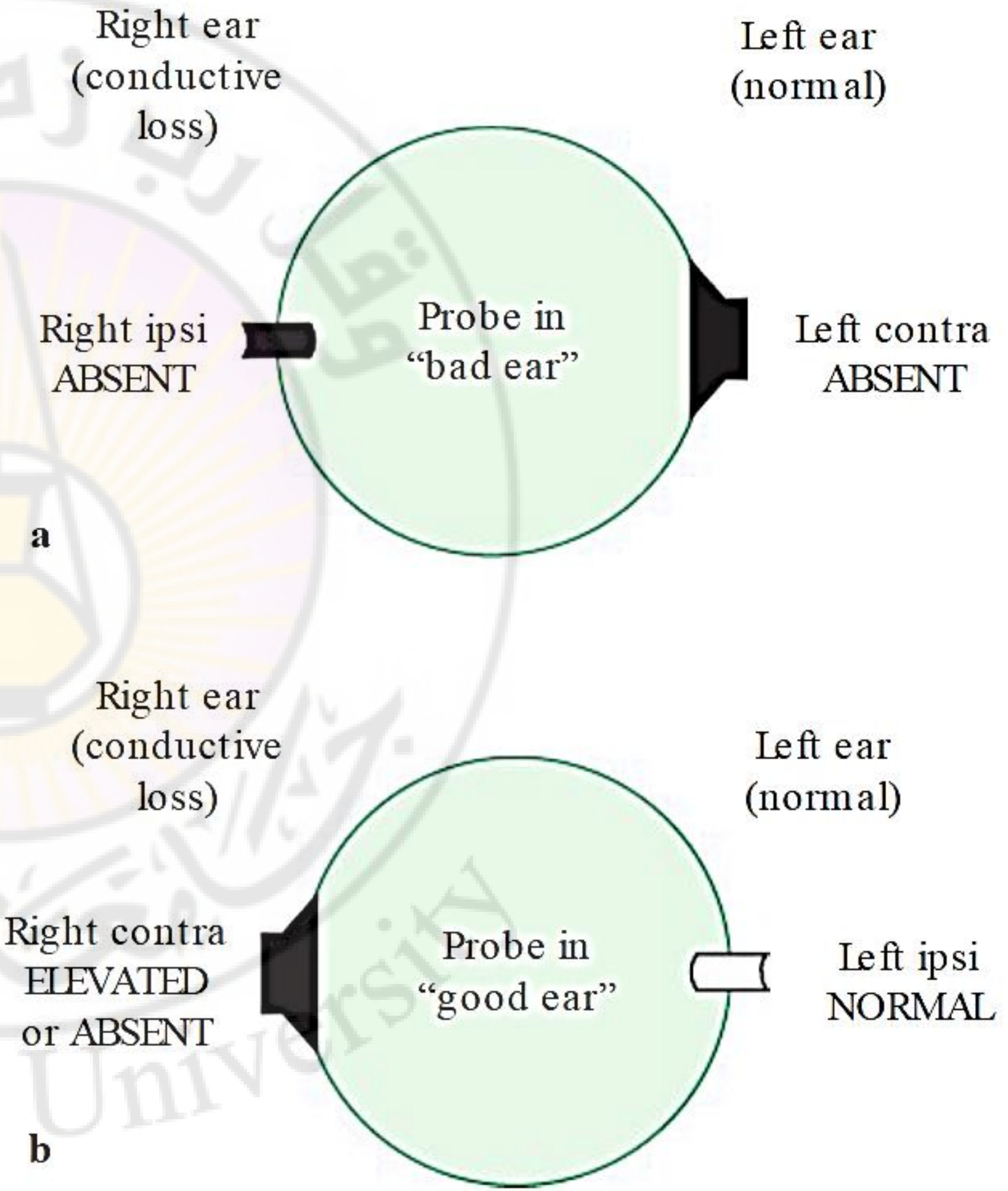
- Acoustic reflexes will be absent when a probe is placed in an ear with a middle ear disorder. This is due to the fact that middle ear disorders typically prevent the probe from measuring a change in compliance when the stapedius muscle contracts. Reflexes will therefore be absent even in the case of a mild conductive hearing loss.
- In the presence of a Type C tympanogram, depending on the degree of negative pressure in the middle ear, reflexes can be either present or absent.
- If acoustic reflexes are present in the probe ear, it is unlikely that a conductive hearing loss exists, except in the rare case of Superior Semicircular Canal Dehiscence (SSCD).



Case 1:

Unilateral Conductive Hearing Loss

Only 10 dB air-bone-gap would be enough to eliminate the AR.



Normal hearing in the right ear & a mild conductive loss in the left ear.

In this example, the raised left contralateral reflex thresholds (probe right, stimulus left) are due to the additional SPL needed to overcome the mild loss in the L ear.

The mild middle ear pathology may affect signals travelling through the left ear or being measured in the left ear. They will either be absent or raised.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	85	85	85	85
	Stim L (contra)	100	100	100	105
Probe L	Stim L (ispi)	X	X	X	X
	Stim R (contra)	X	X	X	X

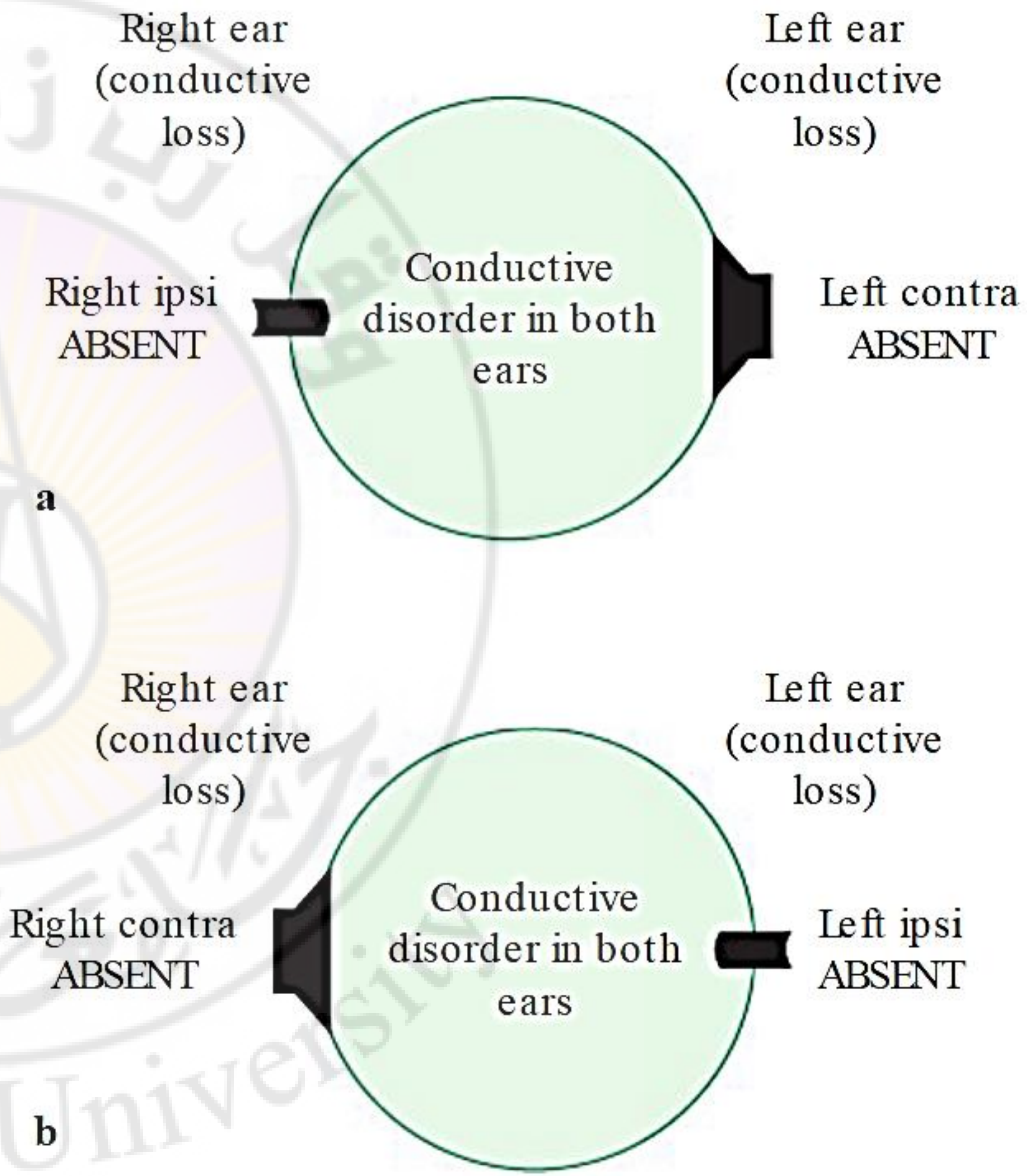
Normal hearing in the right ear & a moderate conductive loss in the left ear

In this example, because of the moderate loss in the left ear, the stimulus (even at max levels) was not loud enough to elicit the stapedius reflex in the left contralateral recording (probe right, stimulus left).

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	85	85	85	85
	Stim L (contra)	X	X	X	X
Probe L	Stim L (ispi)	X	X	X	X
	Stim R (contra)	X	X	X	X

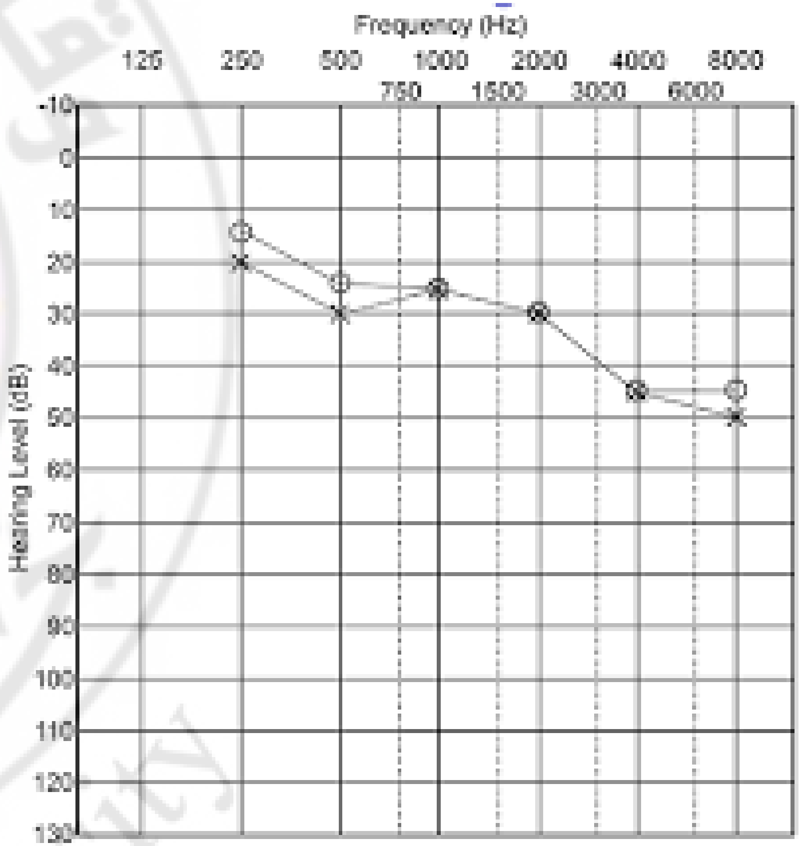
Case 2:

Bilateral Conductive Hearing Loss



Cochlear hearing loss

- In ears with a cochlear hearing loss, it is possible for the acoustic reflex to be elicited at sensation levels (SL) of less than 60dB. The SL is the difference between the ART and the hearing threshold. For example, if the hearing threshold at 1kHz is 50dBHL and the ART is 90dBHL, the sensation level is 40dBSL.
- When the SL is less than 60dB, a positive Metz test is indicated. This indicates a cochlear site of lesion (sensorineural loss) due to the loudness **recruitment** phenomenon.



A mild to moderate cochlear loss in both left & right ears

In this example, note that the ARTs occur at about normal levels. This is because the acoustic reflex threshold in an ear with a cochlear loss may resemble the results of a normal ear when the air conduction thresholds are below about 50dBHL. As the hearing threshold increases above this level, the chance of recording a raised or absent acoustic reflex increases.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	85	80	80	100
	Stim L (contra)	85	90	90	X
Probe L	Stim L (ispi)	85	90	85	100
	Stim R (contra)	90	80	85	X

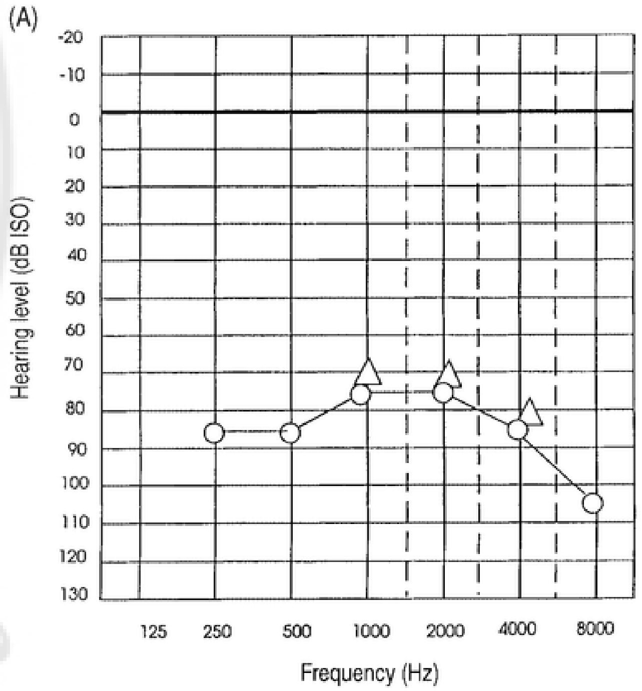
Severe to profound cochlear loss in left ear, normal hearing in the right ear

In this example, the stimulus (even at max levels) was not loud enough to elicit a stapedius reflex due to the severe/profound loss in the left ear. Therefore, whenever a **stimulus** is presented to the affected ear, reflexes will be absent/raised in both ipsilateral and contralateral recordings as shown above.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	85	85	85	95
	Stim L (contra)	X	X	X	X
Probe L	Stim L (ispi)	X	X	X	X
	Stim R (contra)	90	90	90	95

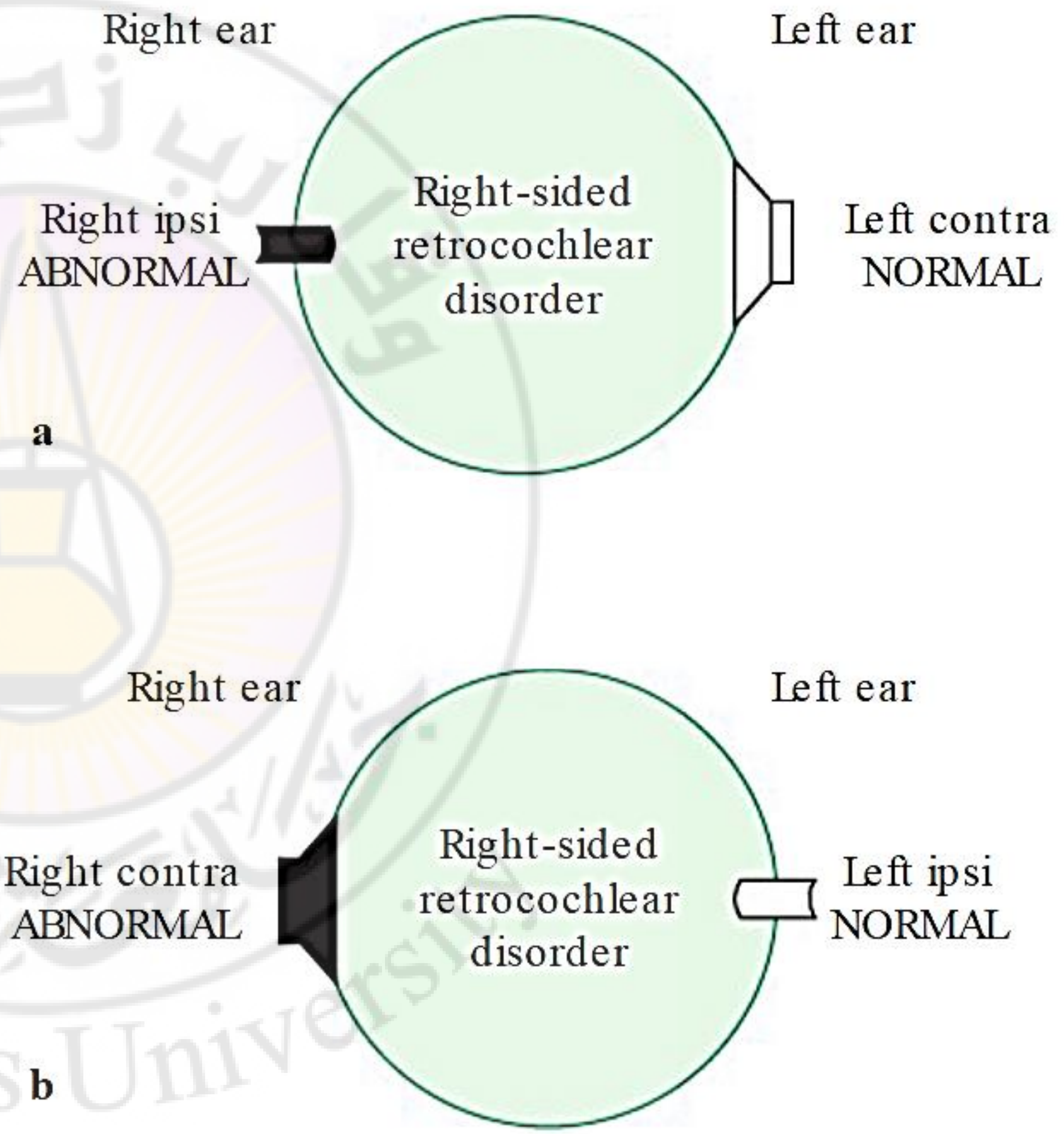
Retrocochlear hearing loss

- ARTs in ears with retrocochlear (CNVII) pathology are usually **elevated** above what they would have been for normal hearing or a cochlear hearing loss. Often they are **absent** at maximum stimulus levels. Keep in mind that ART results should be analyzed in combination with the patient case history, audiogram, speech and tympanometry findings for differential diagnosis.
- Ears with retrocochlear pathology and normal hearing do not have reflexes 30% of the time.
- With a mild 30dB hearing loss, the likelihood of absent reflexes increases.
- The absence of reflexes at 0.5, 1 & 2kHz in the presence of normal/near normal hearing must be considered suspicious unless proven otherwise.
- The affected ear will show absent acoustic reflexes when a **stimulus** is presented to it in the case of CNVIII lesions.



Case 3:

Unilateral SNHL (Retrocochlear origin)



Retrocochlear lesion in the left ear; normal hearing in both ears

In this example, note the raised/absent acoustic reflexes with presentation to the left ear.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	80	80	80	90
	Stim L (contra)	105	110	X	X
Probe L	Stim L (ispi)	110	X	X	X
	Stim R (contra)	85	80	85	95

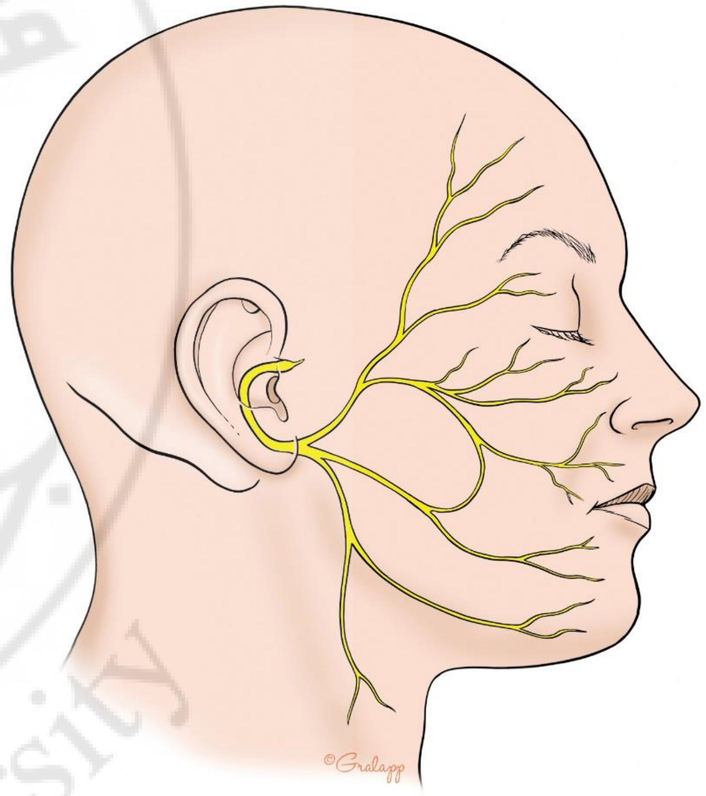
Retrocochlear/CNVIII lesion in the left ear; a mild hearing loss in the left ear & normal hearing in the right ear

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	80	80	85	85
	Stim L (contra)	X	X	X	X
Probe L	Stim L (ispi)	X	X	X	X
	Stim R (contra)	85	85	90	90

In this example, note the absent acoustic reflexes when sound is presented to the left ear.

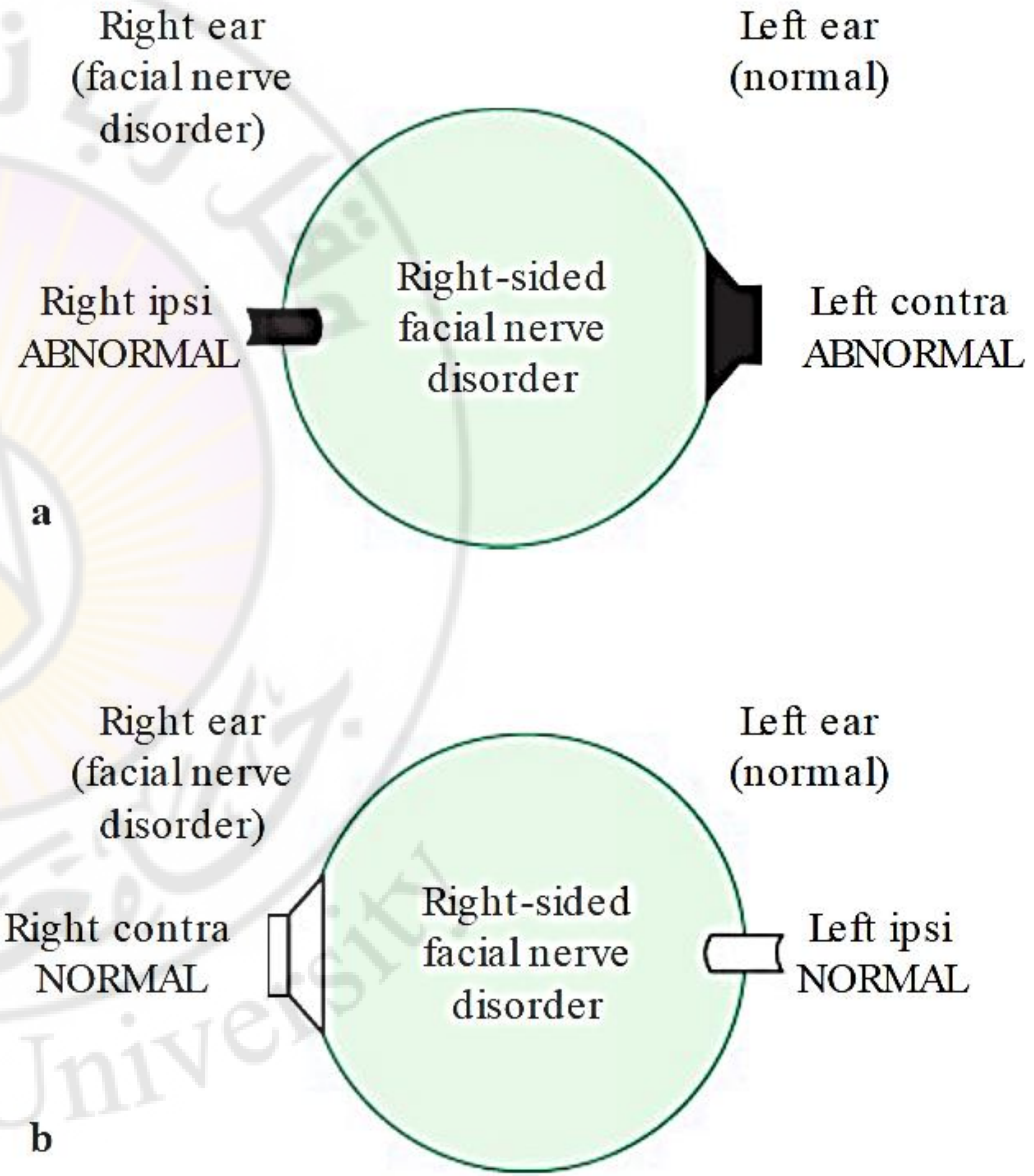
Facial nerve/CNVII involvement

- Acoustic reflexes are absent when measured on the affected side in the case of a facial nerve disorder (e.g., **probe in the affected ear**). This is because the stapedius muscle is innervated by the CNVII.
- Often, CNVII disorders are easily recognizable (e.g., facial paralysis in the case of Bell's Palsy) and measurement of the acoustic reflex is used as a tool to monitor the recovery process in such patients.



Case 4:

Unilateral facial nerve disorder



Facial nerve/CNVII lesion in the left ear due to Bell’s Palsy; normal hearing in both ears

In this example, note that the acoustic reflexes are absent when the probe is coupled to the affected (left) ear. Also, you will recognize this is a similar pattern of results for a CNVIII lesion.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	80	80	85	85
	Stim L (contra)	85	85	85	90
Probe L	Stim L (ispi)	X	X	X	X
	Stim R (contra)	X	X	X	X

Inter-axial brainstem lesion

- Very rare. About 1 in 10 million
- Acoustic reflexes are normal ipsilaterally and absent contralaterally. The left and right pathways are disrupted by a lesion involving the auditory fibers.

Freq		.5kHz	1kHz	2kHz	4kHz
Probe R	Stim R (ispi)	80	80	85	85
	Stim L (contra)	X	X	X	X
Probe L	Stim L (ispi)	85	80	80	85
	Stim R (contra)	X	X	X	X

Intra-axial brainstem lesion; normal hearing in both ears

Case 5:

Intra-axial Brainstem disorder

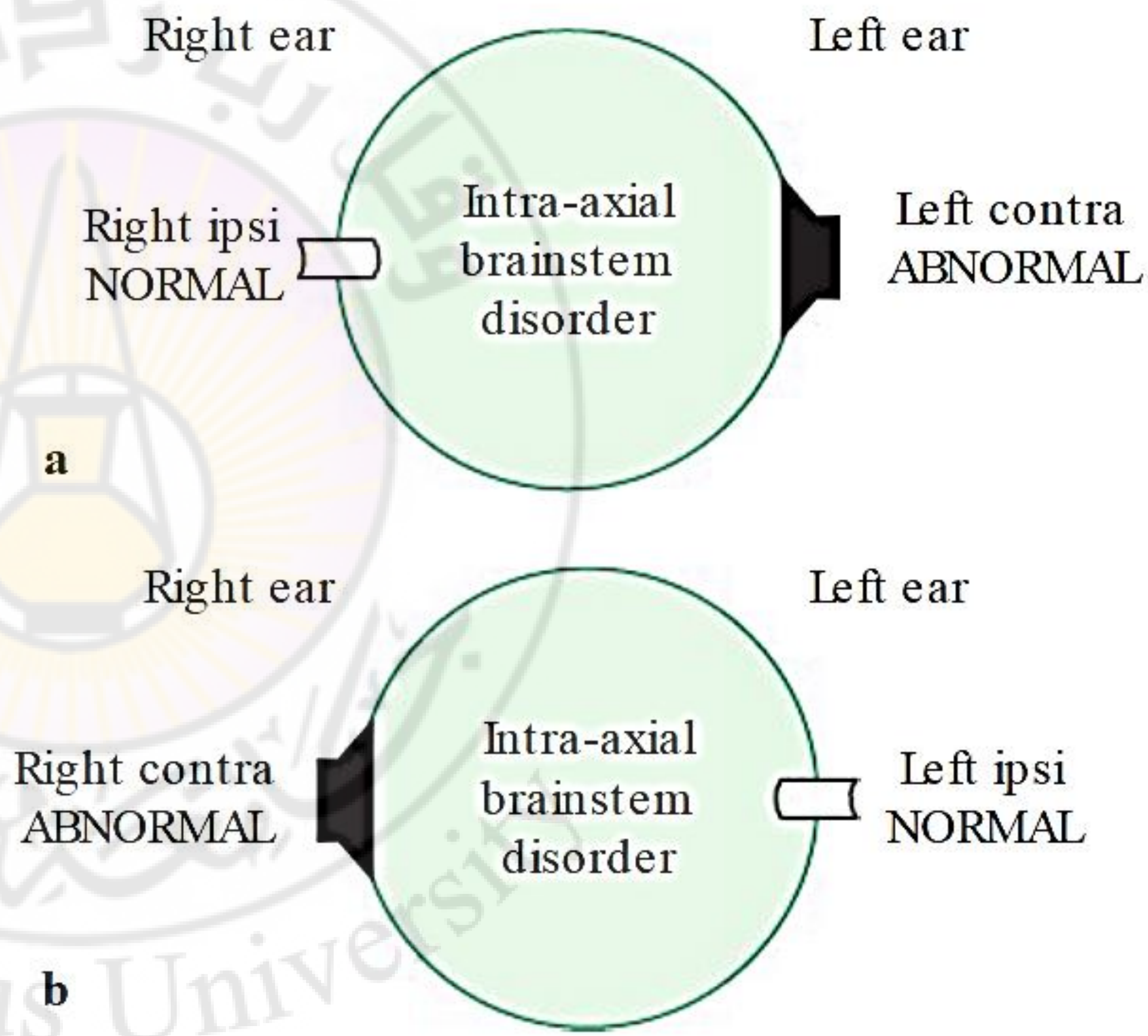


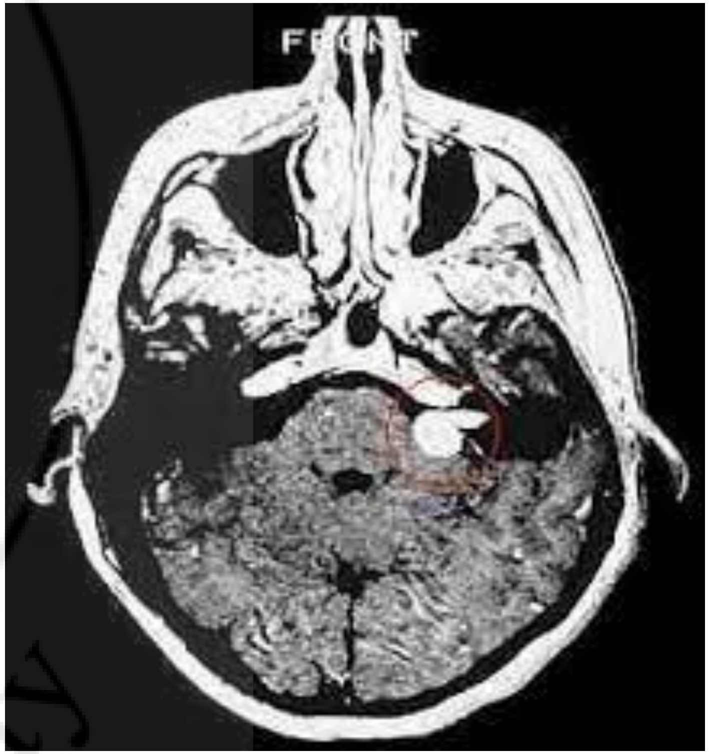
Table 6–1. Patterns of Acoustic Reflex Effects for Various Pathologies for the Affected and Unaffected Ear

Site of Lesion and Laterality	*Ipsi—affected ear*	*Contra—affected ear*	*Ipsi—unaffected ear*	*Contra—unaffected ear*
Middle ear, unilateral	A	A or E depending on severity of the loss	N	A
Middle ear, bilateral	A	A	A	A
Cochlea, unilateral (see Table 6–4)	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss	N	N
Cochlea, bilateral (see Table 6–4)	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss	N, E, A depending on severity of the loss
Eighth cranial nerve, unilateral	E, A, D	E, A, D	N	N
Eighth cranial nerve, bilateral	E, A, D	E, A, D	E, A, D	E, A, D
Seventh cranial nerve, unilateral[a]	A	N	N	A
Seventh cranial nerve, bilateral[a]	A	A	A	A
Brainstem, unilateral, extra-axial	E, A, D	E, A, D	N	A, N
Brainstem, midline/intra-axial	N	A	N	A

For abnormal elevation for any given hearing loss, consult Table 6–4.
[a]Proximal to the stapedial branch.
A, absent; *E*, elevated; *N*, present at normal intensity; *D*, decay.

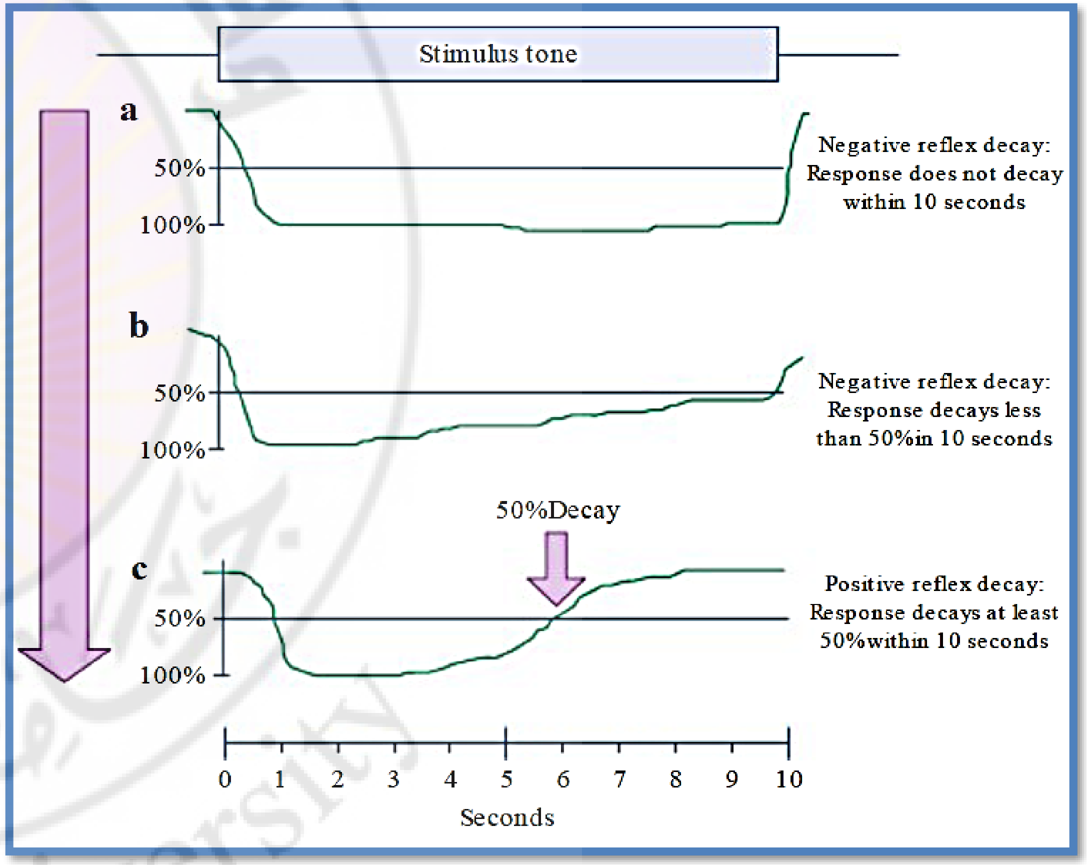
Reflex Decay

- Reflex decay testing can be useful in detecting/confirming **retrocochlear pathology** in patients.
- Generally patients will present with typical retrocochlear indicators (unilateral tinnitus, asymmetrical hearing loss, dizziness/vertigo) and you will have enough information to warrant a referral to an ENT specialist without needing to do this test.
- This test may be useful though when the audiogram and case history are normal, but reflex results show a retrocochlear pattern.
- An acoustic reflex decay test measures whether a reflex contraction is maintained or weakens during continuous stimulation (usually 10 seconds).



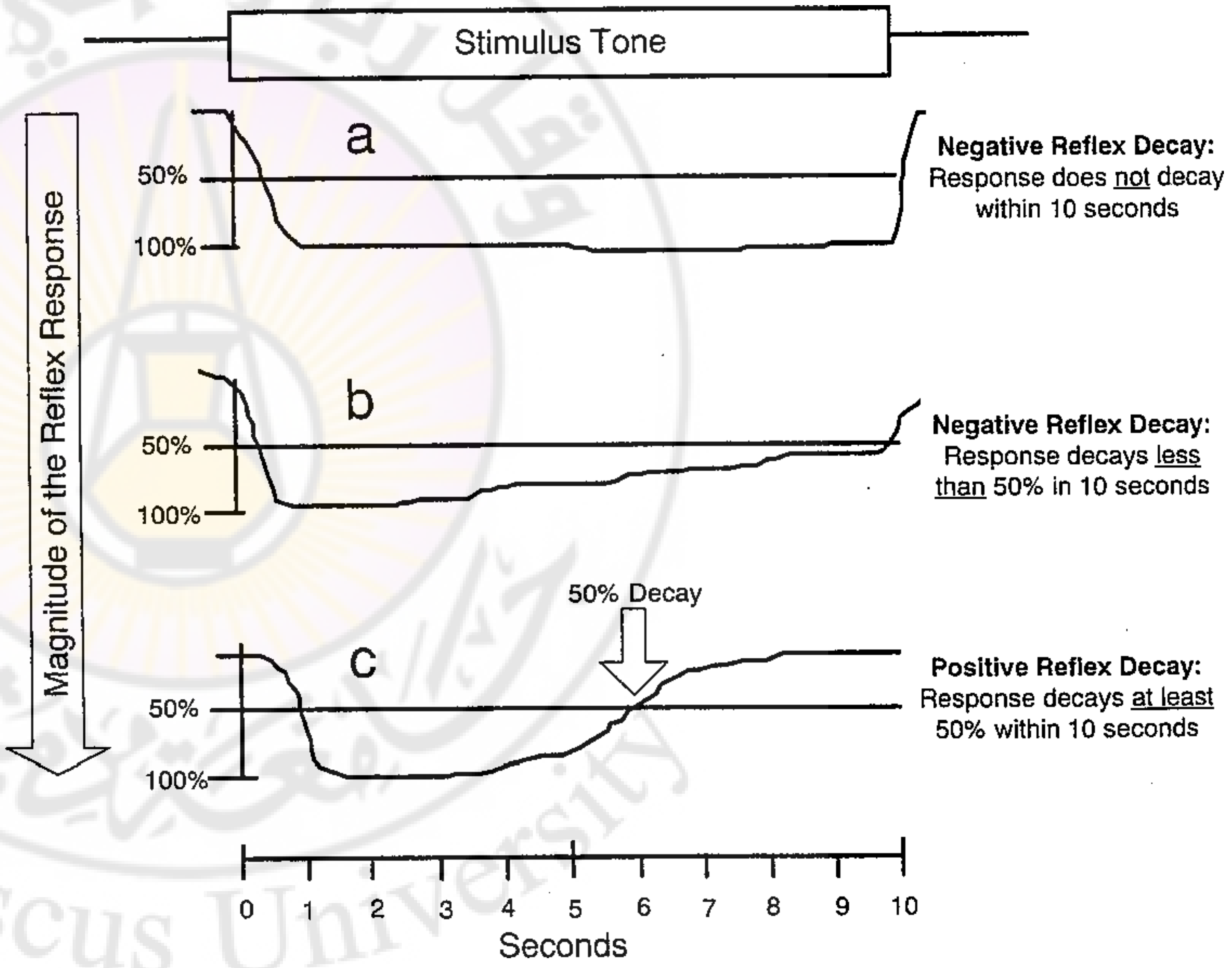
Reflex Decay

- The 226-Hz probe tone is used with a 500- or 1,000-Hz activator for the standard ASR decay test.
- The ipsilateral or contralateral activator is presented for 10 seconds at 10 dB above the ASR threshold for the activator (Should not exceed 105 dB HL).
- The activator should elicit a reflex and a decrease in admittance should be observed that is essentially constant for the entire 10 seconds.
- In ears with **8th nerve disorders**, “abnormal” or “positive” decay is observed, meaning the amplitude of the reflex decreases by half its initial magnitude in less than 10 seconds.



Reflex Decay

Therefore, if the reflex response decreases to 50% of its original magnitude within the 10 seconds of testing, the test would be positive for reflex decay.



Acoustic reflex decay test procedure

1. Perform tympanometry and reflex measurements
2. Take the acoustic reflex threshold at 500Hz or 1000Hz in the ear you want to test and add 10dB. This is the stimulus level you will use for testing (e.g., if the reflex threshold was 80dB at 1000Hz, you would test at 90dB at 1000Hz).
3. Make sure you still have a good seal between the probe and the ear and then press start to run the test.

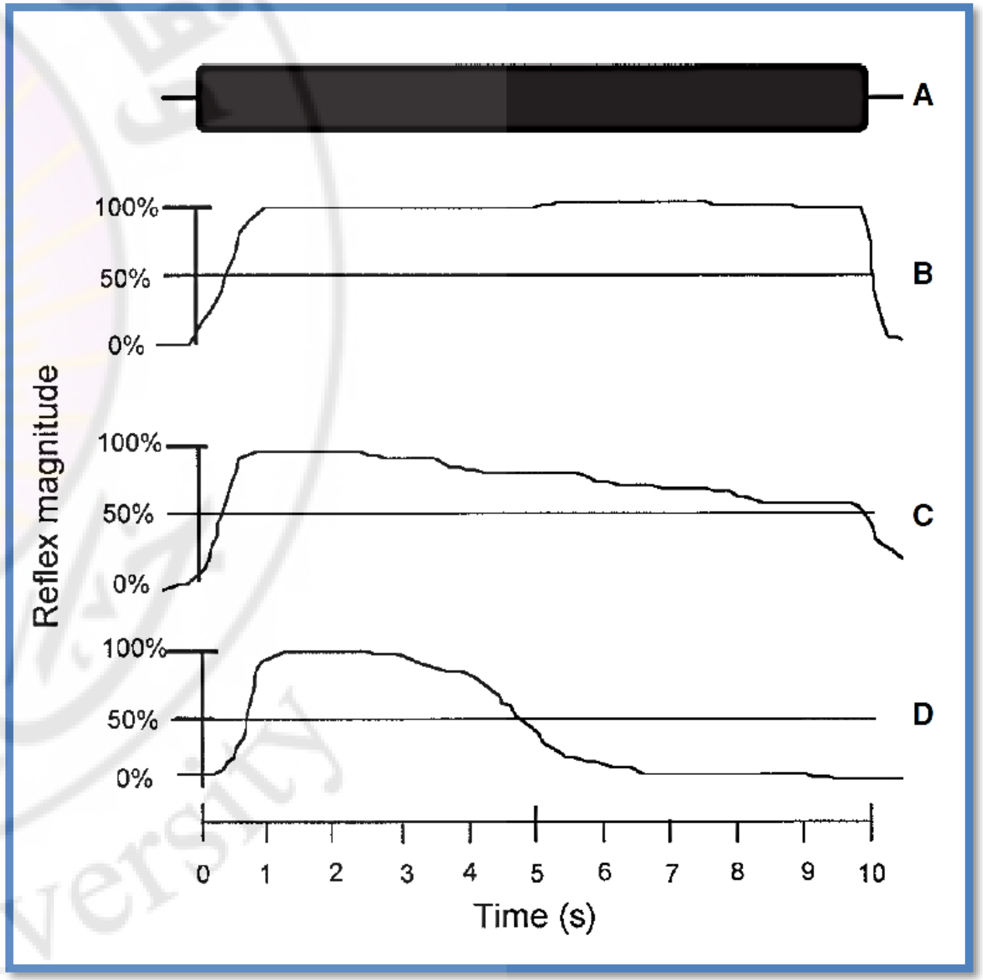
Note: If the reflex decay test is positive, you should check that it was not due to an improper seal, which might produce an artifact similar to a decaying curve.

Disadvantages of Reflex Decay

1. The test often cannot be completed because ASR is absent or elevated to the point that 10 dB sensation level (SL) re: ASR threshold cannot be presented for the decay test.

2. It has poorer sensitivity/specificity than the ABR for retrocochlear disorders.

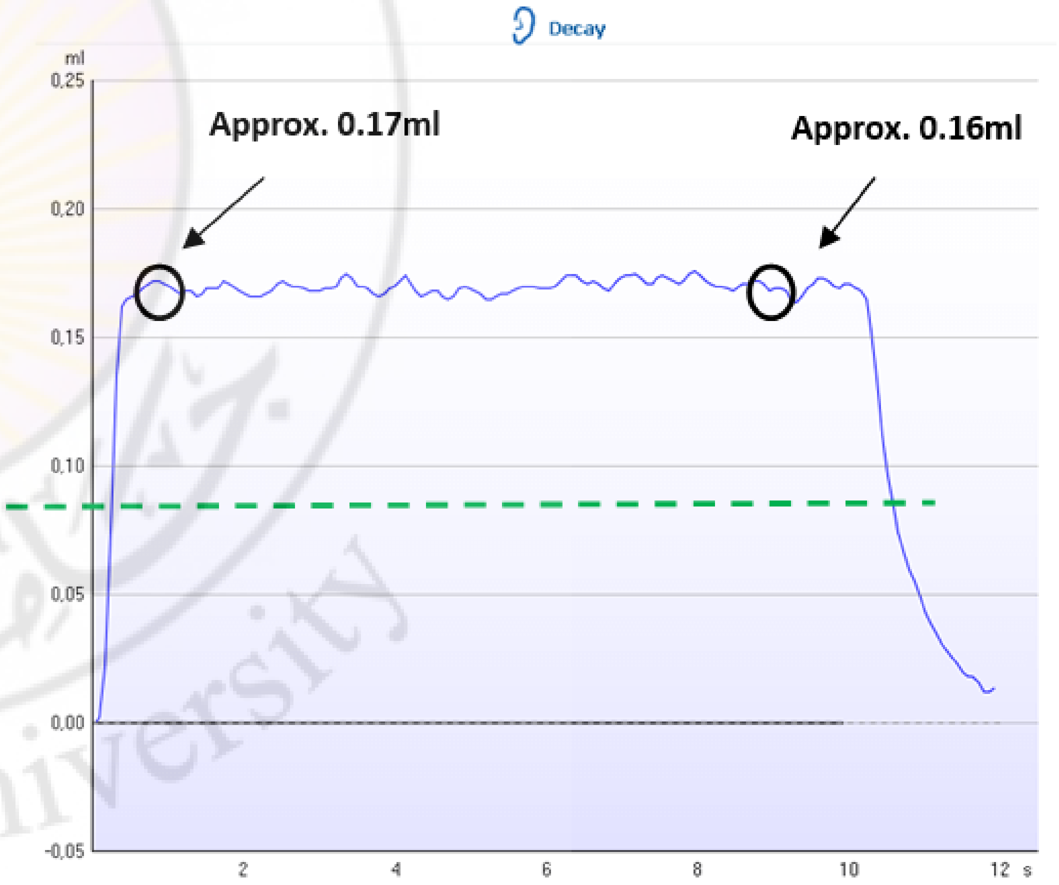
3. Temporary and permanent threshold shifts have been reported with high-level activators.



Interpretation of the acoustic reflex decay test

The decay value is the percentage difference of the two reflex deflection values taken half a second after the stimulus started and half a second before the stimulus stopped.

In this example, the reflex decay test is negative as the response did not decay by more than 50% (drop below green dotted line), during the 10 second test interval. The blue reflex line would have had to drop below the green dotted line for positive reflex decay to be measured.



Interpretation of the acoustic reflex decay test

The decay value is the percentage difference of the two reflex deflection values taken half a second after the stimulus started and half a second before the stimulus stopped.

This example shows a positive reflex decay measurement. The reflex has decayed by more than 50% (indicated by the green dotted line) during the 10 seconds test interval.

Reflex Latency

- The latency of the acoustic reflex varies by activator, but in general it is around **100 ms** which reflects the travel time of the signal from the cochlea through the pathway to the stapedius muscle.
- When the response is being clinically measured, the latency includes the inherent delay of the measurement system.
- ASR increased latencies have been reported in ears with **retrocochlear disorders** such as vestibular schwannomas, and it has been suggested that latency may be useful in separating cochlear from retrocochlear sites of lesion.
- However, ASR latency is not routinely measured clinically

Reflex Latency

Means and 95% Normal Ranges of Acoustic Reflex Latencies[a] (in Milliseconds) of Normal-Hearing Individuals for Tonal, BBN, and Click Stimuli Presented at 10 dB Above the ART

Stimulus	500 Hz	1000 Hz	2000 Hz	4000 Hz	BBN	Clicks (50/sec)
Contralateral						
Mean	102.8	101.9	127.7	147.3	132.3	156.7
95% range	56.0–149.6	51.7–152.1	66.5–188.9	77.9–216.7	59.7–204.9	107.0–206.3
Ipsilateral						
Mean	104.4	102.0	115.2	144.2		
95% range	59.2–149.6	51.4–152.0	70.6–159.8	74.8–213.6		

Data were obtained by using the Grason-Stadler GSI-33 Middle Ear Analyzer, with latencies defined as the point at which the acoustic reflex response magnitude achieves 10% of its eventual maximum value. Based on findings by Qiu & Stucker (1997).

[a] Measured for the admittance (Y) component with a 226-Hz probe tone.

QUESTIONS?

دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Otoacoustic Emissions

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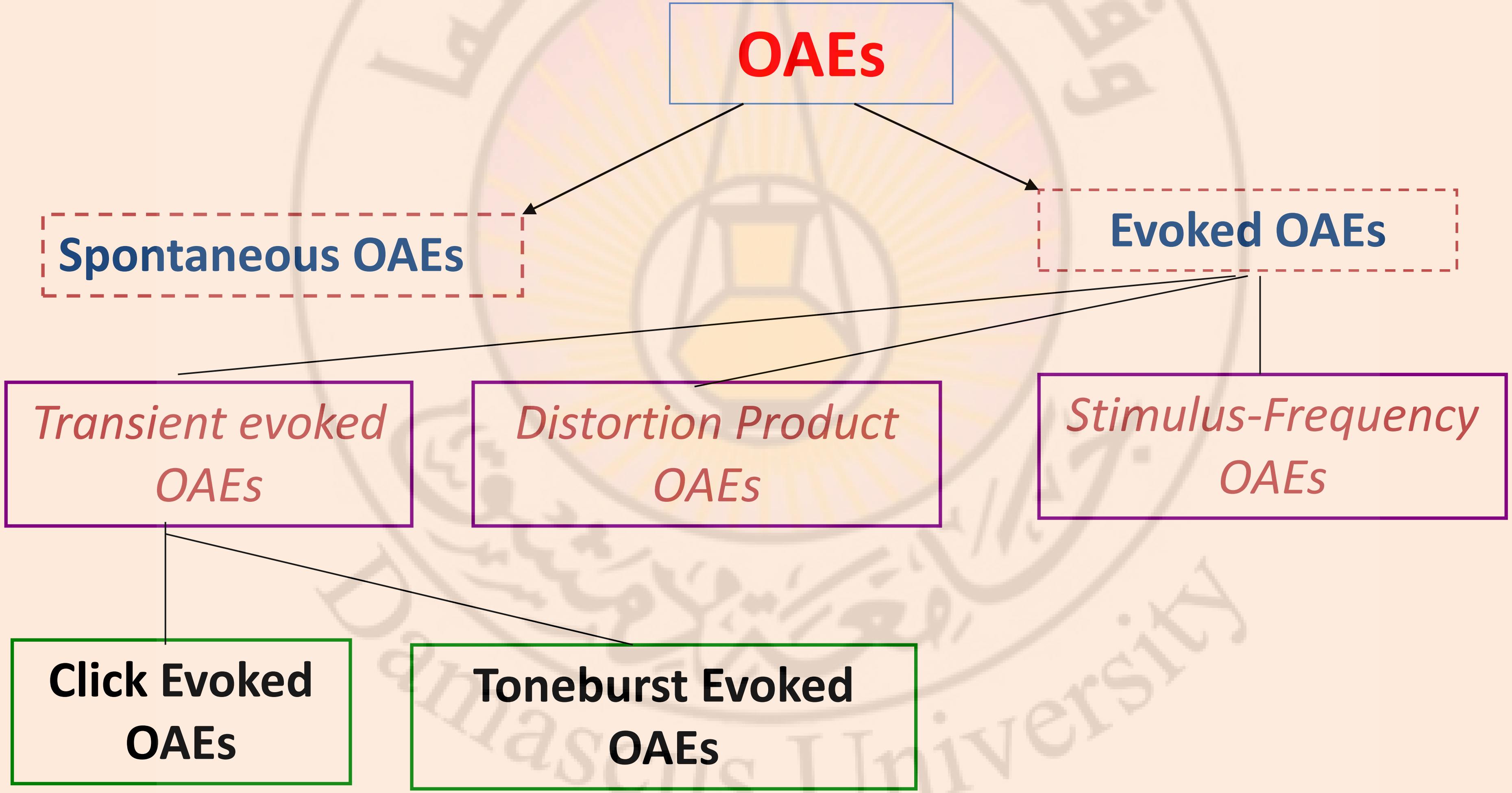
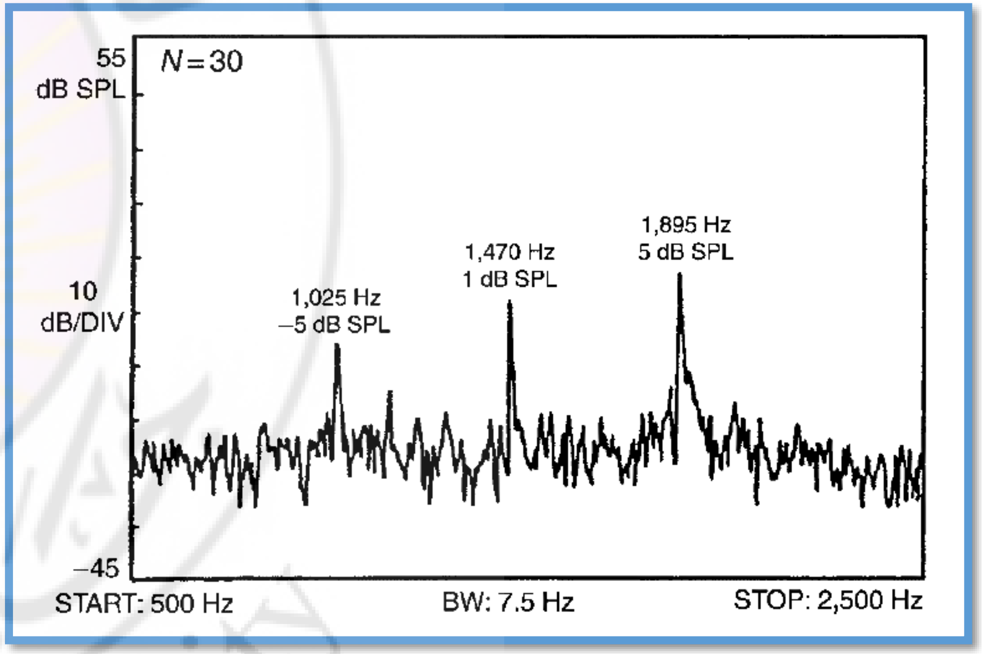
Types of OAEs



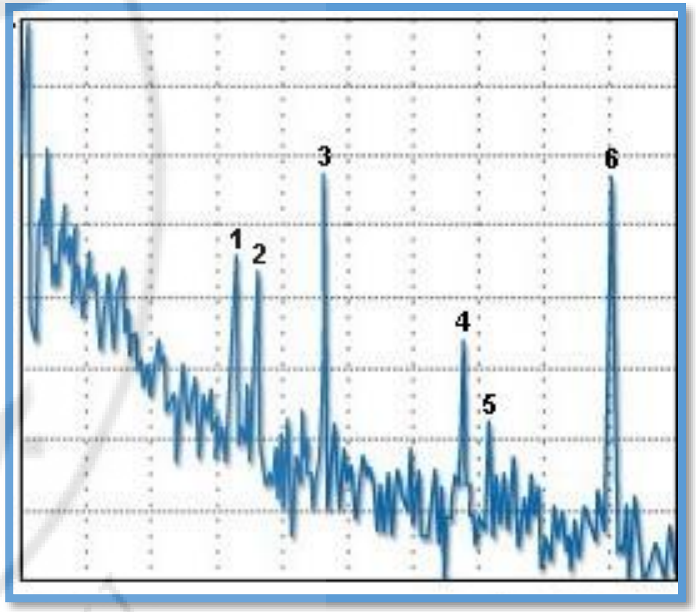
Spontaneous Otoacoustic Emissions (SOAE)

- SOAEs are measured in the absence of external stimulation.
- They can be measured by viewing what is recorded by the microphone in the frequency domain.
- SOAEs appear as puretone-like signals coming from the ear.
- SOAEs are measurable in approximately **50% of normal hearing** children and adults.
- SOAEs can be measured in ears having hearing loss no greater than 25 to 30 dB HL.
- Because they can be measured in only 50% of normal-hearing ears, they are not a useful clinical test.



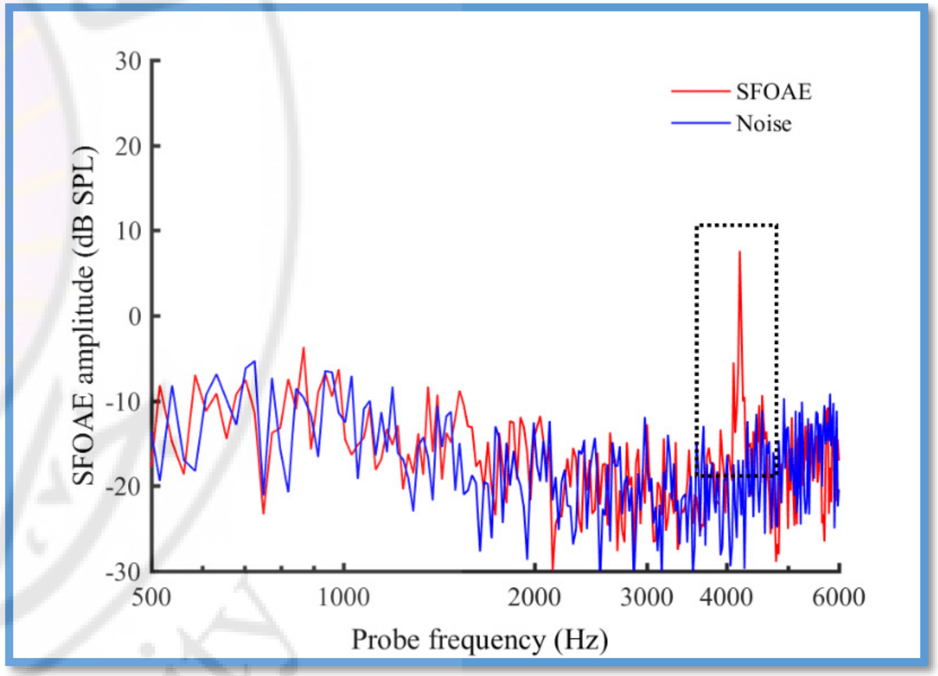
Spontaneous Otoacoustic Emissions (SOAE)

- SOAEs is higher in females than in males and in right ears than in left ears.
- Having an SOAE in one ear increases the likelihood that an SOAE will be present in the other ear.
- Studies examining the connection between **SOAEs** and tinnitus have generally reported that the two phenomena appear to be independent events.



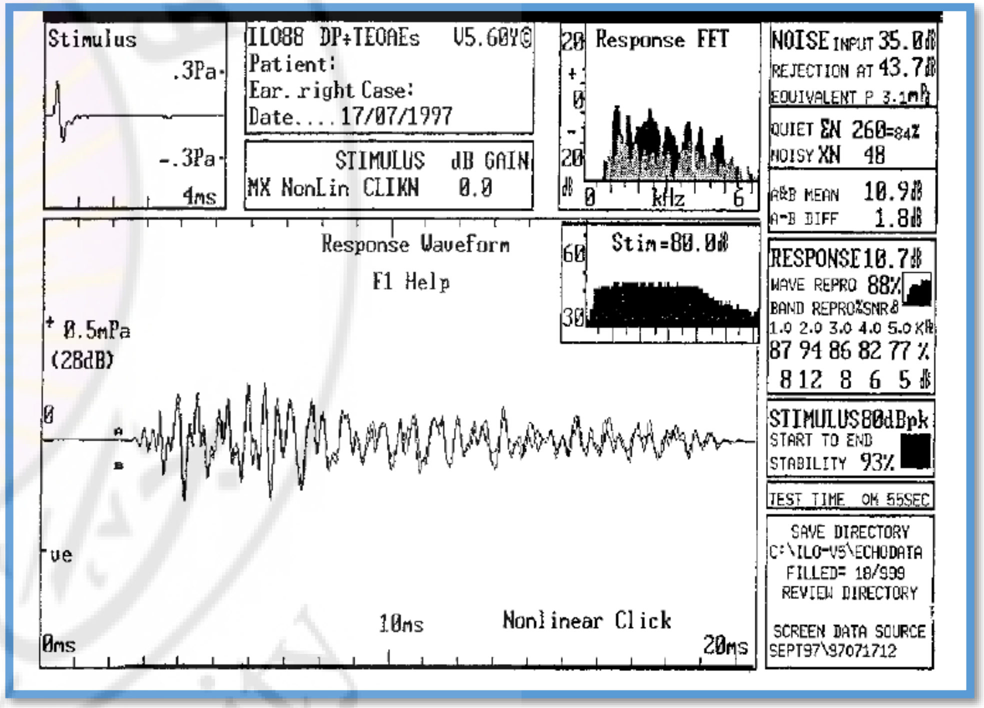
Stimulus-Frequency Otoacoustic Emissions (SFOAE)

- Stimulus-frequency OAEs (SFOAEs) occur at the same frequency and at the same time as a continuous puretone applied to the ear.
- The microphone in the ear canal records the combination of the puretone being presented to the ear and the SFOAE evoked by the puretone; therefore, specialized measurement techniques must be used to extract the SFOAE from the total signal measured in the ear canal.
- Common techniques involve introducing a second stimulus differing in intensity or frequency that takes advantage of the nonlinear properties of the SFOAE.
- SFOAEs have not been used as a routine clinical measure, and there are no commercial devices designed to record SFOAEs.



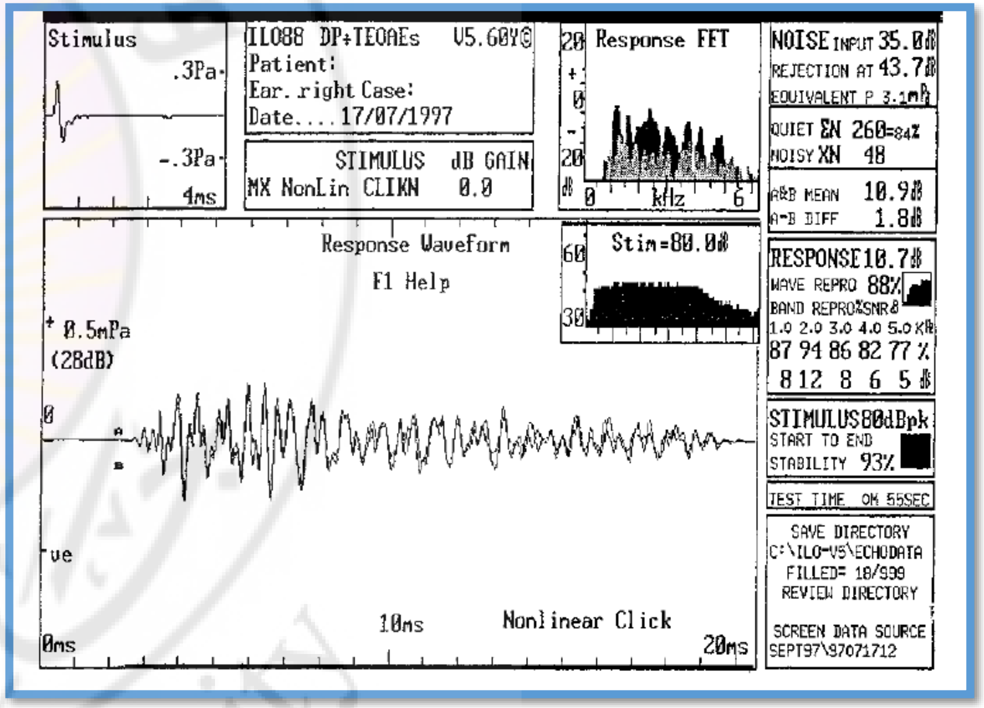
Transient-Evoked Otoacoustic Emissions (TEOAEs)

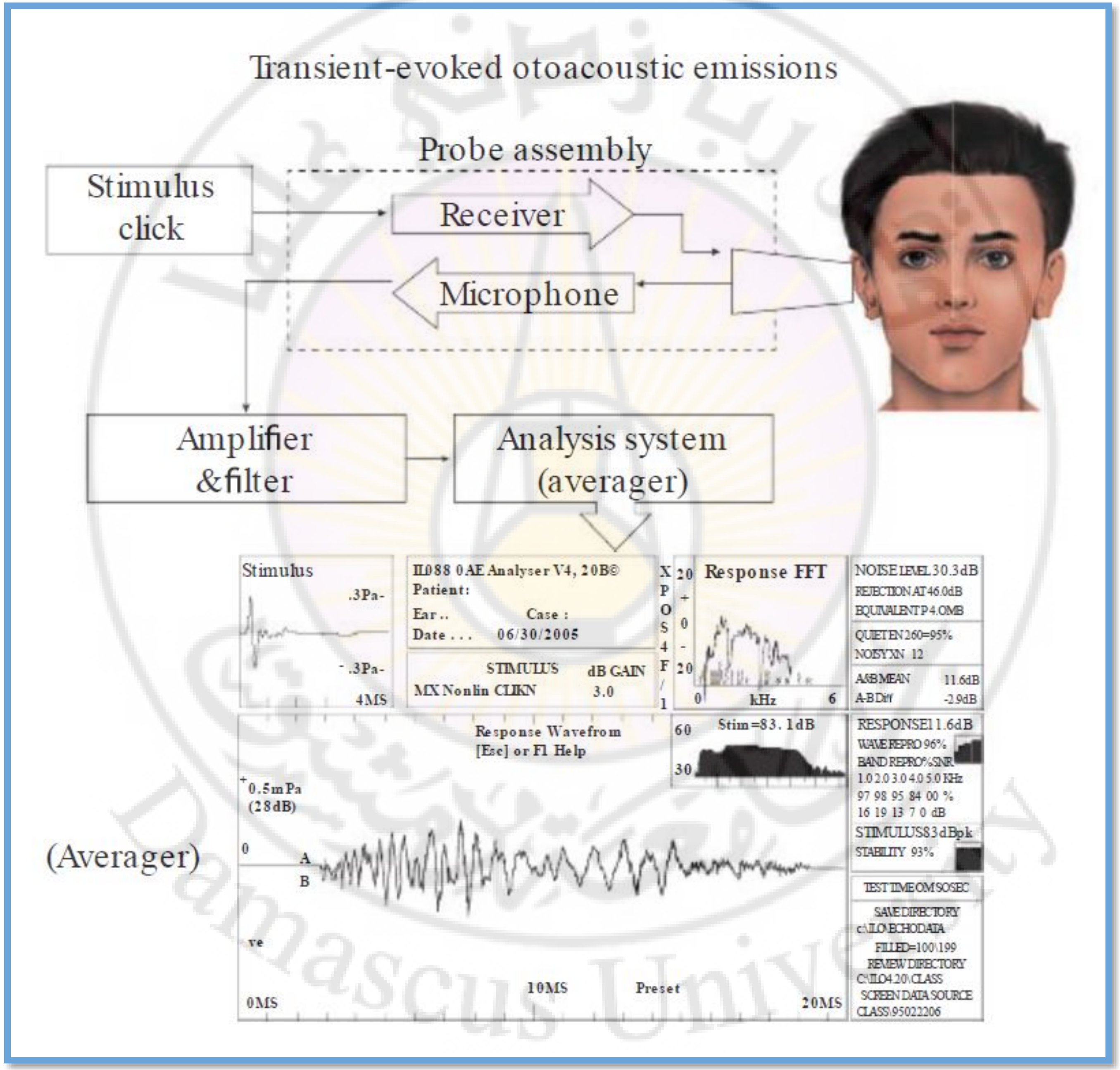
- TEOAEs were the first type of OAE reported in the literature.
- TEOAEs are measured following the presentation of a transient or brief stimulus. A **click or toneburst** is presented to the ear, and the response occurs following a brief time delay.
- Measurement of TEOAEs is accomplished using **time synchronous averaging.**
- Although the averaging reduces the amount of noise in the trace, it does not remove the ***stimulus artifact*** at the start of the recording. Therefore, the first few milliseconds of the trace are usually eliminated from the final averaged waveform to remove energy because of the stimulus.

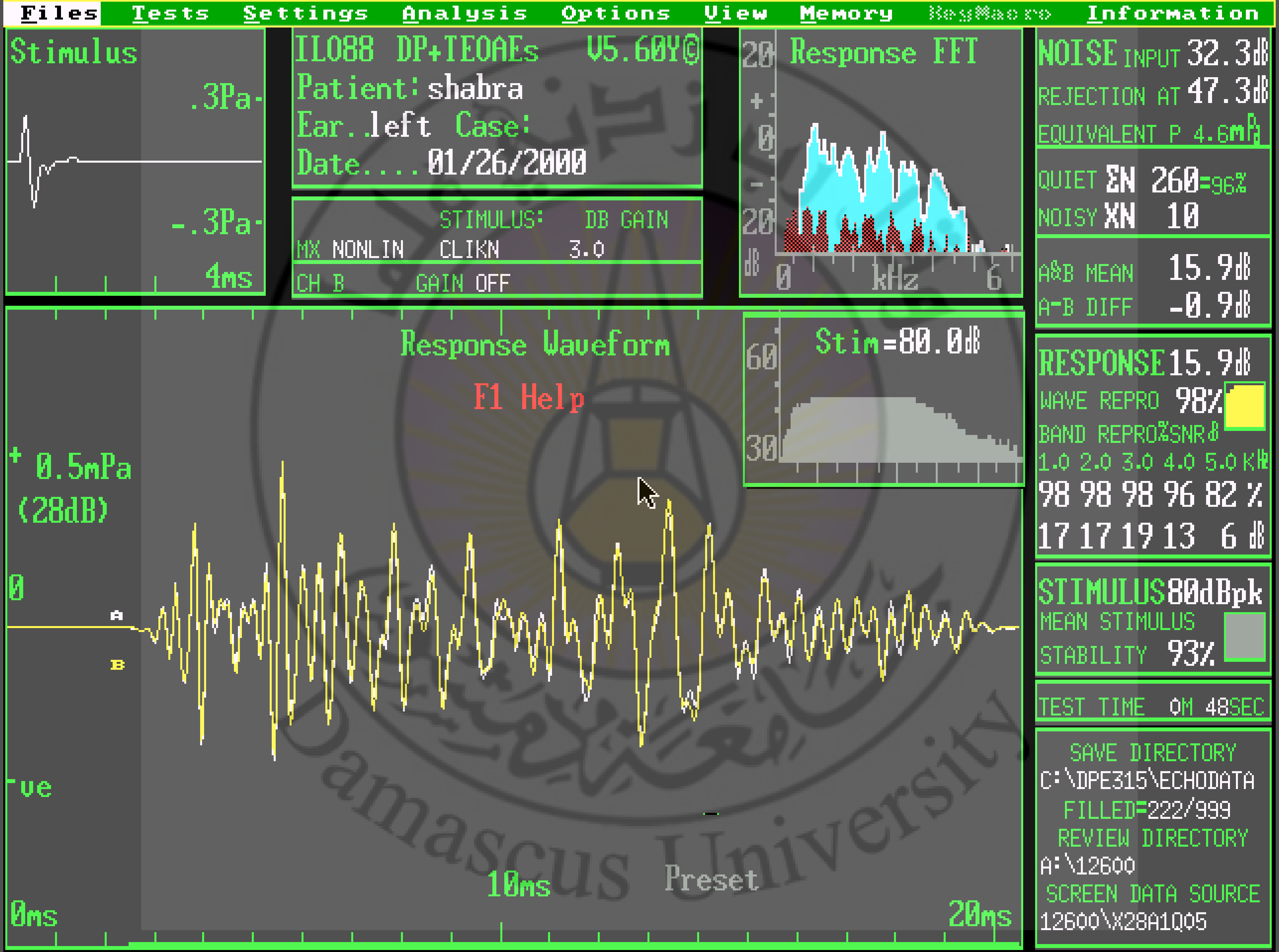


Transient-Evoked Otoacoustic Emissions (TEOAEs)

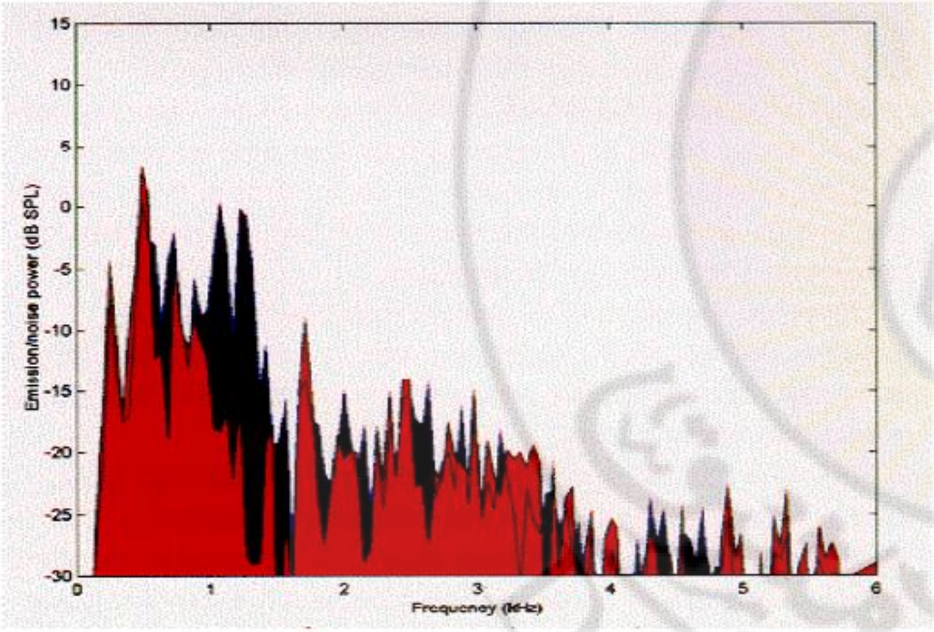
- When a click is used as the stimulus, the resulting TEOAE is often referred to as a click-evoked OAE (COAE or CEOAE).
- Toneburst-evoked OAEs (TBOAEs) are more frequency specific and typically limited to the frequency range of the narrowband stimuli used to evoke them
- TEOAEs are often evaluated in terms of level, percent reproducibility, and TEOAE/noise (sometimes called signal-to-noise ratio or SNR).
- The level of the TEOAE is usually expressed in dB SPL.
- TEOAEs present in almost ALL normal ears.
- **30 to 50 dB** of sensory HL cause elimination of TEOAEs.



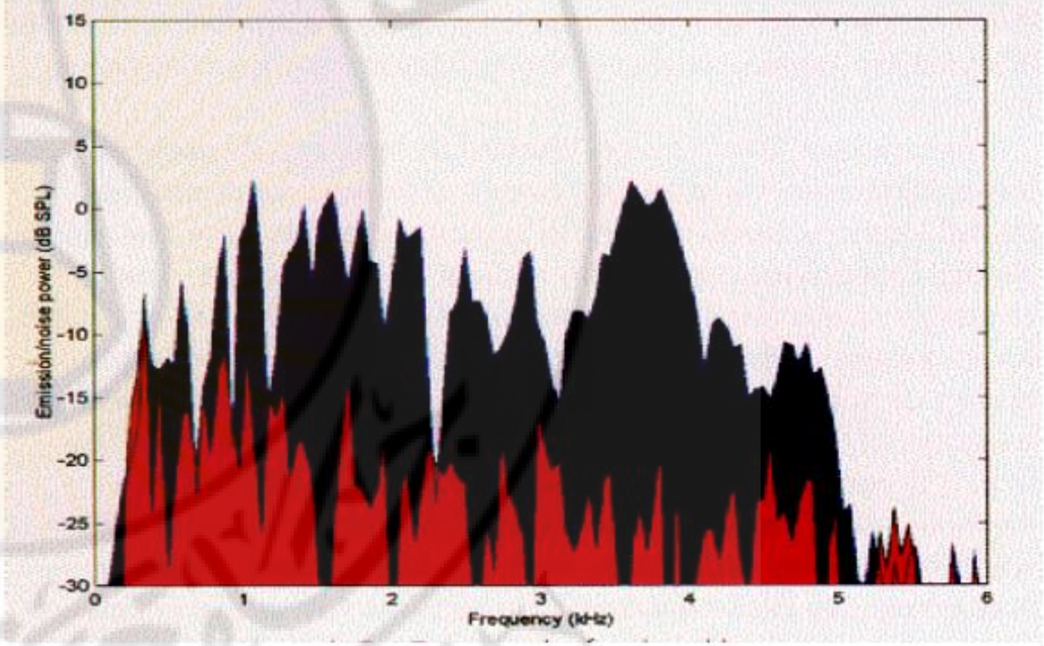

Transient-evoked otoacoustic emissions
Probe assembly
Stimulus click
Receiver
Microphone
Amplifier &filter
Analysis system (averager)
(Averager)
Stimulus
Response FFT
Response Wavefrom
[Esc] or F1 Help
Stim=83.1dB
NOISE LEVEL 30.3dB
RESPONSE11.6dB
0MS
10MS
Preset
20MS


Files Tests Settings Analysis Options View Memory KeyMacro Information
Stimulus
.3Pa
-.3Pa
4ms
IL088 DP+TEOAEs V5.60Y©
Patient: shabra
Ear..left Case:
Date....01/26/2000
STIMULUS: DB GAIN
MX NONLIN CLIKN 3.0
CH B GAIN OFF
Response FFT
20
0
20
dB
0
kHz
6
NOISE INPUT 32.3dB
REJECTION AT 47.3dB
EQUIVALENT P 4.6mPa
QUIET ΣN 260=96%
NOISY XN 10
A&B MEAN 15.9dB
A-B DIFF -0.9dB
Response Waveform
F1 Help
Stim=80.0dB
60
30
+ 0.5mPa
(28dB)
0
A
B
-ve
0ms
10ms
Preset
20ms
RESPONSE 15.9dB
WAVE REPRO 98%
BAND REPRO%SNRdB
1.0 2.0 3.0 4.0 5.0 kHz
98 98 98 96 82 %
17 17 19 13 6 dB
STIMULUS 80dBpk
MEAN STIMULUS
STABILITY 93%
TEST TIME 0M 48SEC
SAVE DIRECTORY
C:\DPE315\ECHODATA
FILLED=222/999
REVIEW DIRECTORY
A:\12600
SCREEN DATA SOURCE
12600\X28A1Q05
Damascus University

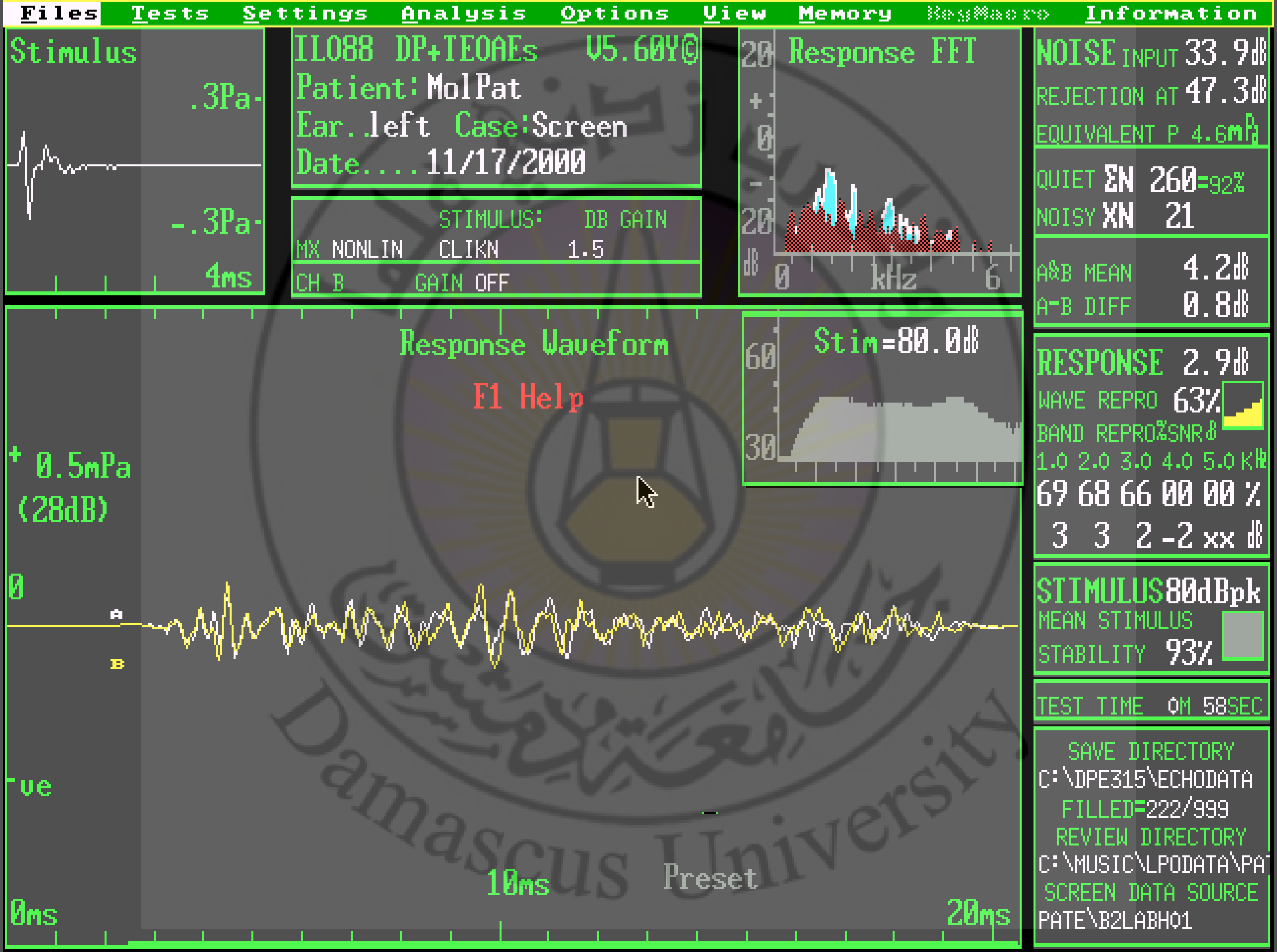
TEOAE waveform: Response FFT

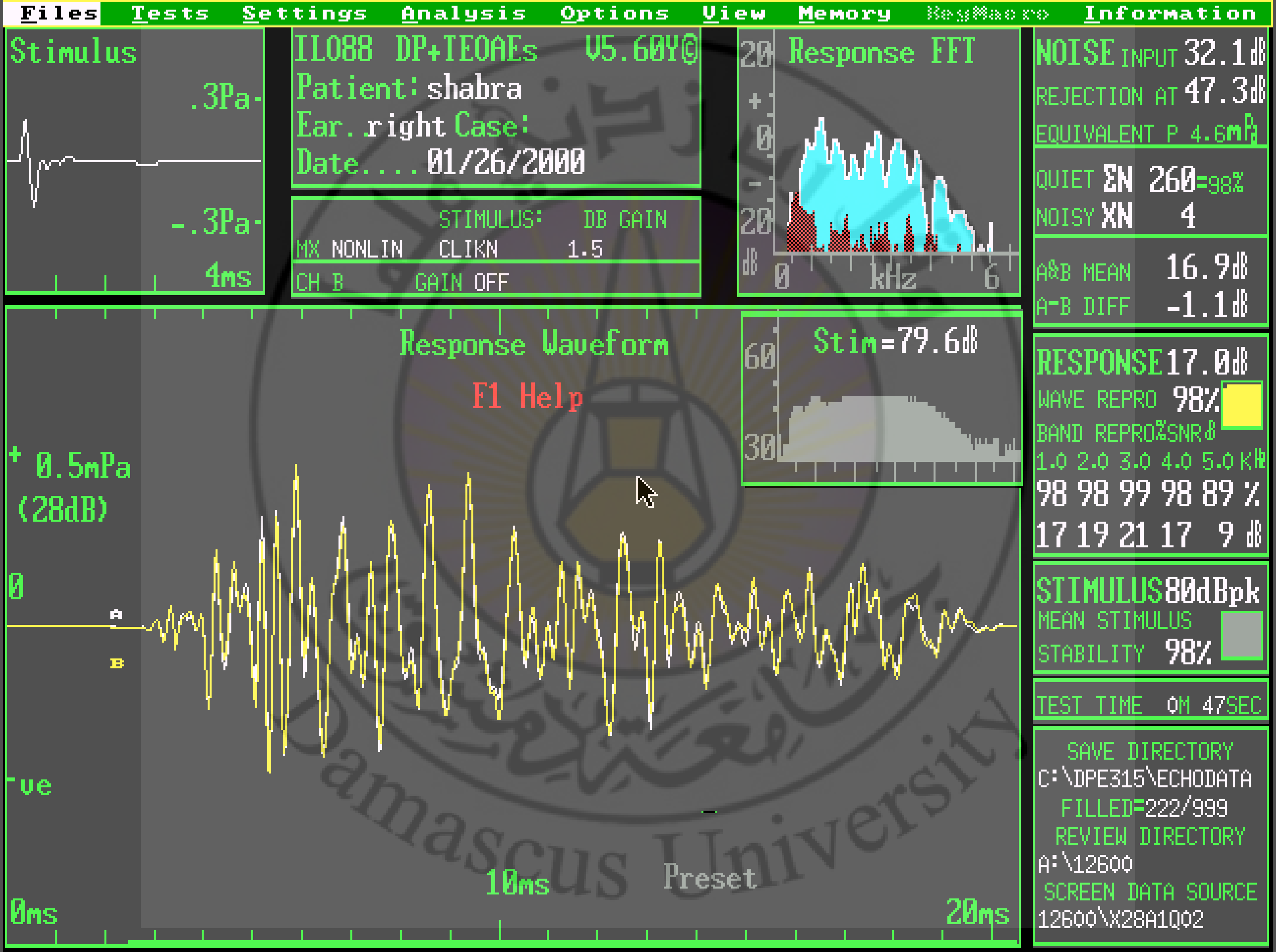


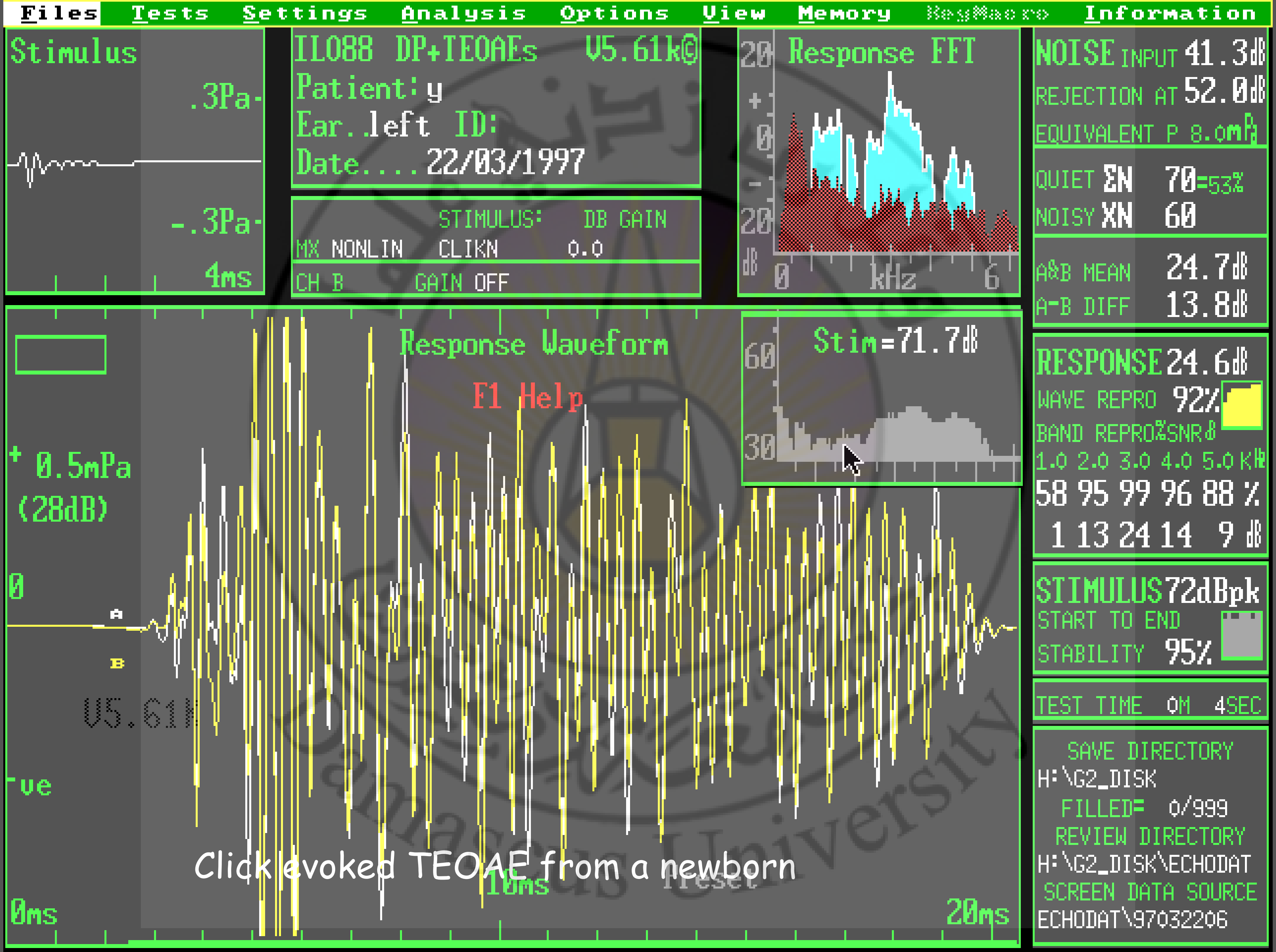
OAE from a damaged ear



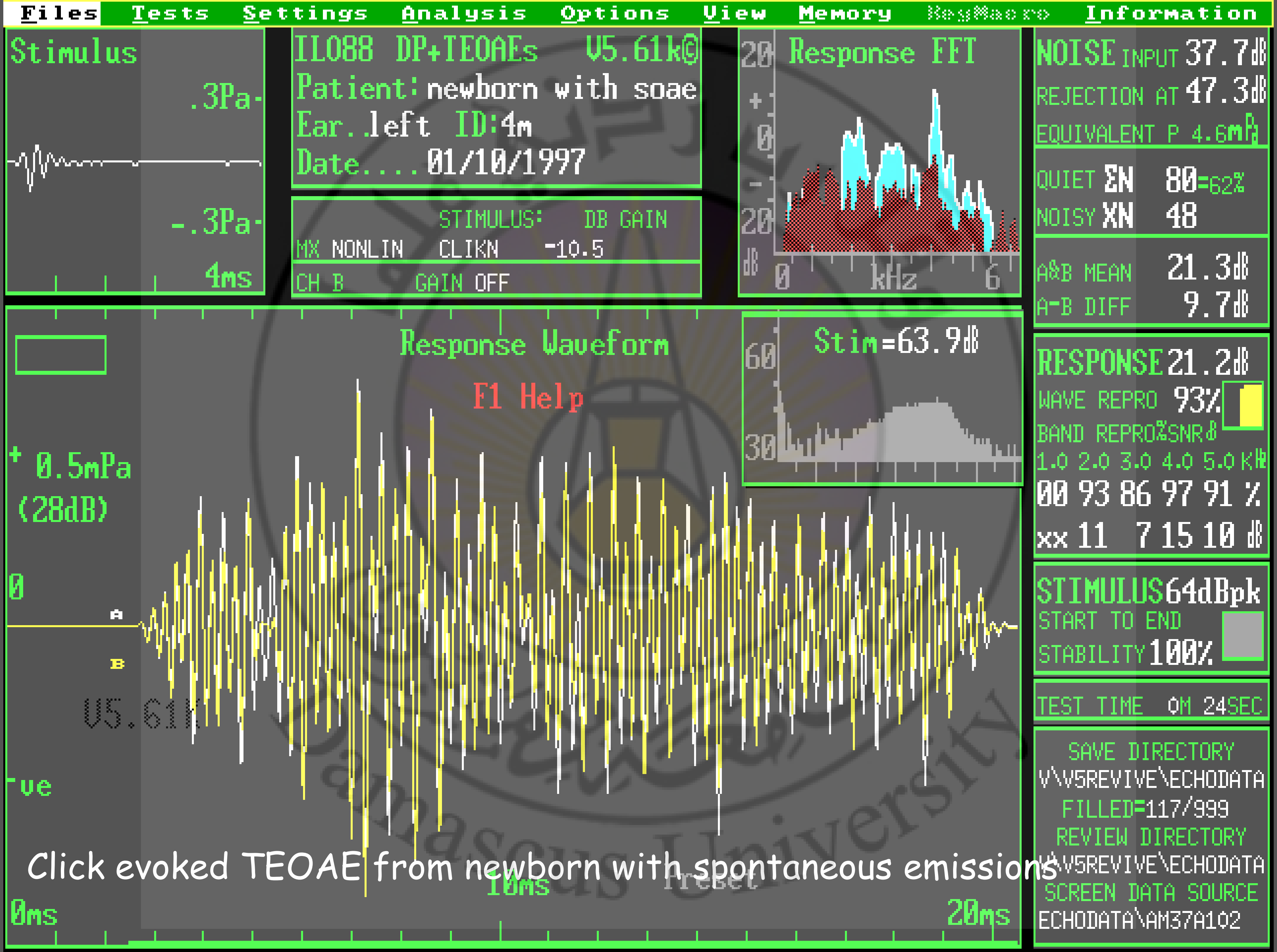
Normal OAE from a healthy ear


Files Tests Settings Analysis Options View Memory KeyMacro Information
Stimulus
.3Pa
-.3Pa
4ms
IL088 DP+TEOAEs V5.60Y©
Patient: MolPat
Ear..left Case:Screen
Date....11/17/2000
STIMULUS: DB GAIN
MX NONLIN CLIKN 1.5
CH B GAIN OFF
Response FFT
20
+
0
-
20
dB
0 kHz 6
NOISE INPUT 33.9dB
REJECTION AT 47.3dB
EQUIVALENT P 4.6mPa
QUIET ΣN 260=92%
NOISY XN 21
A&B MEAN 4.2dB
A-B DIFF 0.8dB
Response Waveform
F1 Help
Stim=80.0dB
60
30
+ 0.5mPa
(28dB)
0
A
B
-ve
0ms
10ms
Preset
20ms
RESPONSE 2.9dB
WAVE REPRO 63%
BAND REPRO%SNRdB
1.0 2.0 3.0 4.0 5.0 KHz
69 68 66 00 00 %
3 3 2 -2 xx dB
STIMULUS 80dBpk
MEAN STIMULUS
STABILITY 93%
TEST TIME 0M 58SEC
SAVE DIRECTORY
C:\DPE315\ECHODATA
FILLED=222/999
REVIEW DIRECTORY
C:\MUSIC\LPODATA\PAT
SCREEN DATA SOURCE
PATE\B2LABH01
Damascus University

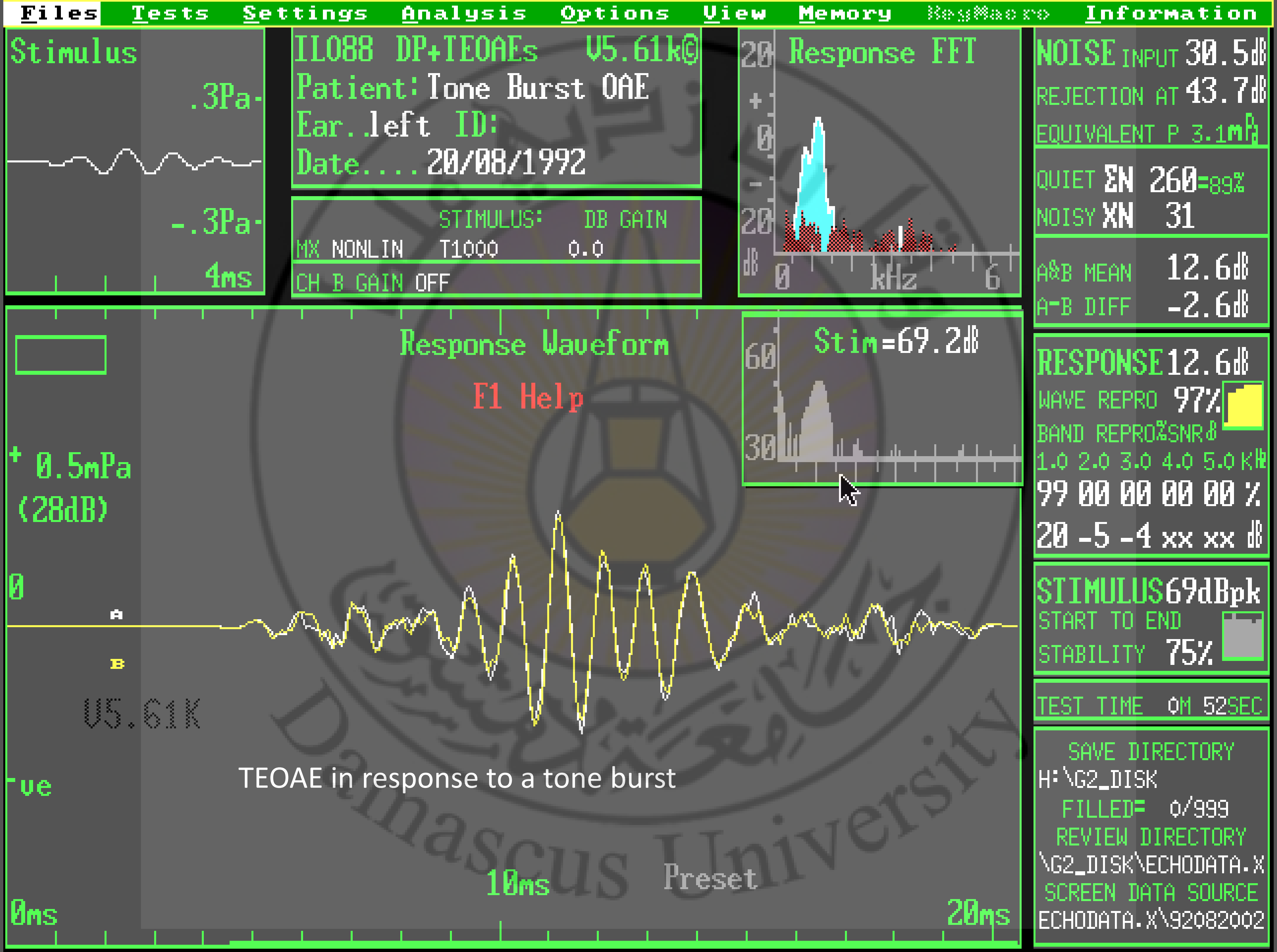

Files Tests Settings Analysis Options View Memory Information
Stimulus
.3Pa
-.3Pa
4ms
IL088 DP+TEOAEs V5.60Y©
Patient: shabra
Ear. right Case:
Date.... 01/26/2000
STIMULUS: DB GAIN
MX NONLIN CLIKN 1.5
CH B GAIN OFF
20 Response FFT
+
0
-
20
dB
0 kHz 6
NOISE INPUT 32.1dB
REJECTION AT 47.3dB
EQUIVALENT P 4.6mPa
QUIET ΣN 260=98%
NOISY XN 4
A&B MEAN 16.9dB
A-B DIFF -1.1dB
Response Waveform
F1 Help
Stim=79.6dB
60
30
+ 0.5mPa
(28dB)
0
A
B
-ve
0ms
10ms
Preset
20ms
RESPONSE 17.0dB
WAVE REPRO 98%
BAND REPRO%SNRdB
1.0 2.0 3.0 4.0 5.0 KHz
98 98 99 98 89 %
17 19 21 17 9 dB
STIMULUS 80dBpk
MEAN STIMULUS
STABILITY 98%
TEST TIME 0M 47SEC
SAVE DIRECTORY
C:\DPE315\ECHODATA
FILLED=222/999
REVIEW DIRECTORY
A:\12600
SCREEN DATA SOURCE
12600\X28A1Q02
Damascus University



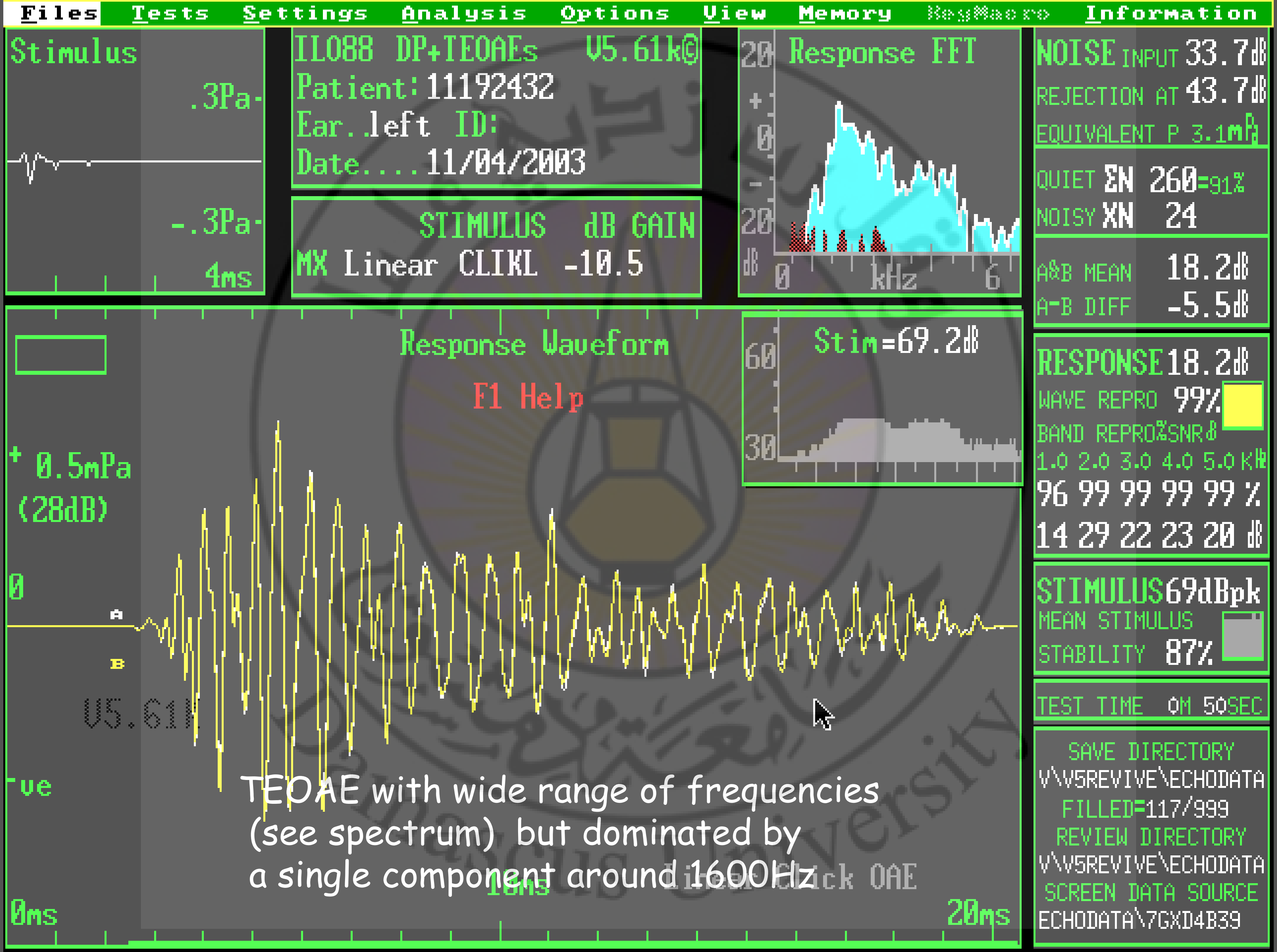
Click evoked TEOAE from a newborn



Click evoked TEOAE from newborn with spontaneous emissions

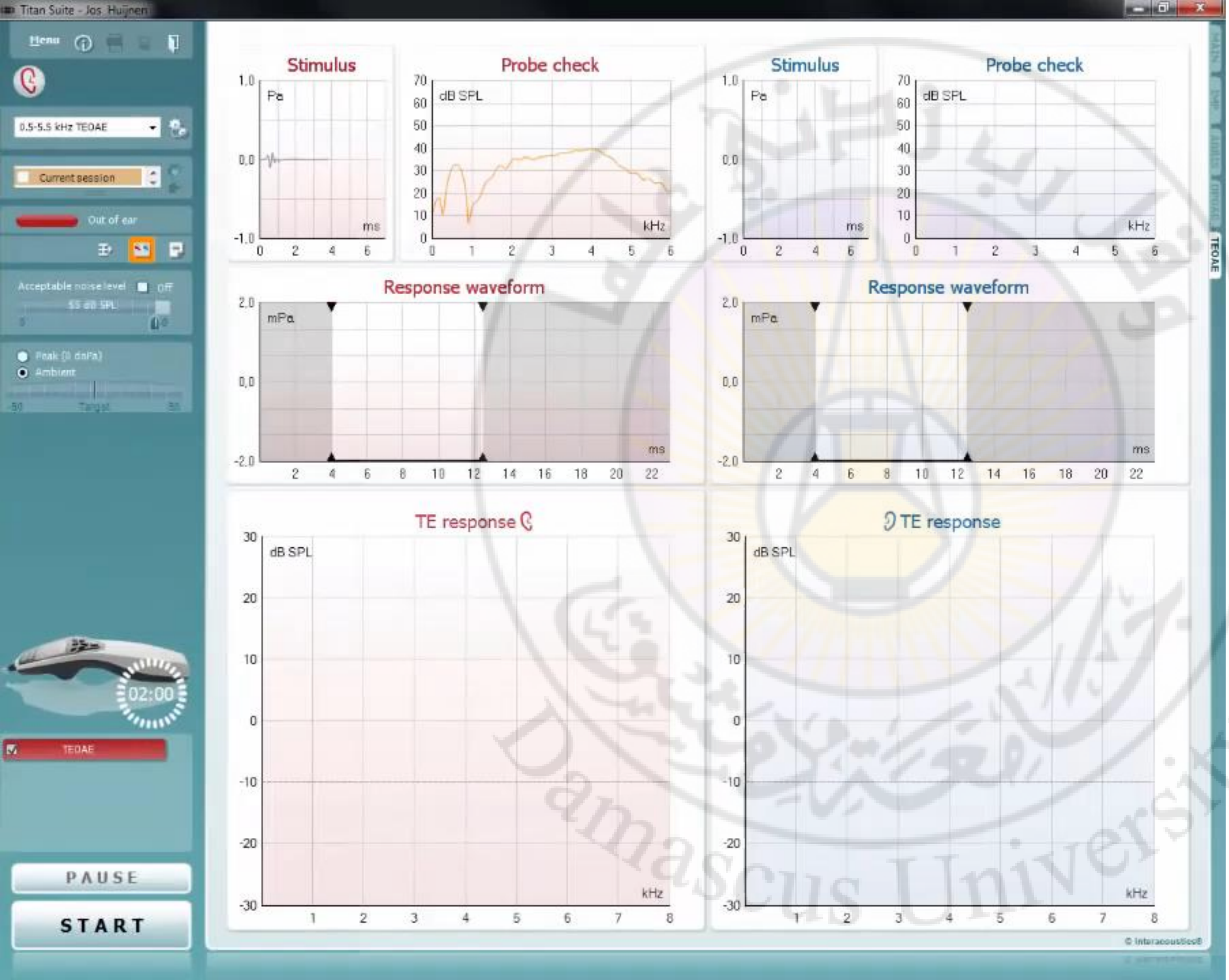


TEOAE in response to a tone burst



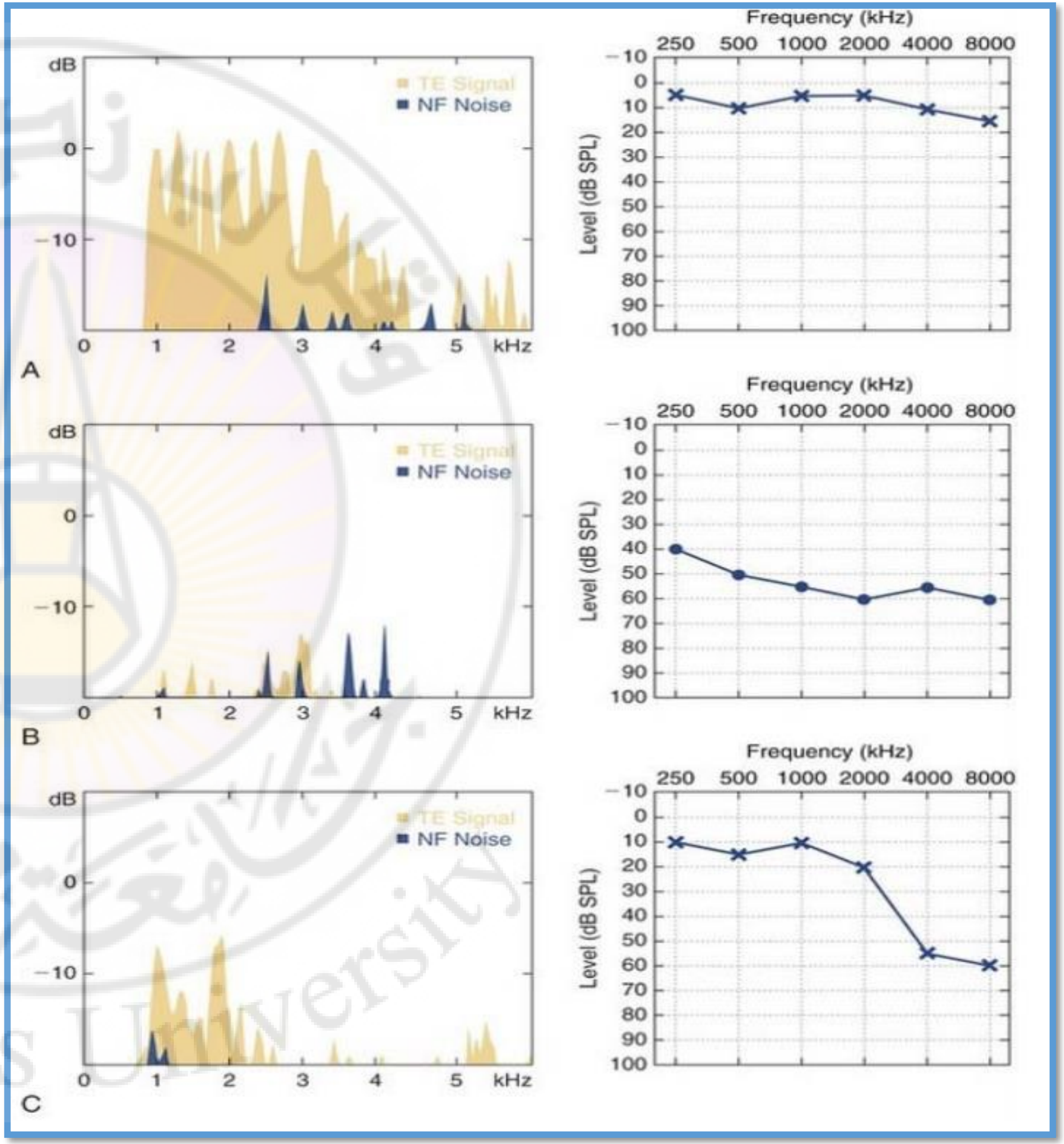
TEOAE with wide range of frequencies (see spectrum) but dominated by a single component around 1600Hz

Spontaneous emissions


Titan Suite - Jos Huijnen
Menu
0.5-5.5 kHz TEOAE
Current session
Out of ear
Acceptable noise level
Off
55 dB SPL
Peak (0 daPa)
Ambient
Target
02:00
TEOAE
PAUSE
START
Stimulus
Pa
ms
Probe check
dB SPL
kHz
Stimulus
Probe check
Response waveform
mPa
Response waveform
TE response
TE response
© Interacoustics®


Titan

TEOAEs and Audiogram



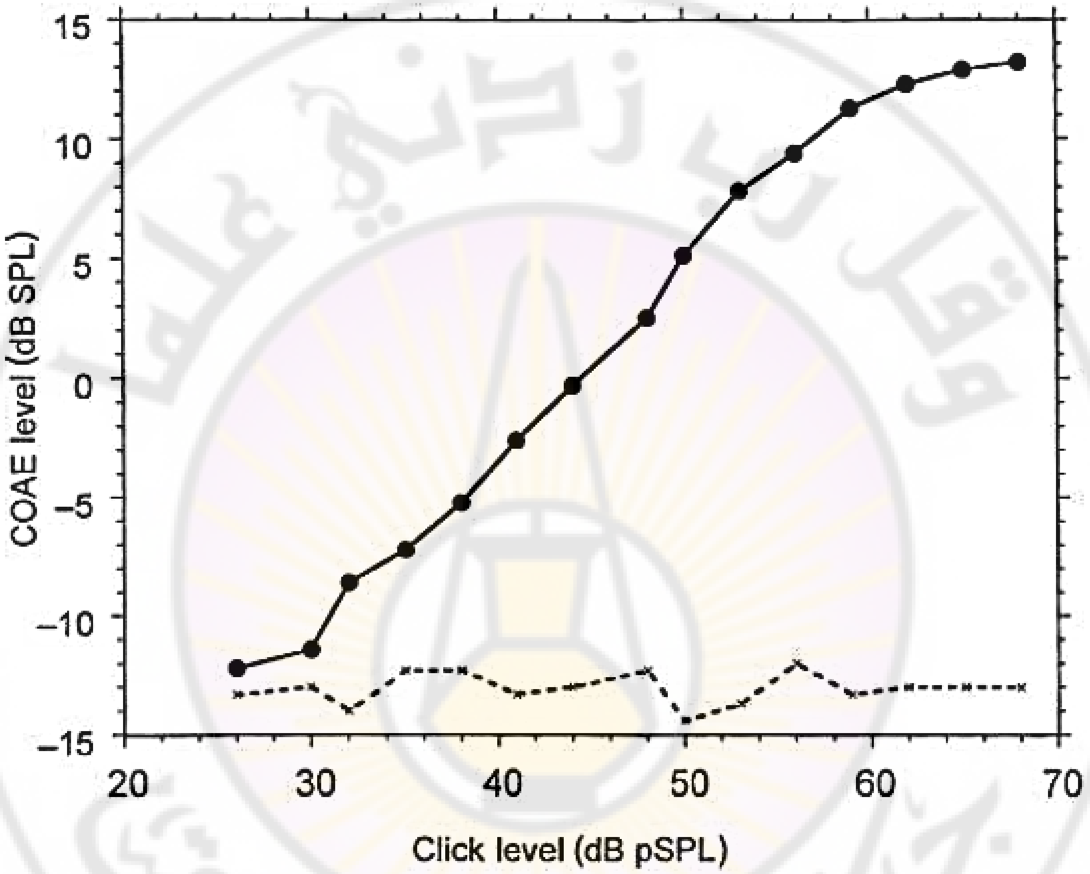
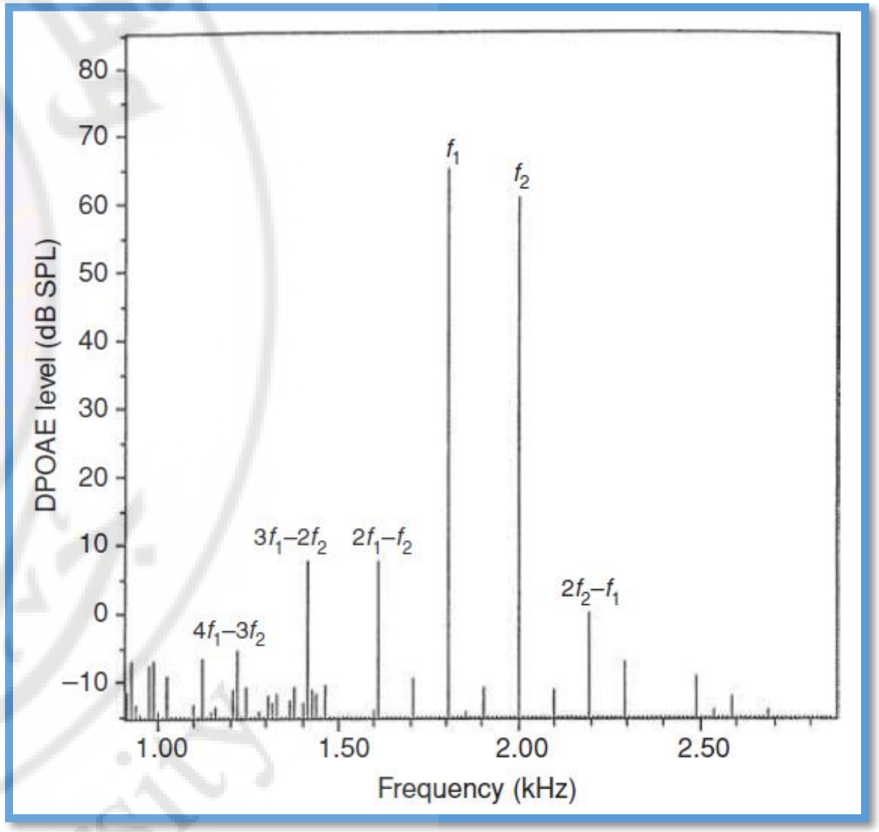
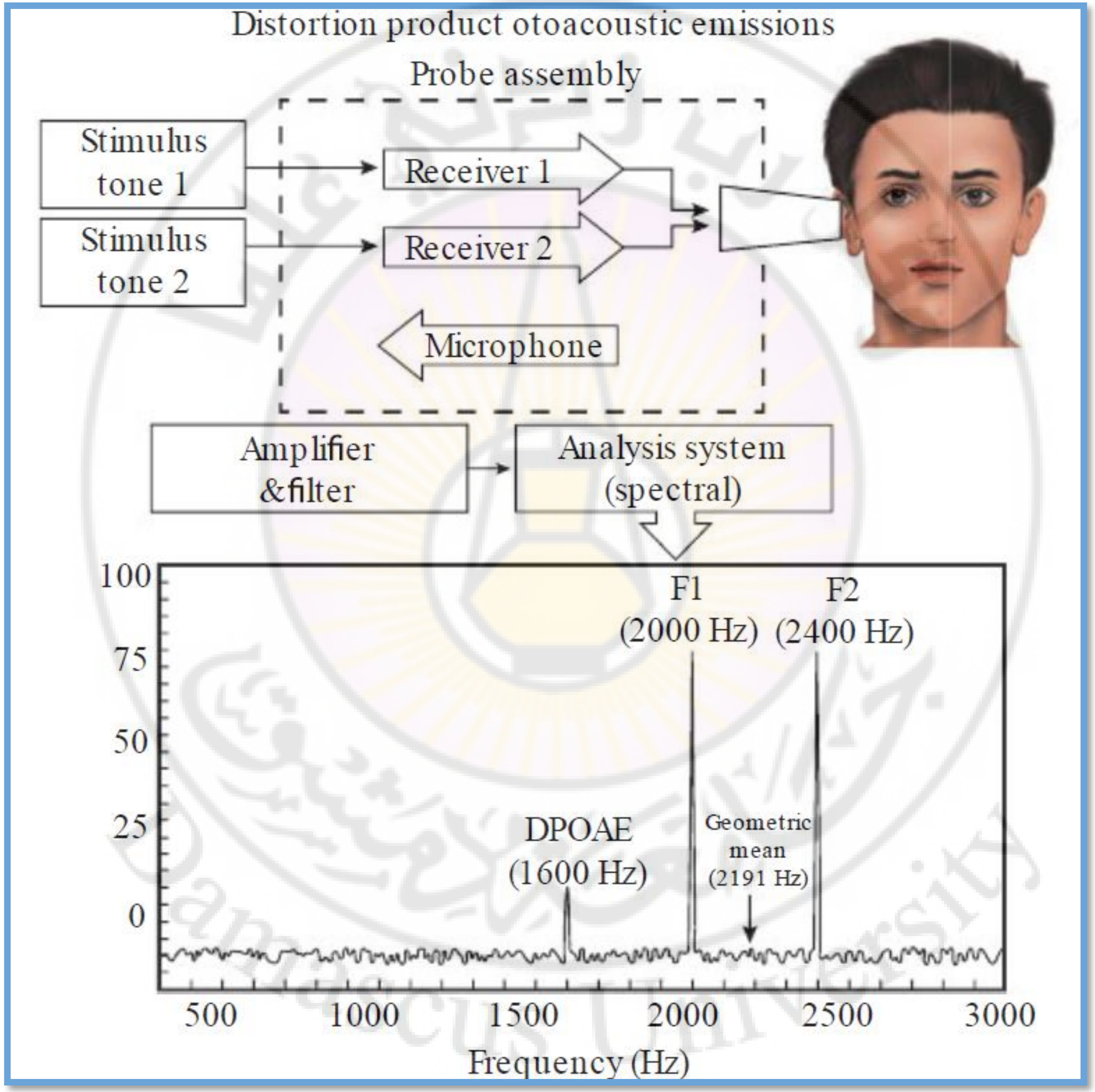


FIGURE 19.5 A COAE growth function recorded from an adult. The *filled circles* indicate COAE levels in dB SPL. The *small Xs connected by dotted lines* indicate the corresponding noise floor levels in dB SPL. The COAE level grows linearly with increases in stimulus levels at low–moderate levels of stimulation; however, the COAE level begins to saturate at higher levels of stimulation (60 to 70 dB pSPL).

Distortion-Product Otoacoustic Emissions (DPOAEs)

- Distortion-product OAEs (DPOAEs) are measured simultaneously with the presentation of two **puretone** stimuli, called "primaries", to the ear.
- The frequencies of the primaries are conventionally designated as "$f1$" and "$f2$" ($f1 < f2$) and the corresponding levels of the primaries as "$L1$" and "$L2$."
- When $f1$ and $f2$ are reasonably close in frequency, interaction of the two primaries on the basilar membrane results in the output of energy by the cochlea at other discrete frequencies that are arithmetically related to the frequencies of the primaries (e.g., $f2–f1$, $2f1–f2$, $3f1–2f2$, $2f2–f1$).
- DPOAEs can therefore be measured using narrowband filtering centered at the frequency of interest.





Distortion product otoacoustic emissions
Probe assembly
Stimulus tone 1
Stimulus tone 2
Receiver 1
Receiver 2
Microphone
Amplifier &filter
Analysis system (spectral)
100
75
50
25
0
F1 (2000 Hz)
F2 (2400 Hz)
DPOAE (1600 Hz)
Geometric mean (2191 Hz)
500
1000
1500
2000
2500
3000
Frequency (Hz)

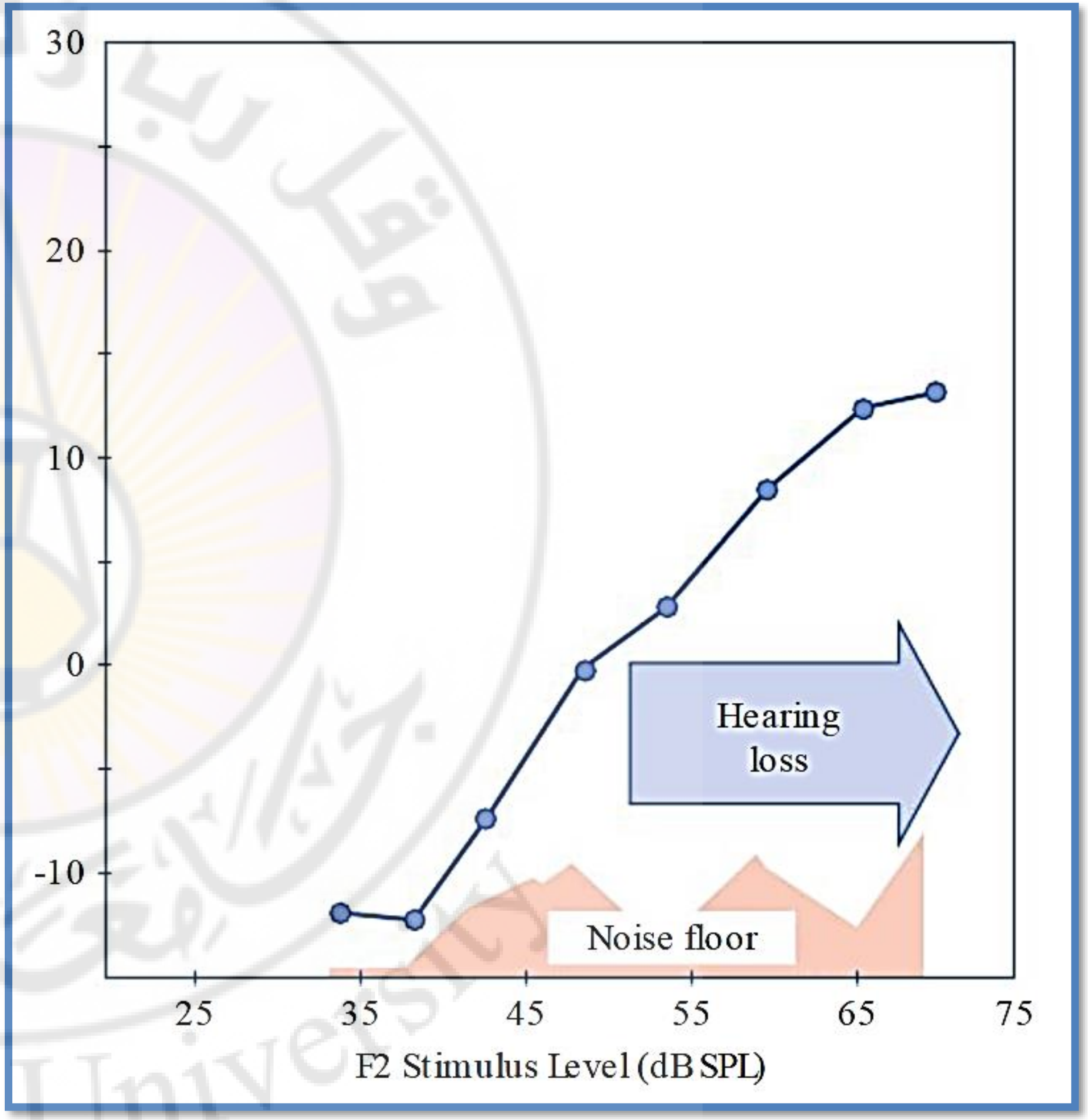
DPOAEs: *ADP*

- DPOAEs measured in the ear canal are a combination of energy from a nonlinear distortion component originating at the region of overlap between the primaries and a reflection component originating from the region of the DPOAE frequency.

DPOAEs

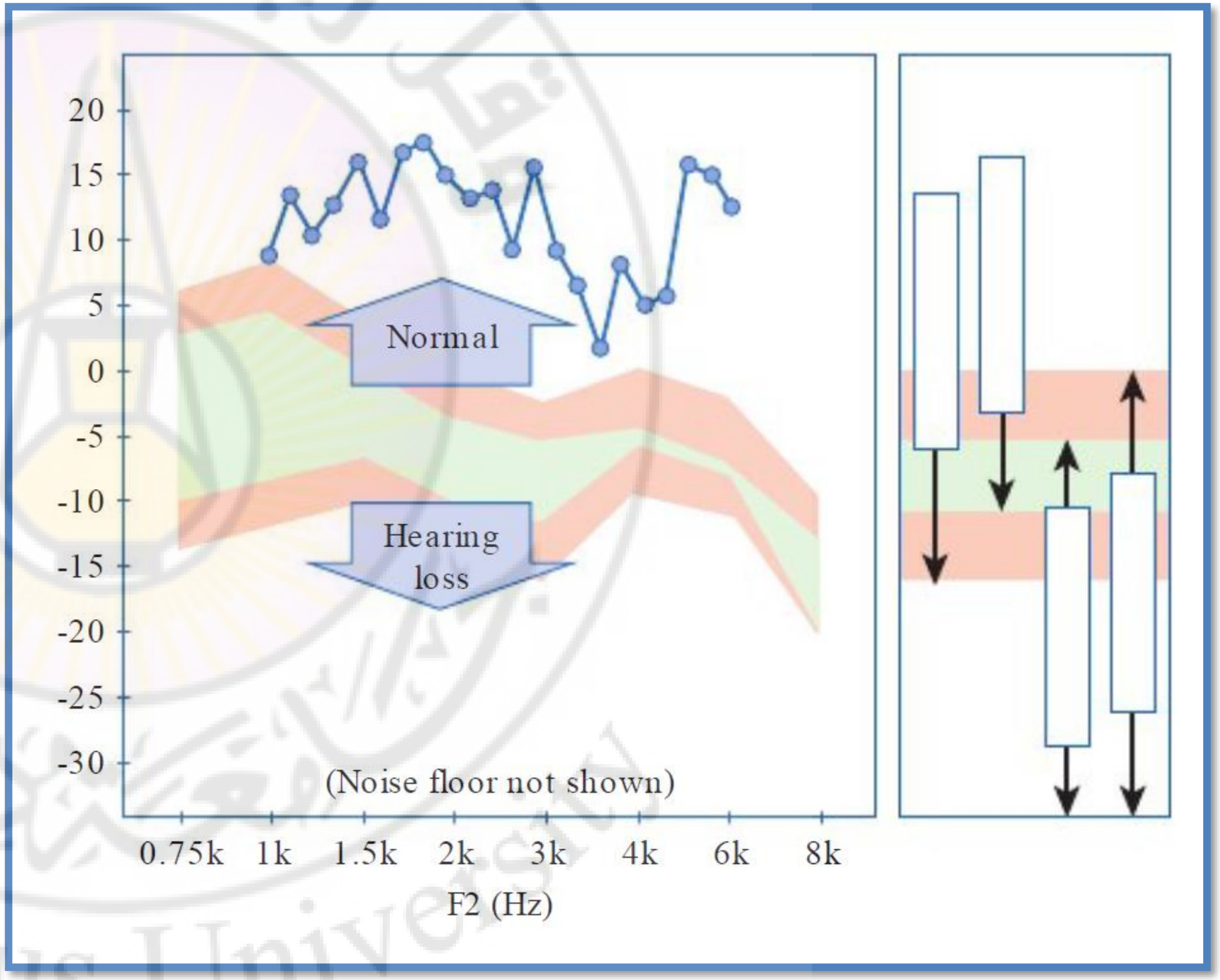
- Two kinds of DPOAE measures based on these properties are the **DPOAE input/output function** and the **DP-gram.**
- The **DPOAE input/output** function is obtained by measuring DPOAE amplitude as a function of stimulus level at a particular frequency (given as either F2 or the geometric mean of F1 and F2).
- **The DP-gram** (sometimes called the DP audiogram or DPOAE audiogram) is obtained by presenting the stimulus tones at fixed levels *(e.g., L1 at 65 SPL and L2 at 55 dB SPL)* across a range of frequencies (expressed as either F2 or the geometric mean of F1 and F2).
- In other words, it shows DPOAE amplitude as a function of frequency.

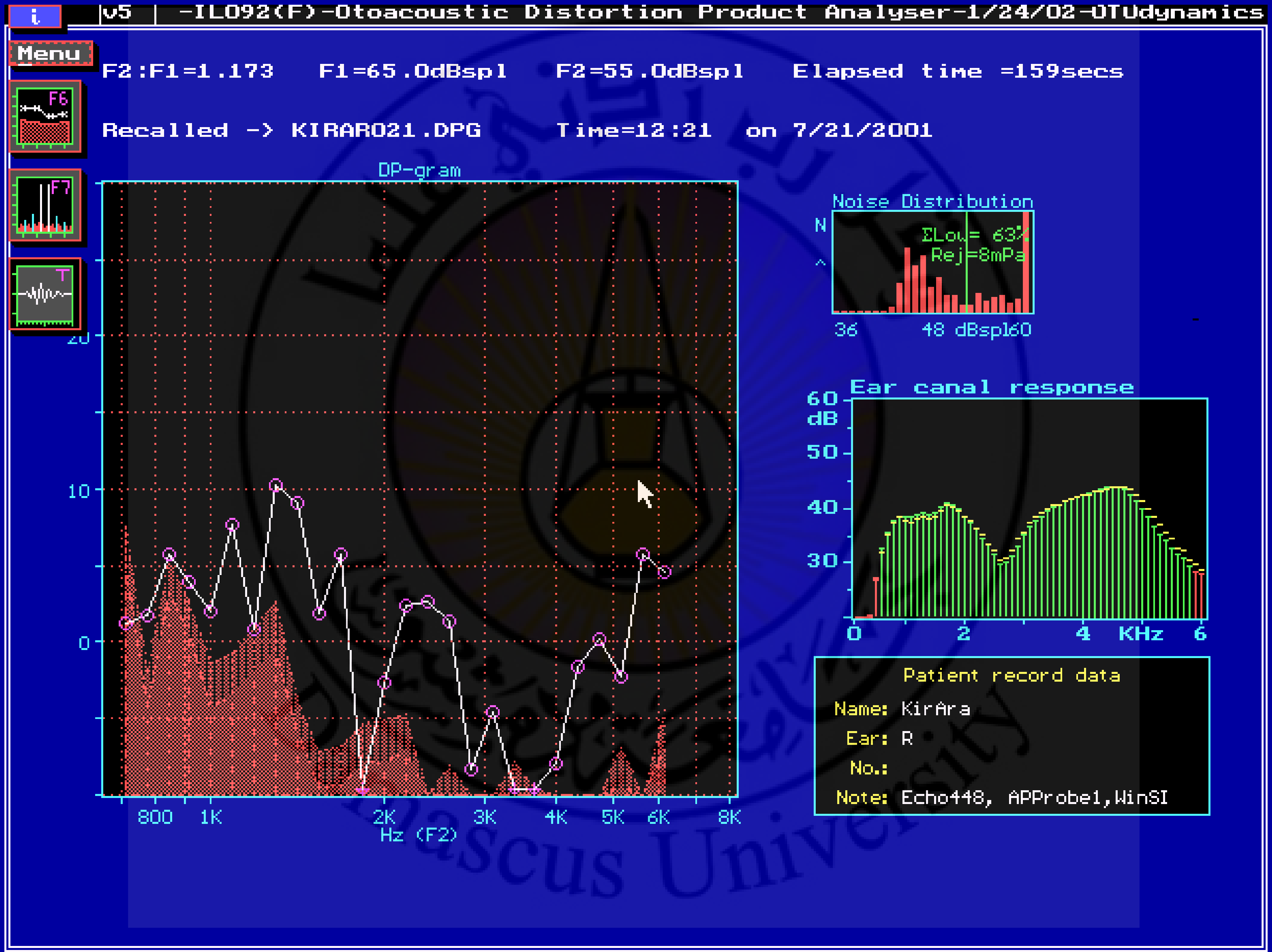
Example of normal results on the distortion product otoacoustic emission (DPOAE) **input/output function**. It depicts DPOAE amplitude as a function of stimulus level for an F2 frequency of 1000 Hz.

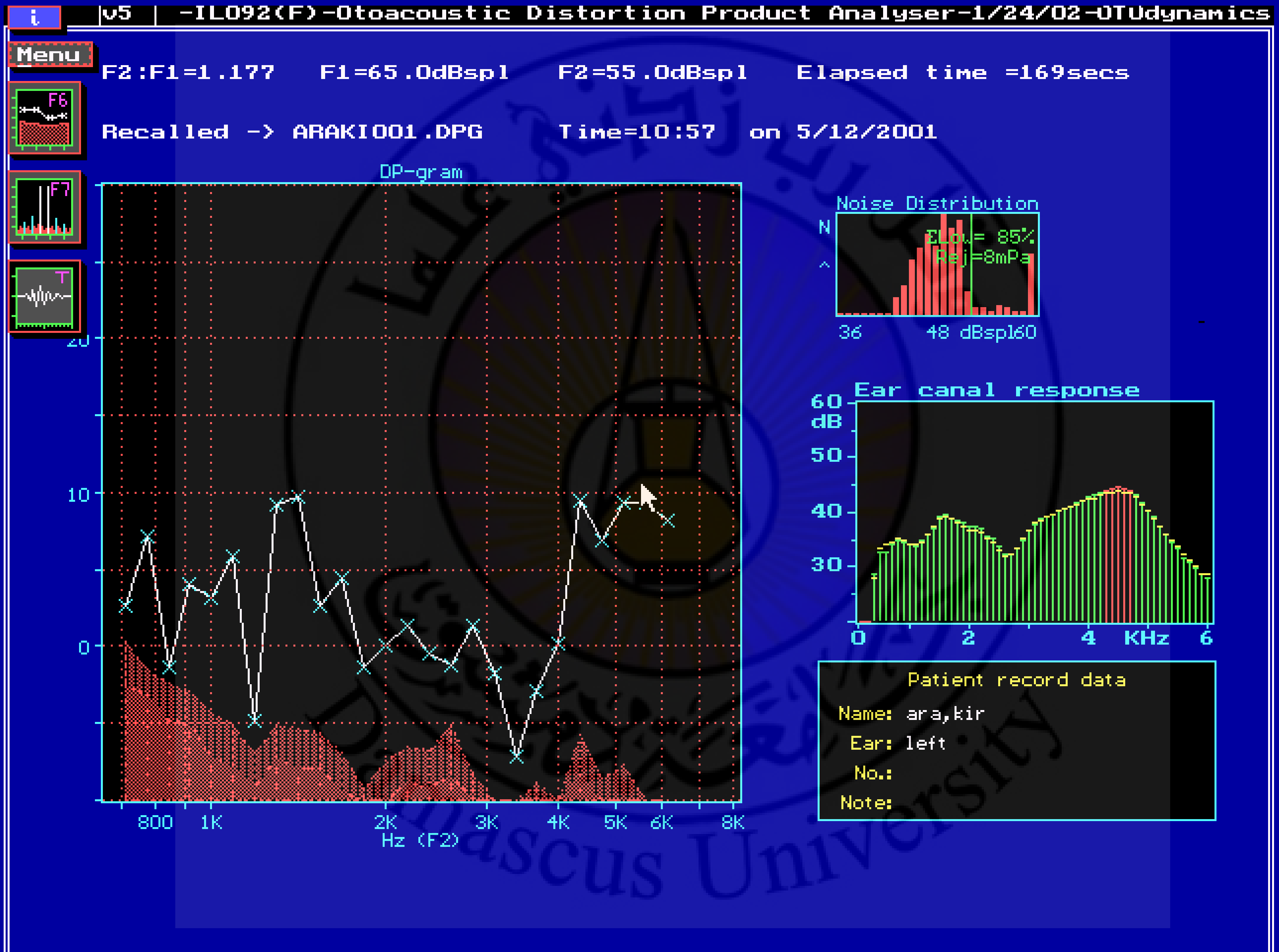


Example of normal results on the **DP-gram**.

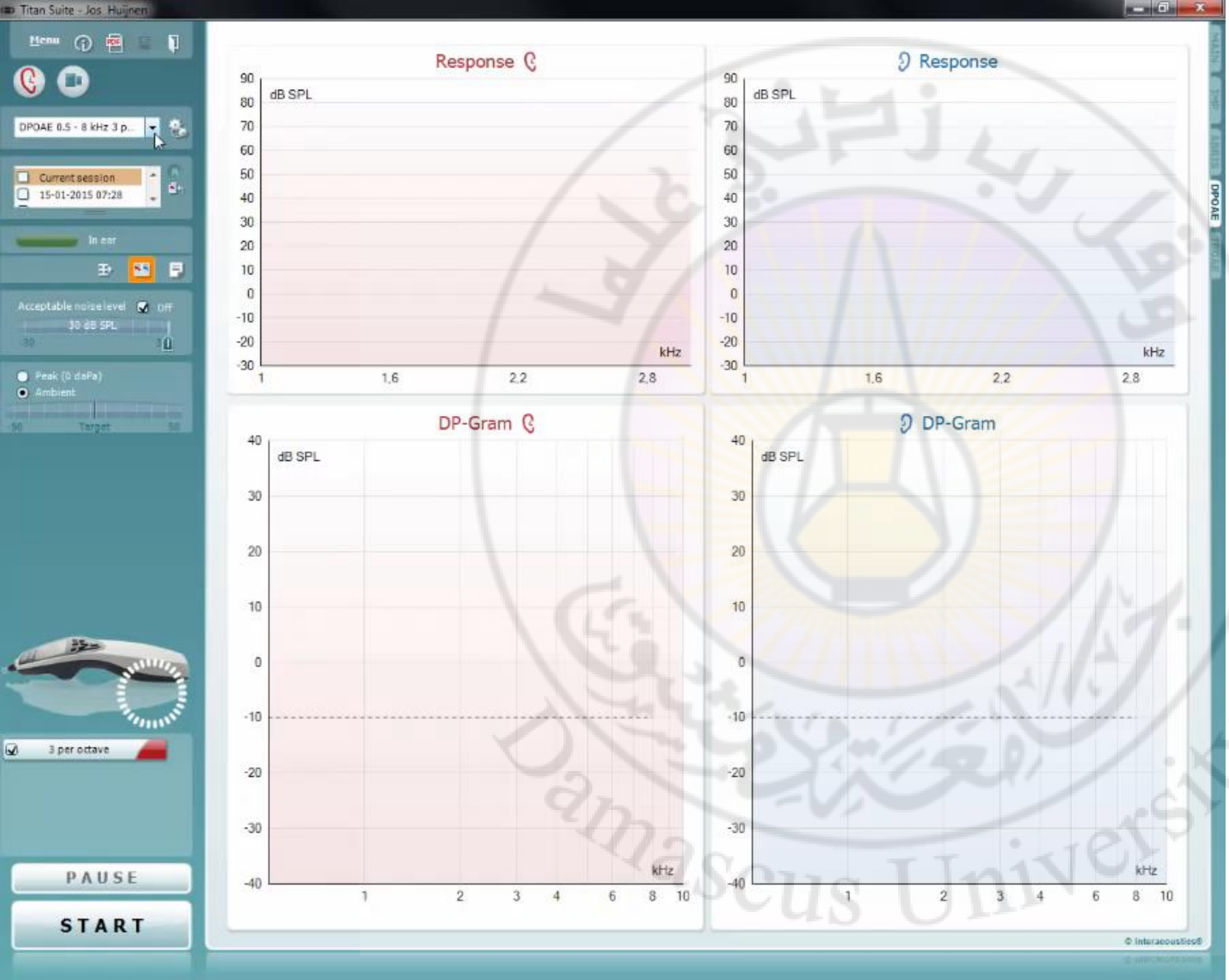
Distortion product otoacoustic emission (DPOAE) amplitudes are shown as a function of F2 frequencies between 1000 and 6000 Hz when the stimulus levels were kept fixed at 65 dB SPL for F1 and 55 dB SPL for F2.




v5
-ILO92(F)-Otoacoustic Distortion Product Analyser-1/24/02-OTOdynamics
Menu
F2:F1=1.173 F1=65.0dBspl F2=55.0dBspl Elapsed time =159secs
Recalled -> KIRAR021.DPG Time=12:21 on 7/21/2001
DP-gram
F6
F7
T
20
10
0
800
1K
2K
3K
4K
5K
6K
8K
Hz (F2)
Noise Distribution
N
ΣLow= 63%
Rej=8mPa
36
48 dBspl60
Ear canal response
60 dB
50
40
30
0
2
4
KHz
6
Patient record data
Name: KirAra
Ear: R
No.:
Note: Echo448, APProbe1,WinSI



v5
-ILO92(F)-Otoacoustic Distortion Product Analyser-1/24/02-OTOdynamics
Menu
F2:F1=1.177 F1=65.0dBspl F2=55.0dBspl Elapsed time =169secs
Recalled -> ARAKI001.DPG Time=10:57 on 5/12/2001
DP-gram
20
10
0
800 1K 2K 3K 4K 5K 6K 8K
Hz (F2)
Noise Distribution
N
ΣLow= 85%
Rej=8mPa
36 48 dBspl60
Ear canal response
60 dB
50
40
30
0 2 4 KHz 6
Patient record data
Name: ara,kir
Ear: left
No.:
Note:

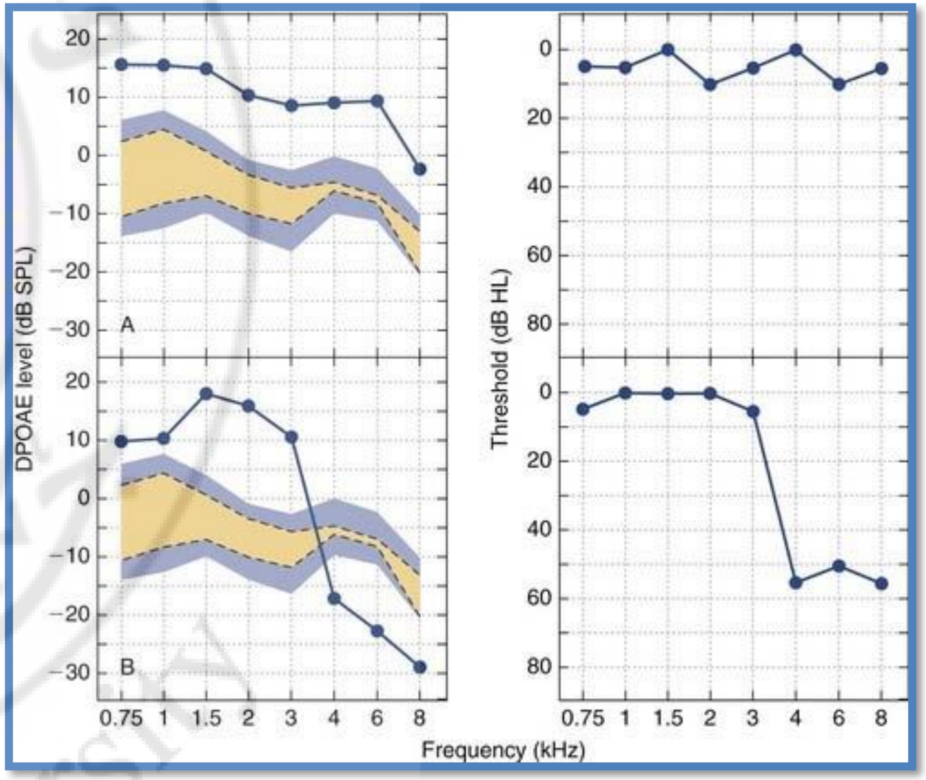


Titan Suite - Jos Huijnen
Menu
DPOAE 0.5 - 8 kHz 3 p...
Current session
15-01-2015 07:28
In ear
Acceptable noise level
Off
30 dB SPL
Peak (0 daPa)
Ambient
Target
3 per octave
PAUSE
START
Response
dB SPL
kHz
DP-Gram
DPOAE
© Interacoustics®

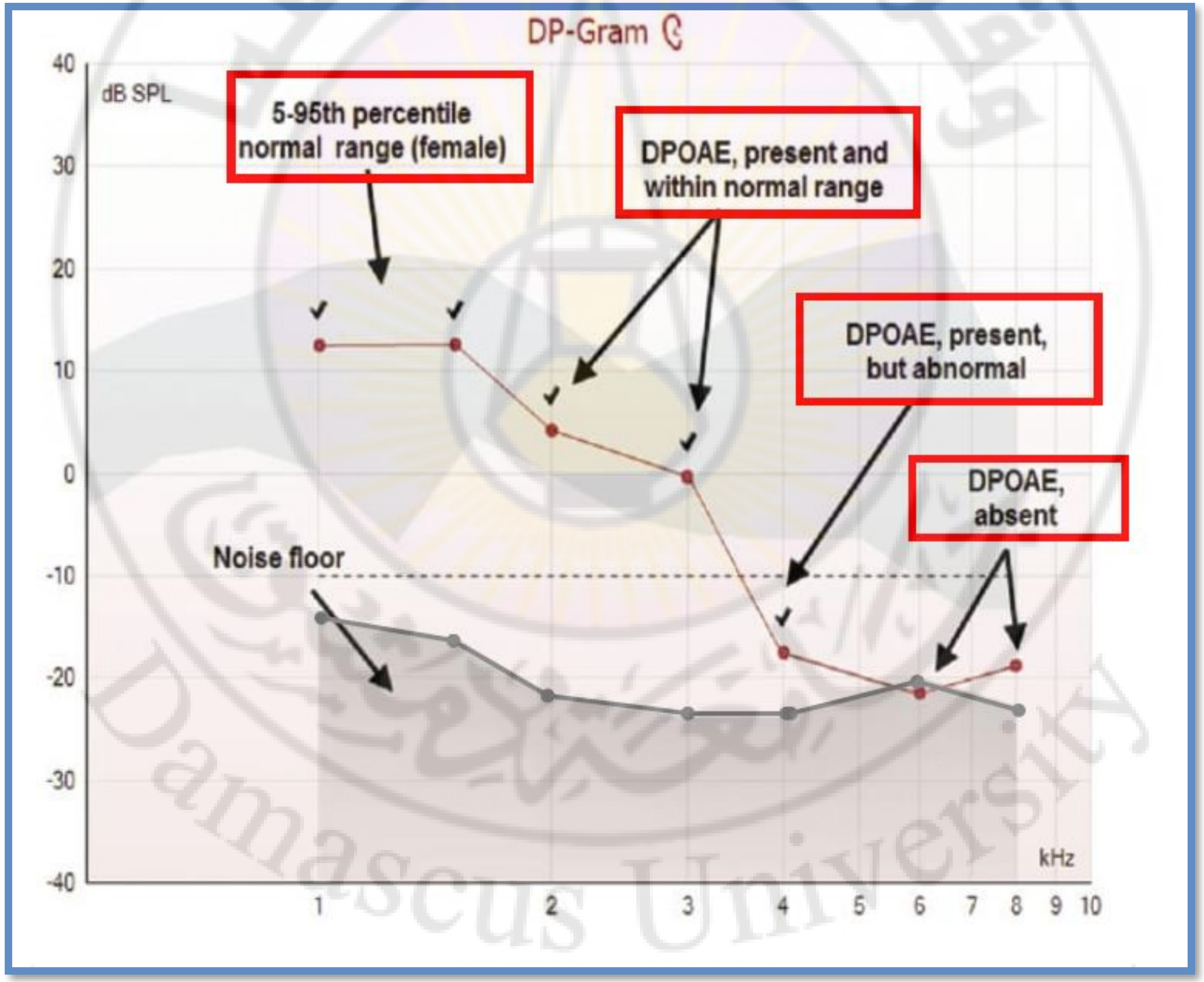
Titan

Distortion-Product Otoacoustic Emissions (DPOAEs)

- DPOAE measurement systems provide a measure of both the DPOAE and surrounding noise level.
- The noise level is most often determined by averaging the levels in several frequency bins on either side of the DPOAE of interest.
- The presence of a particular DPOAE is determined by comparing the level measured within its frequency bin with the noise levels in the surrounding frequency bins and employing some difference criterion.
- For instance, the DPOAE might be considered present if its level is **3 dB or more** above the level of the surrounding noise floor, or if its level exceeds 2 standard deviations above the mean noise level.

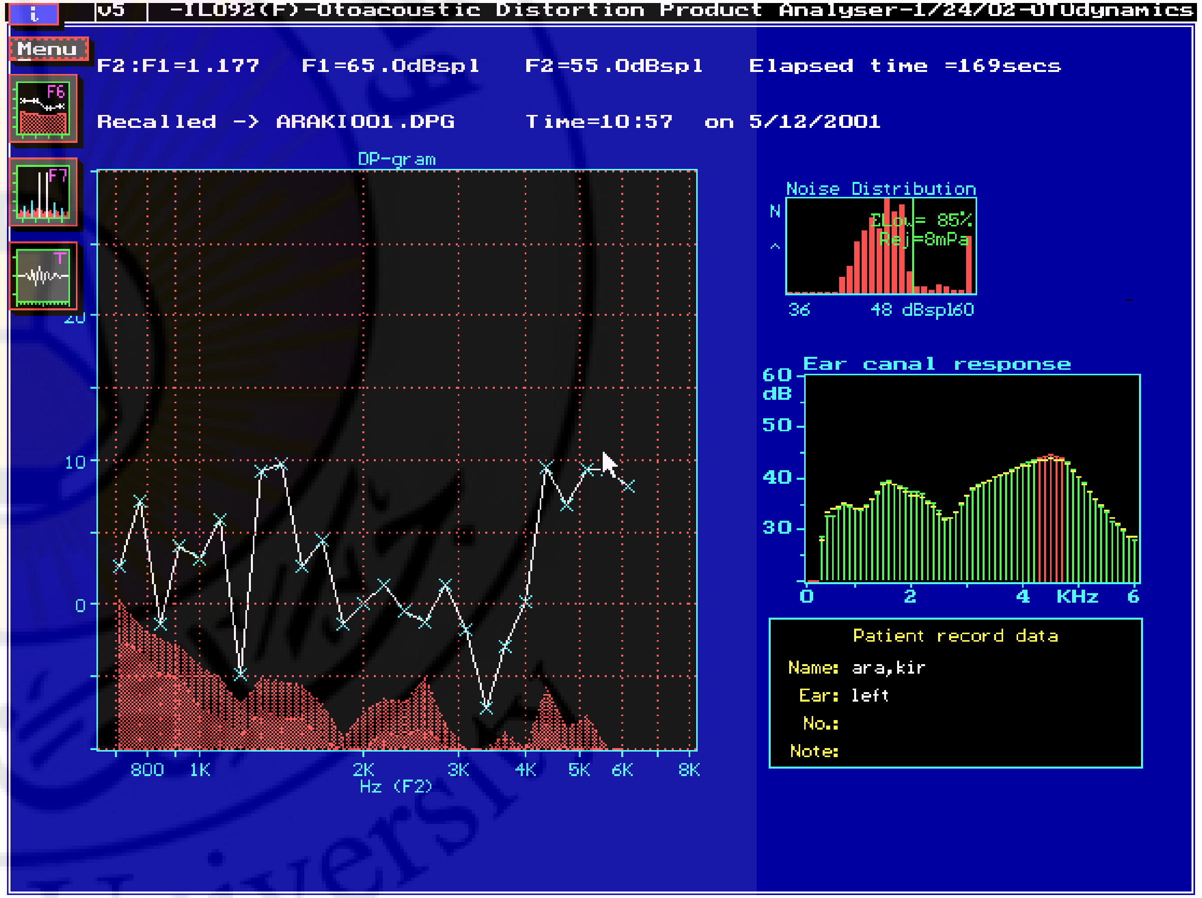


DPOAE waveform analysis



Distortion-Product Otoacoustic Emissions (DPOAEs)

- On average, the **2*f*1–*f*2 DPOAE** has the largest level in human and other mammalian ears compared to other DPOAEs.
- As a result, 2*f*1–*f*2 is the DPOAE that has been the most extensively investigated, particularly for clinical purposes.
- The 2*f*1–*f*2 DPOAE has sometimes been referred to as the **cubic difference tone (CDT).**



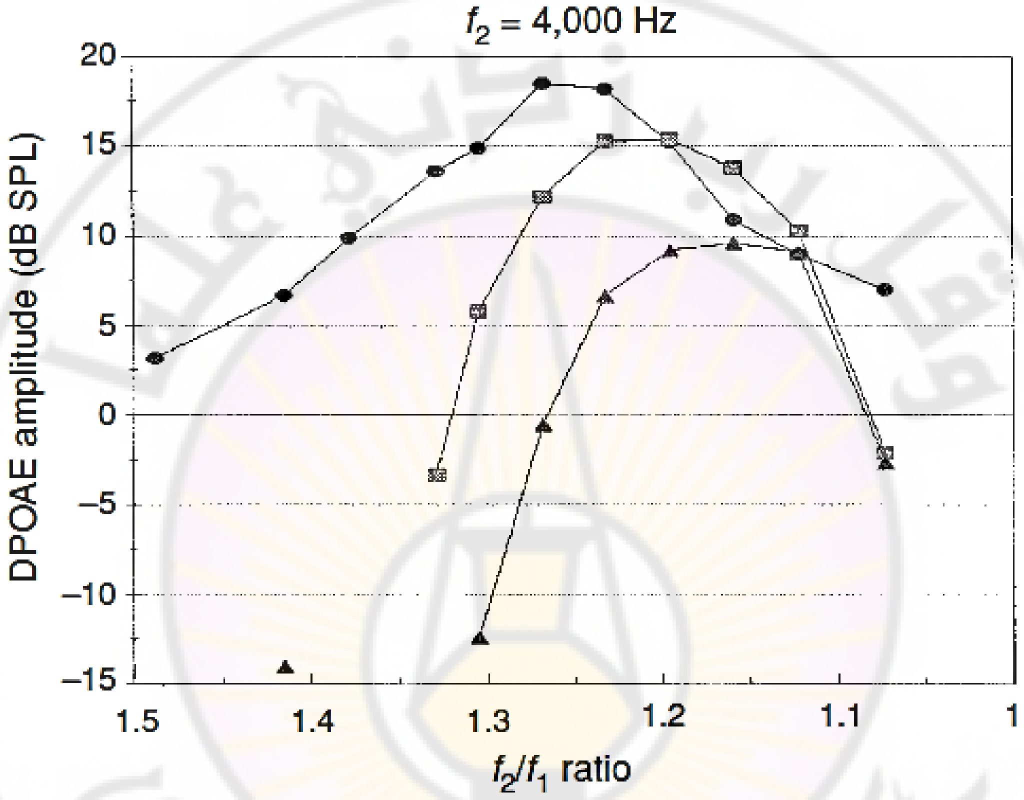


FIGURE 19.7 A graph of DPOAE level as a function of f_2/f_1 ratio from an adult ear at three different stimulus levels ($f_2 = 4{,}000$ Hz). The primary levels used to evoke the DPOAEs were $L_1 = 75$ and $L_2 = 60$ dB SPL (*circles*), $L_1 = 65$ and $L_2 = 50$ dB SPL (*squares*), and $L_1 = 55$ and $L_2 = 40$ dB SPL (*triangles*). As the ratio f_2/f_1 is decreased from a value of approximately 1.5, the DPOAE level increases to a broad maximum at ratios of 1.2 to 1.3 and then declines as the ratio is further decreased. The band-pass-shaped function is typical in both infants and adults.

DPAOE simulation

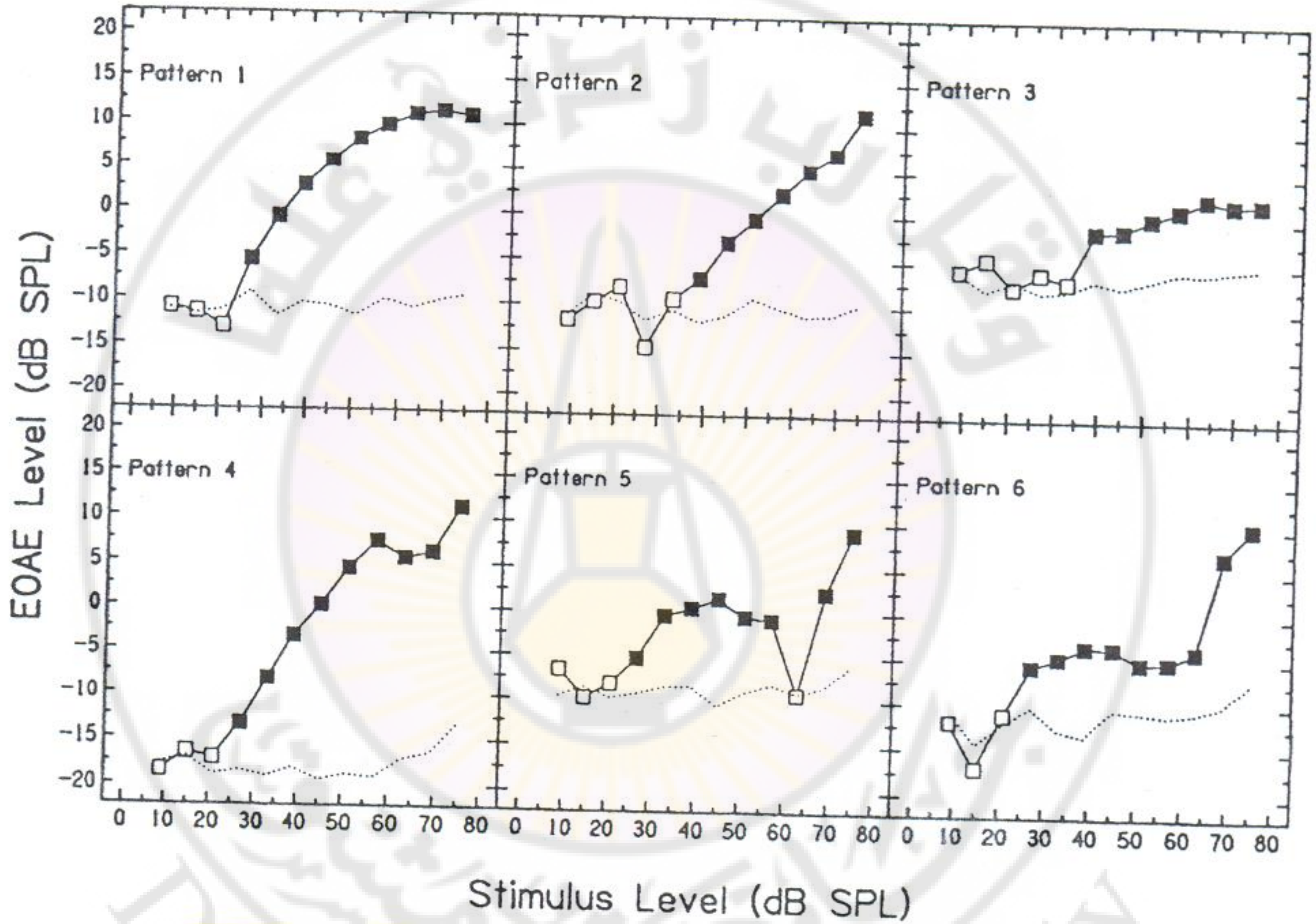


Figure 22.9. Examples of the various DPOAE I/O functions that may be measured from individual ears. Typical patterns include *(1)* growth followed by saturation at high stimulus levels, *(2)* monotonic growth, *(3)* flat patterns, *(4–5)* complex patterns with dips or decreases in DPOAE level with increases in overall stimulus level, and *(6)* growth with changes in slope. (Reprinted with permission from Stover L, Norton SJ (1993) The effects of aging on otoacoustic emissions. J Acoust Soc Am; 94: 2670–2681, ©1993, Acoustical Society of America.)

TEOAEs and DPOAEs and Patient Characteristics

- TEOAE and DPOAE levels change with **development** from infancy to adulthood; however, the exact time course remains uncertain.
- COAE and DPOAE levels in neonates (infants less than 1 month of age) are larger than in adults.
- TEOAEs and DPOAEs are also significantly larger in infants than in toddlers, older children, and adults.
- Differences in level with development are frequency dependent, with infants and children having higher EOAE levels than older children and adults for the higher frequencies but not lower frequencies.
- The differences in EOAE levels across age groups have most often been attributed to **anatomical changes in the outer or middle-ear systems** that occur with development.

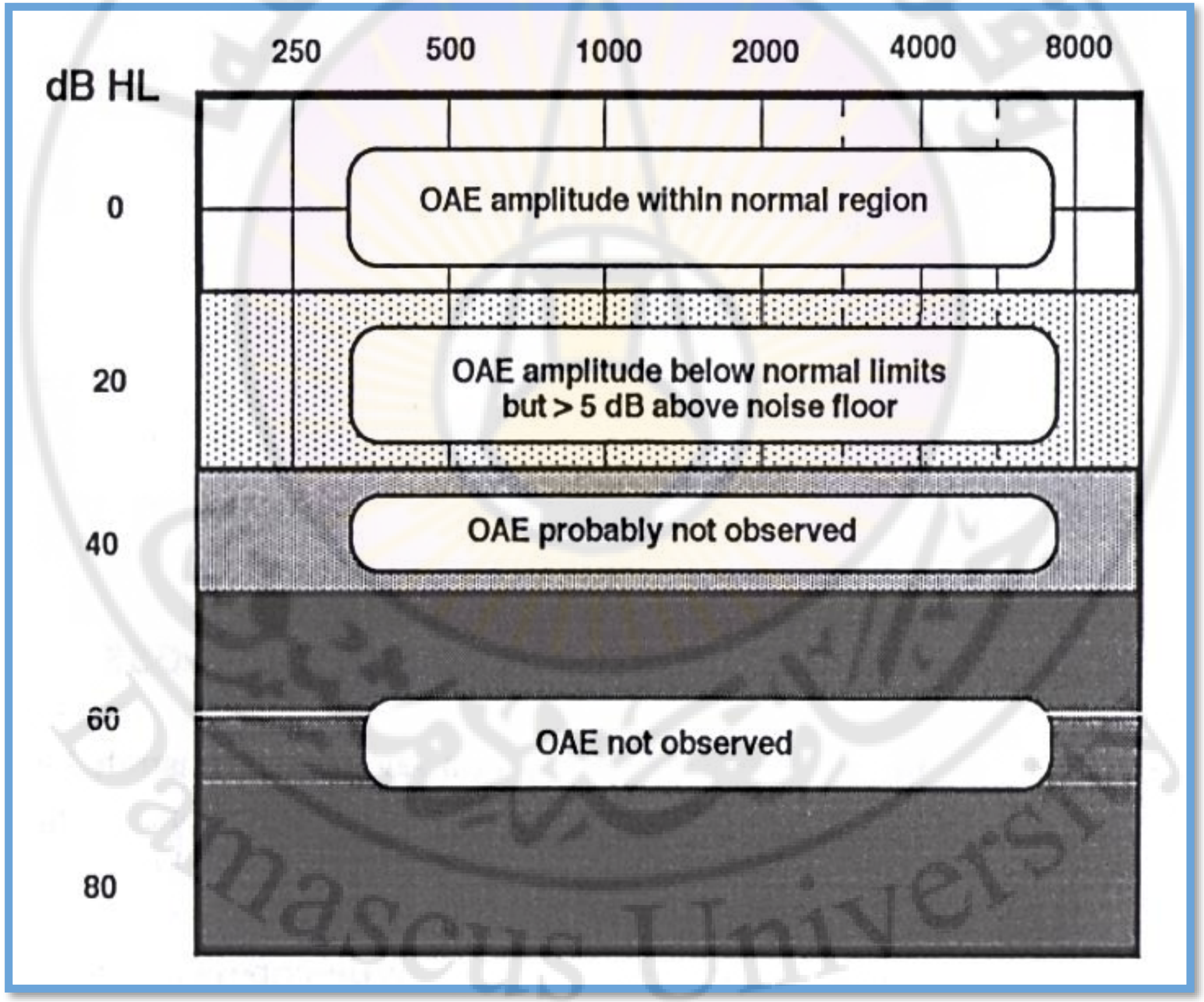
TEOAEs and DPOAEs and Patient Characteristics

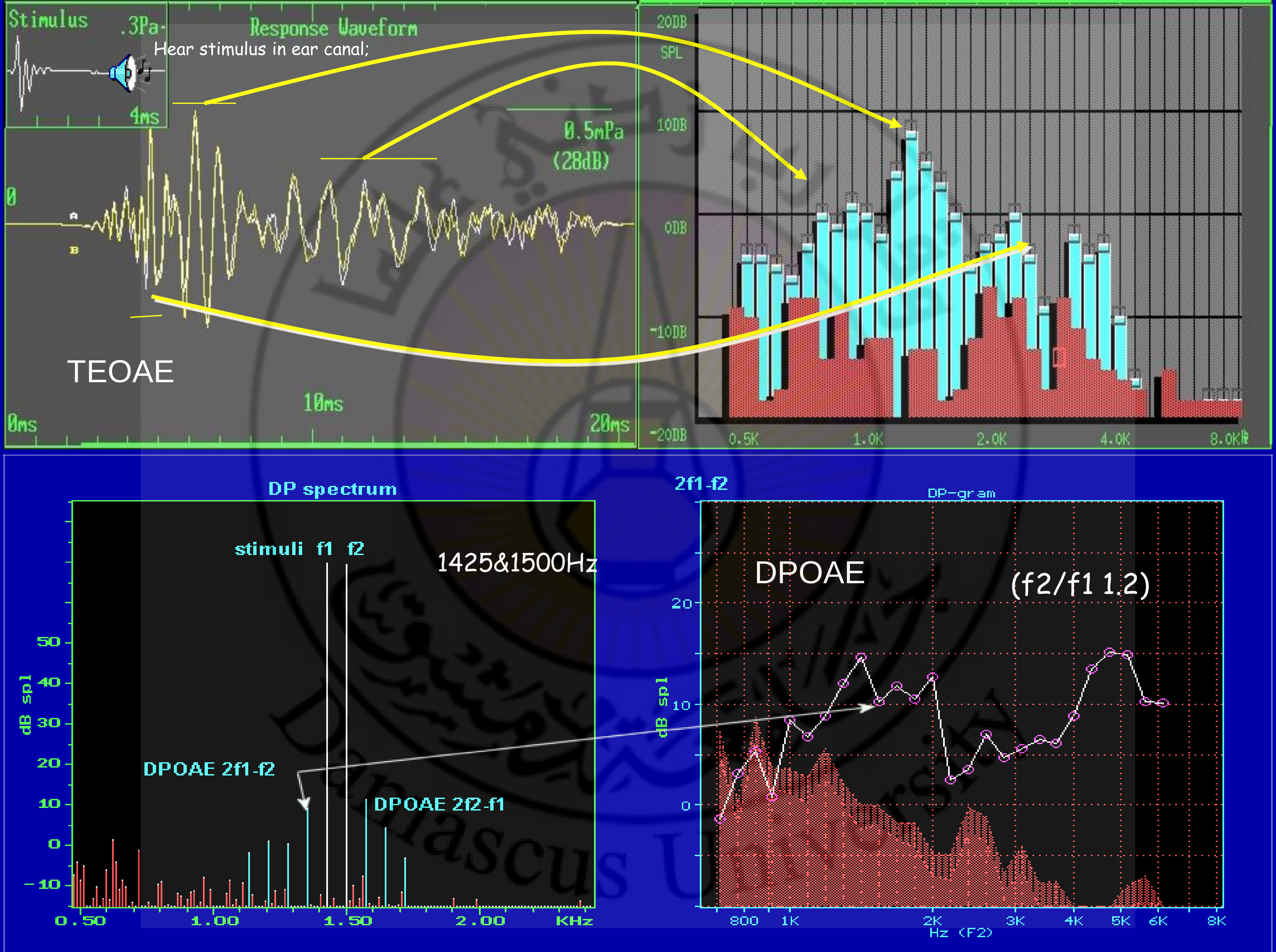
- The effect of **increased age** on COAEs and DPOAEs has been more difficult to study, because behavioral thresholds tend to worsen with increasing age, creating a confounding factor.
- Several early studies reported decreasing COAE and DPOAE levels with increasing age; however, they did not control for auditory threshold.
- The results of most studies that attempted to control for behavioral thresholds indicated no aging effects on TEOAEs.
- Older ears have lower DPOAE levels at 8,000 Hz, but the difference is small and has little clinical significance

TEOAEs and DPOAEs and Patient Characteristics

- Females, on average, have larger TEOAEs than males.
- Right ears, on average, have larger TEOAEs than left ears.
- The smaller size of the female ear canal on average compared to the male ear canal may result in the higher TEOAE levels measured in female ears.
- The greater number of SOAEs measured in right ears as compared to left ears and in females as compared to males may also contribute to the noted TEOAE level differences.
- For DPOAEs, some researchers have found that DPOAE levels are larger in females than in males. Others have reported significant differences between the sexes at only select frequencies.
- The **presence of SOAEs** also affects the spectrum of TEOAEs. SOAEs can synchronize to the evoking stimulus, resulting in peaks at those frequencies in the TEOAE spectrum.

OAEs and Sensory Hearing Loss





Stimulus
.3Pa
4ms
Hear stimulus in ear canal;
Response Waveform
0.5mPa
(28dB)
TEOAE
0ms
10ms
20ms
20DB SPL
10DB
0DB
-10DB
-20DB
0.5K
1.0K
2.0K
4.0K
8.0KHz
DP spectrum
stimuli f1 f2
1425&1500Hz
DPOAE 2f1-f2
DPOAE 2f2-f1
dB spl
0.50
1.00
1.50
2.00
kHz
2f1-f2
DP-gram
DPOAE
(f2/f1 1.2)
dB spl
Hz (F2)
800
1K
2K
3K
4K
5K
6K
8K

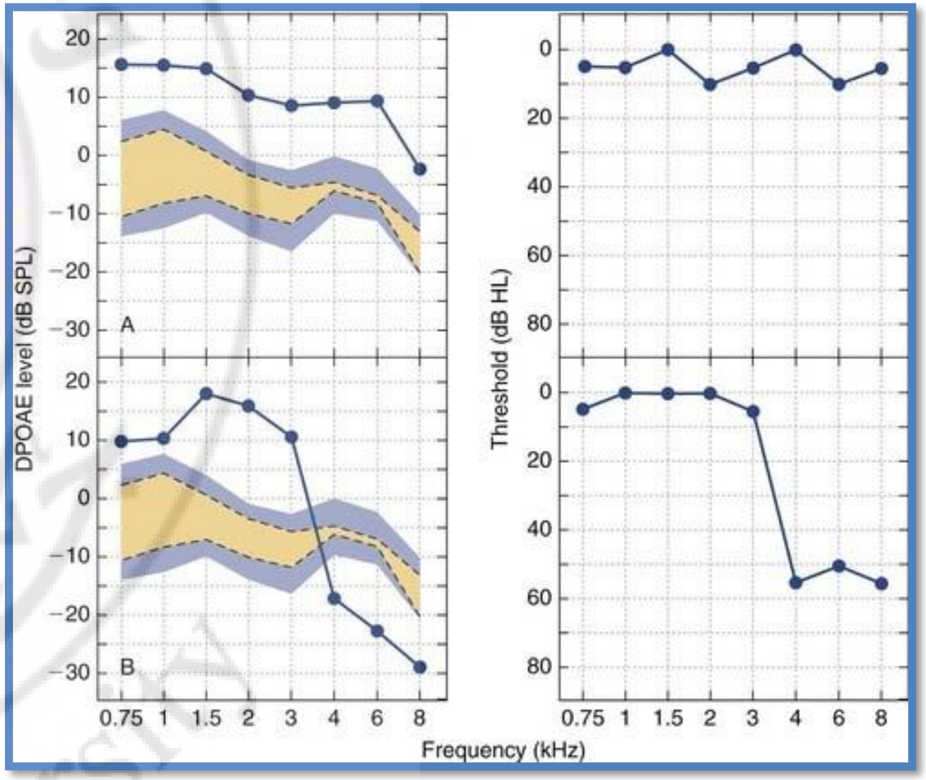
دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Otoacoustic Emissions

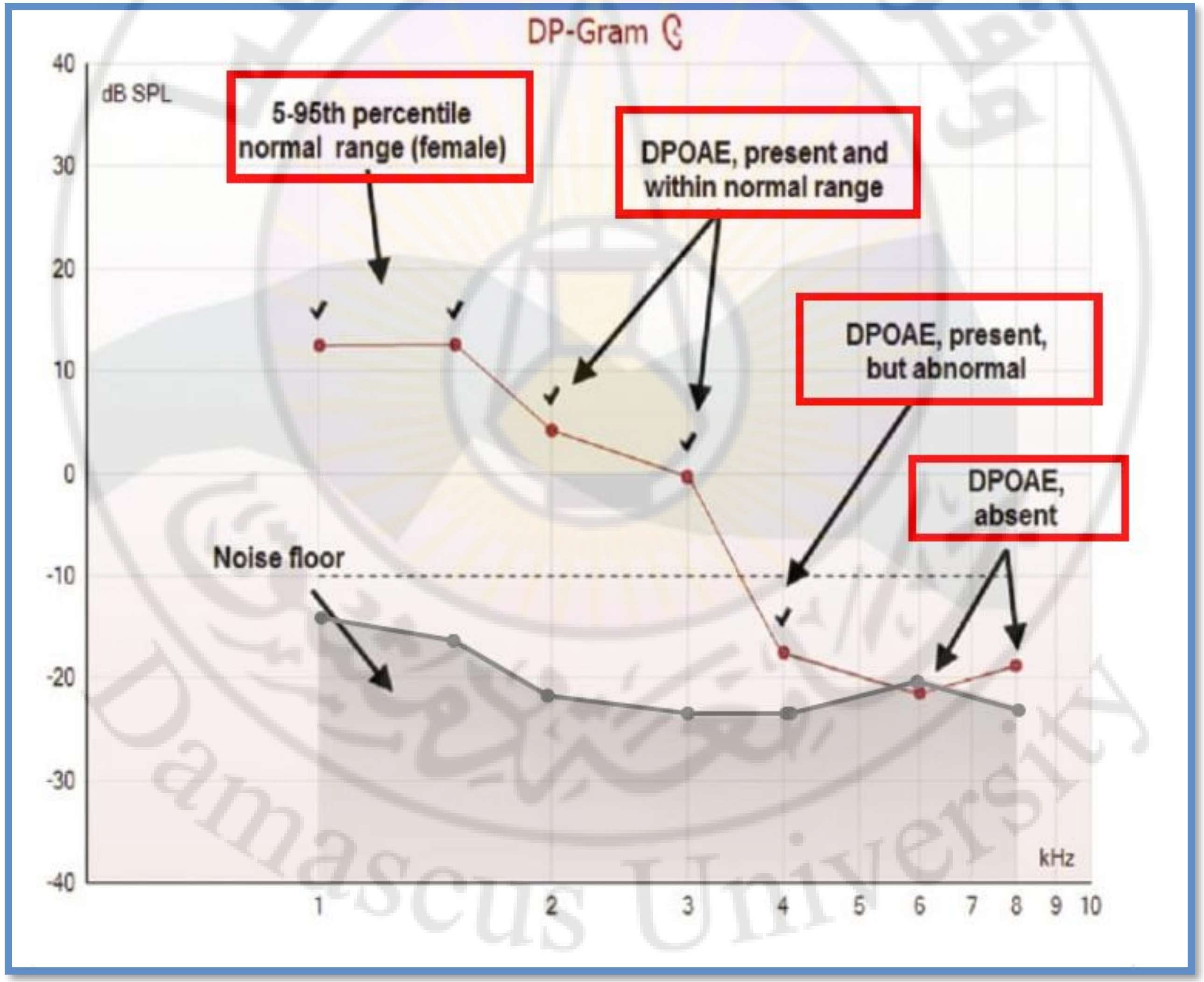
Mohsen Ahadi, Ph.D.
Associate Professor of Audiology
Iran University of Medical Sciences
Rehabilitation Research Center
ahadi.m@iums.ac.ir

Distortion-Product Otoacoustic Emissions (DPOAEs)

- DPOAE measurement systems provide a measure of both the DPOAE and surrounding noise level.
- The noise level is most often determined by averaging the levels in several frequency bins on either side of the DPOAE of interest.
- The presence of a particular DPOAE is determined by comparing the level measured within its frequency bin with the noise levels in the surrounding frequency bins and employing some difference criterion.
- For instance, the DPOAE might be considered present if its level is **3 dB or more** above the level of the surrounding noise floor, or if its level exceeds 2 standard deviations above the mean noise level.



DPOAE waveform analysis



Distortion-Product Otoacoustic Emissions (DPOAEs)

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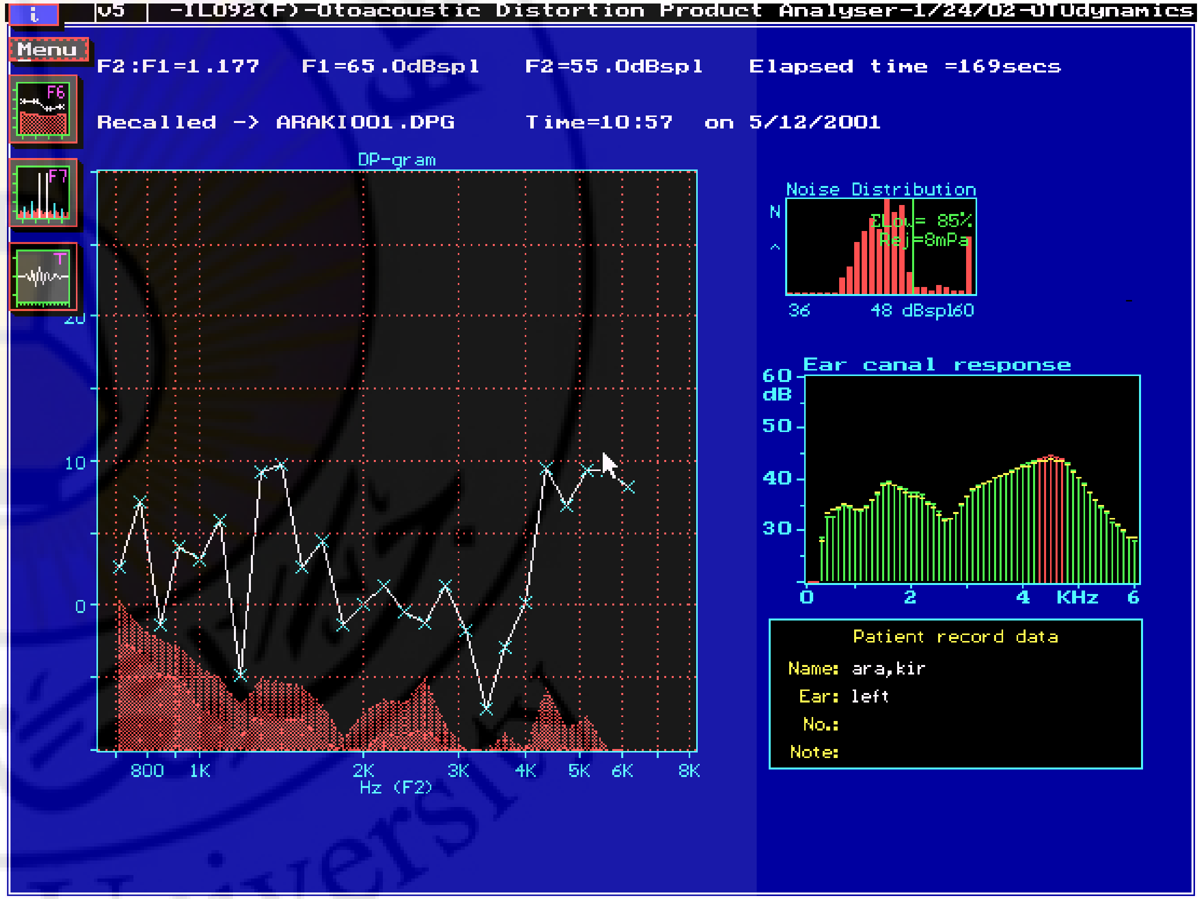
- As a result, 2*f*1–*f*2 is the DPOAE that has been the most extensively investigated, particularly for clinical purposes.
- The 2*f*1–*f*2 DPOAE has sometimes been referred to as the **cubic difference tone (CDT).**



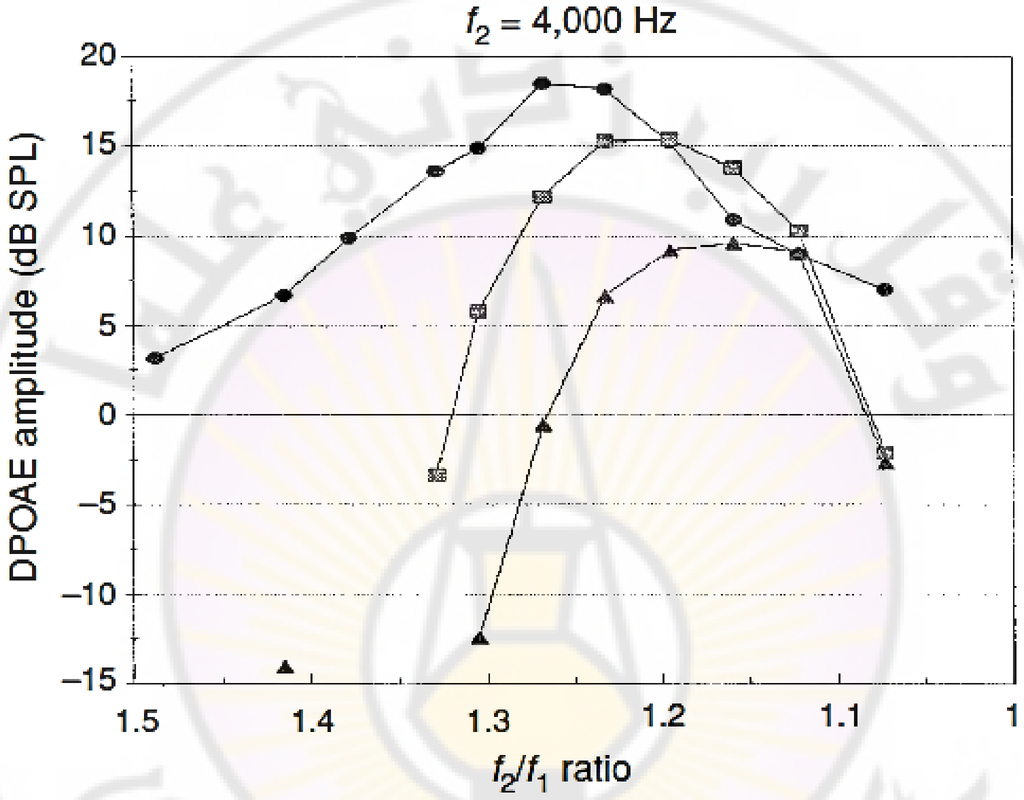


FIGURE 19.7 A graph of DPOAE level as a function of f_2/f_1 ratio from an adult ear at three different stimulus levels ($f_2 = 4{,}000$ Hz). The primary levels used to evoke the DPOAEs were $L_1 = 75$ and $L_2 = 60$ dB SPL (*circles*), $L_1 = 65$ and $L_2 = 50$ dB SPL (*squares*), and $L_1 = 55$ and $L_2 = 40$ dB SPL (*triangles*). As the ratio f_2/f_1 is decreased from a value of approximately 1.5, the DPOAE level increases to a broad maximum at ratios of 1.2 to 1.3 and then declines as the ratio is further decreased. The band-pass-shaped function is typical in both infants and adults.

DPAOE simulation

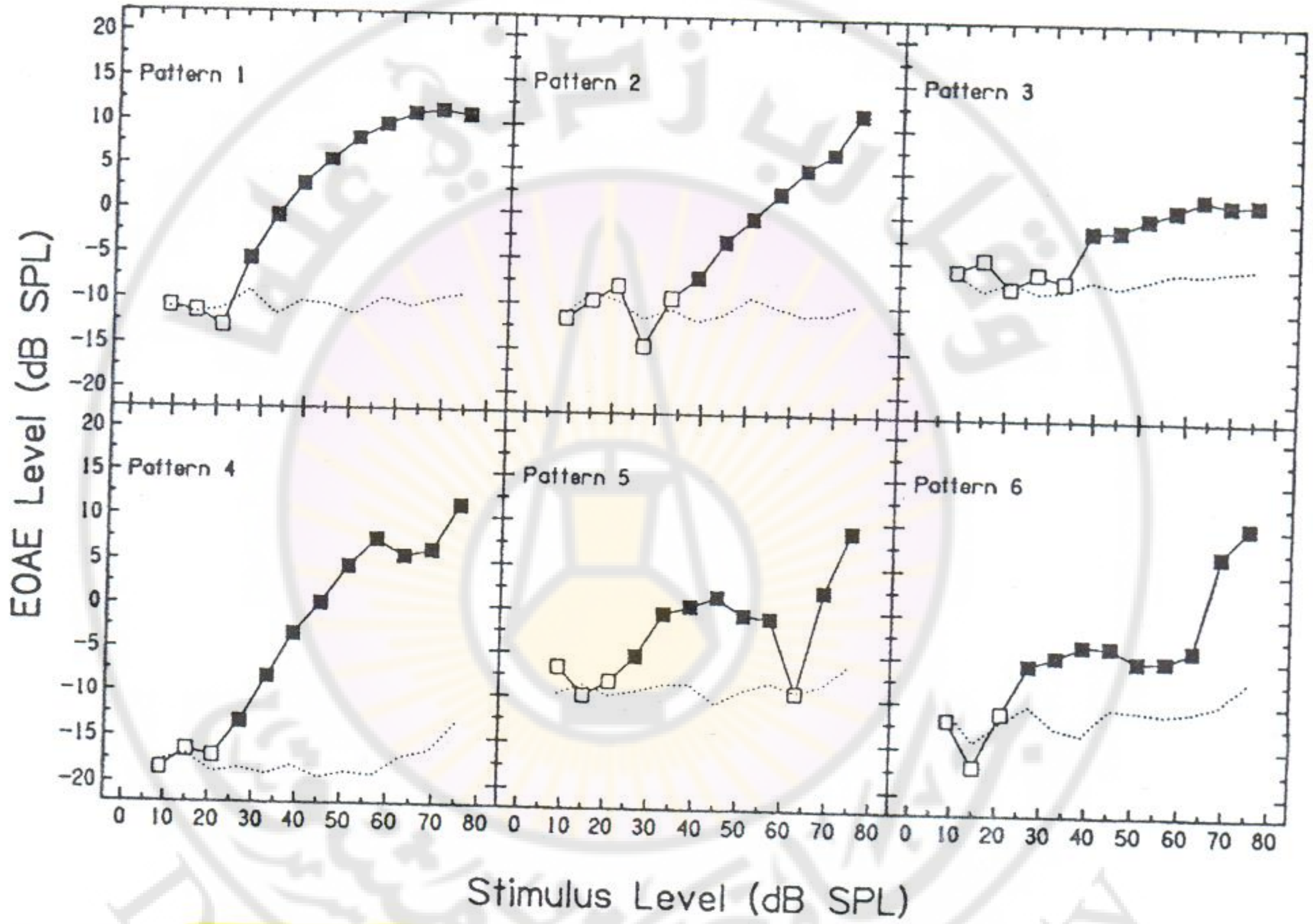


Figure 22.9. Examples of the various DPOAE I/O functions that may be measured from individual ears. Typical patterns include *(1)* growth followed by saturation at high stimulus levels, *(2)* monotonic growth, *(3)* flat patterns, *(4–5)* complex patterns with dips or decreases in DPOAE level with increases in overall stimulus level, and *(6)* growth with changes in slope. (Reprinted with permission from Stover L, Norton SJ (1993) The effects of aging on otoacoustic emissions. J Acoust Soc Am; 94: 2670–2681, ©1993, Acoustical Society of America.)

TEOAEs and DPOAEs and Patient Characteristics

- TEOAE and DPOAE levels change with **development** from infancy to adulthood; however, the exact time course remains uncertain.
- COAE and DPOAE levels in neonates (infants less than 1 month of age) are larger than in adults.
- TEOAEs and DPOAEs are also significantly larger in infants than in toddlers, older children, and adults.
- Differences in level with development are frequency dependent, with infants and children having higher EOAE levels than older children and adults for the higher frequencies but not lower frequencies.
- The differences in EOAE levels across age groups have most often been attributed to **anatomical changes in the outer or middle-ear systems** that occur with development.

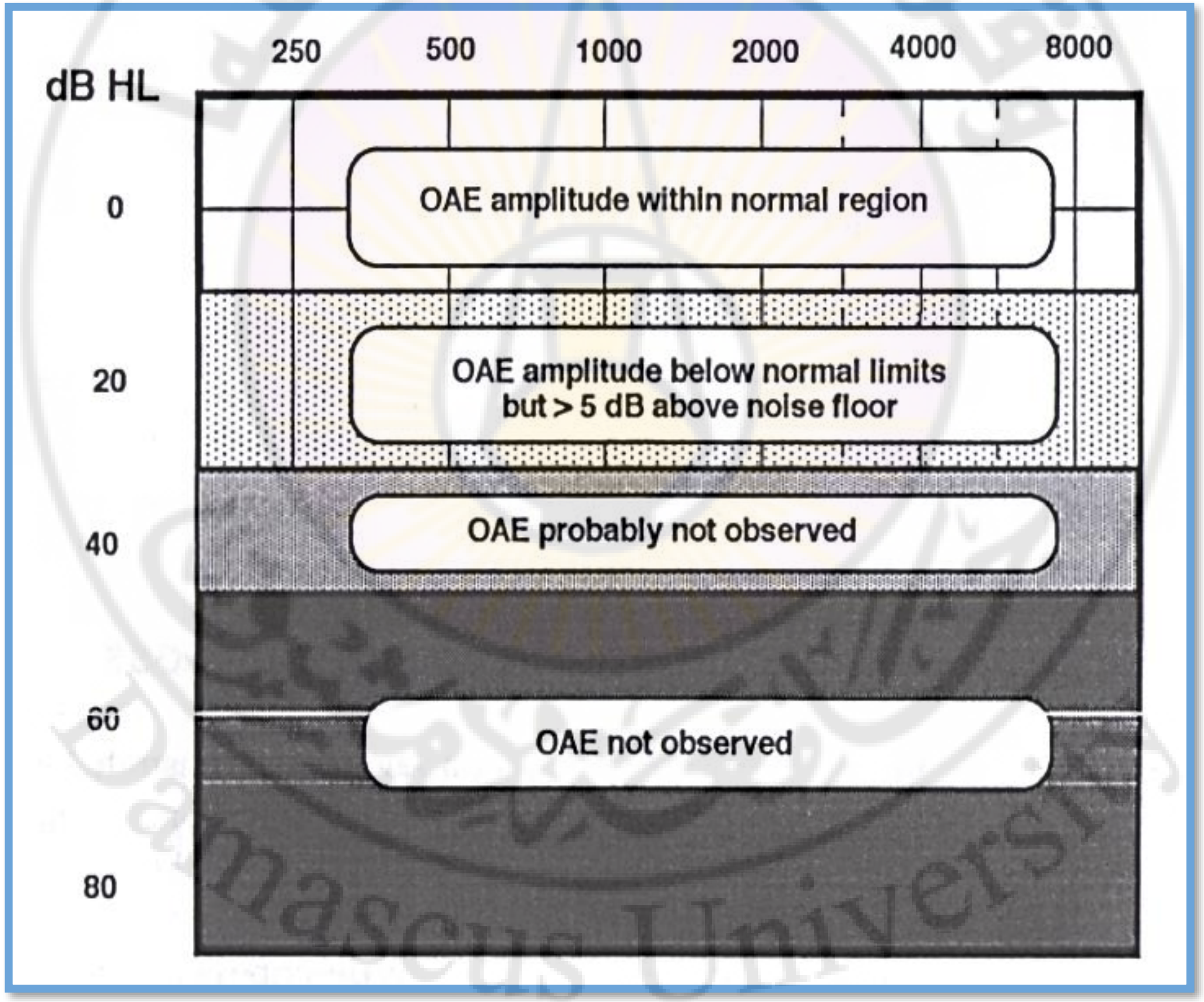
TEOAEs and DPOAEs and Patient Characteristics

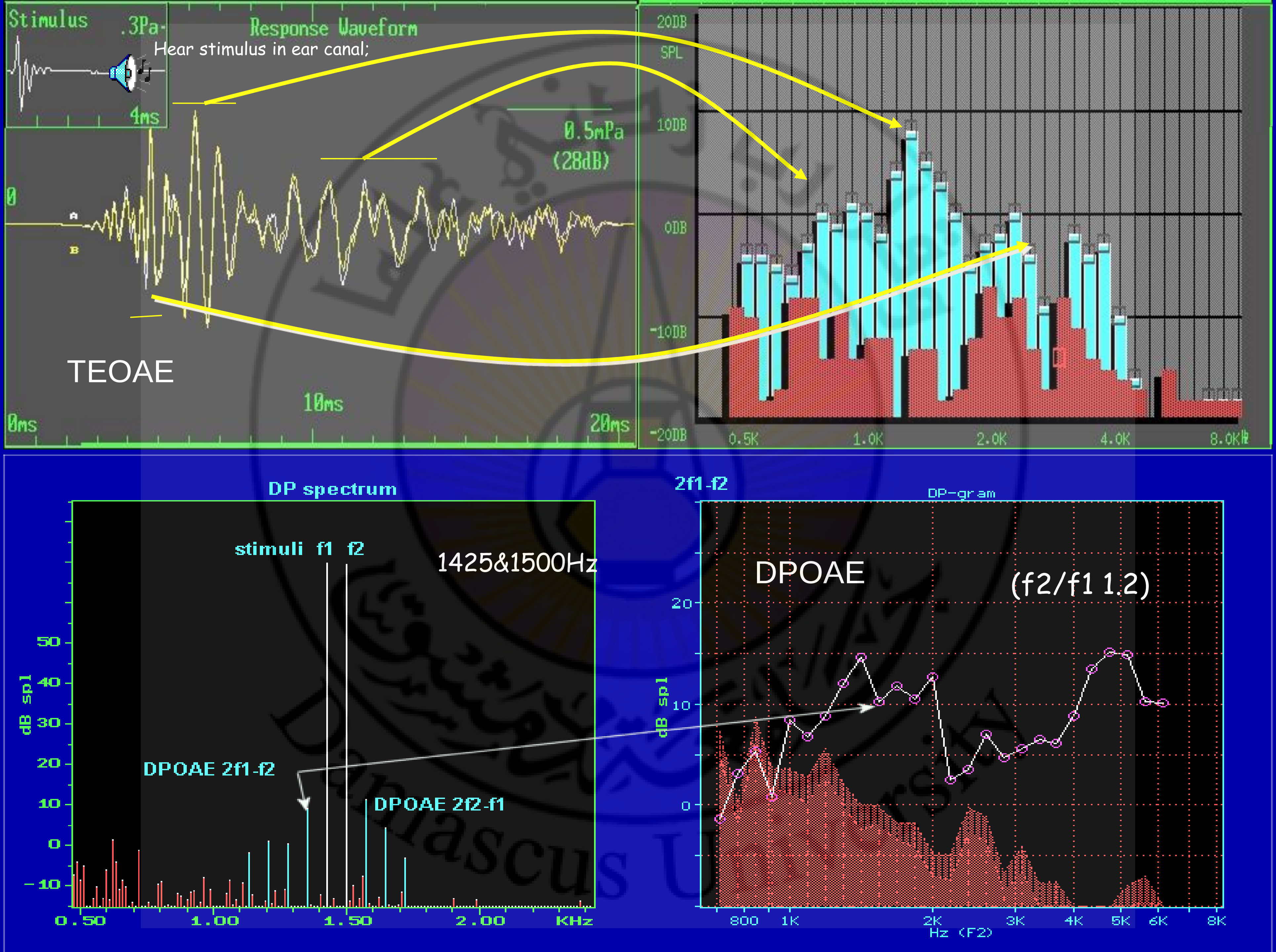
- The effect of **increased age** on COAEs and DPOAEs has been more difficult to study, because behavioral thresholds tend to worsen with increasing age, creating a confounding factor.
- Several early studies reported decreasing COAE and DPOAE levels with increasing age; however, they did not control for auditory threshold.
- The results of most studies that attempted to control for behavioral thresholds indicated no aging effects on TEOAEs.
- Older ears have lower DPOAE levels at 8,000 Hz, but the difference is small and has little clinical significance

TEOAEs and DPOAEs and Patient Characteristics

- Females, on average, have larger TEOAEs than males.
- Right ears, on average, have larger TEOAEs than left ears.
- The smaller size of the female ear canal on average compared to the male ear canal may result in the higher TEOAE levels measured in female ears.
- The greater number of SOAEs measured in right ears as compared to left ears and in females as compared to males may also contribute to the noted TEOAE level differences.
- For DPOAEs, some researchers have found that DPOAE levels are larger in females than in males. Others have reported significant differences between the sexes at only select frequencies.
- The **presence of SOAEs** also affects the spectrum of TEOAEs. SOAEs can synchronize to the evoking stimulus, resulting in peaks at those frequencies in the TEOAE spectrum.

OAEs and Sensory Hearing Loss

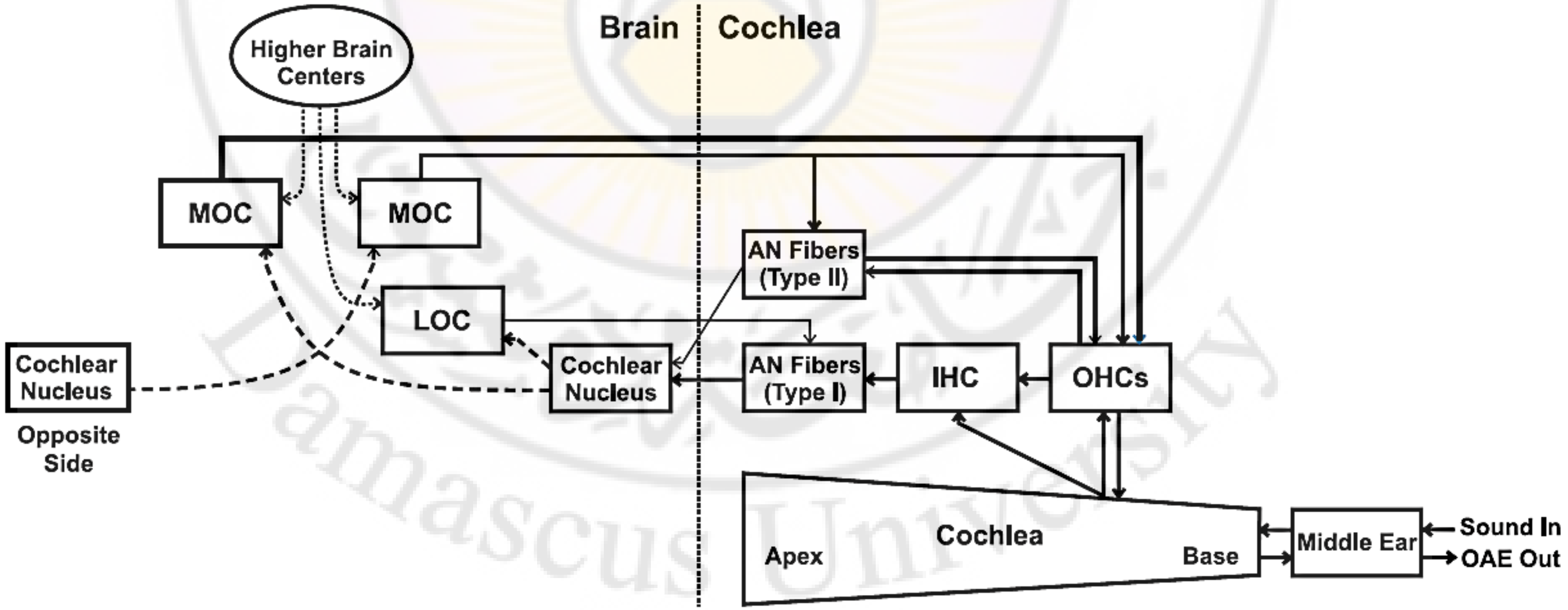




Stimulus
.3Pa
4ms
Response Waveform
Hear stimulus in ear canal;
0.5mPa
(28dB)
0
A
B
TEOAE
0ms
10ms
20ms
20DB SPL
10DB
0DB
-10DB
-20DB
0.5K
1.0K
2.0K
4.0K
8.0K
DP spectrum
stimuli f1 f2
1425&1500Hz
DPOAE 2f1-f2
DPOAE 2f2-f1
dB spl
50
40
30
20
10
0
−10
0.50
1.00
1.50
2.00
KHz
2f1-f2
DP-gram
DPOAE
(f2/f1 1.2)
dB spl
20
10
0
800
1K
2K
3K
4K
5K
6K
8K
Hz (F2)

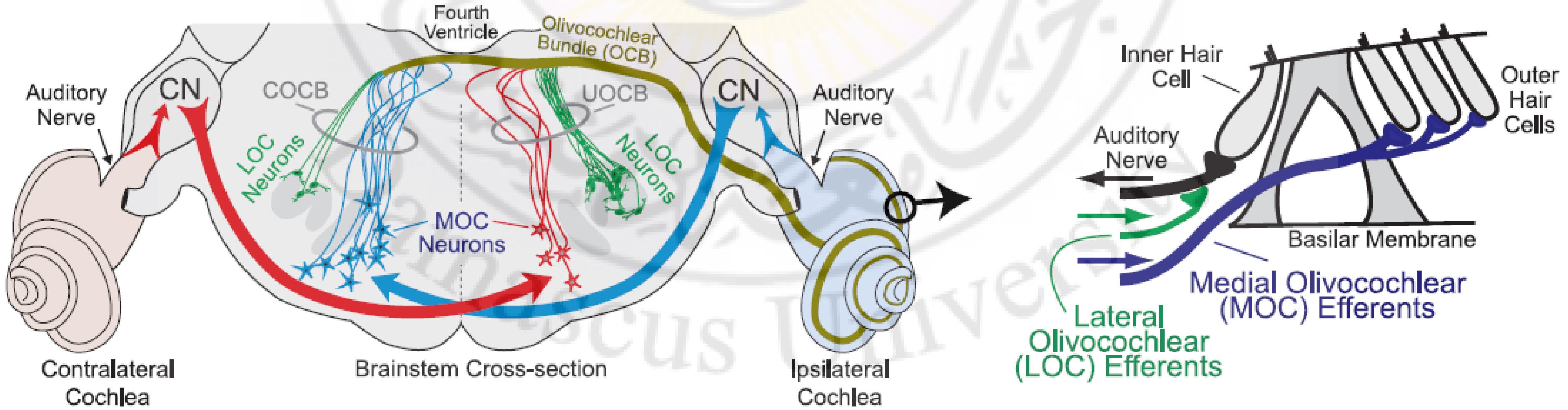
OAE Suppression: Introduction

- Two of the most exciting findings in hearing research of the past years have certainly been the **discovery of active mechanisms in the cochlea** (Davis, 1983) and of **two distinct efferent auditory pathways between the brain and the cochlea** (Rasmussen, 1946; Warr and Guinan, 1978), which imply that auditory input can be modified before it reaches the brain.



OAE Suppression: Introduction

- The first population of efferent neurons, thin and unmyelinated, arises from the **lateral superior olivary complex** and synapses with cochlear afferent neuron dendrites, close to the **inner hair cells (IHCs)** which are the primary, sensory receptors of the auditory system.
- The second population of neurons, known as the **medial olivocochlear system (MOCS),** is composed of large myelinated neurons originating from the medial nuclei of the superior olivary complex. These neurons project mainly contralaterally to innervate the **outer hair cells (OHCs)** which are presumably the source of cochlear active mechanisms (CAMs).



OAE Suppression: Introduction

- The MOCS is thought to protect the cochlea against **acoustic injury**.
- This system also seems to be involved in the **detection of signals in noise**, such as speech sounds, by modulating CAMs.
- Evidence of this modulation comes mainly from numerous studies on otoacoustic emissions (OAEs). OAEs are thought to be the by-products of CAMs, i.e., the activity of OHCs.

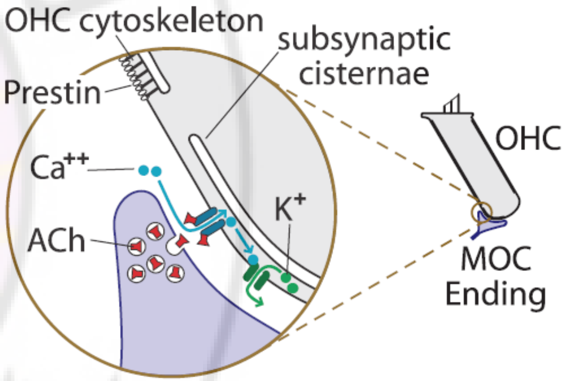
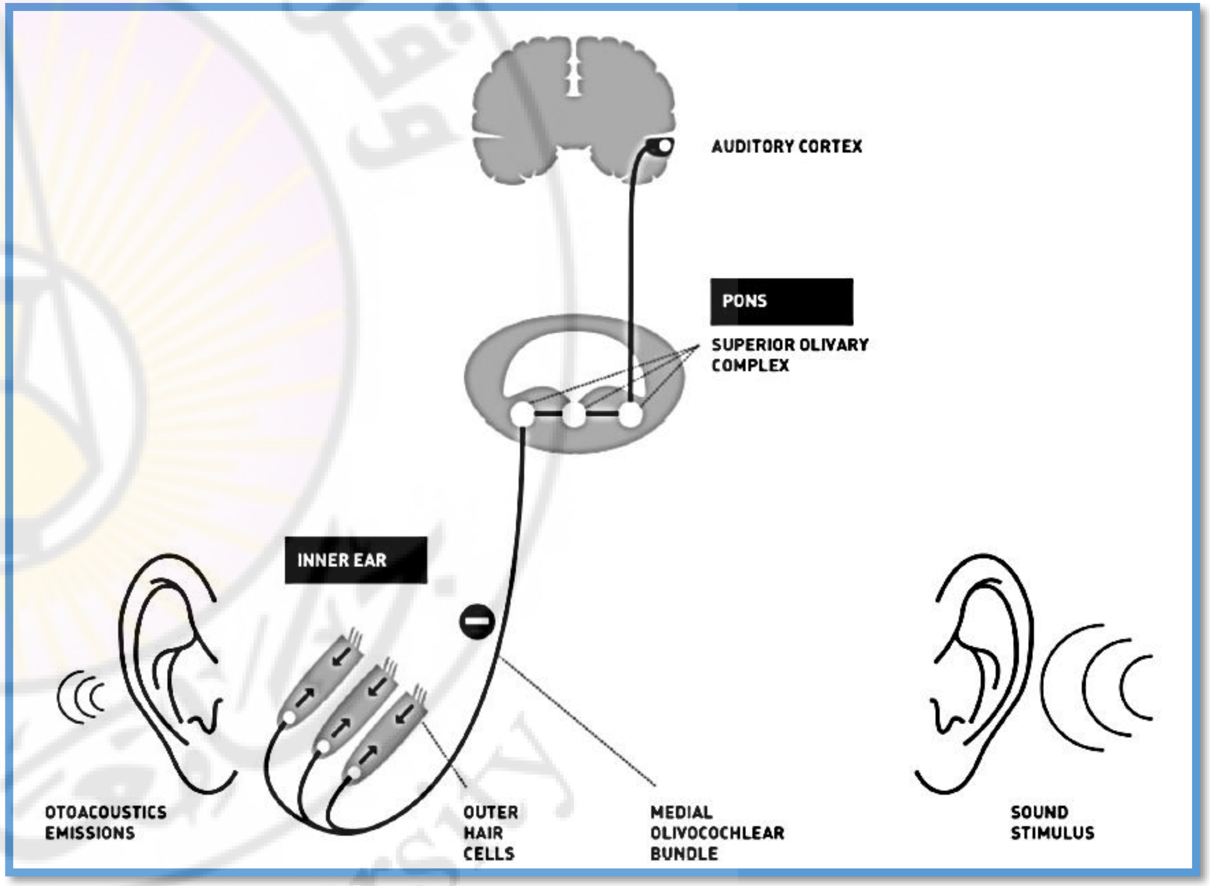


Figure 3. Schematic of an MOC synapse (purple) on an OHC (gray). ACh, acetylcholine; Ca^{++}, calcium ions; K^{+}, potassium ions.

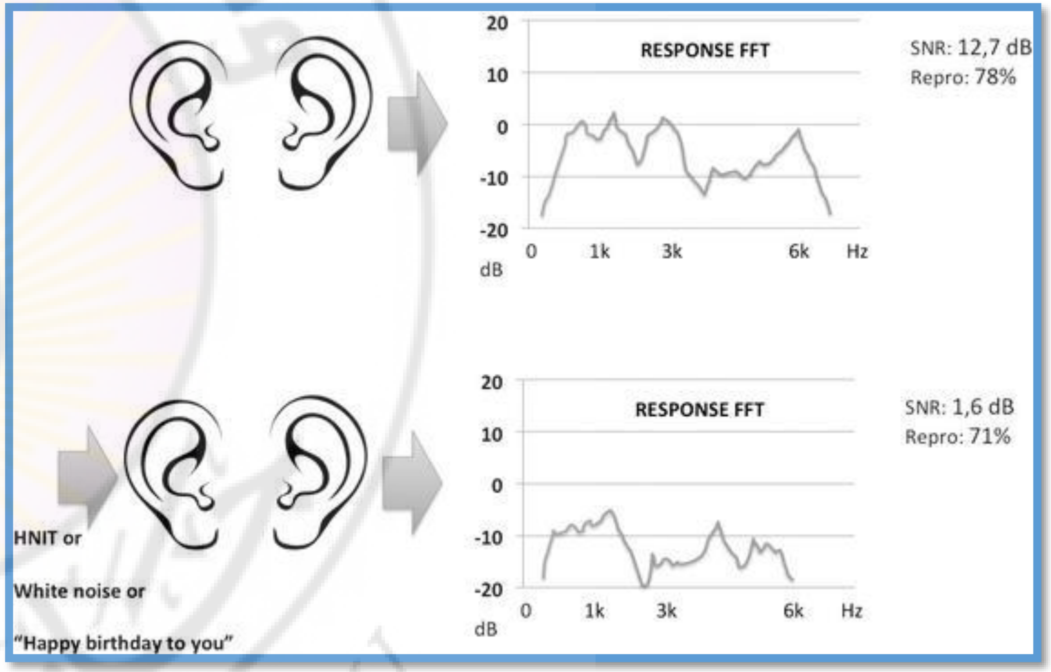
OAE Suppression: Introduction

- Since Buno (1978) and Murata's work (1980) showing that acoustic stimulation of one cochlea may modify afferent fiber responses in the contralateral cochlea, other experiments have shown a method of studying the MOCS' activity non-invasively in adults by coupling contralateral stimulation with OAE recording.
- The result is a frequency specific decrease of OAE amplitude. This technique is objective and non-invasive and may be applied to neonates and infants.



How to Record Efferent Suppression

- In neonates, suppression is usually explored by stimulating the MOCS with a **white noise** presented to the ear contralateral to TEOAE recording.
- A common way to record TEOAEs is to elicit them with 80 ųsec linear clicks at 60-65 dB SPL.
- The continuous white noise in the contralateral ear is 5 dB above the click stimulus with the level being monitored throughout testing.
- An average of two hundred responses repeated twice for each recording is sufficient to explore MOCS function.



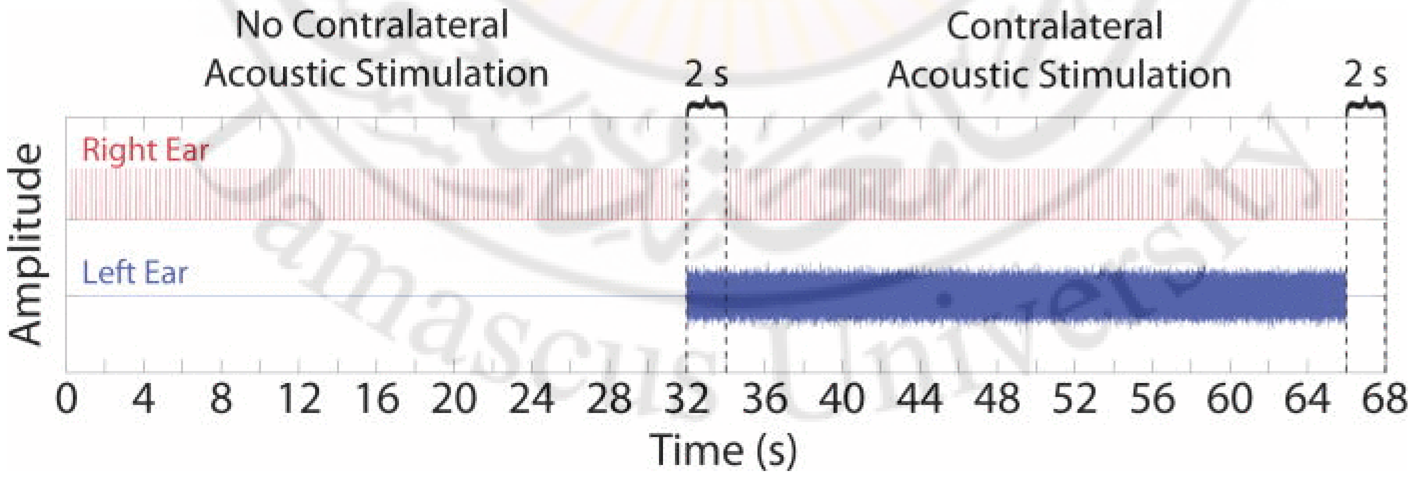
How to Record Efferent Suppression

- The contralateral noise can be delivered through an earphone embedded in a foam cushion on which infants lie on their bellies, -- one ear down for noise, one ear up for TEOAE testing.

- It is important to record suppression in a very quiet environment. Larger suppression can be found in infants tested post-isolette (2.177 dB) over pre-isolette (1.455 dB).

How to Record Efferent Suppression

- In infants it is of the up-most importance to be sure that the TEOAE probe does not move during the 2 consecutive recordings without and with noise recordings.
- MOCS function or suppression of TEOAEs is determined by subtracting the "with noise" average from the "without noise" average.
- MOCS activity can also be investigated with binaural and ipsilateral stimulation. In this case, the noise used to activate the MOCS precedes the click used to elicit TEOAEs (forward masking paradigm).

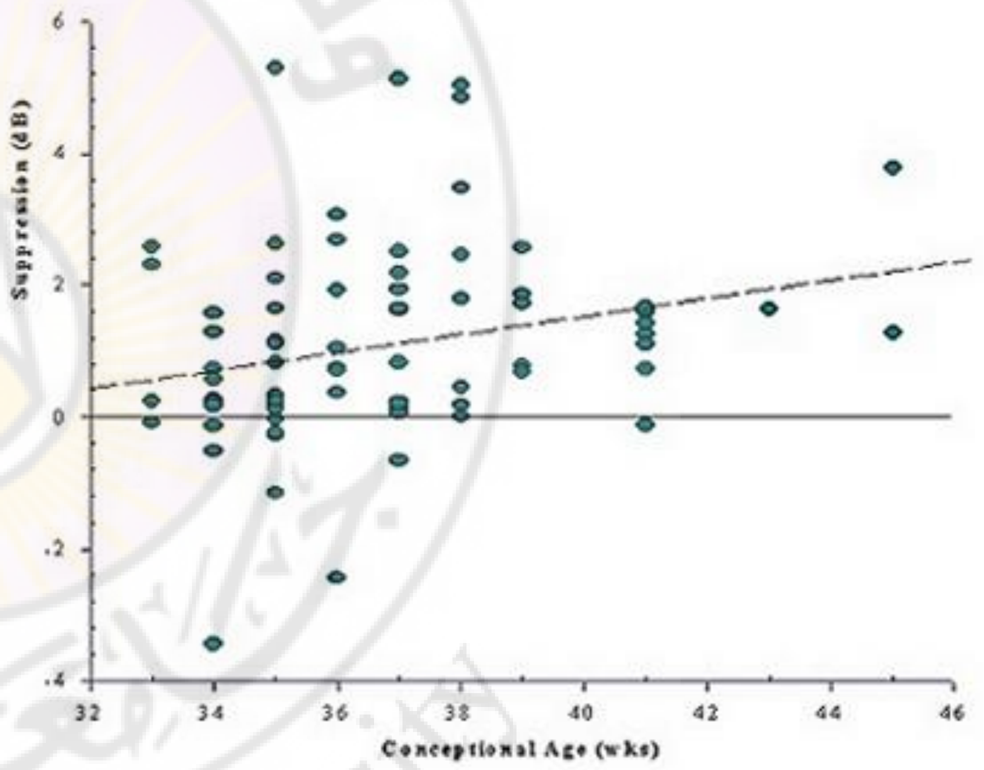


Characteristics of Suppression in Adults

- With a classical 20 ms TEOAE recording, the majority of suppression takes place **between 8 and 18 ms**.
- **Binaural stimulation** with white noise appears to be the most powerful stimulus for eliciting efferent suppression of TEOAEs in humans.
- **MOCS activity is frequency specific**: the efferent system appears to be more functional at low and middle frequencies than at high frequencies.
- The MOCS appears to be more efficient in right ear than in left ear.
- **Auditory Neuropathy** patients have no efferent suppression of TEOAEs with binaural, contralateral or ipsilateral noise.
- Some **hyperacousic** patients show abnormally large efferent suppression.

Efferent Suppression in Neonates

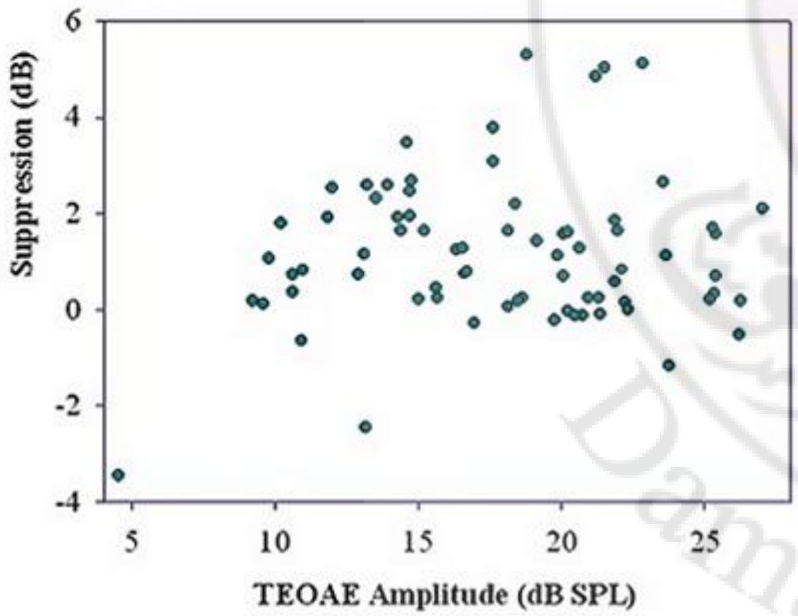
- Efferent suppression is not present at an early age whereas cochlear active mechanism asymmetries are already present (i.e., in young pre-term neonates).
- Suppression progressively appears.
- The MOCS does not appear to be fully mature at full-term birth.



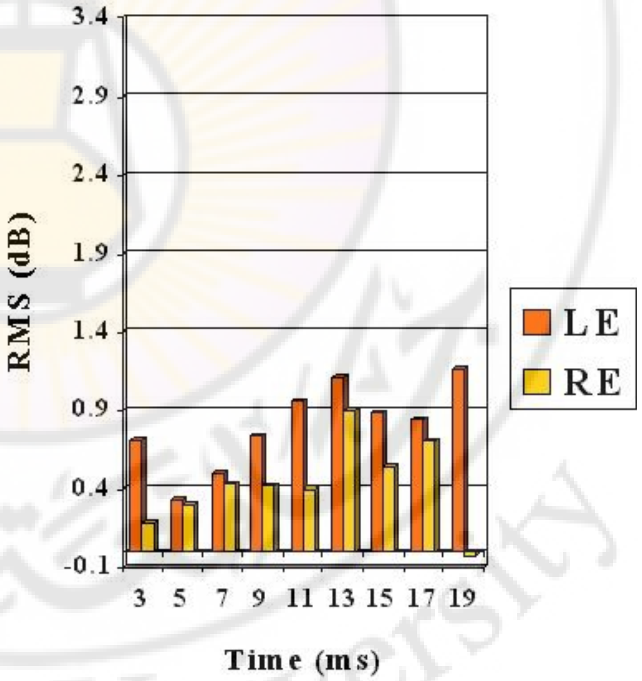
Efferent Suppression Increases with Conceptional Age

Efferent Suppression in Neonates

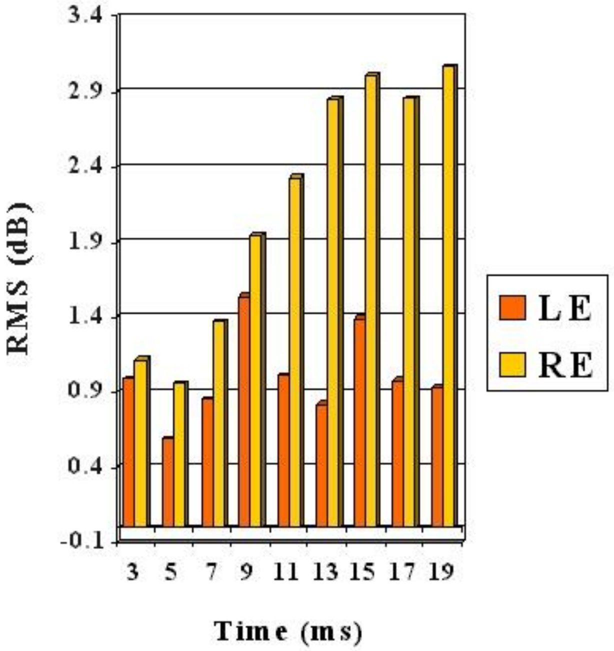
- There is no relation in infants between TEOAE amplitude and amount of suppression as in adults.



- Its development was found to be asymmetrical.



Conceptional age < 36 weeks

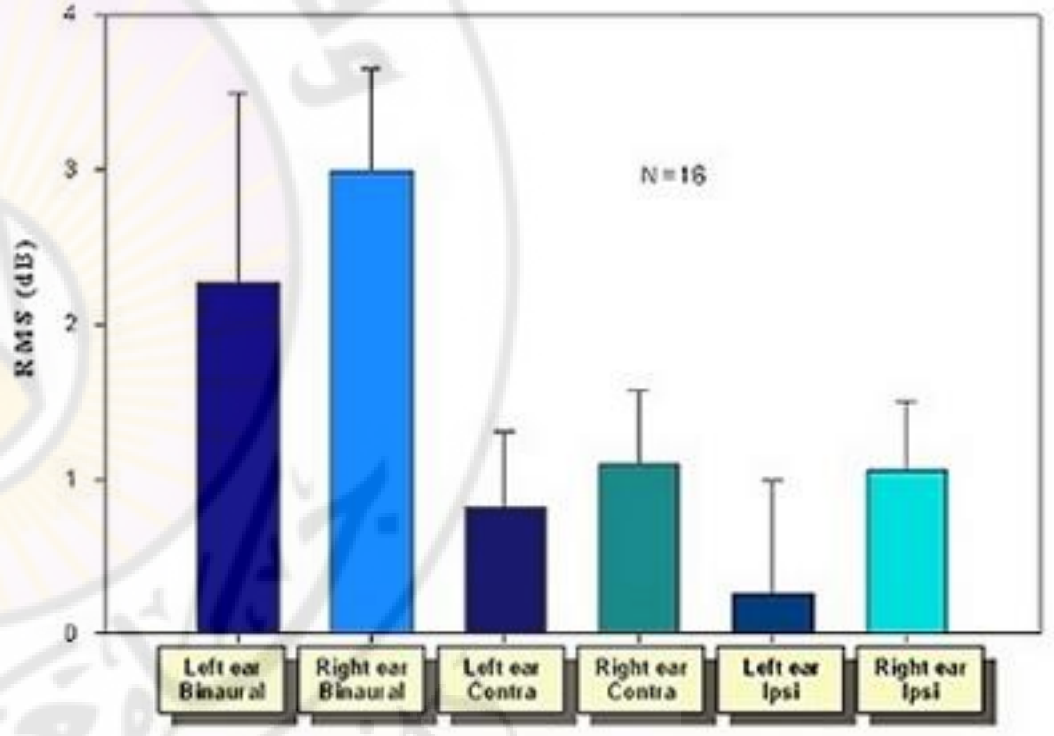


Conceptional age > 36 weeks

Efferent Suppression in Neonates

- Because it is not clear as to when in development the efferent system begins to function, it is not a useful diagnostic tool at birth as are OAE.

- However, if no efferent suppression is noticed 2-3 months after birth, other tests of the auditory function are recommended.



Efferent Suppression in Normal Children

دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Otoacoustic Emissions

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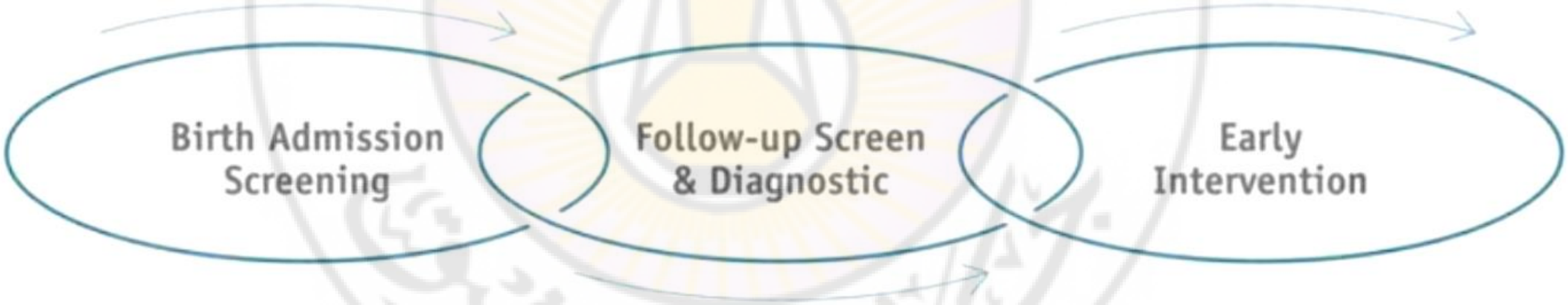
Clinical Applications

- **Newborns and Infants**
- Hearing Screening
- **Adults**
- Subclinical hearing loss identification
- Differential Diagnosis of Hearing Loss
  - Auditory Neuropathy
  - Acoustic Neuroma
  - Sudden Hearing loss
  - Nonorganic hearing loss
- Detection of central auditory disorders (OAE suppression)
- Cochlear implant candidacy

JCIH 2007	EHDI Benchmarks	JCIH 2019
1 month	Hearing Screening Outpatient Rescreen (if needed)	1 month
3 months	Diagnostic Hearing Evaluation by Audiologist Medical and Otologic Evaluation	2 months
6 months	Early Intervention Enrollment in Part C Services	3 months

Programs that currently meet the 1-3-6 benchmark goals should strive for a 1-2-3 timeline to further promote early access to optimal language and learning.

Three Key Components of Early Hearing Detection & Intervention Programs



Otoacoustic Emissions (OAE)

- OAEs – either transient-evoked OAEs (TEOAEs) or distortion product OAEs (DPOAEs) – are measured using a sensitive probe microphone inserted into the infant's ear canal.
- OAEs are a direct measure of outer hair cell and cochlear function in response to acoustic stimulation. They yield an indirect estimate of peripheral hearing sensitivity.
- OAEs are not sensitive to disorders central to the outer hair cells, such as auditory neuropathy.
- OAEs will be absent when there is outer or middle ear dysfunction or debris/blockage in the ear canal.

Otoacoustic Emissions (OAE)

- **Stimuli:** **TEOAEs** use a high-level click, approximately 80 dB pSPL, and a subtraction (*nonlinear*) paradigm to reduce stimulus artifact. **DPOAEs** use mid-level stimuli (f1 primary = 65 dB SPL and f2 primary = 55 dB SPL).

- **Response Criteria:** At least three test frequencies – of 2000 Hz, 3000 Hz, and 4000 Hz – are evaluated during the screening. Usually, signal-to-noise ratios (SNRs) of at least 6 dB are used; however, some manufacturers will set their own SNRs. DPOAE SNRs vary, depending on whether mean SNR is calculated or mean plus 1 or 2 standard deviations of noise. In addition, a minimum absolute DPOAE level of 5 dB SPL is imposed.

Otoacoustic Emissions (OAE)

- **Procedure:** The infant should be asleep or resting quietly for the test and positioned to reduce muscle artifact.
- A snug probe fit is essential for valid and reliable recordings. Ears should be screened one at a time, with the infant placed on his/her side and the ear being screened facing up. The screener visually inspects the outer part of the ear canal to ensure that the canal is patent and clear of debris. Prior to insertion of the probe, a gentle massage of the area below the tragus helps to open a collapsed canal or dislodge debris that may be blocking the canal.
- After stimulus-level requirements have been met, OAEs are collected to meet stopping criteria.
- If OAEs do not appear to be present, the probe is taken out and inspected to determine if the probe is blocked with cerumen or vernix. A blocked probe should be cleaned and reinserted, and the screening should be repeated.

NCHAM National Center for Hearing Assessment and Management Utah State University
JEHDI
The Journal of Early Hearing Detection and Intervention
2019; 4(2): 1–44

Newborn Hearing Screening

Year 2019 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

The Joint Committee on Infant Hearing

- The goal of EHDI is to assure that all infants are identified as early as possible, and appropriate intervention initiated, no later than 3–6 months of age.
- Objectively-determined physiologic measures must be used to screen newborns and young infants to identify those who may be deaf or hard of hearing.
- Automated OAE protocols use either transient-evoked OAEs (TEOAE) or distortion-product OAEs (DPOAE).
- Use of OAE as a screening tool is likely to result in a higher fail rate in the immediate post-birth period as compared with AABR.
- Because EOAEs do not detect **auditory neuropathy** or dys-synchrony, EOAEs are not recommended for use as the primary screening tool in the neonatal intensive care nursery.

Timing of Screening

- Newborns cared for in the well-baby nursery are screened as close to hospital discharge as possible and prior to 1 month of age.
- NICU newborns are screened when they are ready for discharge and/or when they are medically stable.
- Newborns who have initially passed a hearing screening are rescreened if readmitted to the hospital in the first month of life or if risk factors for hearing loss develop during the infant's hospital stay following the initial screening.
- Regional laws and hospital protocols may vary regarding which hospital is responsible for screening newborns who are transferred from one hospital to another.

Testing Environment

- Screening can be done in a nursery or a quiet room with the infant resting quietly or sleeping. A sound booth is not needed.
- The preferred method for testing is to have the newborn resting quietly in his/her bassinette – although, if needed, the newborn can be held.

Pass/Refer Indications

- A newborn must pass the screening in both ears during one session for the screening to be considered a "pass." Otherwise, the newborn will be referred for rescreening.

- If the newborn does not pass in one ear, both ears must be rescreened.

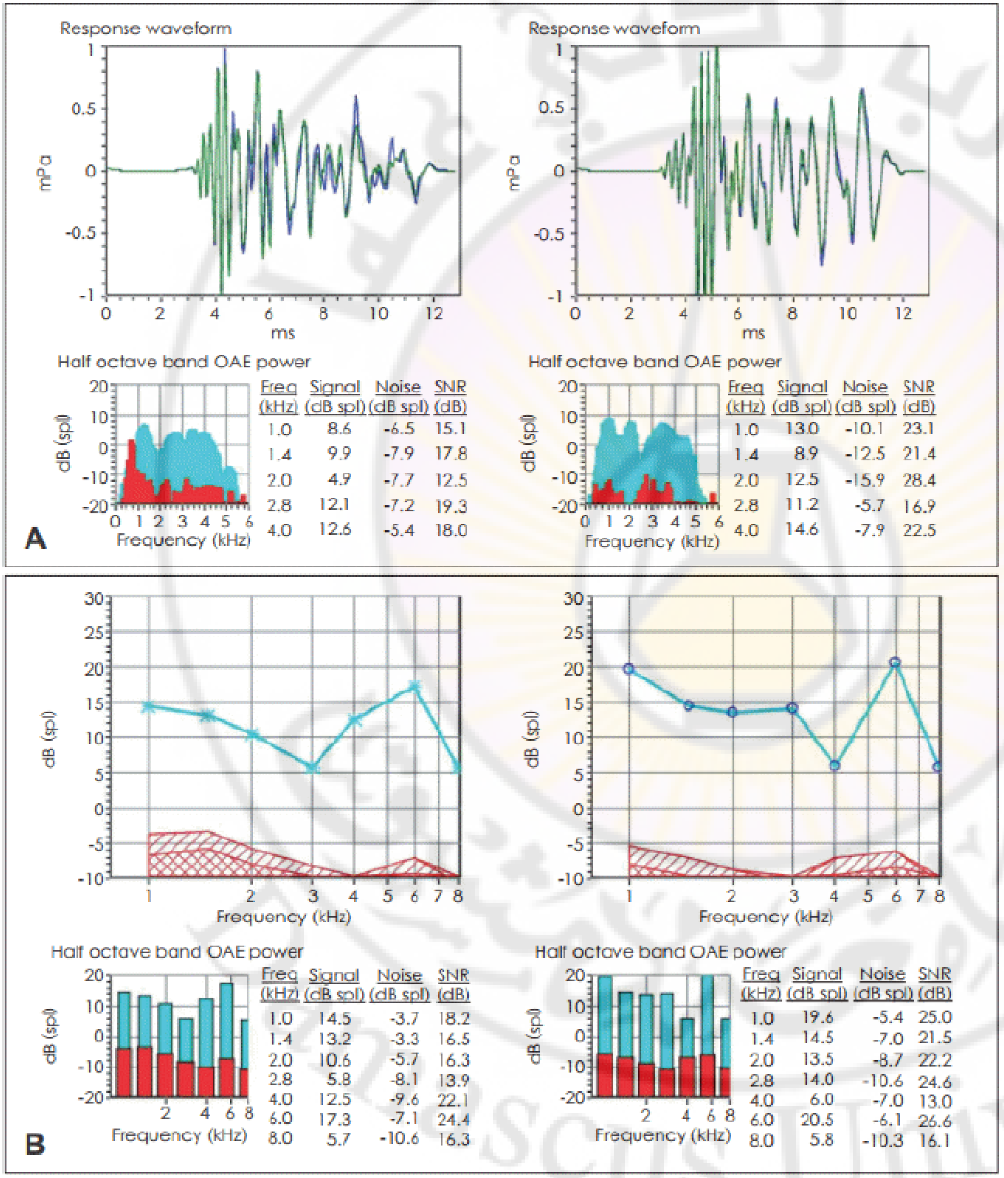
- If the newborn passes the screening or the rescreening and has no risk factors for late-onset or progressive hearing loss, then the screening is complete.

- If the newborn passes the screening or the rescreening and has risk factors for late-onset or progressive hearing loss, then it will be very important to monitor the newborn's hearing during early childhood.


Done!
TEOAE
Pass
dB SPL
30
20
10
0
-10
-20
-30
14
16
12
13
11
0.5
1
2
4
8
kHz
Wave repro
88 %
Sweeps
40
Time
3 sec
Print
Save
Delete
Done!
DP-Gram
Pass
1
1.5
2
3
4
6
kHz
Time
13 sec
Print
Save
Delete
PASS

TEOAE

DPOAE



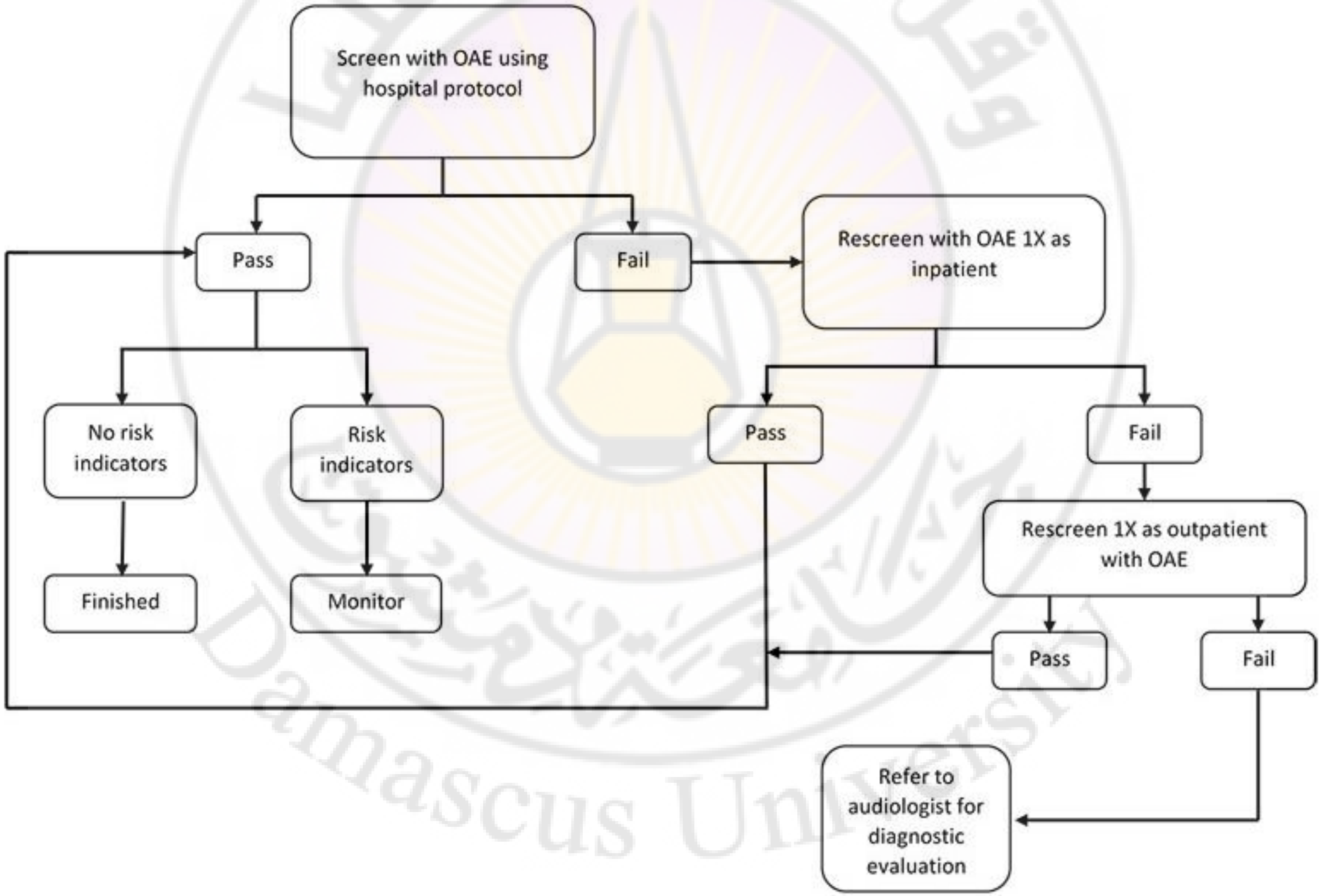
Freq (kHz)	Signal (dB spl)	Noise (dB spl)	SNR (dB)
1.0	8.6	-6.5	15.1
1.4	9.9	-7.9	17.8
2.0	4.9	-7.7	12.5
2.8	12.1	-7.2	19.3
4.0	12.6	-5.4	18.0

Freq (kHz)	Signal (dB spl)	Noise (dB spl)	SNR (dB)
1.0	13.0	-10.1	23.1
1.4	8.9	-12.5	21.4
2.0	12.5	-15.9	28.4
2.8	11.2	-5.7	16.9
4.0	14.6	-7.9	22.5

Freq (kHz)	Signal (dB spl)	Noise (dB spl)	SNR (dB)
1.0	14.5	-3.7	18.2
1.4	13.2	-3.3	16.5
2.0	10.6	-5.7	16.3
2.8	5.8	-8.1	13.9
4.0	12.5	-9.6	22.1
6.0	17.3	-7.1	24.4
8.0	5.7	-10.6	16.3

Freq (kHz)	Signal (dB spl)	Noise (dB spl)	SNR (dB)
1.0	19.6	-5.4	25.0
1.4	14.5	-7.0	21.5
2.0	13.5	-8.7	22.2
2.8	14.0	-10.6	24.6
4.0	6.0	-7.0	13.0
6.0	20.5	-6.1	26.6
8.0	5.8	-10.3	16.1

Screening With OAE Only: Well-baby nursery

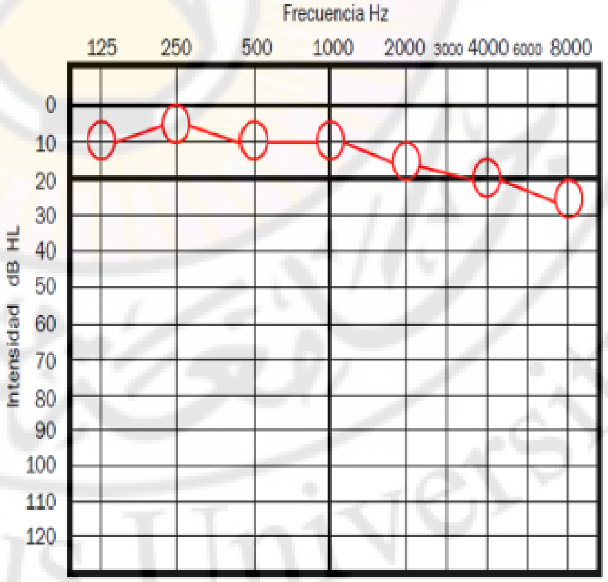


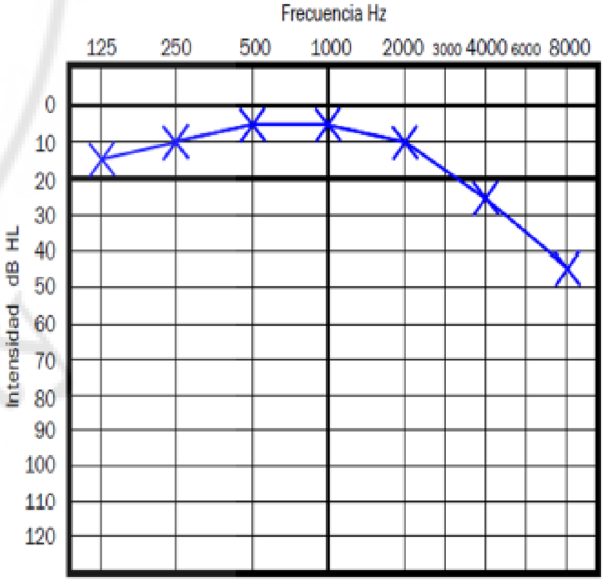
Middle-ear status

- It should be noted that middle-ear status has an effect on EOAE measurements.
- Stimuli used to evoke the EOAE must pass through the middle ear to stimulate the cochlea, and the EOAE energy must pass through the middle ear for it to be detected in the ear canal.
- Middle-ear pathology may reduce OAE amplitude or eliminate the ability to measure OAEs entirely, depending on the type and severity of the pathology.
- The majority of the clinical research studies of OAEs have attempted to include only ears free of middle-ear pathology, usually confirmed by routine immittance testing and/or the absence of any air-bone gaps on the audiogram.
- Obtaining middle-ear measures to elucidate middle-ear function is essential for interpretation of OAE results.

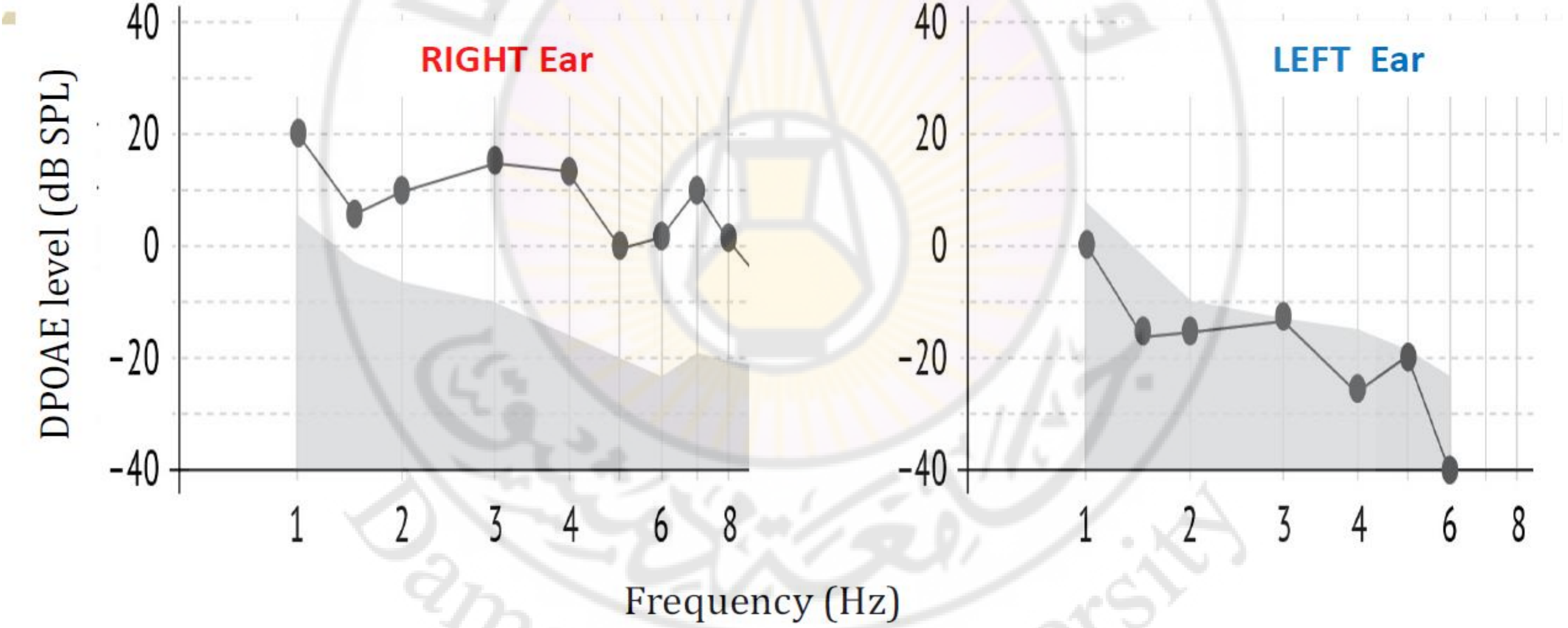
Subclinical hearing loss identification

- 45 years; Female
- CC: Tinnitus + Ear fullness [Left Ear]
- 1.5 years history of chemotherapy
- Otoscopy: unremarkable
- Bilateral type An tympanograms
- Bilateral normal ARTs





Subclinical hearing loss identification



Auditory Neuropathy Spectrum Disorder (ANSD)

Scand Audiol 25 1996

Auditory Nerve Disease of Both Ears Revealed by Auditory Brainstem Responses, Electrocochleography and Otoacoustic Emissions

Kimitaka Kaga[1], Masaichi Nakamura[1], Masanobu Shinogami[1], Toshihiro Tsuzuku[2], Katsushi Yamada[2] and Mitsuko Shindo[3]

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Brain (1996), **119**, 741–753

Auditory neuropathy

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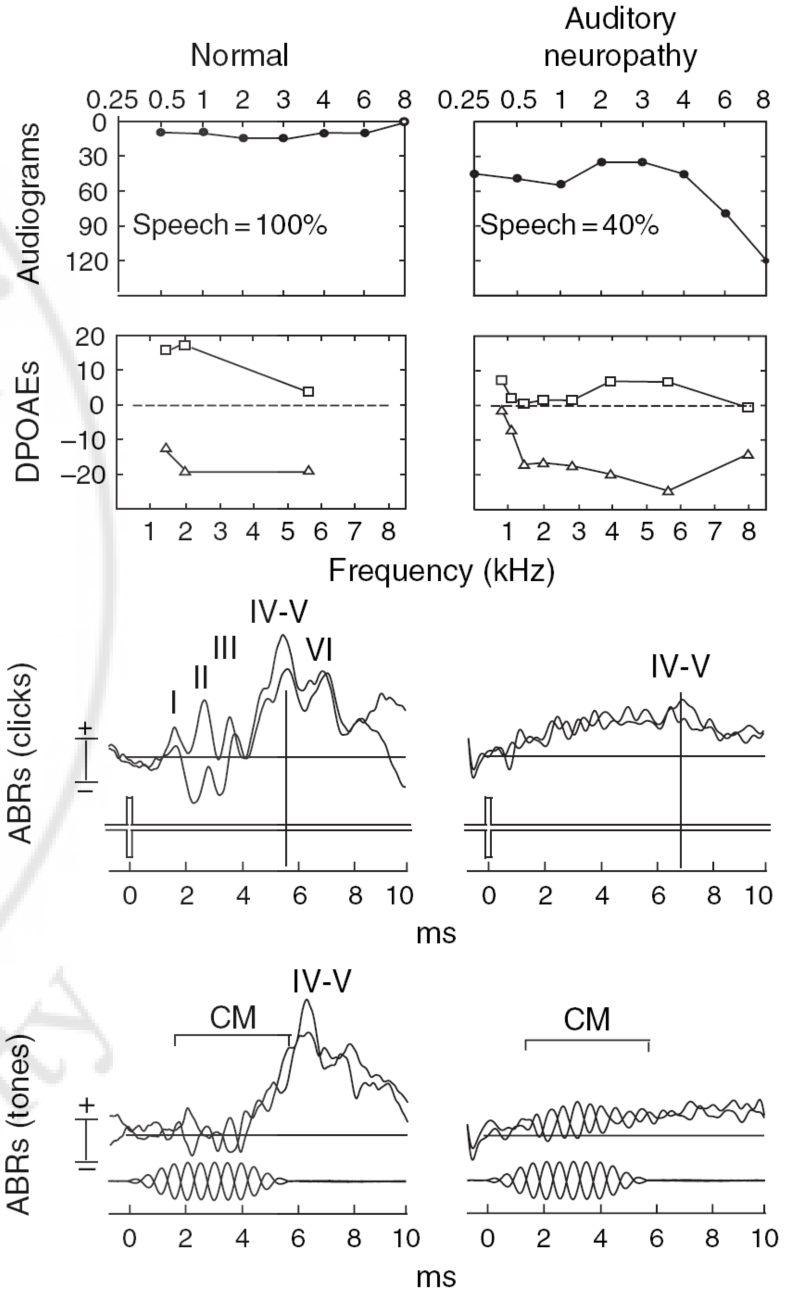
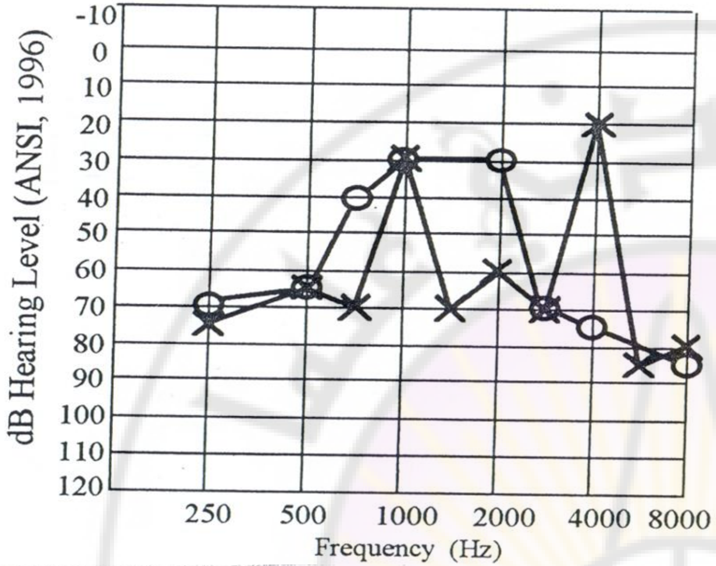
Auditory Neuropathy Spectrum Disorder (ANSD)

- *Auditory neuropathy spectrum disorder* (ANSD) is a term that is used to describe disorders that are operationally defined based on a constellation of clinical findings.
- In **older children**, auditory neuropathy is defined by an absent auditory brainstem response (ABR), poor speech perception, varying levels of hearing sensitivity loss, absence of acoustic reflexes, and a preservation of some cochlear function as evidenced by the preservation of OAEs or cochlear microphonics.
- In **infants**, auditory neuropathy is defined by absent ABR and preserved OAEs or cochlear microphonics.



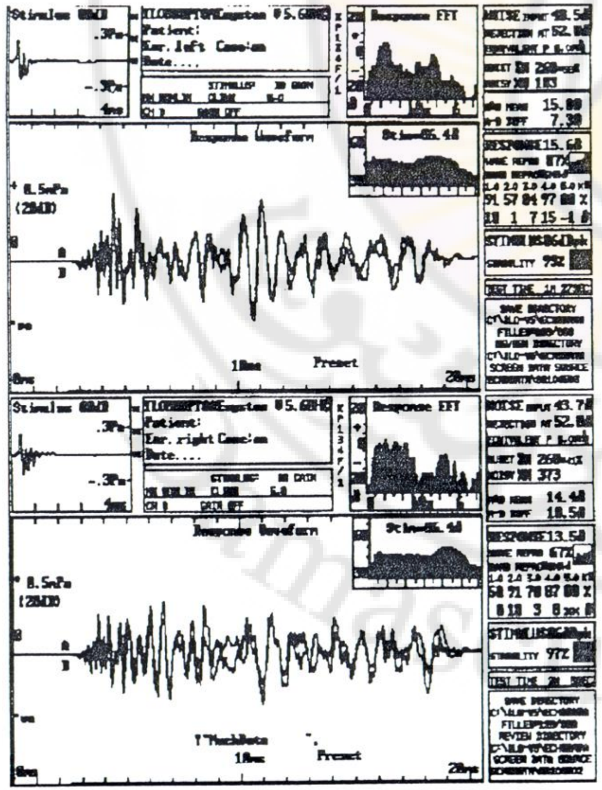
AUDIOGRAM



Speech Awareness Threshold (SAT) -
Right Ear = 20 dBHL
Left Ear = 25 dBHL
Speech Discrimination -
Right Ear = 28%
Left Ear = 8%
Tympanometry = WNL
Acoustic Reflex Threshold = Absent

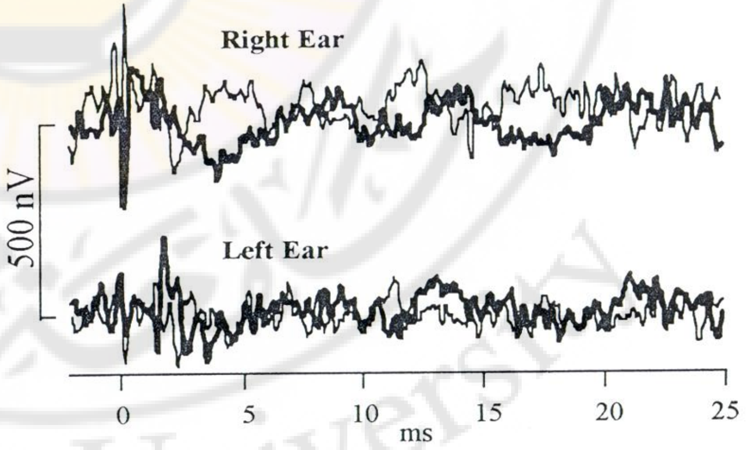
O Right Ear
X Left Ear

Transient-Evoked Otoacoustic Emission



Auditory Brainstem Response

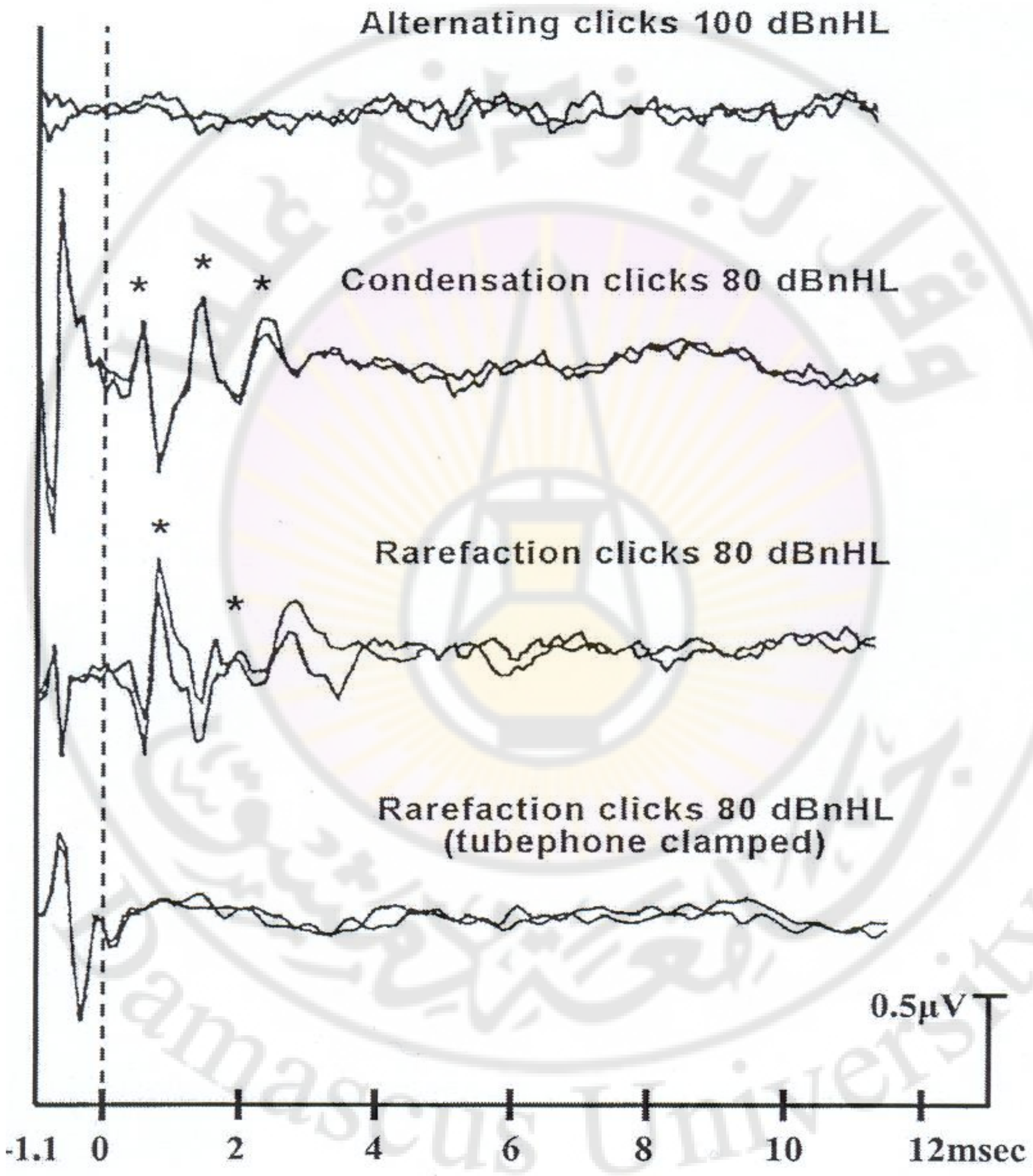
Click Stimulus 25/second 80dBnHL Insert Earphones
Rarefaction and Condensation Overlayed

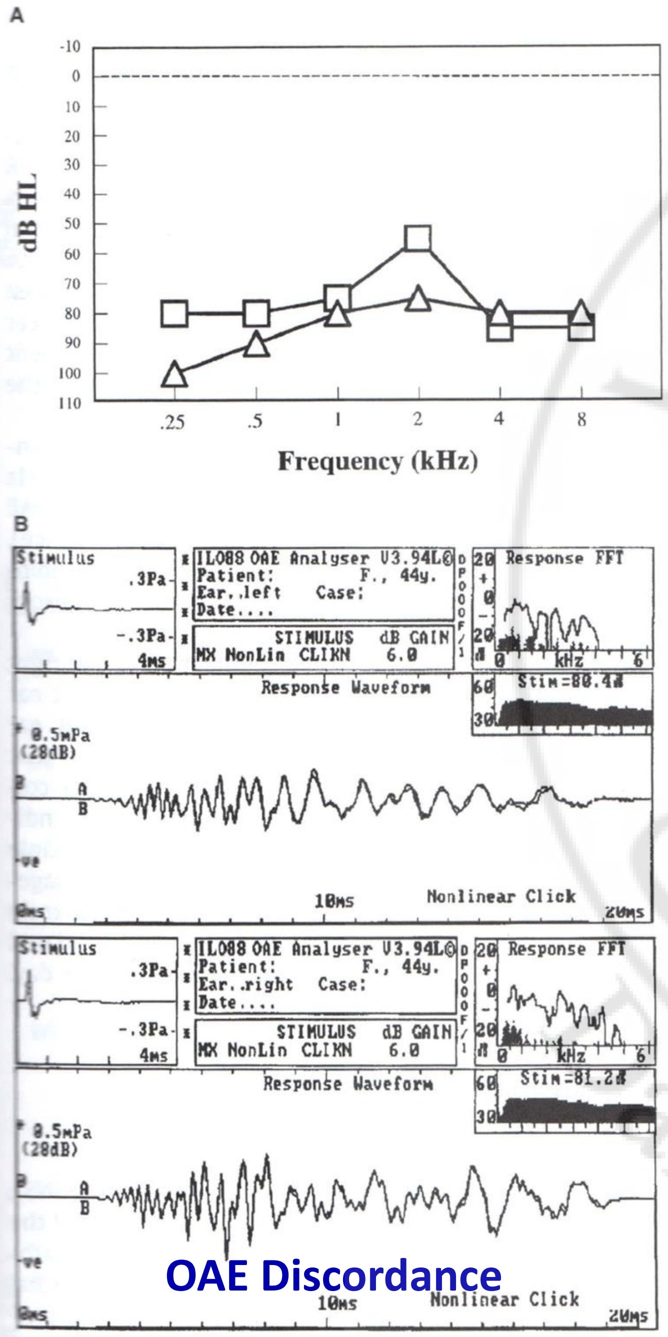


	Anatomy	Dysfunction	Location	Auditory Test
SENSORY CELLS	*IHC* - *(auditory receptors)* - each synapses with myelinated dendrites of multiple Type I spiral ganglion neurons (receive a few OCB axons) *OHC* - *(modulating)* - groups synapse with unmyelinated dendrites of one Type II spiral ganglion neuron (innervated by OCB axons)	HAIR CELL DEATH/ DAMAGE	*IHC* *OHC*	*OAE? CM?* *OAE CM*
SYNAPSE	*Hair cells with* **dendrites** of the **spiral ganglion neurons**	SYNAPTIC BLOCK	*Synapse*	*No specific test*
SPIRAL GANGLION NEURONS	*Type I (first order auditory neurons) myelinated dendrites synapse with IHC; axons project to brainstem CN* *Type II (sensory neurons) small unmyelinated dendrites synapse with OHC; physiologic properties unknown; axons project to brainstem CN*	NEURONOPATHY (ganglionapathy)	*Spiral ganglion*	*No specific test*

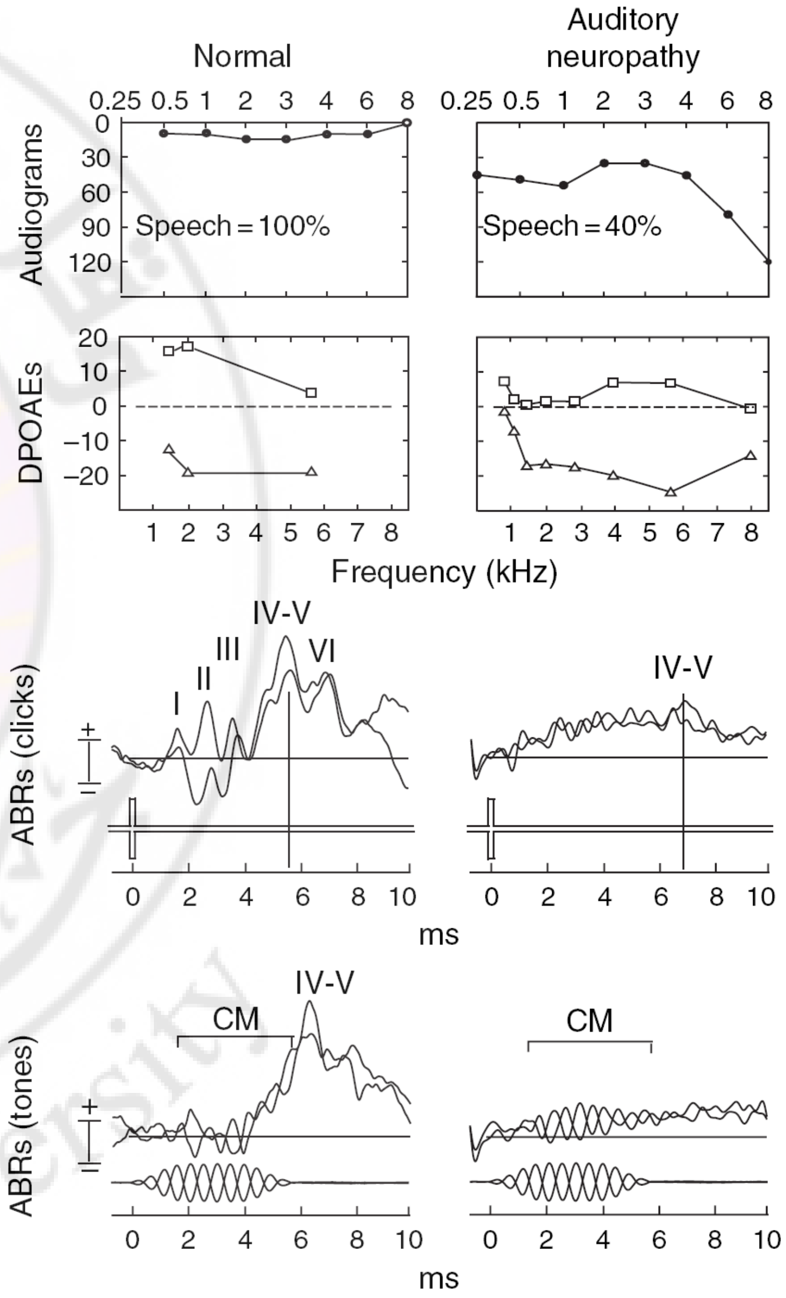
It is becoming apparent that the term *auditory neuropathy,* as it is defined clinically, may represent at least two fairly distinct disorders, one preneural or sensory and the other neural.

Level	Structures	Disorder	Site	Tests
VIII[th] NERVE	***Afferent auditory axons*** *(95% = Auditory Type I)*: myelinated axons; synapse with neurons of the CN *(5% = Modulating Type II)*: scarce unmyelinated axons; synapse with neurons of the CN	**NEUROPATHY** Demyelinating Axonal Mixed	*Auditory Type I*	*ABR Wave I* *ABR Wave II* *MEMR (acoustic)*
	Efferent OCB axons (auditory) Axons from SOC via Medial OC (myelinated); target: OHC Sparse lateral OC (unmyelinated); target: dendrites of Type I SGN		*OCB*	*OAE suppression* *(OHC activity modified though efferent MOC connections)*
	Afferent vestibular axons Myelinated vestibular axons (first order neurons) synapse with 2[nd]-order vestibular neurons in BS		*Vestibular*	*Vestibular tests*
BRAINSTEM PATHWAY	***Cochlear nucleus*** (second order auditory neurons) ***Superior olivary complex*** ***Inferior colliculus***	**BRAINSTEM DISORDER**	*Brainstem*	*ABR Wave III*, *ABR Wave V* } SOC to IC *MEMR (acoustic & tactile)*
THALAMUS	***Medial geniculate*** *body*	**THALAMO-CORTICAL DISORDER**	*Thalamo-cortex*	*MLR* *MMN*
CORTEX	***Primary auditory cortex*** (Heschl's gyrus) ***Secondary auditory cortex*** (superior temporal gyrus)		*Cerebral cortex*	*CAEP* *late obligatory event related potentials*


Alternating clicks 100 dBnHL
Condensation clicks 80 dBnHL
Rarefaction clicks 80 dBnHL
Rarefaction clicks 80 dBnHL
(tubephone clamped)
0.5μV
-1.1
0
2
4
6
8
10
12msec



OAE Discordance



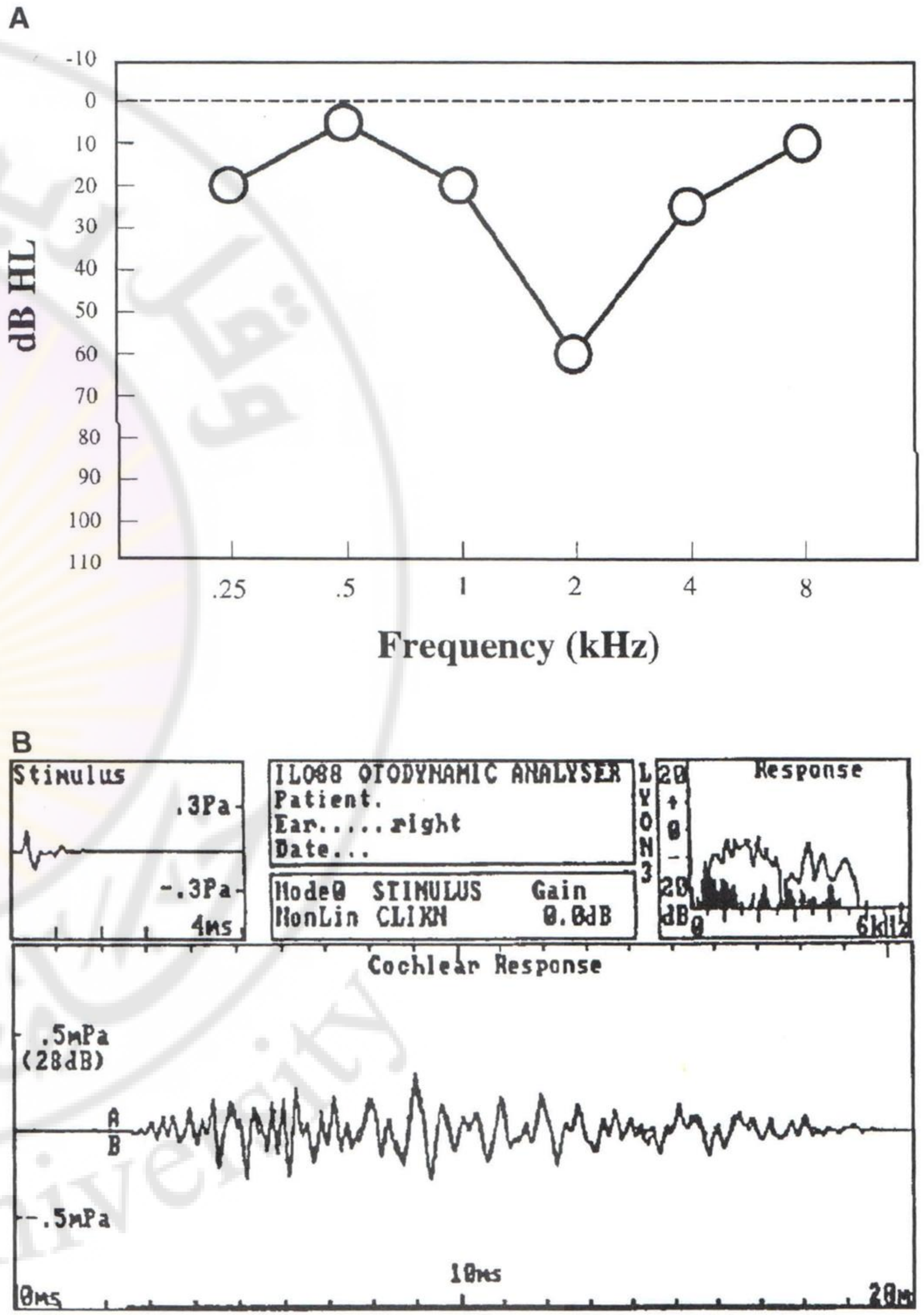
In 30% of Auditory Neuropathy cases, OAE will gradually disappear

- Middle ear disease (ear infections) ??
- Loss of neural input (??)
- Noise exposure from amplification (??)
- Change in OHC function ??

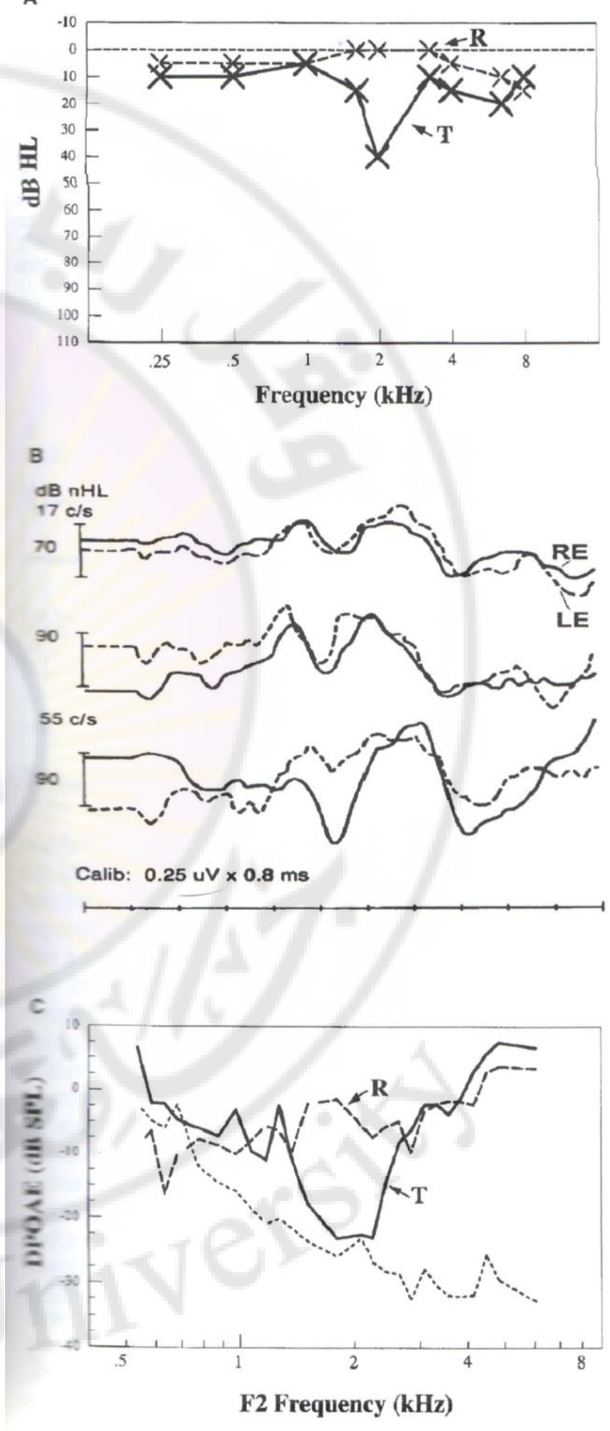
- Loss of OAEs does NOT mean that the loss is now sensory!

- The presence of an OAE is a **Sufficient** diagnostic criteria **but not a Necessary one.**

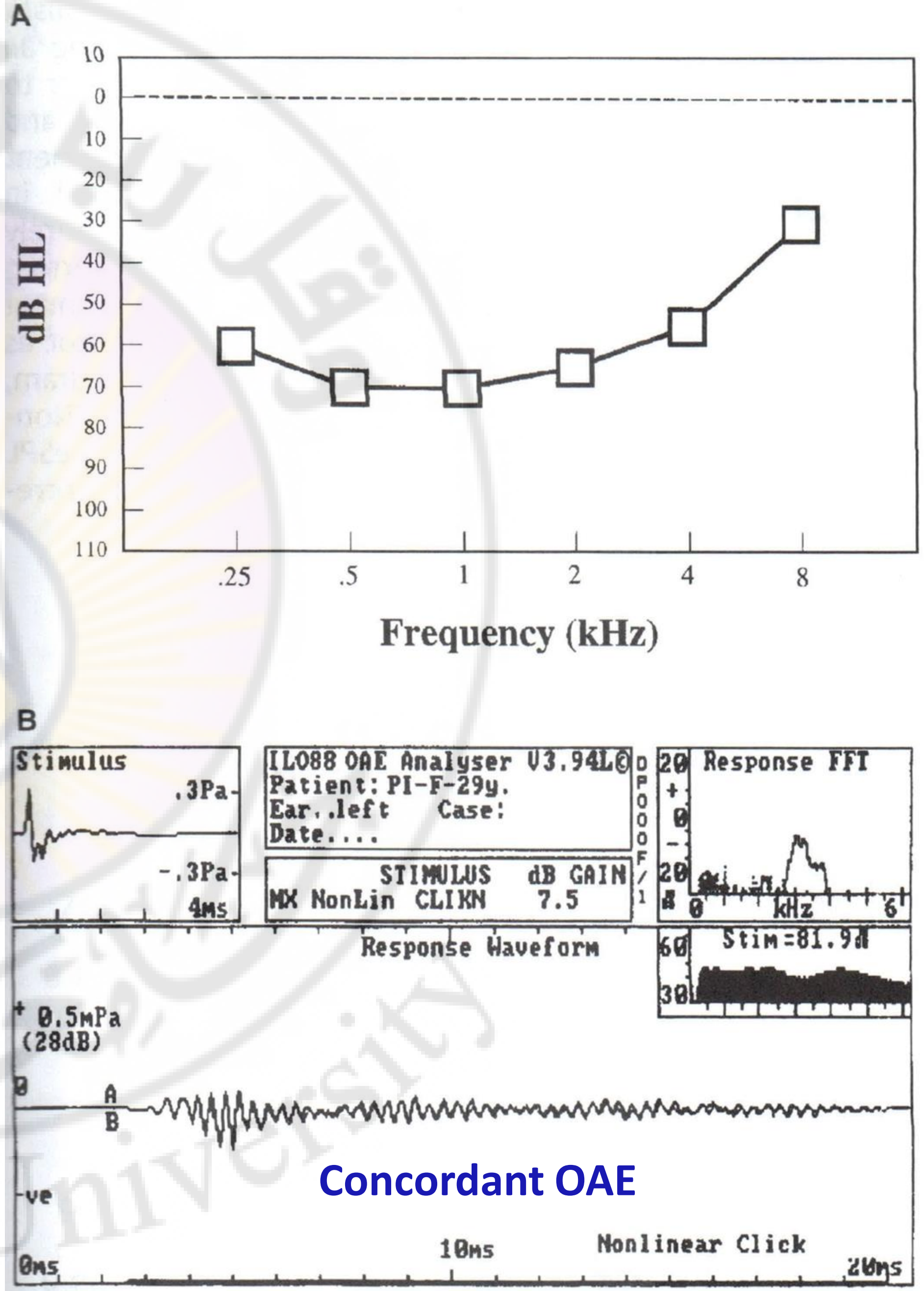
Acoustic Neuroma



Sudden SNHL


A
dB HL
Frequency (kHz)
R
T
B
dB nHL
17 c/s
70
90
55 c/s
90
RE
LE
Calib: 0.25 uV x 0.8 ms
C
DPOAE (dB SPL)
R
T
F2 Frequency (kHz)

Sudden SNHL

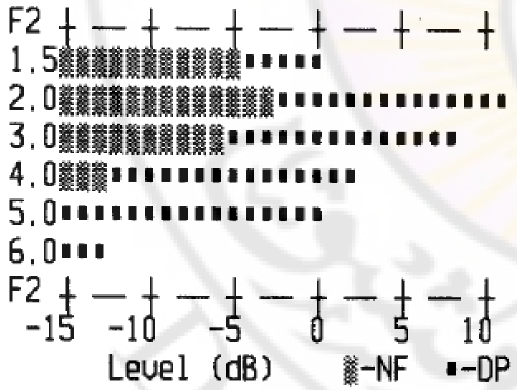


Concordant OAE

Non-organic Hearing loss

NAME:

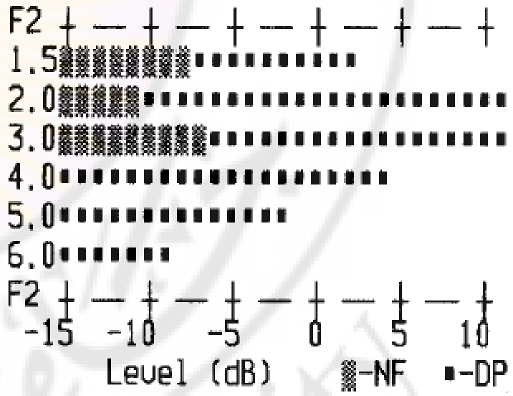
F2	P1	P2	DP	NF	SN	
1.5	64	55	0	-5	6	
2.0	66	55	11	-3	14	P
3.0	65	55	8	-6	14	P
4.0	65	55	2	-13	16	P
5.0	65	55	0	-18	18	P
6.0	65	55	-13	-18	5	



Right : Pass

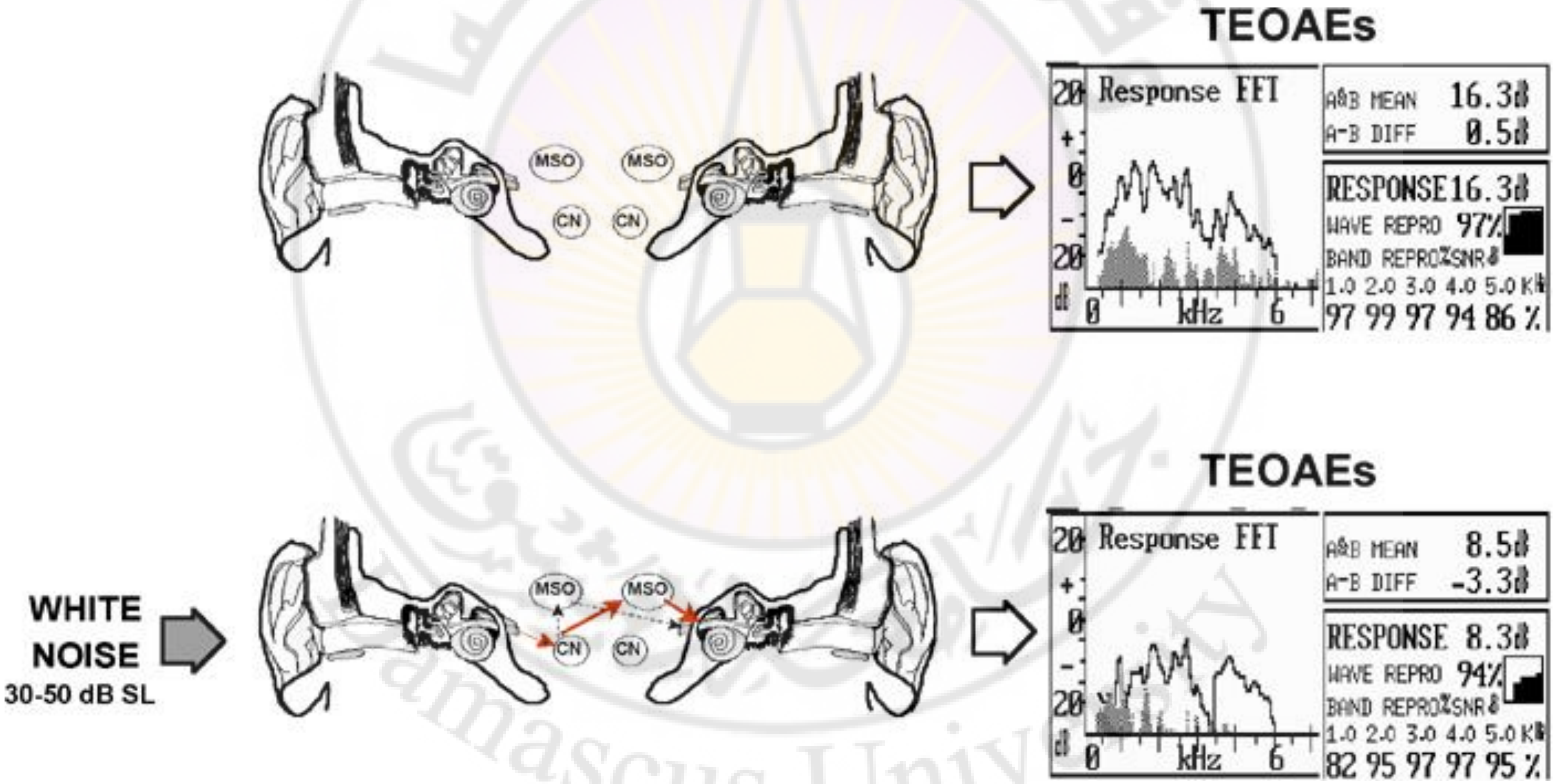
NAME:

F2	P1	P2	DP	NF	SN	
1.5	66	55	2	-8	10	P
2.0	66	55	13	-11	25	P
3.0	65	55	12	-7	19	P
4.0	65	55	4	-16	20	P
5.0	65	55	-2	-16	14	P
6.0	65	55	-9	-18	9	P



Left : Pass

Detection of central auditory disorders (OAE suppression)



Cochlear Implant Candidacy

TEOAE Test Report

Diagnostic TEOAE test was conducted to assess the cochlear function *(click stimulation, 80 dB SPL)*:

TEOAE results

Right ear: Normal TEOAE amplitudes (8.4 dB SPL) and high waves reproducibility (86%), suggesting normal cochlear function

Left ear: No obvious TEOAE responses were recorded due to middle ear effusion

Recommendation

ENT follow-up for medical treatment

TEOAE Test Report

Diagnostic TEOAE test was conducted to assess the cochlear function *(click stimulation, 80 dB SPL)*:

TEOAE results

Reduced TEOAE amplitudes across different frequencies and low waves reproducibility (36%), suggesting ***damaged (degraded) cochlear function*** in both ears

DPOAE Test Report

Diagnostic DPOAE test was conducted to assess the cochlear function (L2=65, L1=55 dB SPL; f2/f1=1.2):

DPOAE results

- DPOAEs were present and robust (1500-5000 Hz), suggesting normal cochlear function
- DPOAE amplitudes were within normal limits in both ears (1500-5000 Hz), suggesting normal cochlear function

Meet The Manufacturers

Otodynamics

Echoport

Otoport

GRASON-STADLER (GSI)

CORTI

NOVUS

AUDERA PRO

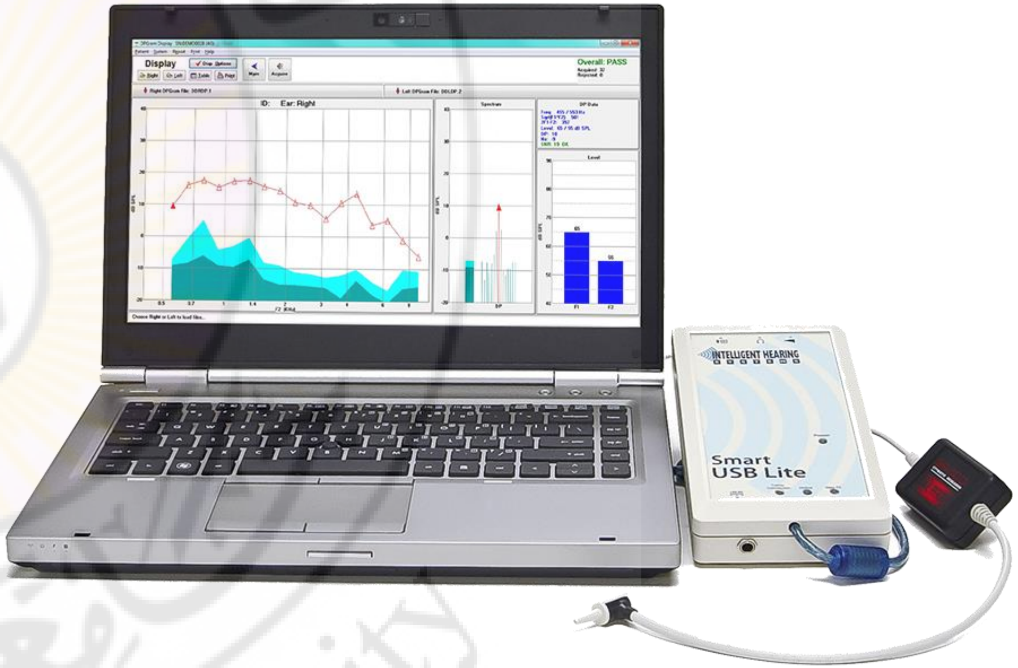
Natus Medical Inc.

Echo-Screen® III

AccuScreen®

Intelligent Hearing Systems (IHS)

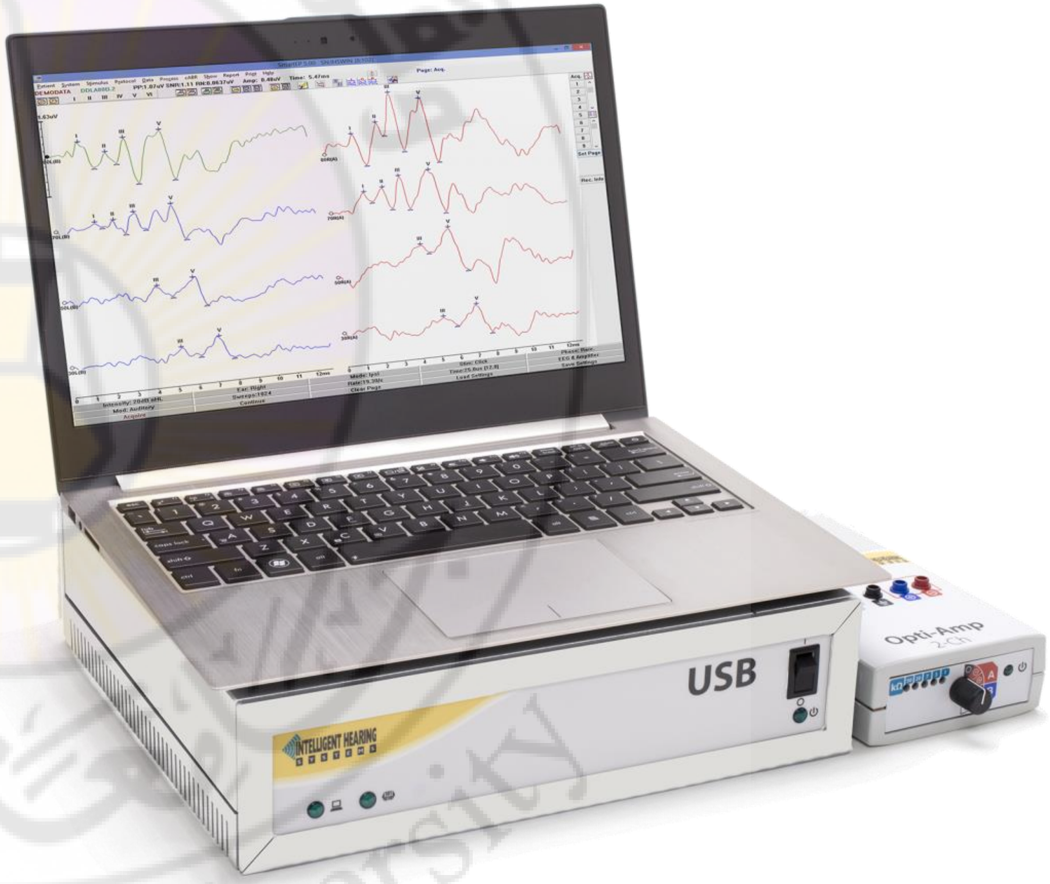
Duet



USBLite

Intelligent Hearing Systems (IHS)

SmartScreener-Plus 2



SmartOAE

Interacoustics

Titan

OtoRead

Interacoustics

Sera

Lyra

Maico

ERO•SCAN

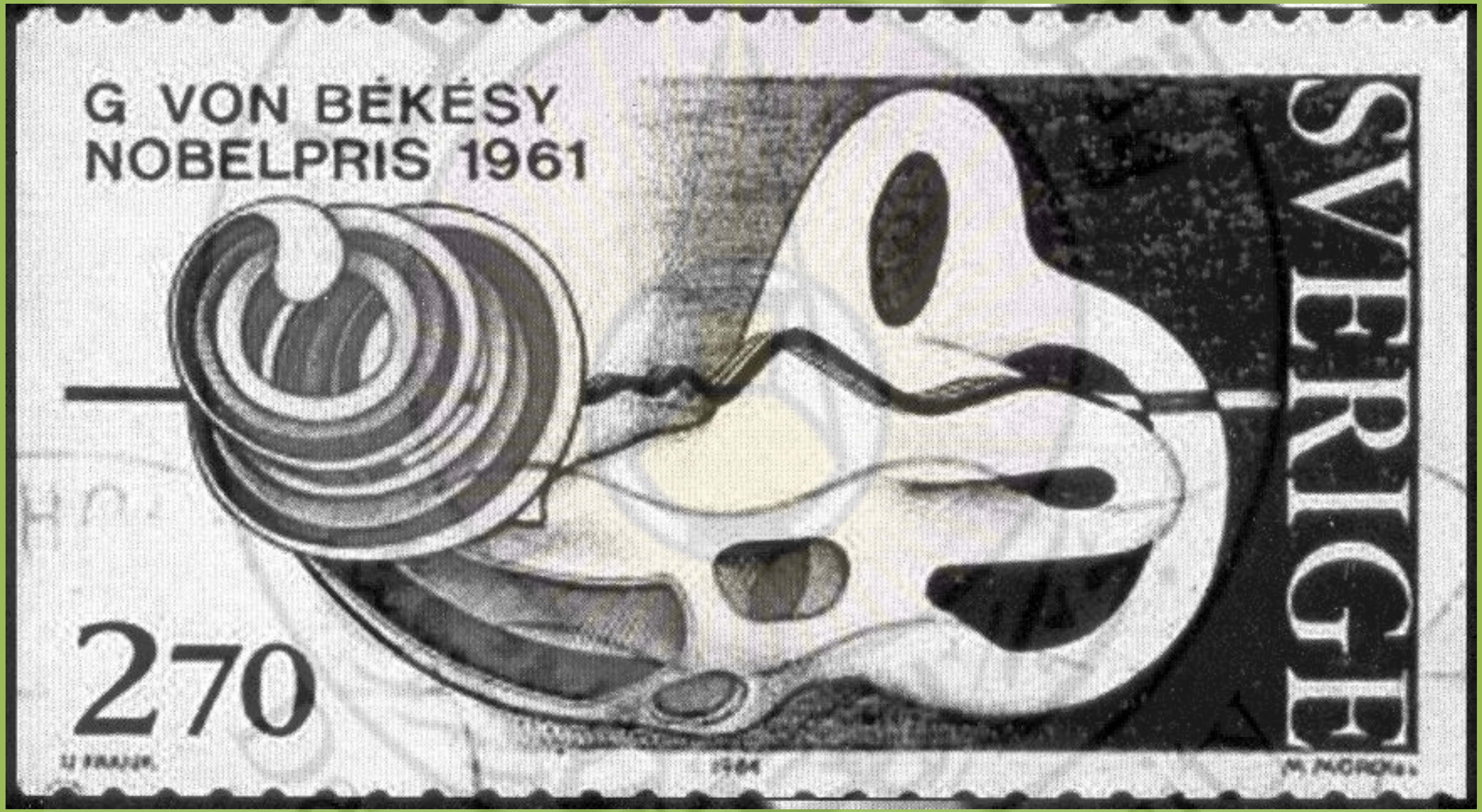
easyScreen

Vivosonic

Aurix

WelchAllyn

Welch Allyn OAE Hearing Screener


G VON BÉKÉSY
NOBELPRIS 1961
270
SVERIGE