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Wideband Acoustic Immittance in Children, in partnership with Seminars in Hearing

Navid Shahnaz, Ph.D.
The University of British Columbia,
School of Audiology & Speech Sciences
Co-authors: Sreedevi Aithal Ph.D. & Gabriel A. Bargen Ph.D.

Navid Shahnaz, PhD

Dr. Navid Shahnaz is currently an Associate Professor of Audiology in the School of Audiology & Speech Sciences at the University of British Columbia (UBC), where he has been a faculty member since July 2002. He has been a SpeechLanguage and Audiology Canada (SAC) certified member since November 1995. He was a member of the national (CASLPA) Audiology Examination Committee between 2002 and 2008, and a member of the CASLPA Board of Governors (2011-2014), where he was the representative of the Canadian Council of University Programs in Communication Sciences and Disorders. His main area of research interest includes multi-frequency tympanometry, Wideband Acoustic Immittance, otoacoustic emission, and acoustic reflex studies in adults, children, and infants. His new research interests also focus on the assessment of the balance systems using vestibular evoked myogenic potentials, and the development of test batteries for assessment of the hidden hearing loss.

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- Susan Voss
- Erik Hagerstrom M.D
- Proper references have been made to other authors
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Outline

- Background
- Wideband Acoustic Immittance Principles
- Some practical issues
- WAI in Children with different middle ear pathologies
- Cases
- Summary
- Future direction

Disclosures

- **Presenter Disclosure**: Financial: Navid Shahnaz is employed by the University of British Columbia (UBC). He received an honorarium for this presentation. Non-financial: Navid Shahnaz has no relevant non-financial relationships to disclose.
- **Content Disclosure**: This learning event does not focus exclusively on any specific product or service.
- **Sponsor Disclosure**: There is no external sponsor for this course.

Learning Outcomes

After this course, participants will be able to:

- Describe the use of wideband acoustic immittance (WAI) in diagnosing middle ear pathologies in children between the ages of 3 and 12 years.
- Explain the difference between wideband absorbance at ambient pressure (WBA amb) and wideband absorbance at tympanometric peak pressure (WBA TPP) and how they aid in diagnosing middle ear disorders in children.
- Explain how to analyze and interpret absorbance data in cases of otitis media with effusion and compare it to age-appropriate normative data.

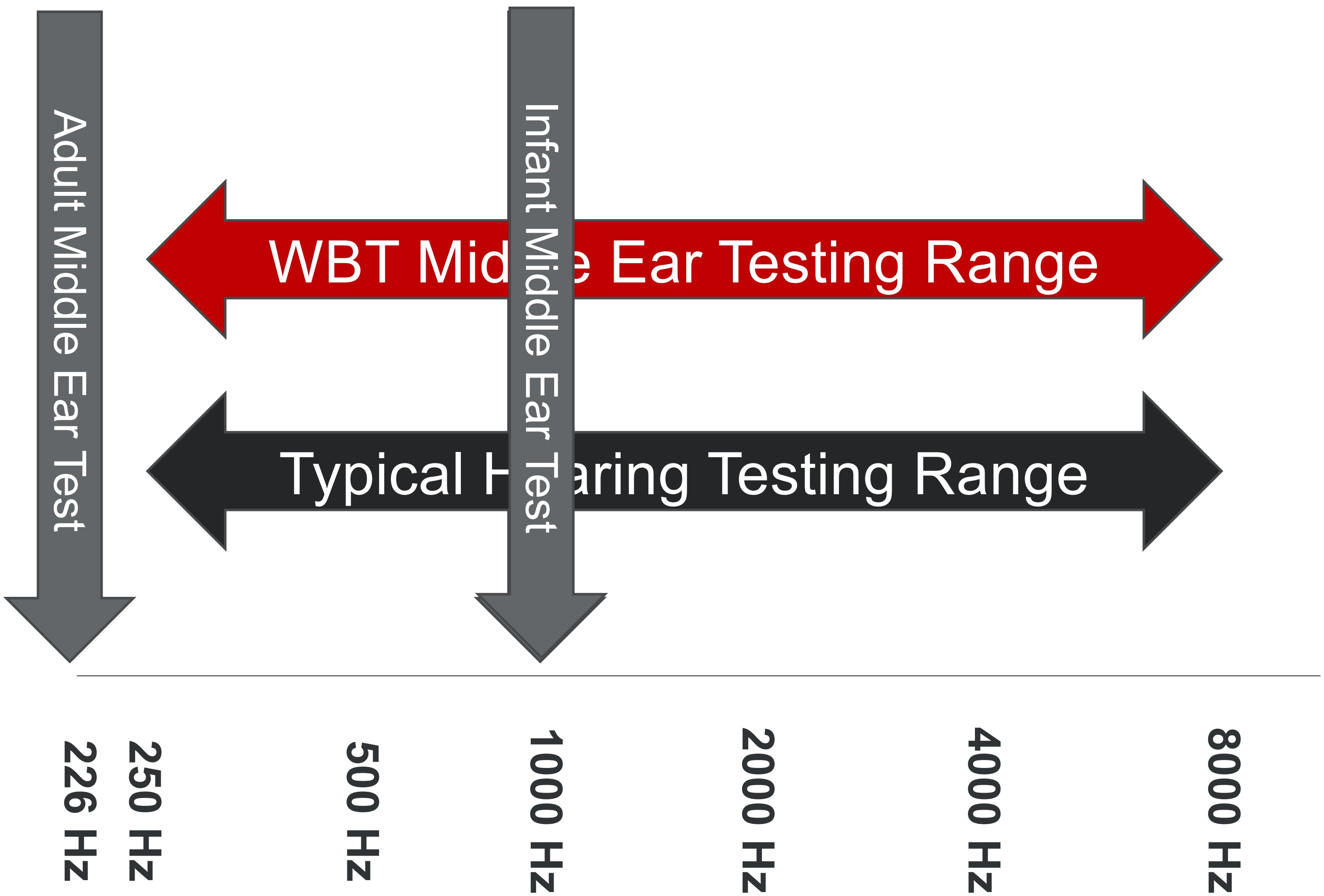
Background

continuED Hearing

History

THE RISE AND FALL OF AURAL ACOUSTIC IMMITTANCE ASSESSMENT TOOLS/SHAHNAZ ET AL SEMINARS IN HEARING/VOLUME 44, NUMBER 1 2023

Frequency Range for Middle Ear Testing



Roots of Wideband Tympanometry Measures

- Wideband research system developed by Douglas Keefe (Keefe, Bulen, Arehart, & Burns, 1993)
- Application in clinical assessment of the middle ear has occurred in the past 2 decades.
- Provides more accurate measures, especially at higher frequencies (Stinson, Shaw, & Lawton, 1982; Huang, Rosowski, & Peake, 2000; Voss & Allen, 1994).
- Frequency ranges can be tested up to 10 kHz for adults and 20 kHz for infants due to small ear canal diameter and length in infants (Keefe et al., 1993).

David Kemp on Timelines in our Field

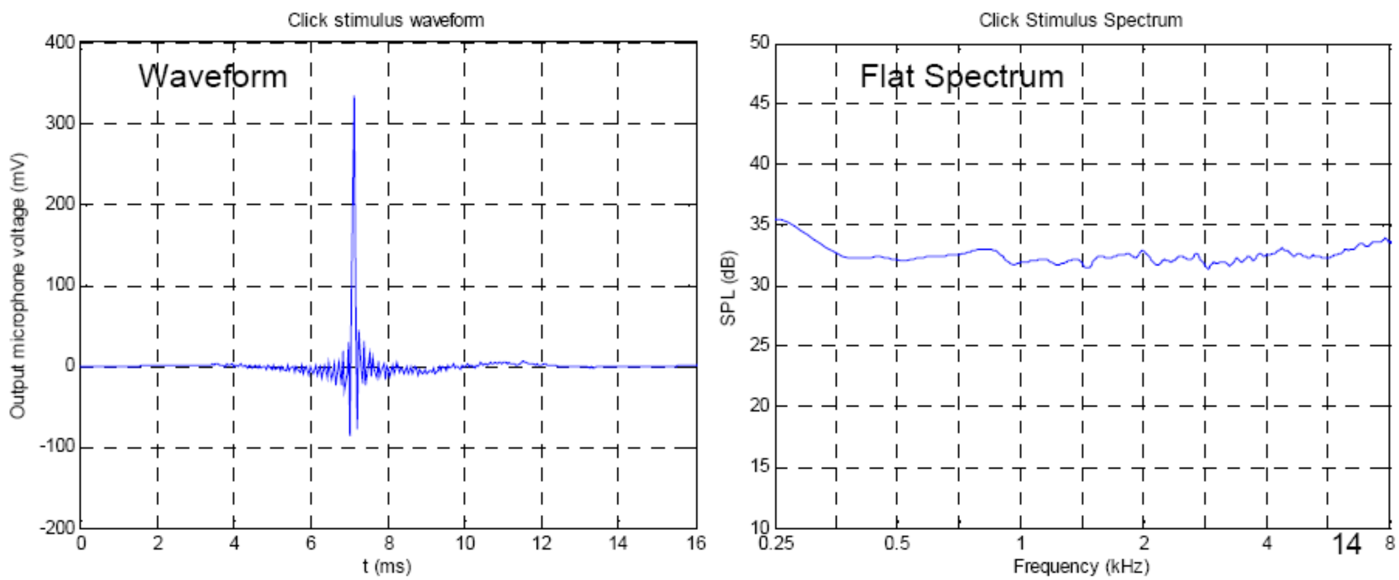
- 10 years from first discovery / first article / patent to a general acceptance among researchers about feasibility.
- 10-15 years before that acceptance makes products available and makes daily clinical practice start.

Advantages of WAI

- Fast (2 seconds), objective, non-invasive
- Can be conducted at ambient pressure
  - Unlike tympanometry which requires compensation of the ear canal volume to measure admittance at the plane of tympanic membrane (Ytm), the magnitude of the power reflectance does not depend on the distance between the probe tip and the eardrum.
- Wide frequency range
  - Possible to measure more than one resonant frequency
- Has the potential to predict the conductive hearing loss (Keefe & Simmons, 2003; Piskorski et al., 1999)

Properties of the WAI Stimulus

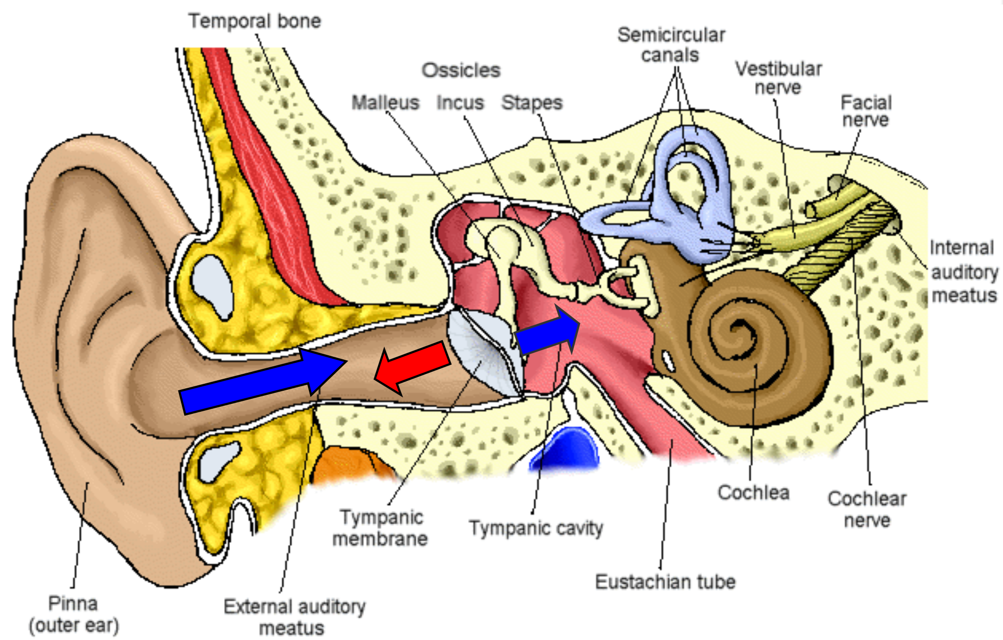
Short duration "Click"
Bandwidth: 226Hz to 8kHz
Intensity: 60dB nHL (95dB peSPL)



WAI Principles

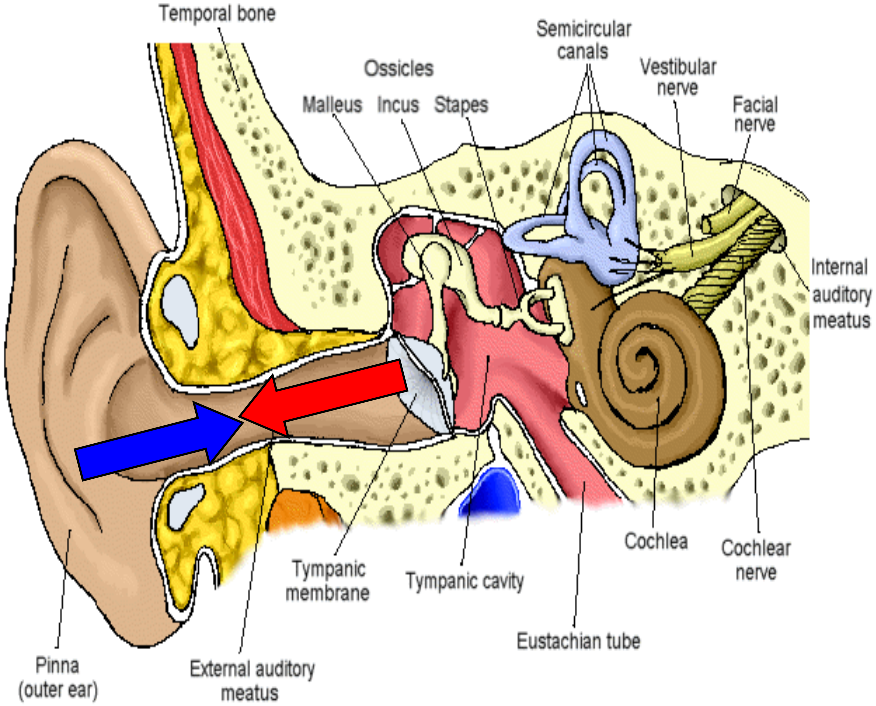
- Pressure reflectance R (f) is a complex number that is the ratio of the forward-moving (incident) pressure wave to the reflected (retrograde) pressure wave. The square of the pressure reflectance magnitude is called the power reflectance $|R\ (f)\ |^2$ or energy reflectance-ER (Allen, Jeng, & Levitt, 2005).

$$\text{Energy Reflectance} = \frac{\text{Reflected Energy}}{\text{Incident Energy}}$$



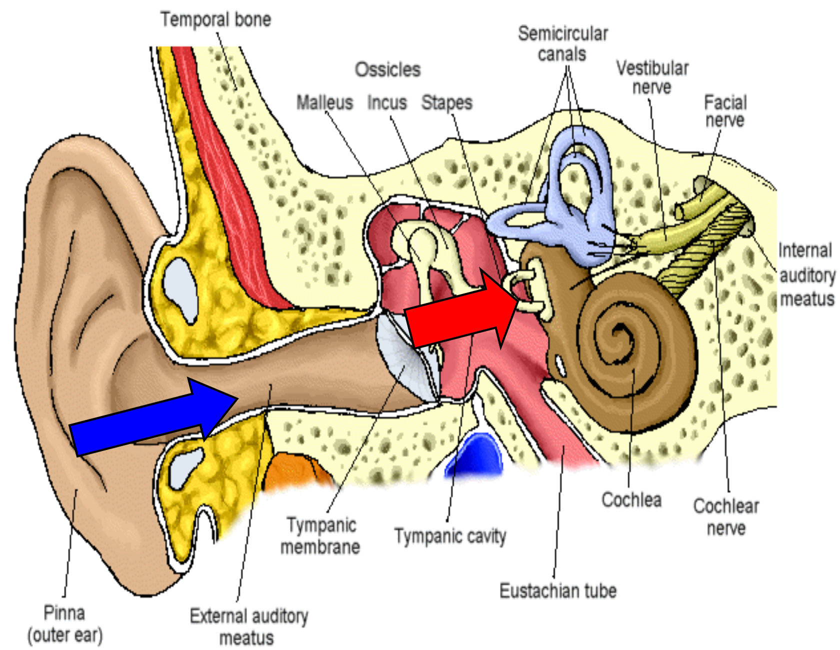
WBR Principles

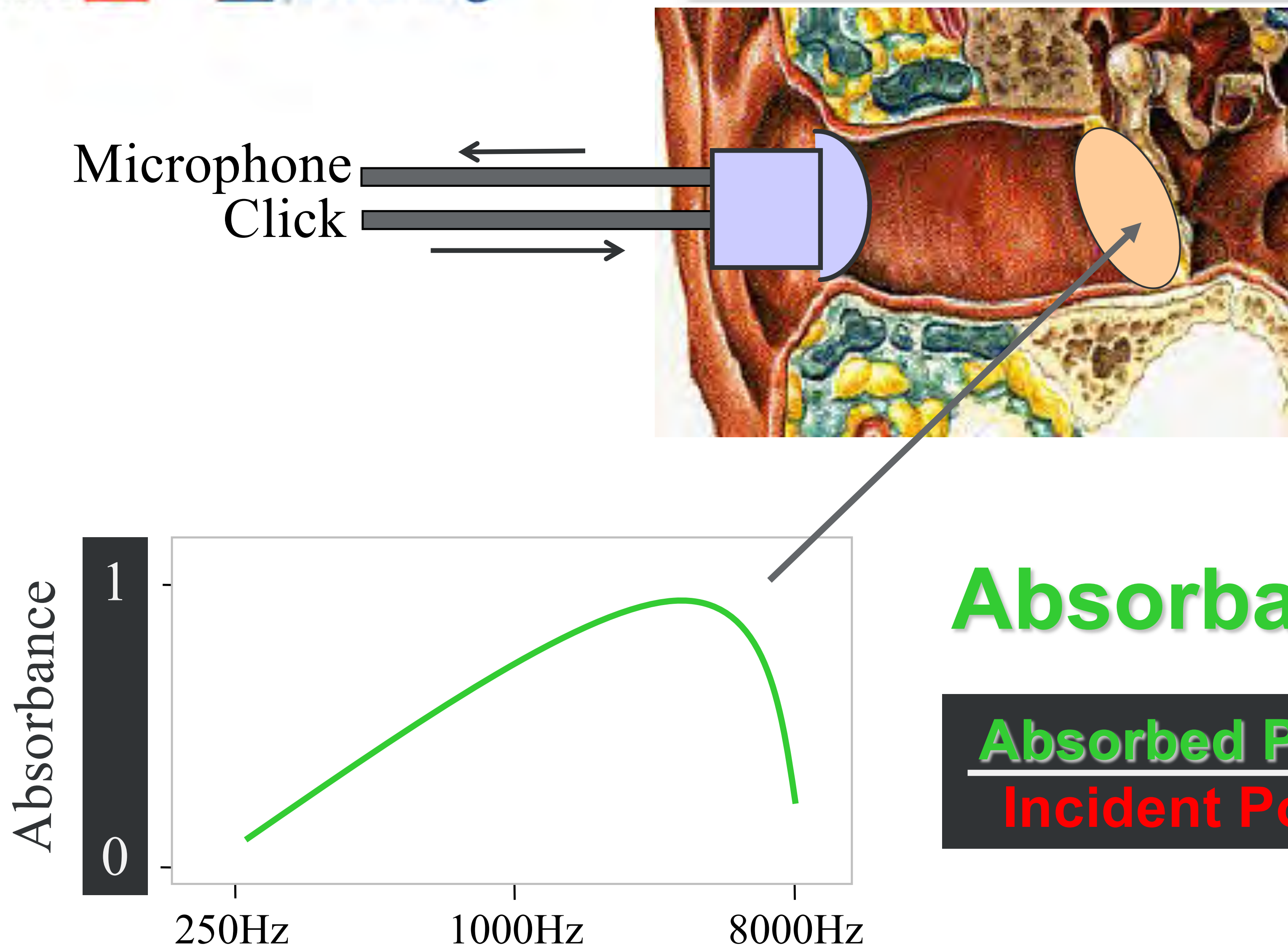
- If all the energy is reflected from the eardrum the energy reflectance is 1



WBR Principles

- If all the energy is transferred into the middle ear the energy reflectance is 0





Absorbance

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

Give me the name…..

The Names

- **Absorbance**
  - Covers the same as:
    - Reflectance
    - WideBand Reflectance (WBR)
    - WideBand Energy Reflectance
    - Ambient Reflectance
    - Power Reflectance
    - Energy Reflectance
    - Middle Ear Power Absorption
    - Wideband Acoustic Transfer Function

- **WideBand Tympanometry (WBT) (EW: Wideband Acoustic Immittance (WAI))**
  - A collective term for:
    - <u>Absorbance</u> (EW: Absorbance)
    - <u>Absorbance Tympanometry</u> (EW: WAI Tympanometry)
    - <u>Averaged WB Tympanogram</u>

This is NOT ”Reflectometry”!

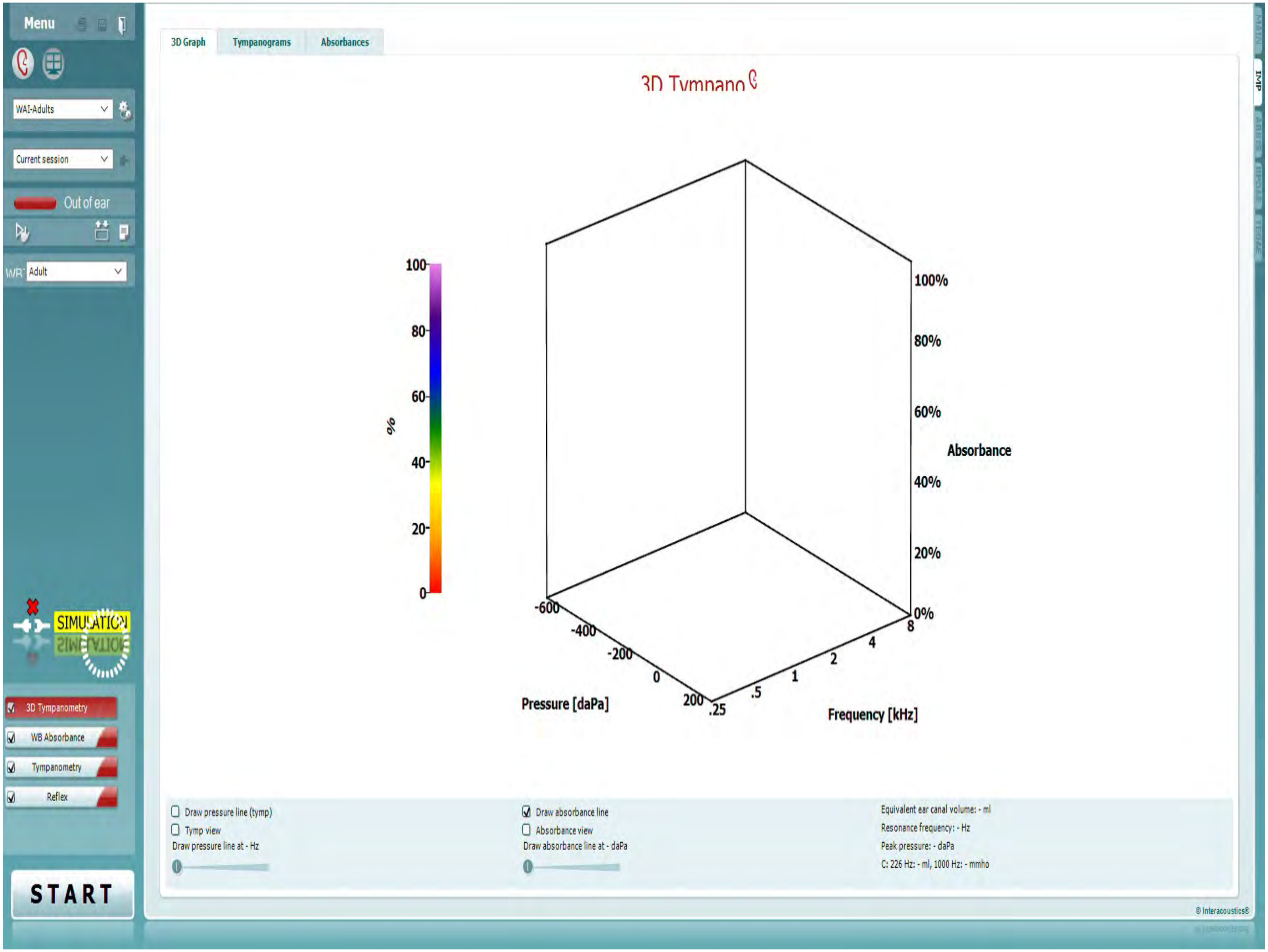
Instrumentation Ambient (Static)

Components of the Mimosa Acoustics – Otostat (left) and Hear ID (right) wideband acoustic immittance.

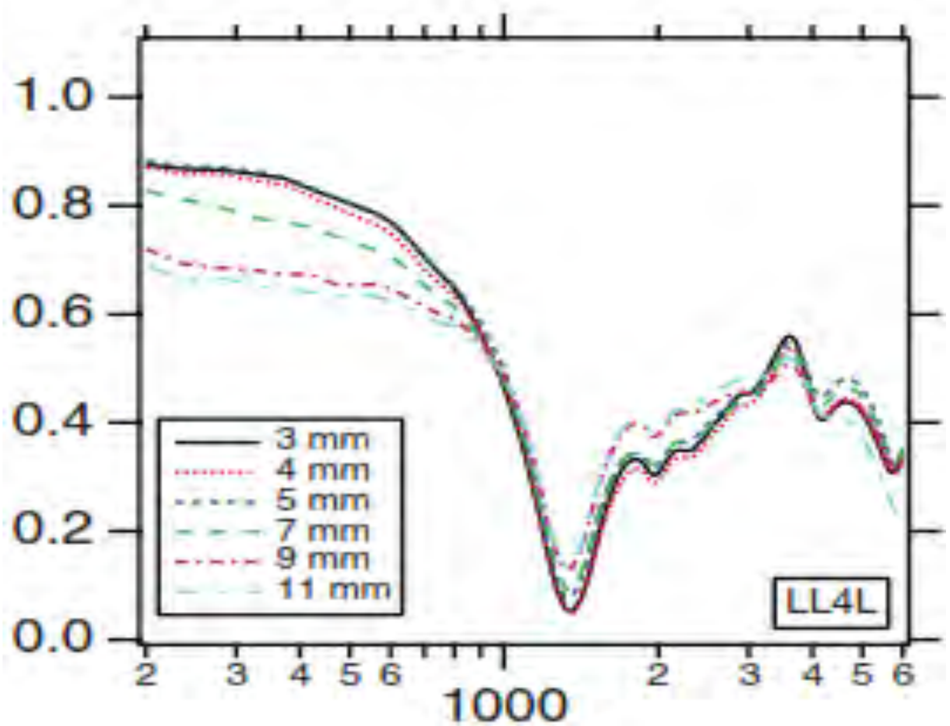
Handheld WBT, OAE,Tymp, & Middle ear Muscle Reflex-Titan Interacoustics

New Tympstar Pro

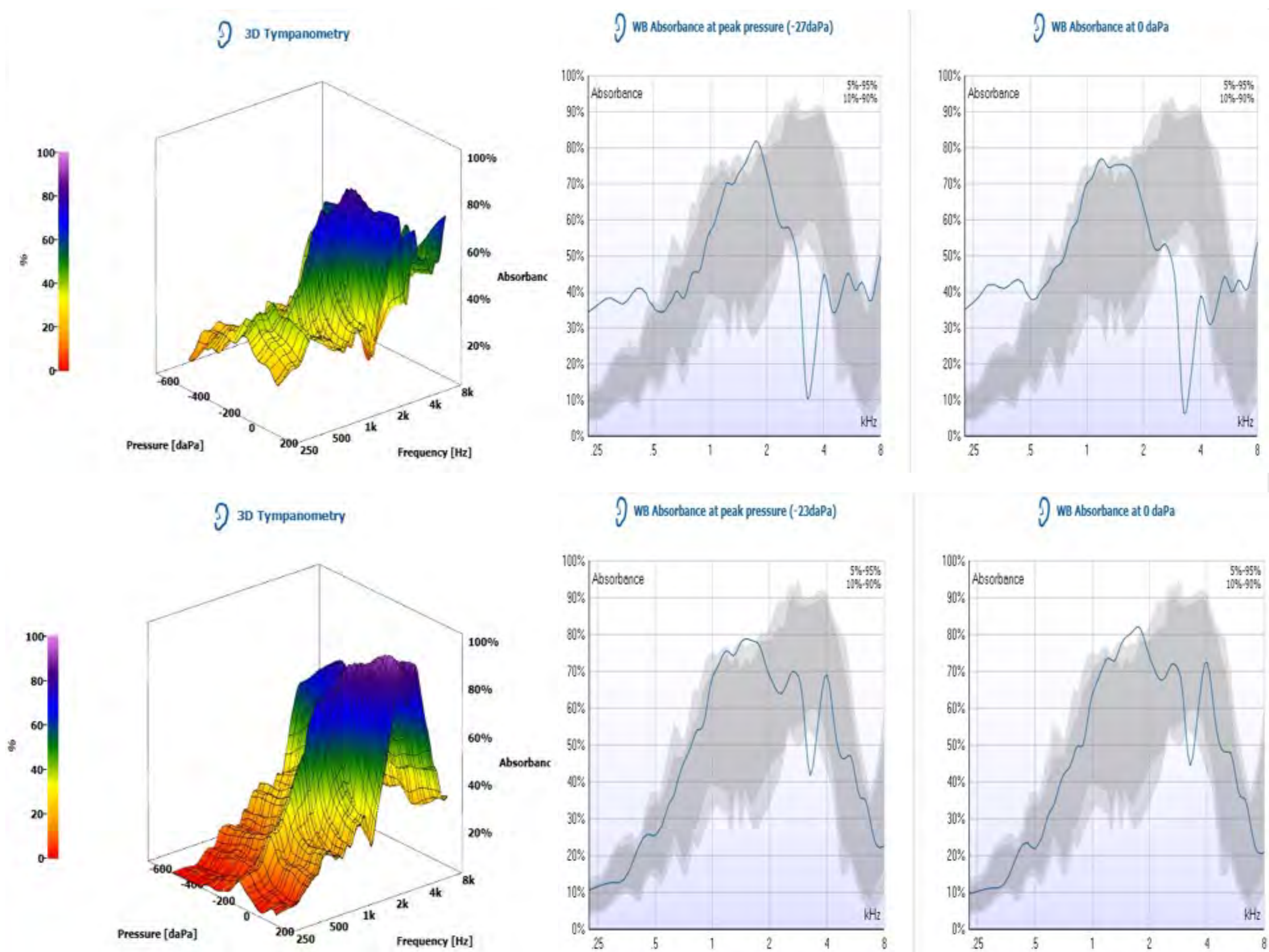
Demonstration of Absorbance Tympanometry



Practical Issues
Effect of Insertion Depth



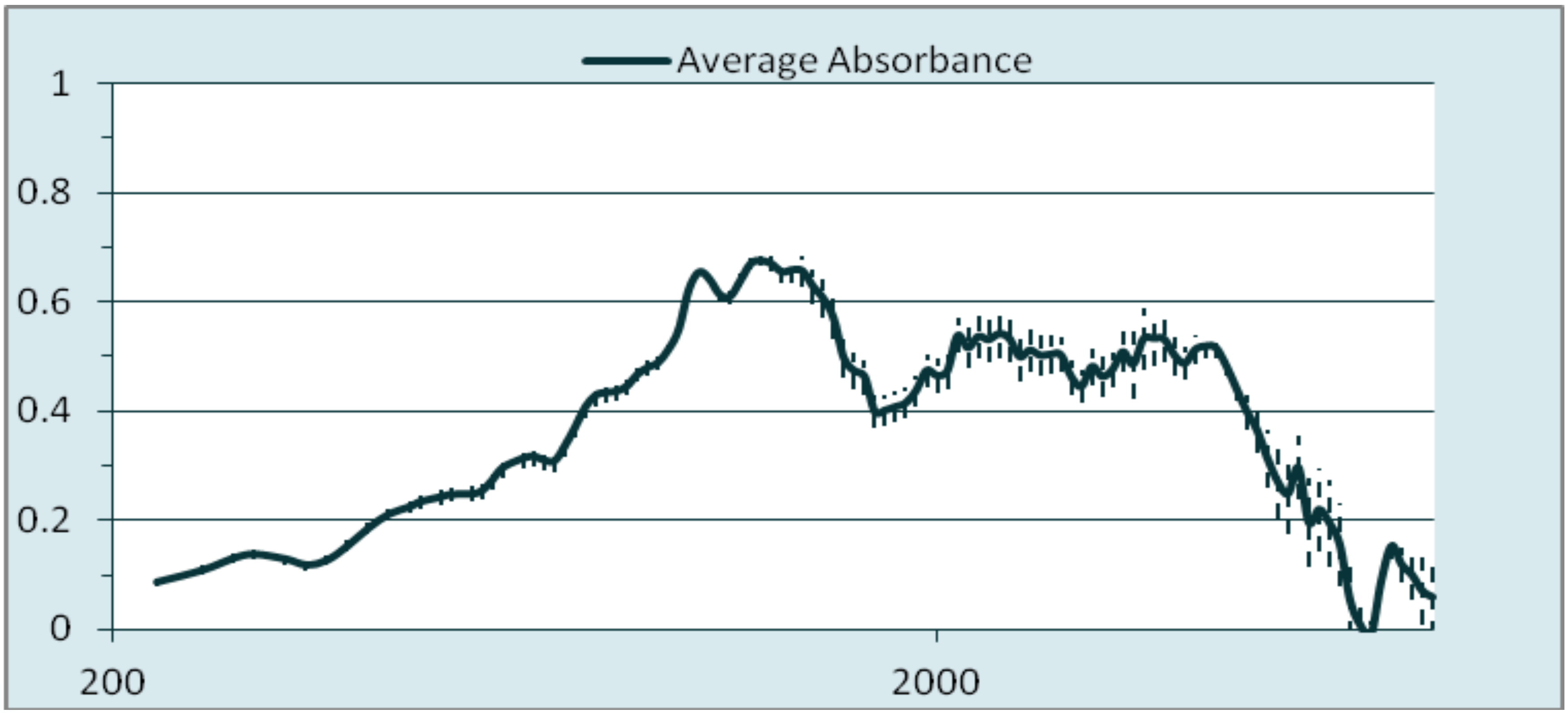
Source: Voss et al. (2008). Ear & Hearing 29; 651–665: Absorbance generally increases with distance from the TM, consistent with loss in the ear canal



3D Tympanometry
%
Pressure [daPa]
Frequency [Hz]
Absorbanc
WB Absorbance at peak pressure (-27daPa)
WB Absorbance at 0 daPa
Absorbance
5%-95%
10%-90%
kHz
3D Tympanometry
WB Absorbance at peak pressure (-23daPa)
WB Absorbance at 0 daPa

Short Term Test / Retest

10 Separate deep probe insertions.



Data: Jos Huijnen

Long Term Test Retest Reliability

Feeney et al., 2014 Ear & Hear

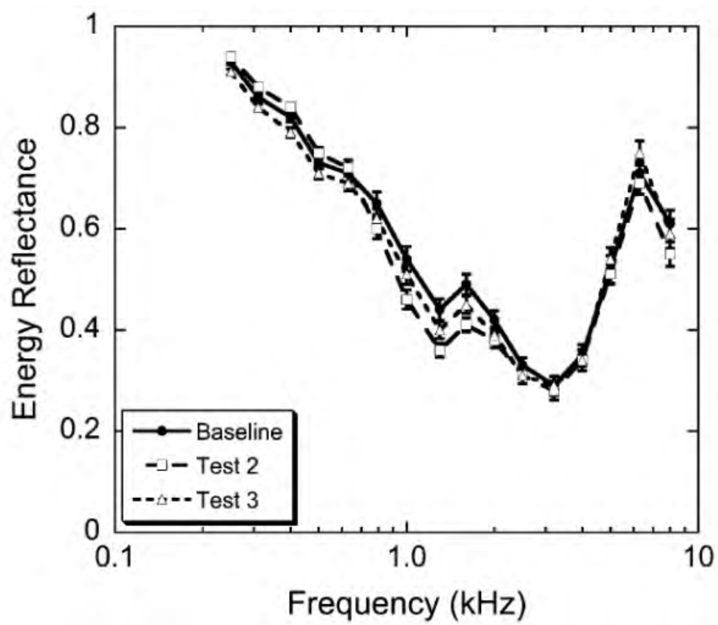


Figure 7. Mean ER for three annual tests for subjects with normal hearing and normal 0.226-kHz tympanometry. The thick solid line represents the mean ER of 64 ears for the first annual test, the long dashed line represents the mean ER for the same 64 ears for the second test obtained an average of 423 days later, and the short dashed line represents the mean ER for the same 64 ears for the third test obtained an average of 396 days later. Error bars represent ±1 standard error.

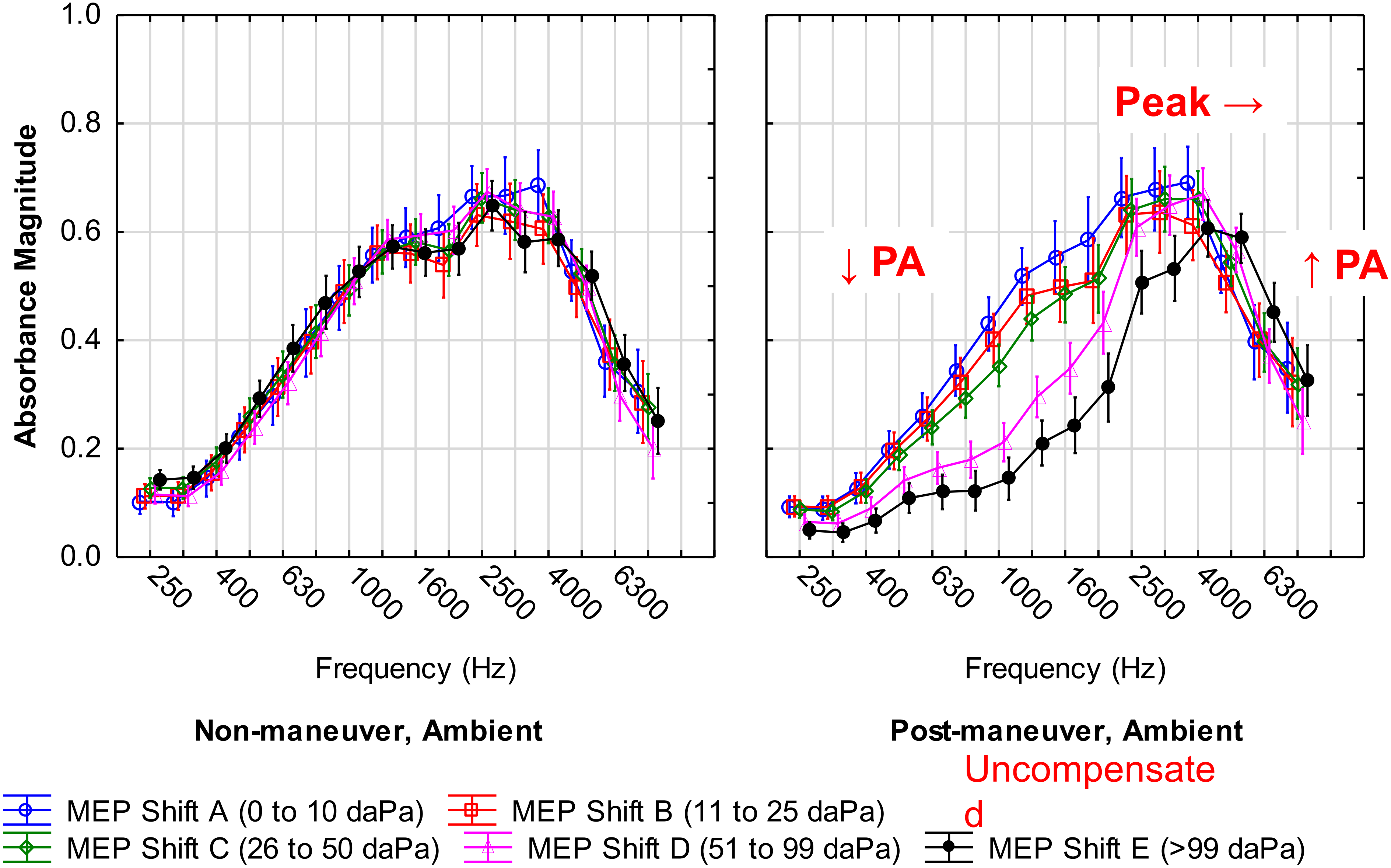
Take Home Message!

Use deep probe tip insertion

Impact of Pressure on WAI
Rae Riddler Thesis

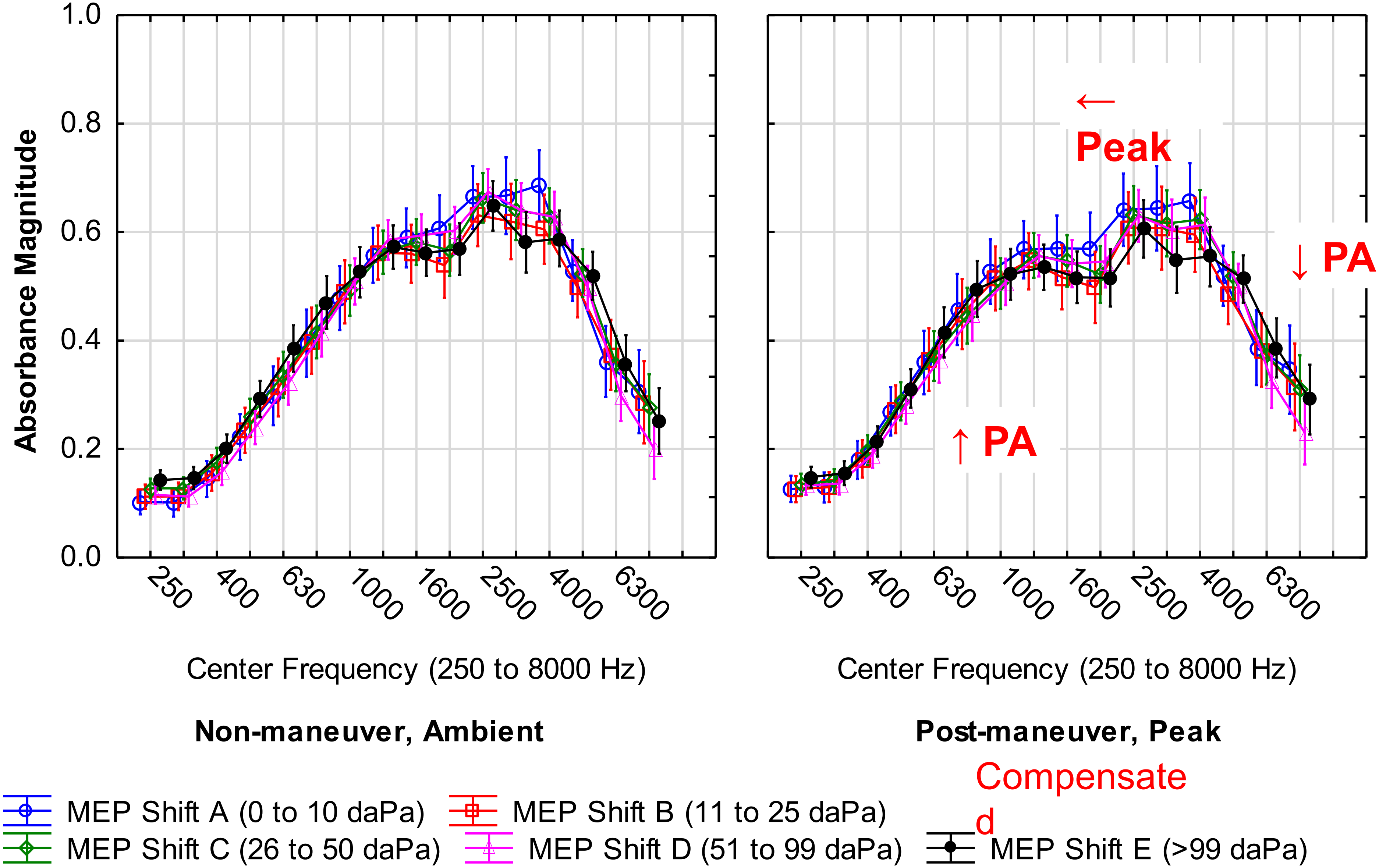
Comparison of Absorbance Magnitude Between Test Conditions (Non-maneuver Ambient versus Post-maneuver Ambient), as a Function of Absolute MEP Shift Magnitude and Center Frequency, with the Analysis Collapsed Across Gender and Ethnicity

[F(60, 3030)=15.658, p=.0000]



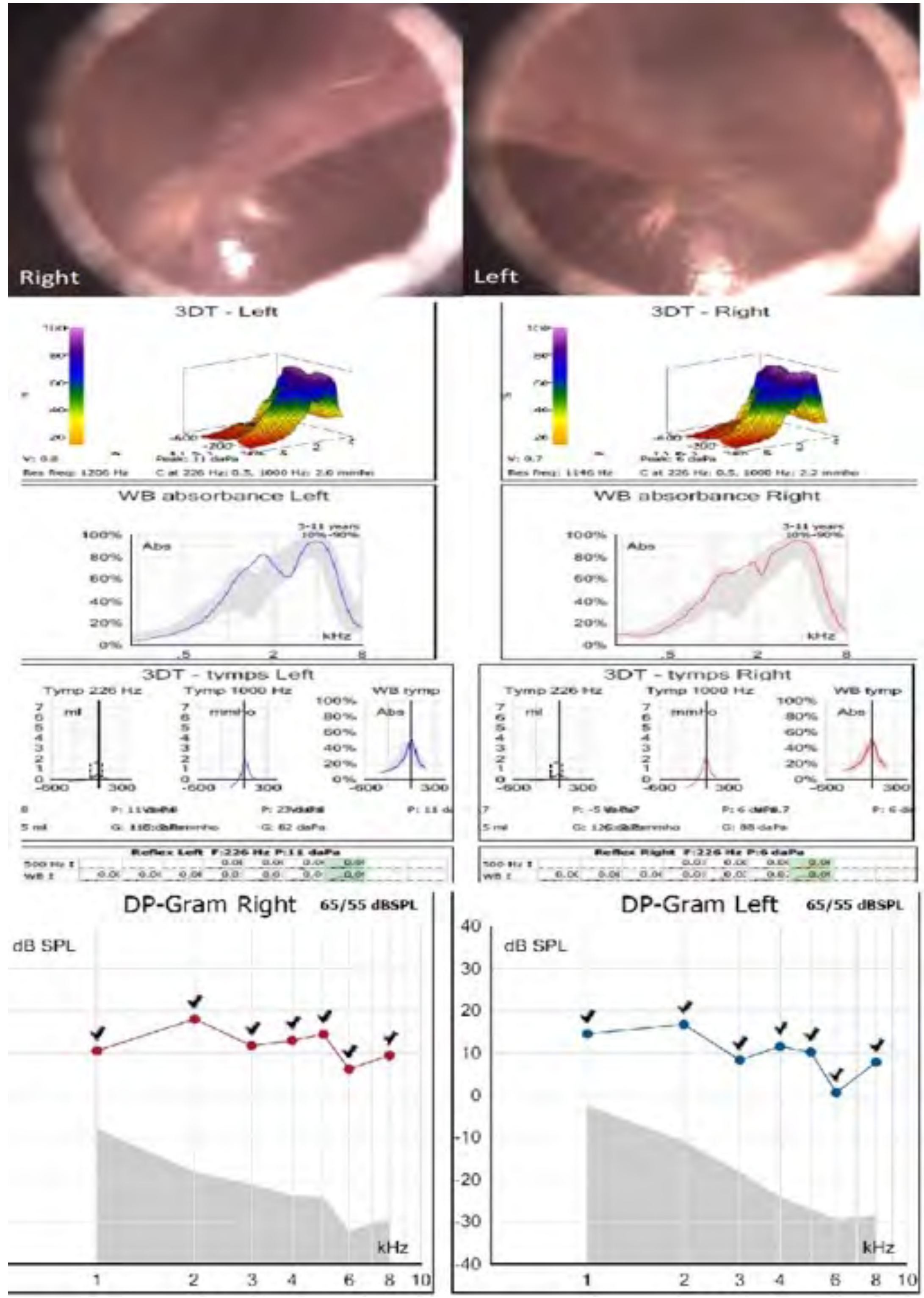
Comparison of Absorbance Magnitude Between Test Conditions (Non-maneuver Ambient versus Post-maneuver Peak) as a Function of Cetner Frequency and Absolute MEP Shift Magnitude, with the Analysis Collapsed Across Gender and Ethnicity

$[F(60, 3030)=0.8576, p=.79525]$



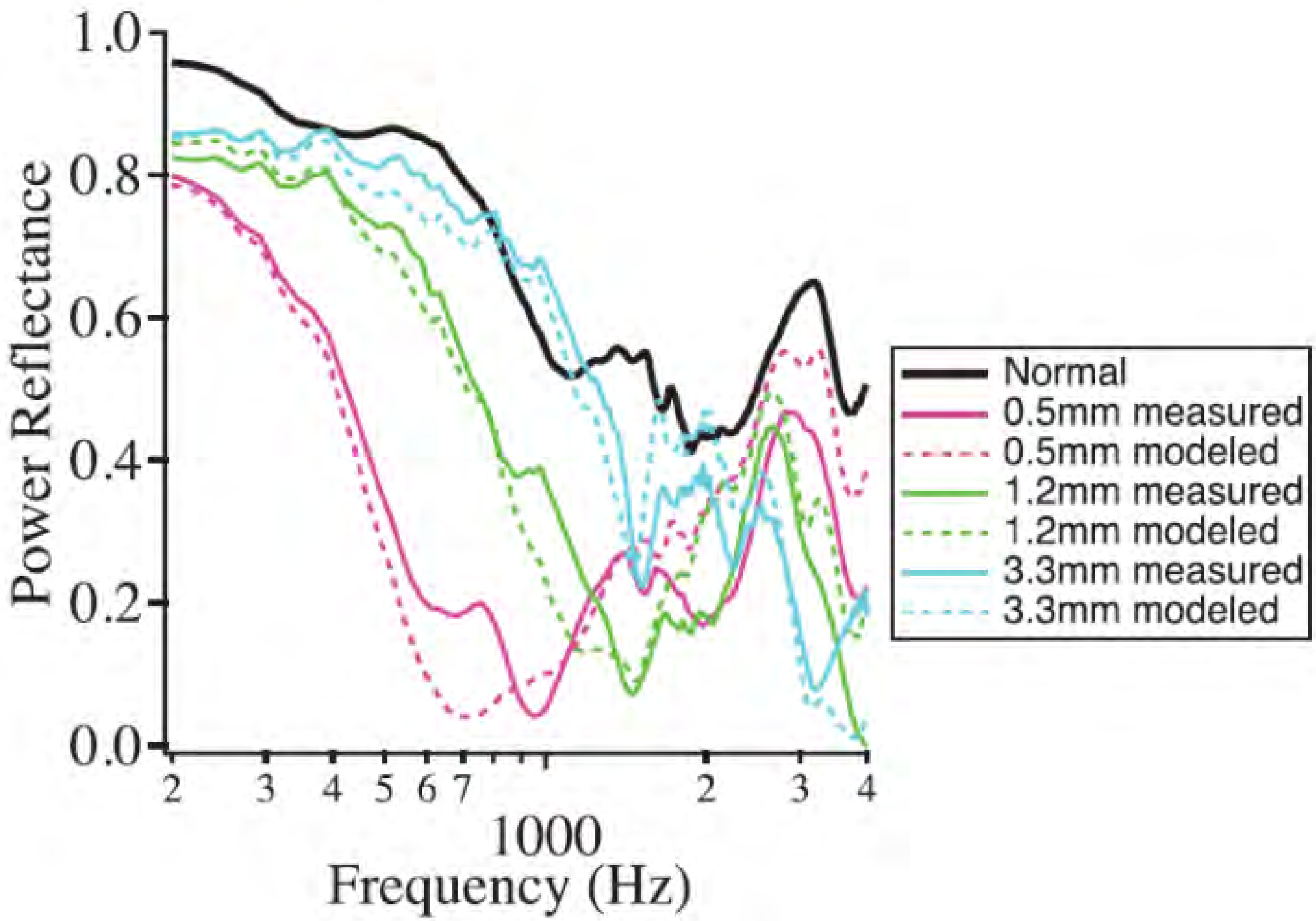
WAI in Children

Normal



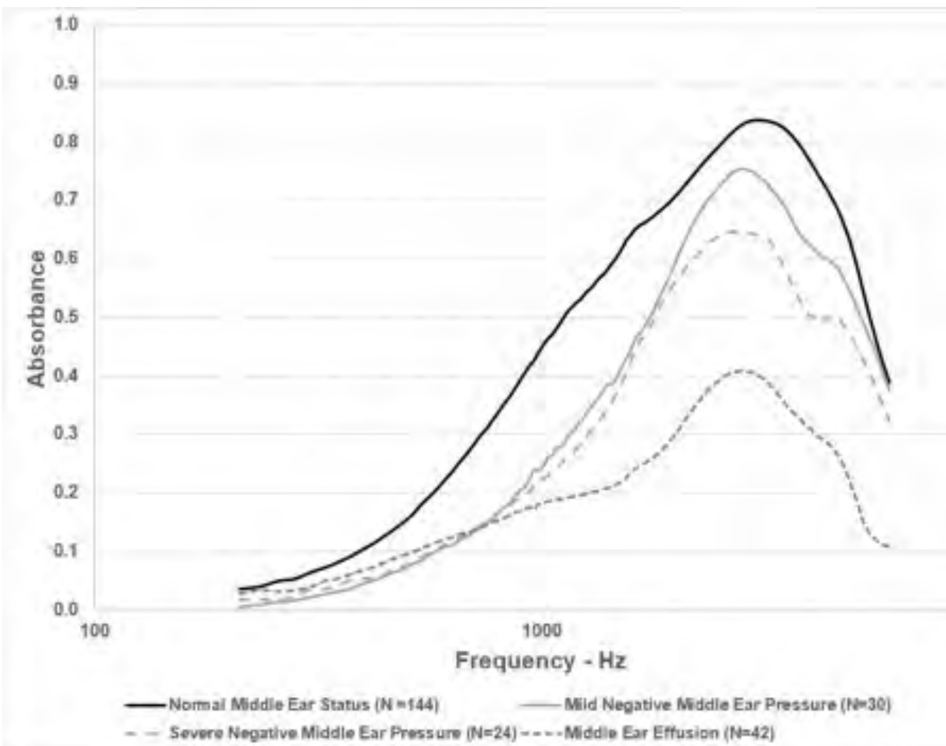
Right
Left
3DT - Left
3DT - Right
WB absorbance Left
WB absorbance Right
Abs
kHz
3DT - tymps Left
3DT - tymps Right
Tymp 226 Hz
Tymp 1000 Hz
WB tymp
DP-Gram Right
65/55 dBSPL
DP-Gram Left
65/55 dBSPL
dB SPL
kHz

Effect of Tympanic Membrane Perforation Voss et al. 2012 Ear Hear. 2012 ; 33(2): 195–208



WAI in Children

Beers et al., 2010 Ear & Hear



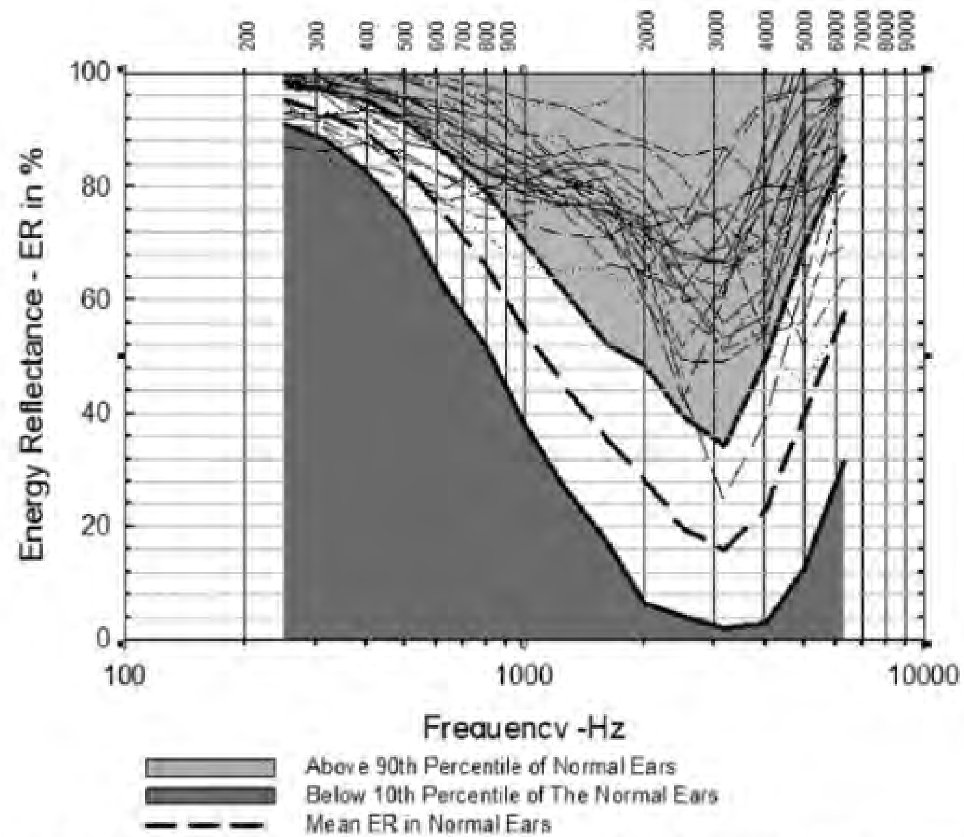


Fig. 5. The individual energy reflectance (ER) values between 211 and 6000 Hz for all 42 ears with middle ear effusion are shown. The mean ER and 80% range (10th to 90th percentile) for the normal ears are also shown.

WAI in OME & PE Tube

Sanford & Brockett J Am Acad Audiol 25:425–440 (2014)

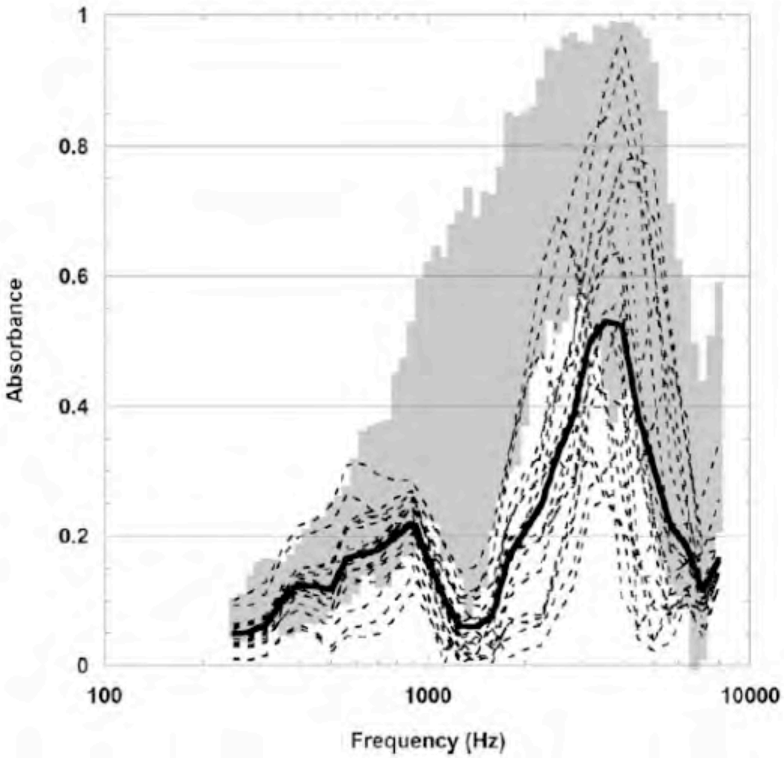


Figure 4. Ambient absorbance for individual (dashed lines) and mean (solid line) data from 20 ears in the sOME group (n = 11 participants; mean age, 25.5 mo). The shaded region represents the 10th to 90th percentiles for absorbance for children with normal middle-ear function (n = 59 ears; mean age, 1.8 yr; age range, 0.5-7 yr; unpublished data from Boys Town National Research Hospital).

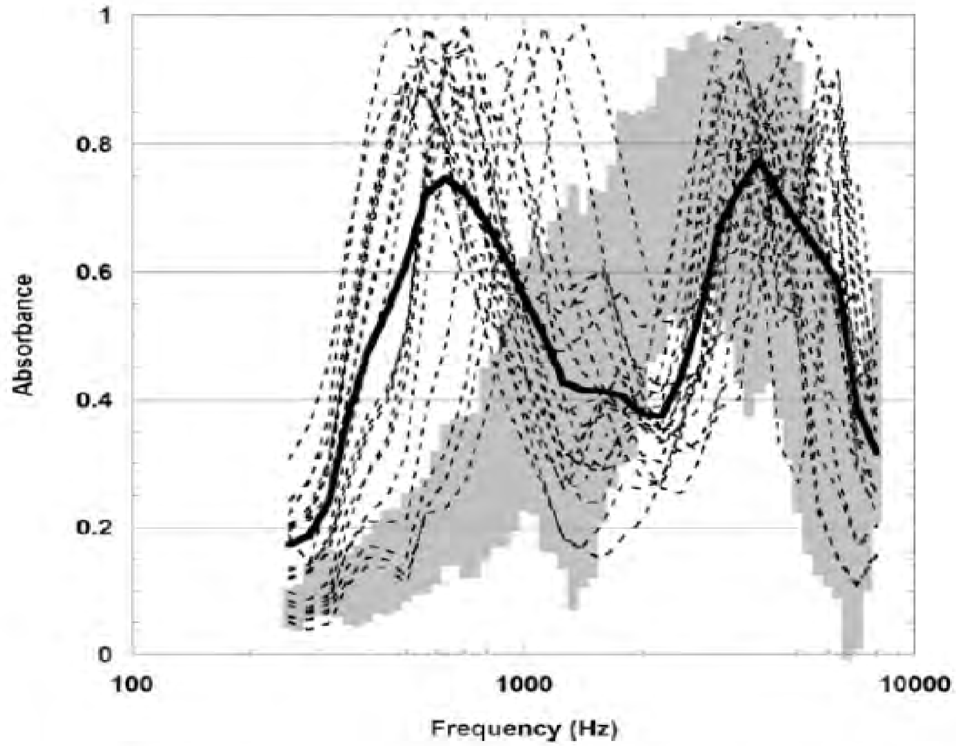
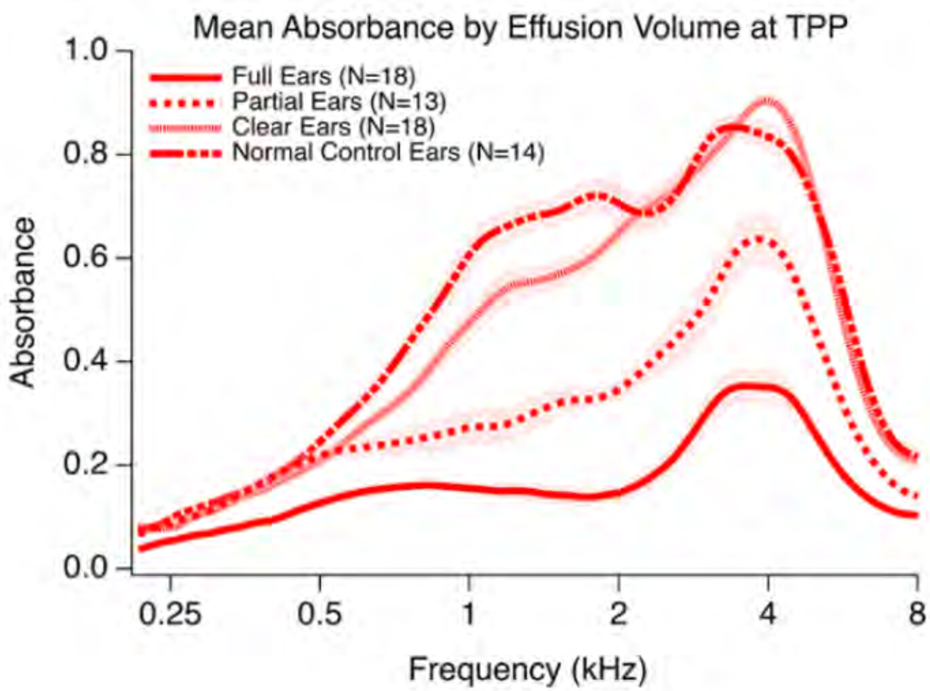
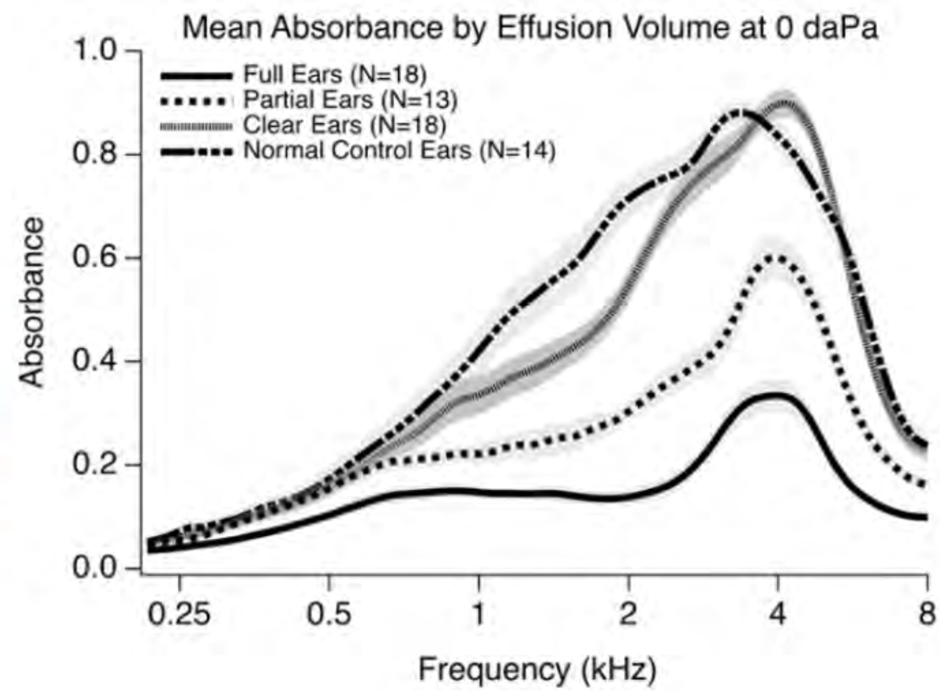


Figure 7. Ambient absorbance for individual (dashed lines) and mean (solid line) data from 19 ears in the PE tube group (n = 10 participants; mean age, 27.8 mo). The shaded region represents the 10th to 90th percentiles for absorbance for children with normal middle-ear function (n = 59 ears; mean age, 1.8 yr; age range, 0.5-7 yr; unpublished data from Boys Town National Research Hospital).

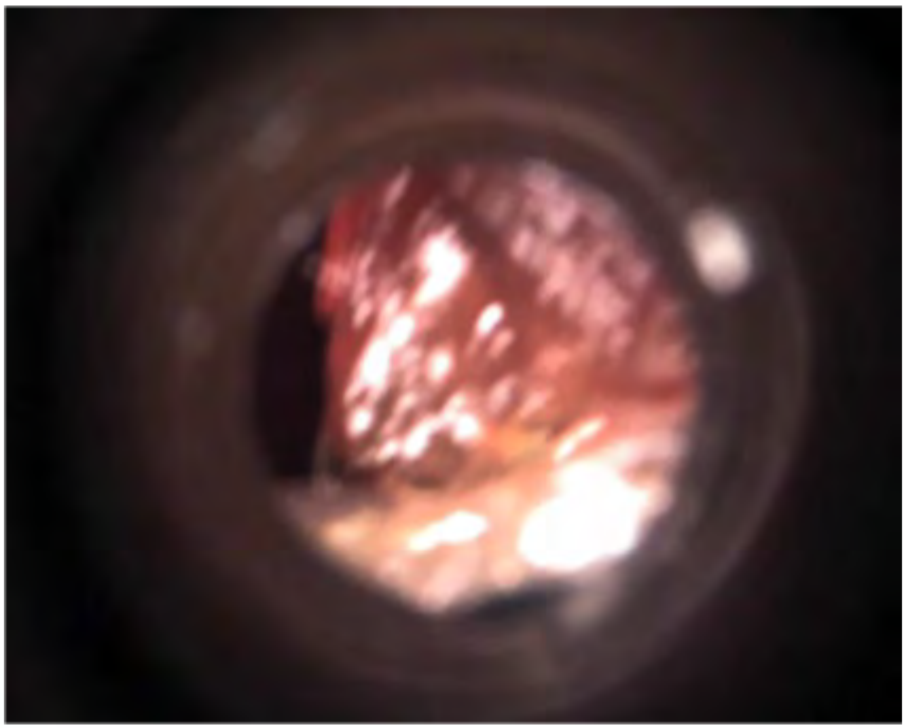
Merchant et al., 2021



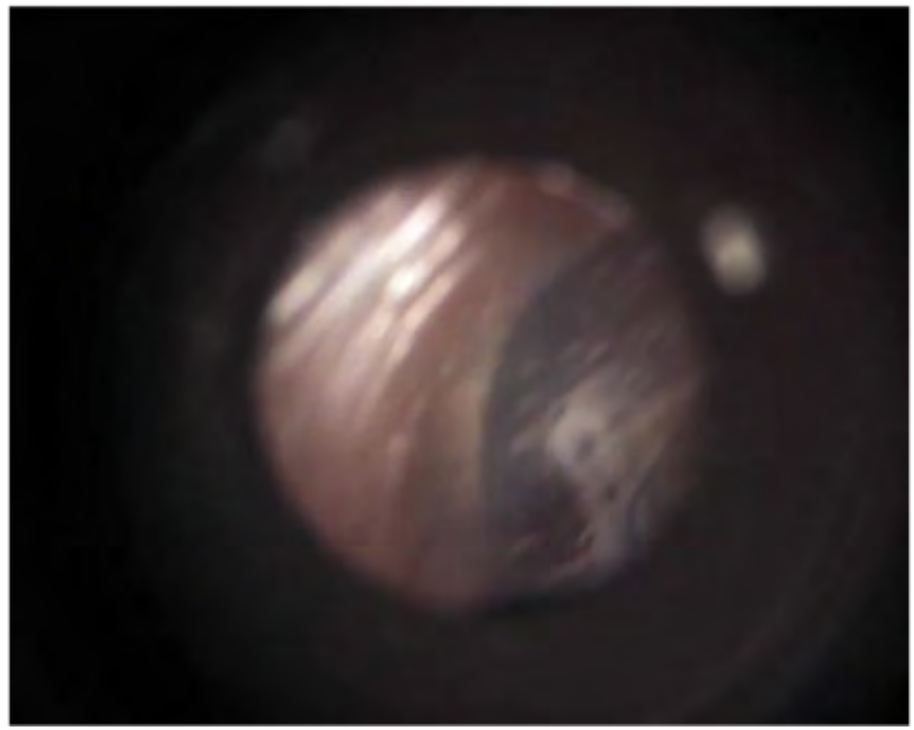


PE Tube R and Fluid Left
Age 3 yrs old

Left Ear

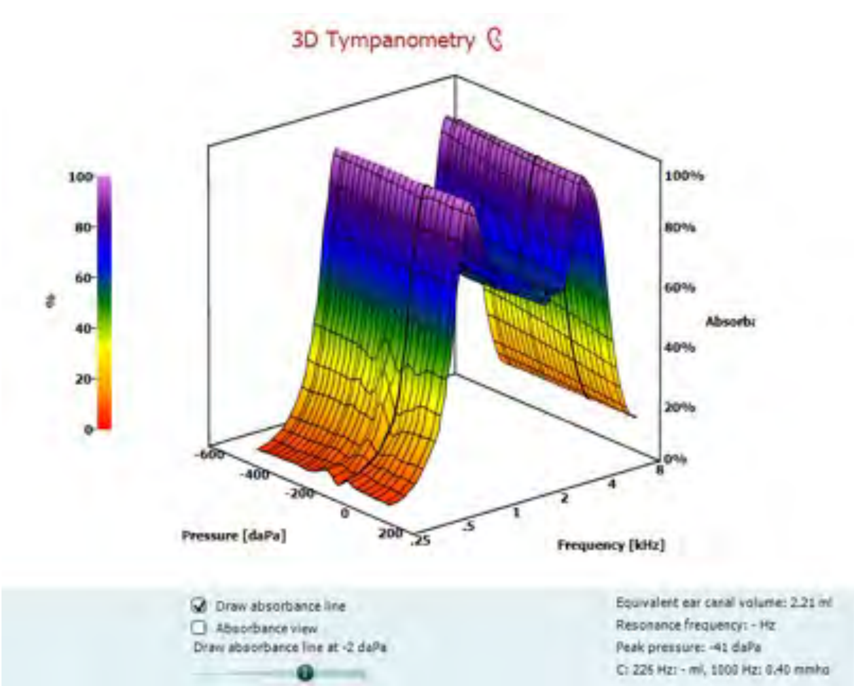


Right Ear

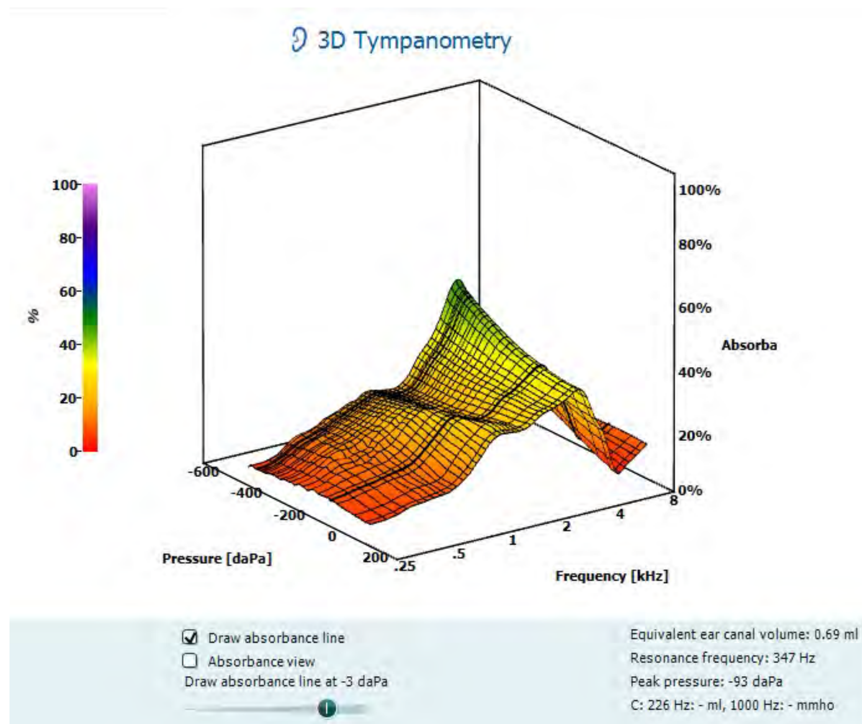


PE Tube R and Fluid Left
Age 3 yrs old

Right Ear

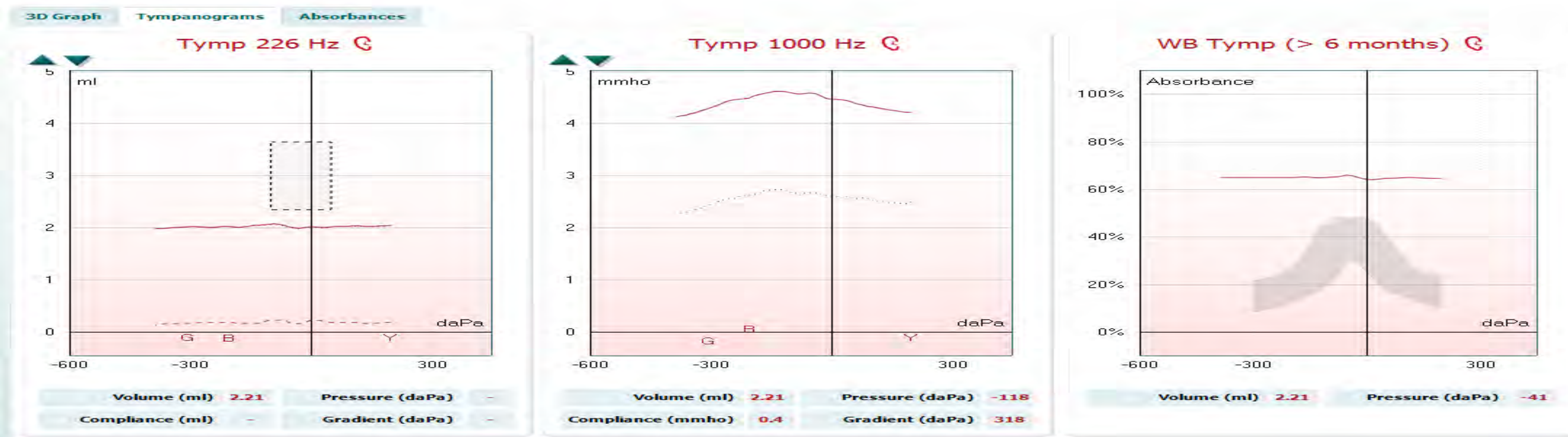


Left Ear

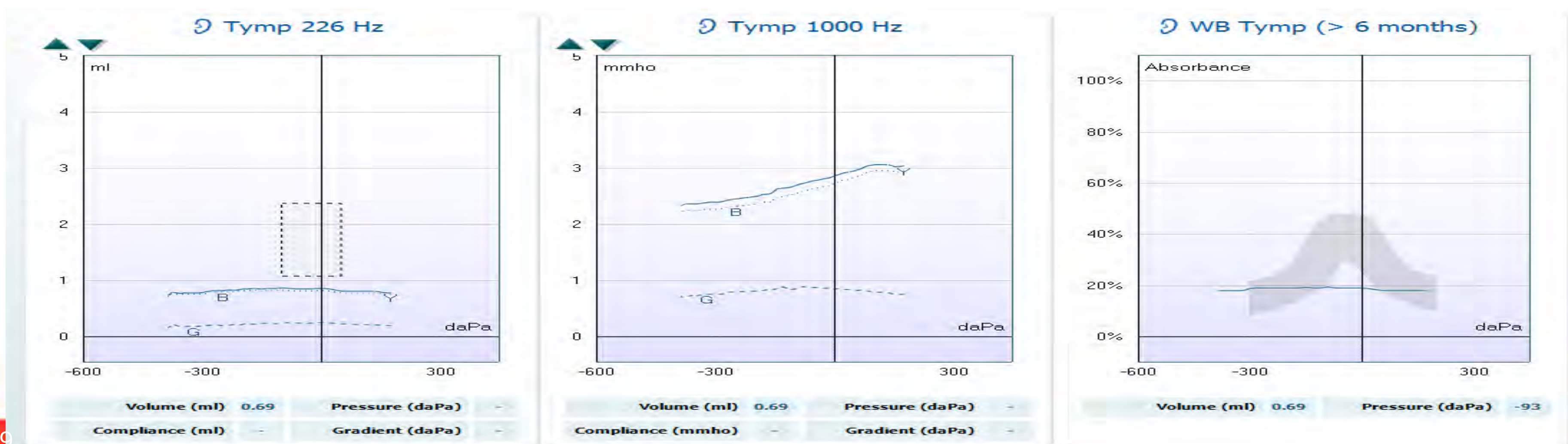


PE Tube R and Fluid Left Age 3 yrs old

Right-PE Tube

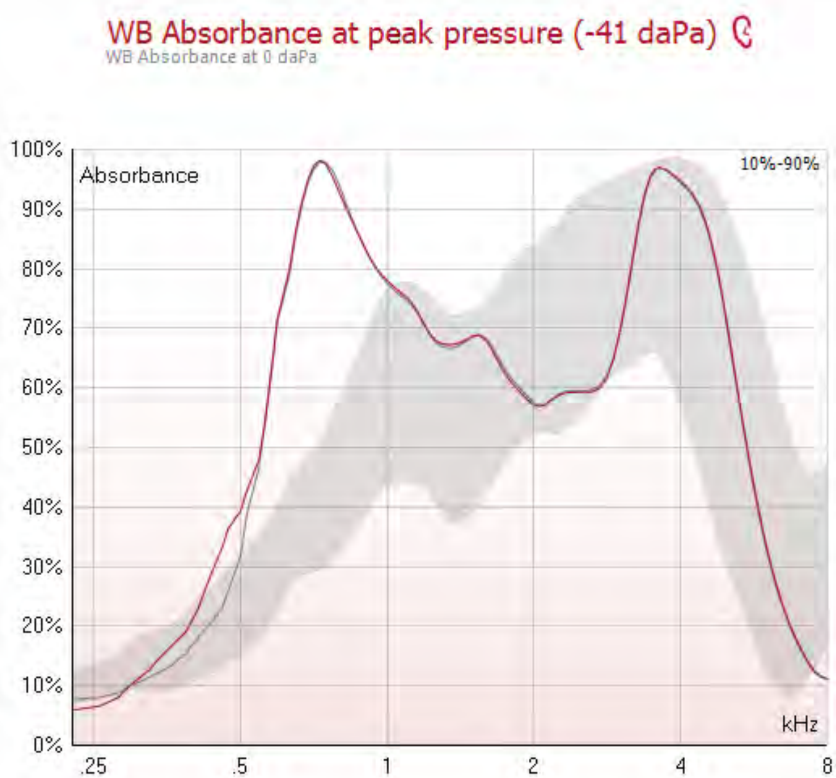


Left Fluid

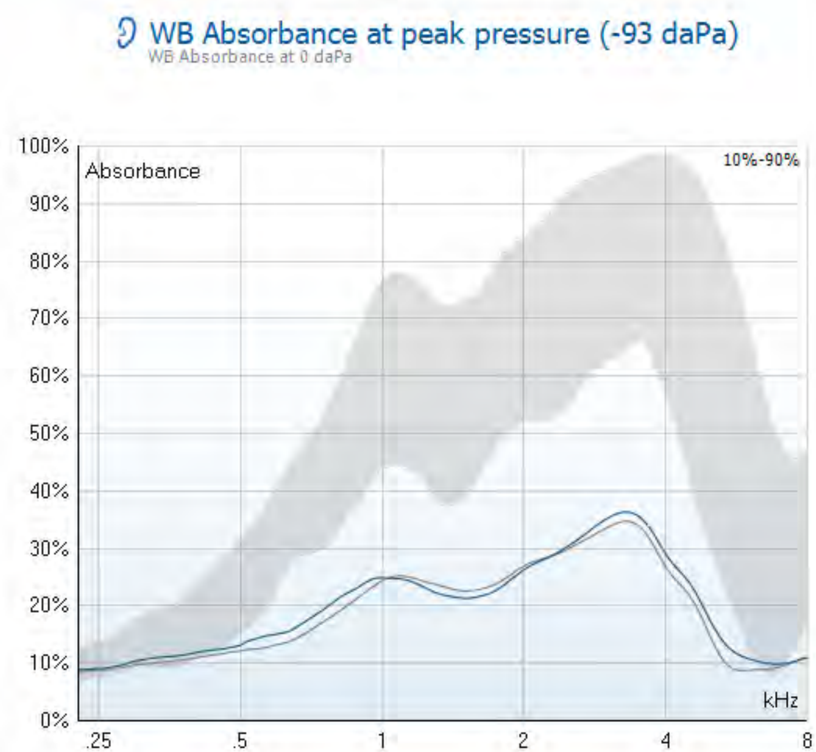


PE Tube R and Fluid Left
Age 3 yrs old

Right Ear

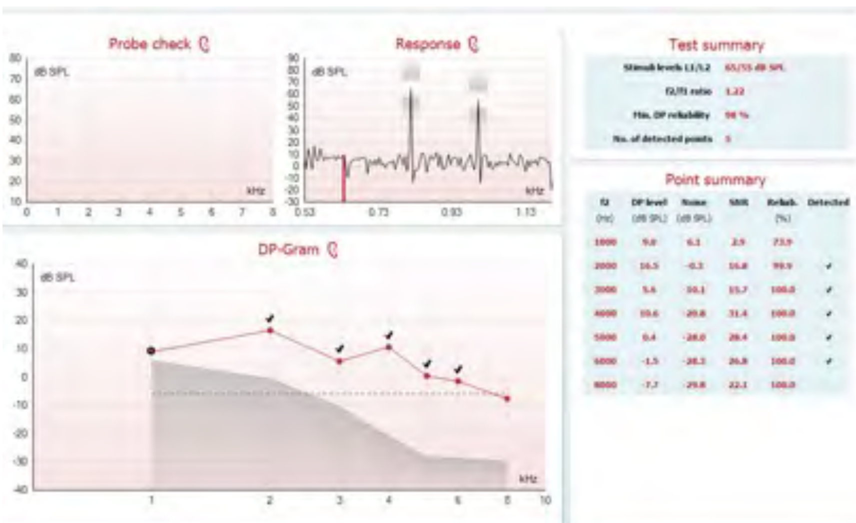


Left Ear

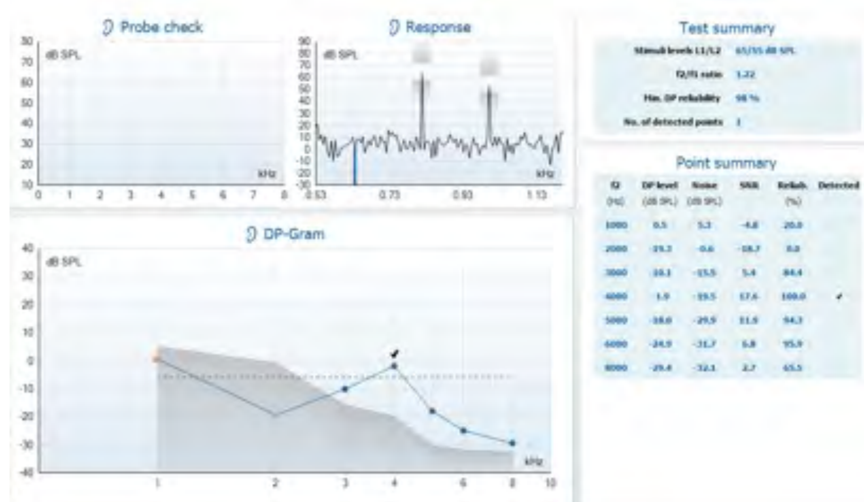


PE Tube R and Fluid Left
Age 3 yrs old

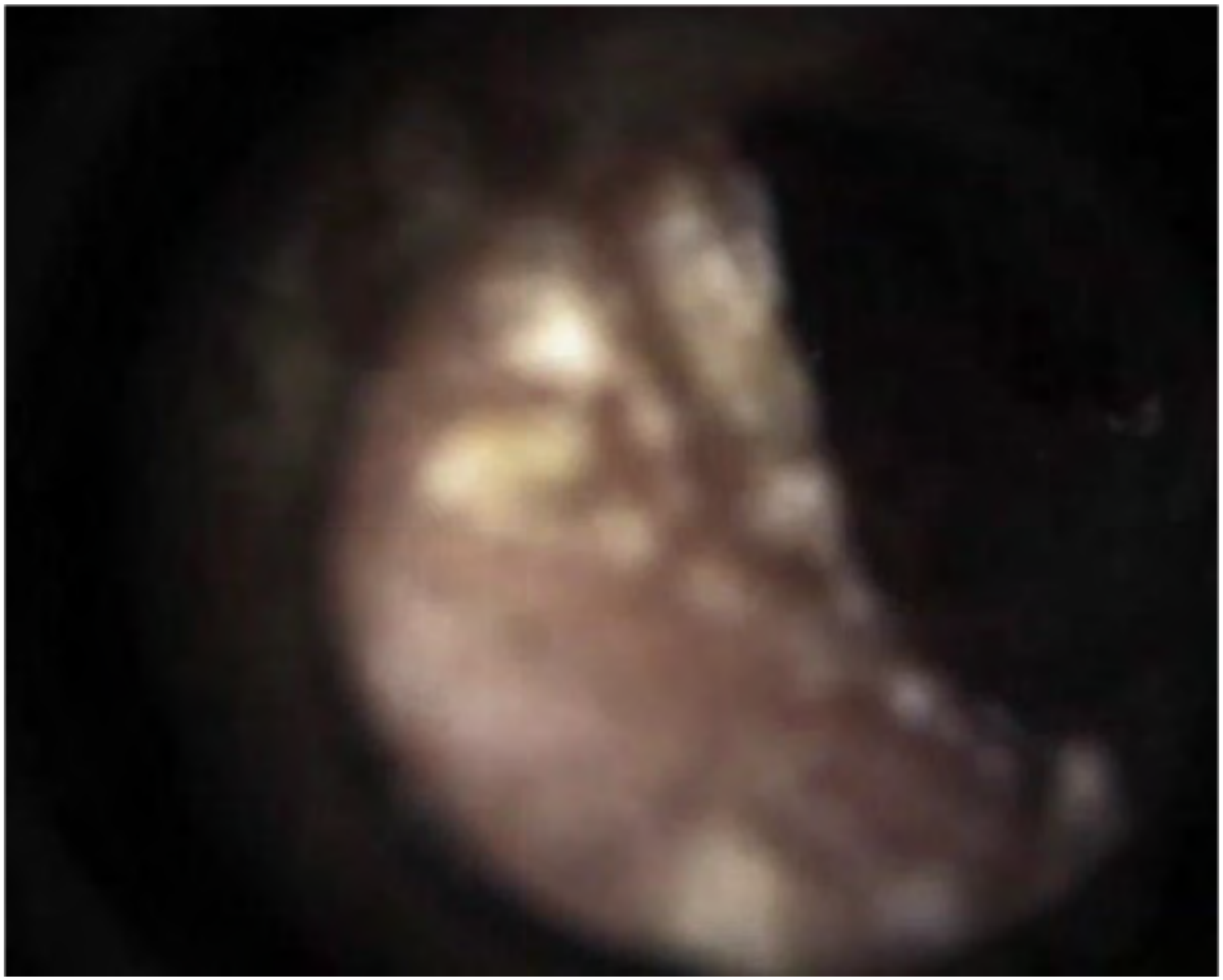
Right Ear



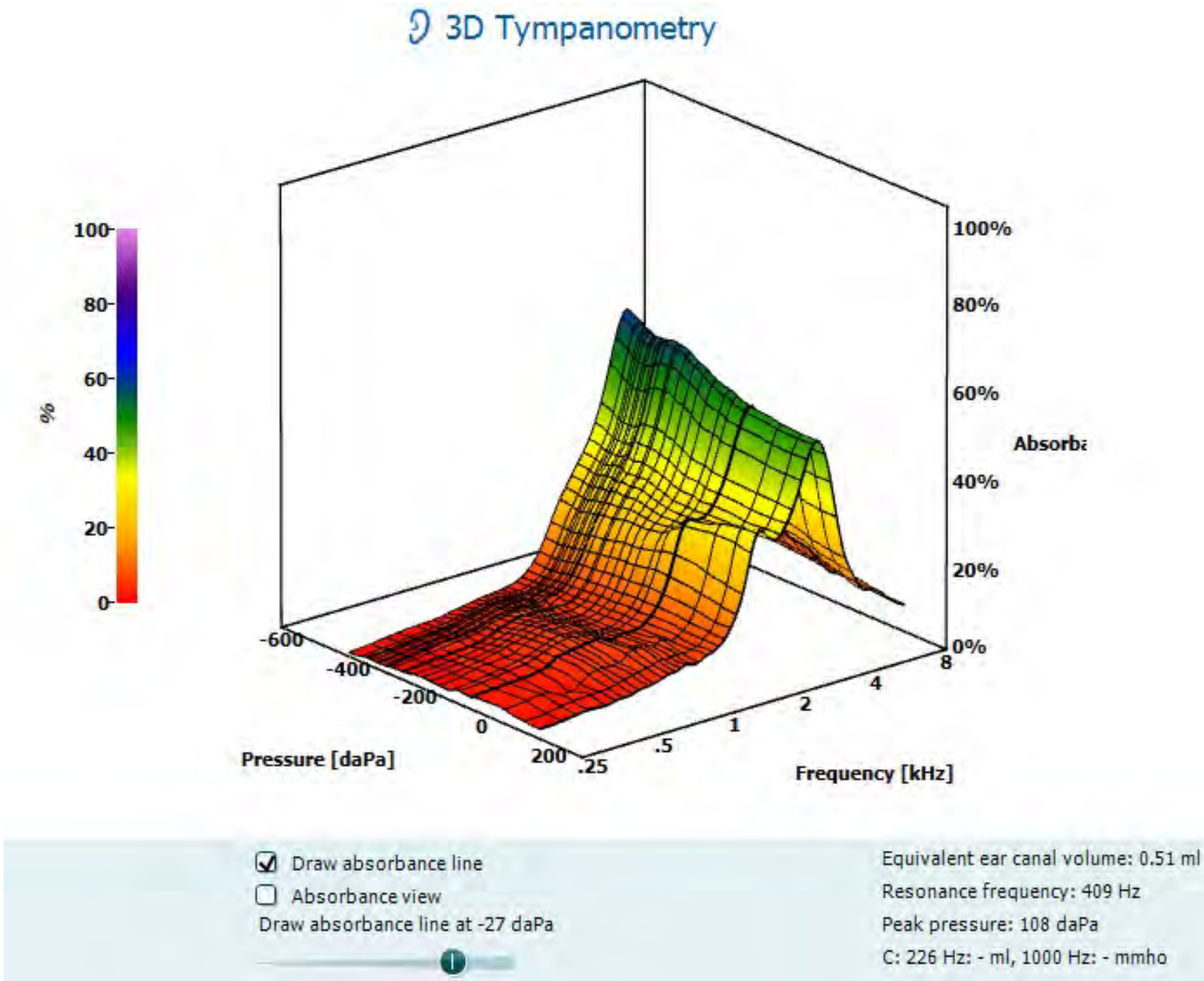
Left Ear



AOM 6 yrs old – Left Ear

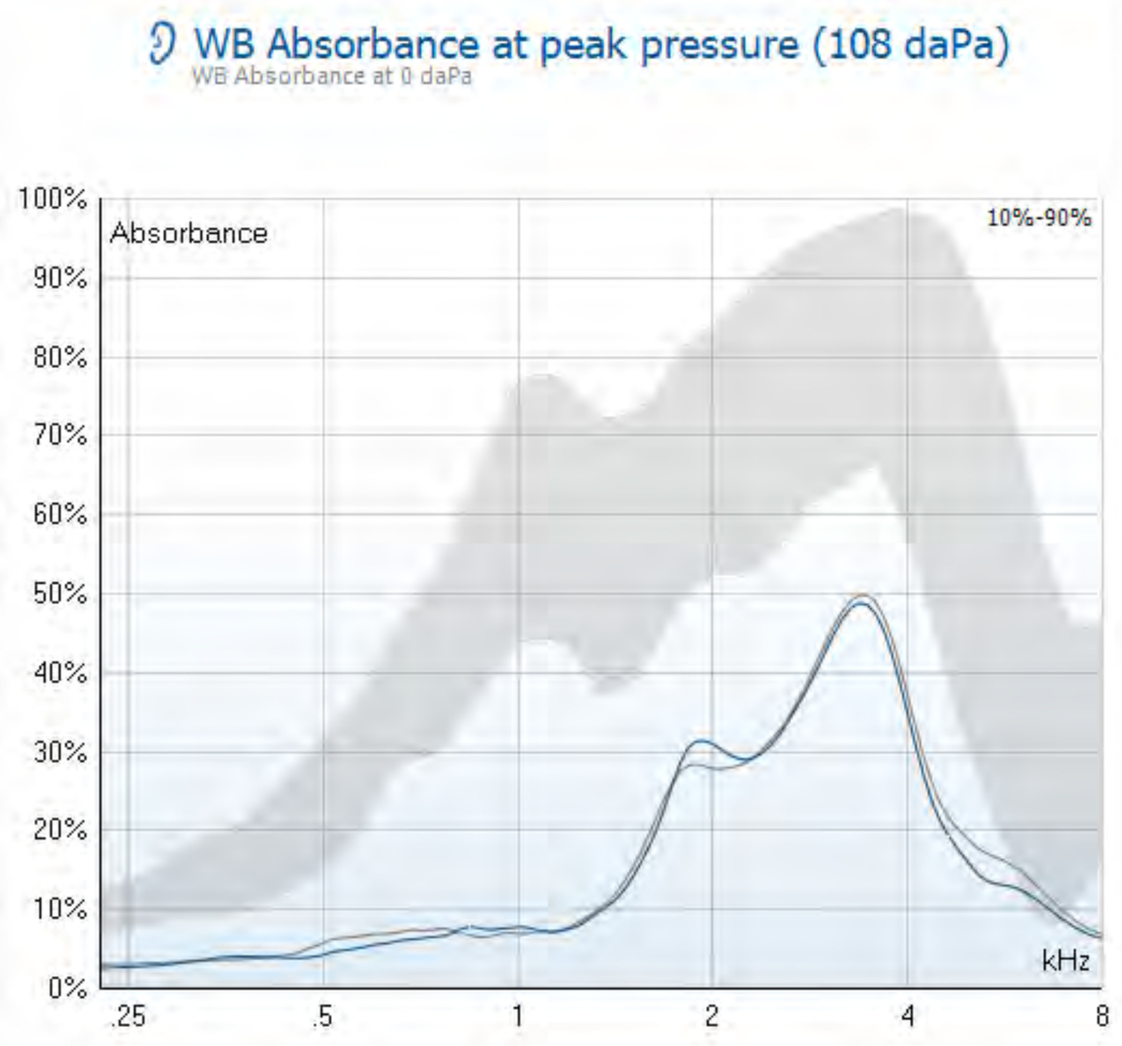


AOM 6 yrs old – Left Ear

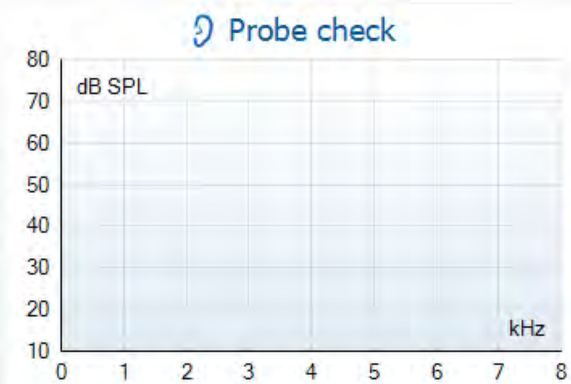


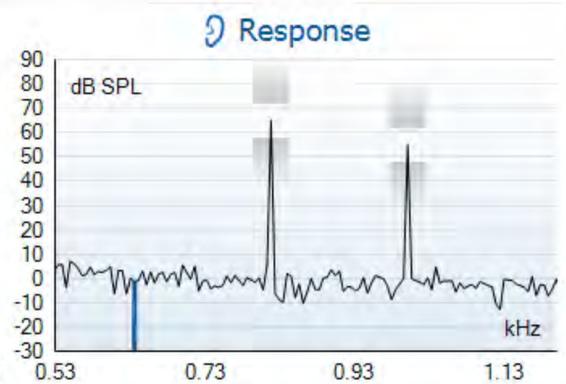
AOM 6 yrs old – Left Ear

AOM 6 yrs old – Left Ear



AOM 6 yrs old – Left Ear





Test summary

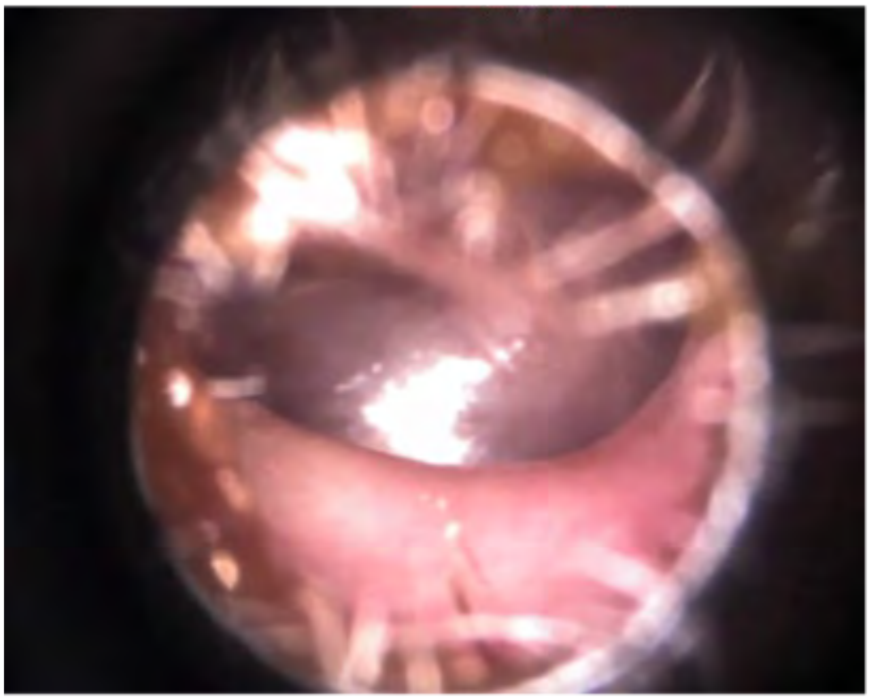
Stimuli levels L1/L2	65/55 dB SPL
f2/f1 ratio	1.22
Min. DP reliability	98 %
No. of detected points	0

Point summary

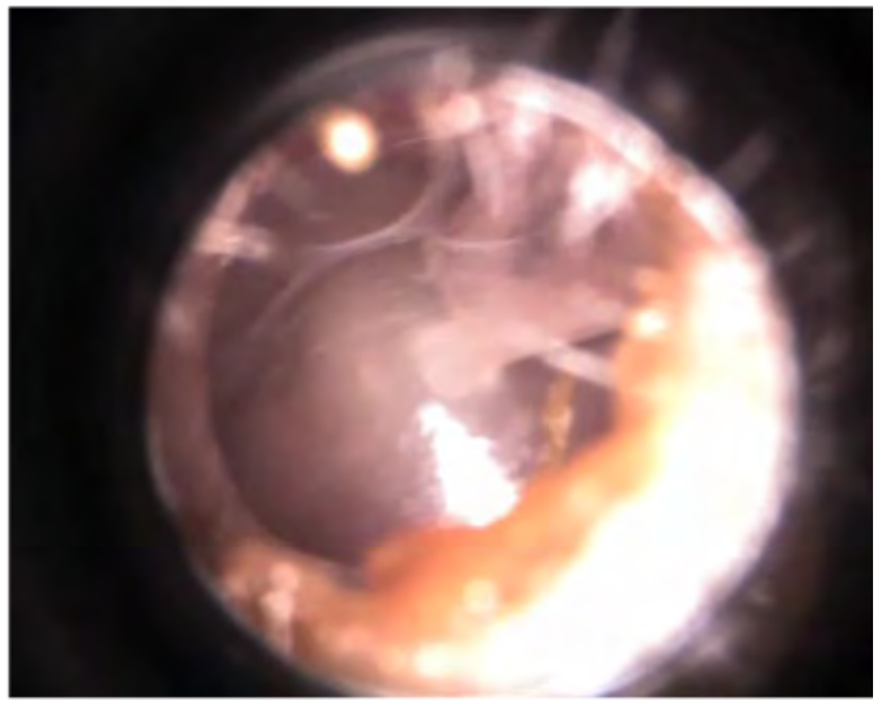
f2 (Hz)	DP level (dB SPL)	Noise (dB SPL)	SNR	Reliab. (%)	Detected
1000	-1.3	1.6	-2.9	16.9	
2000	-4.2	-8.5	4.3	80.5	
3000	-28.4	-16.2	-12.2	2.5	
4000	-13.3	-19.7	6.4	91.3	
5000	-30.1	-24.0	-6.1	12.1	
6000	-27.3	-23.5	-3.8	26.1	
8000	-19.7	-19.6	-0.1	49.2	

Effect of Negative Middle Ear Pressure – 5 yrs old

Left Ear

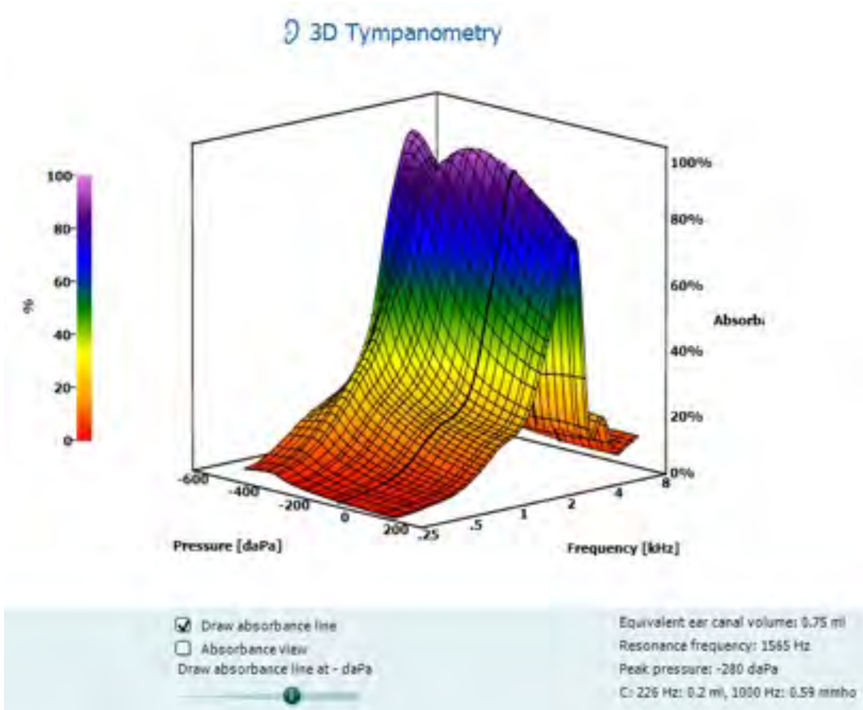


Right Ear

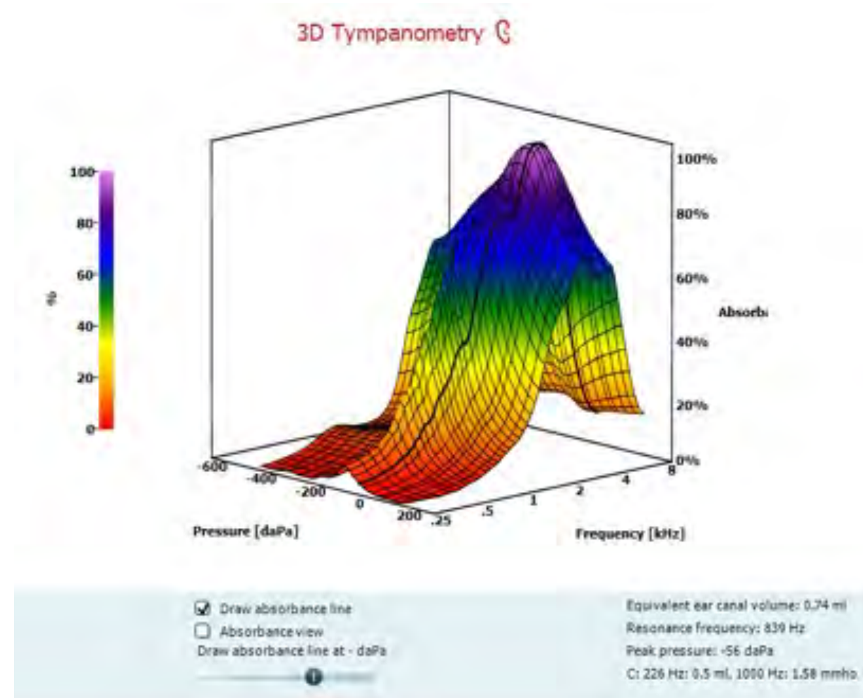


Effect of Negative Middle Ear Pressure – 5 yrs old

Left Ear

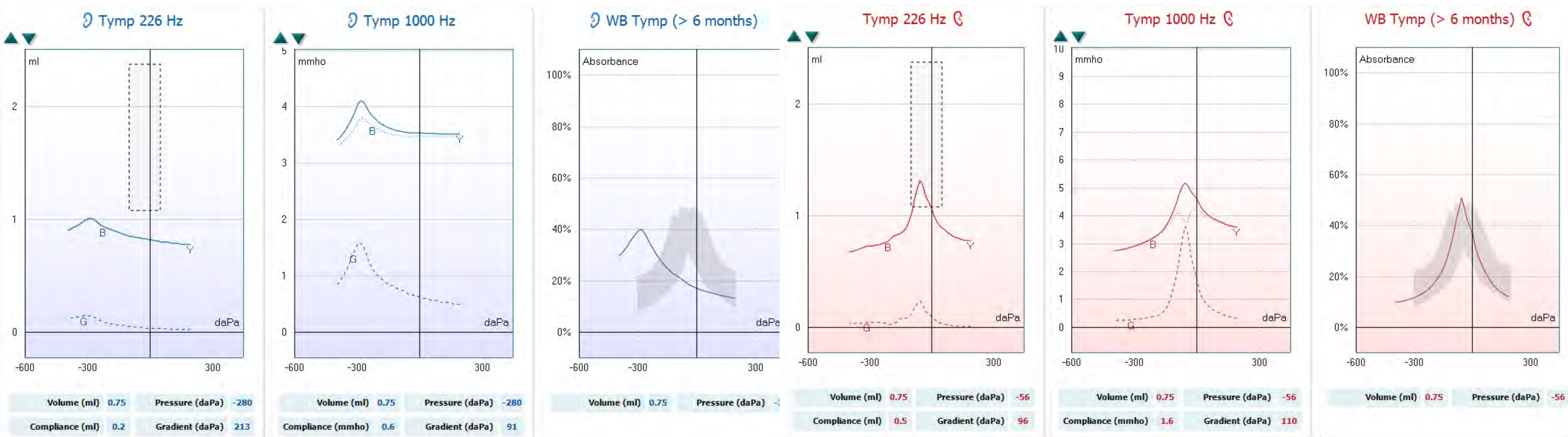


Right Ear



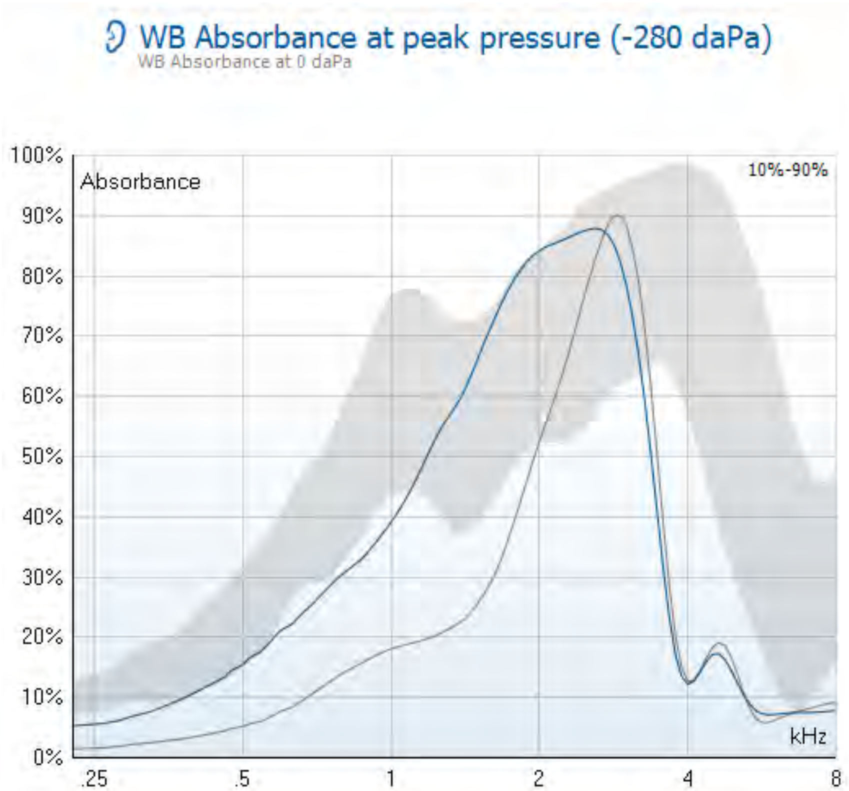
Effect of Negative Middle Ear Pressure – 5 yrs old

Left Ear **Right Ear**

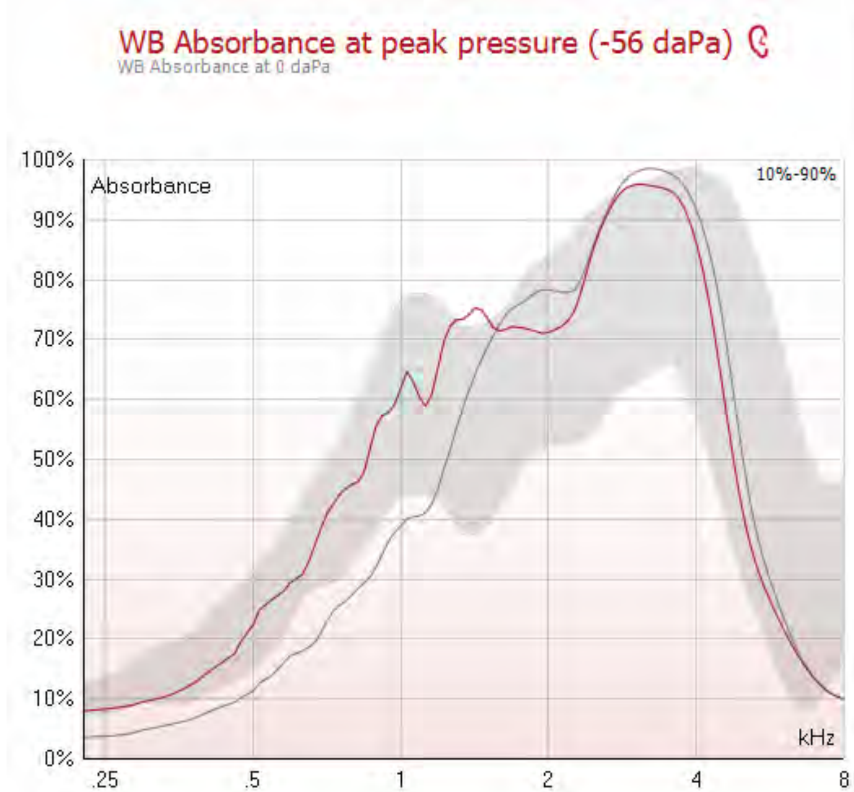


Effect of Negative Middle Ear Pressure – 5 yrs old

Left Ear

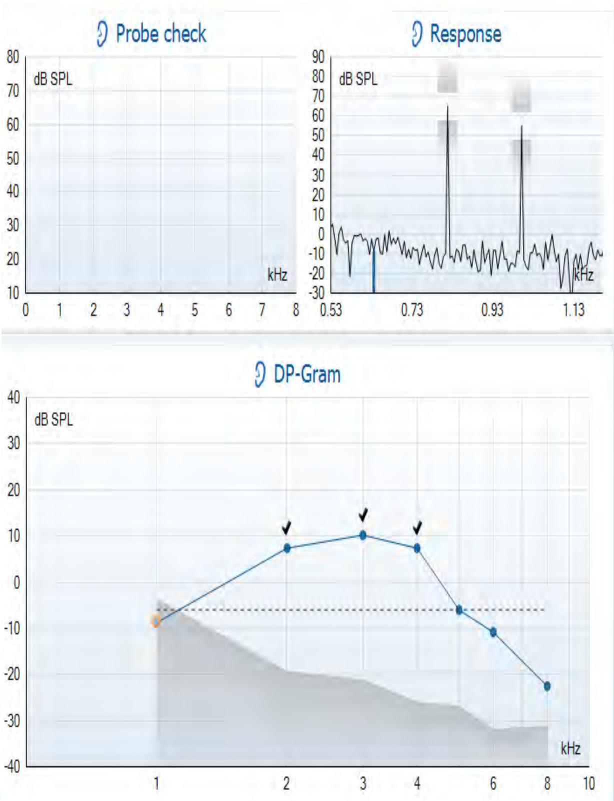


Right Ear



Effect of Negative Middle Ear Pressure – 5 yrs old

DPOAE Left- at Ambient



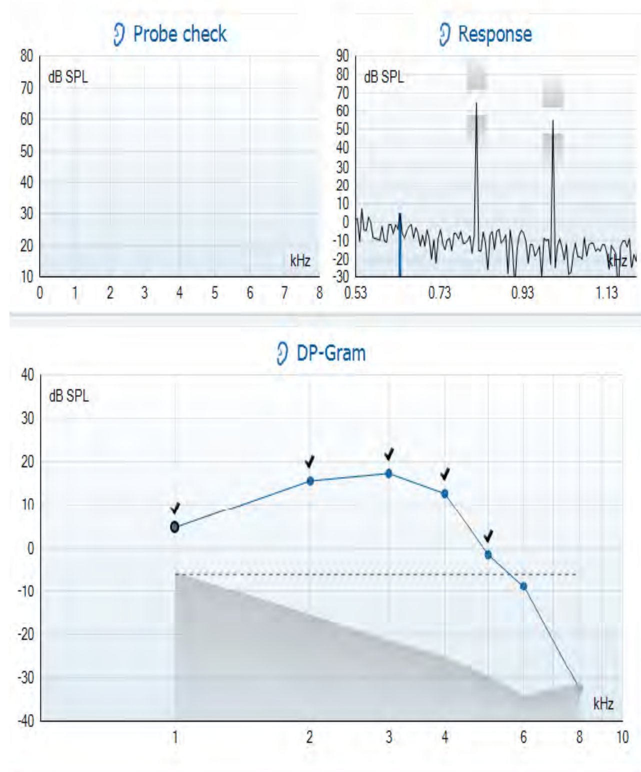
Test summary

Stimuli levels L1/L2	65/55 dB SPL
f2/f1 ratio	1.22
Min. DP reliability	98 %
No. of detected points	3

Point summary

f2 (Hz)	DP level (dB SPL)	Noise (dB SPL)	SNR	Reliab. (%)	Detected
1000	-8.7	-3.5	-5.2	13.6	
2000	7.4	-19.2	26.6	100.0	✓
3000	10.2	-21.0	31.2	100.0	✓
4000	7.4	-25.8	33.2	100.0	✓
5000	-6.0	-26.7	20.7	100.0	
6000	-10.8	-31.7	20.9	100.0	
8000	-22.5	-31.1	8.6	88.9	

DPOAE Left- at Peak



Test summary

Stimuli levels L1/L2	65/55 dB SPL
f2/f1 ratio	1.22
Min. DP reliability	98 %
No. of detected points	5

Point summary

f2 (Hz)	DP level (dB SPL)	Noise (dB SPL)	SNR	Reliab. (%)	Detected
1000	4.8	-5.4	10.2	99.7	✓
2000	15.6	-15.4	31.0	100.0	✓
3000	17.3	-21.2	38.5	100.0	✓
4000	12.7	-24.9	37.6	100.0	✓
5000	-1.5	-29.6	28.1	100.0	✓
6000	-8.8	-34.1	25.3	100.0	
8000	-32.5	-31.3	-1.2	41.3	

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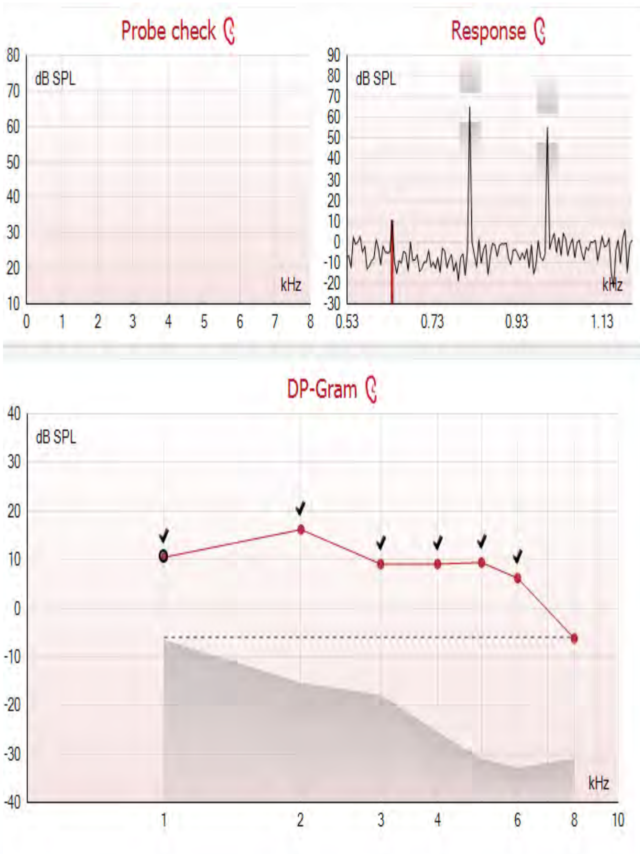
Effect of Negative Middle Ear Pressure – 5 yrs old

DPOAE Left- at Ambient



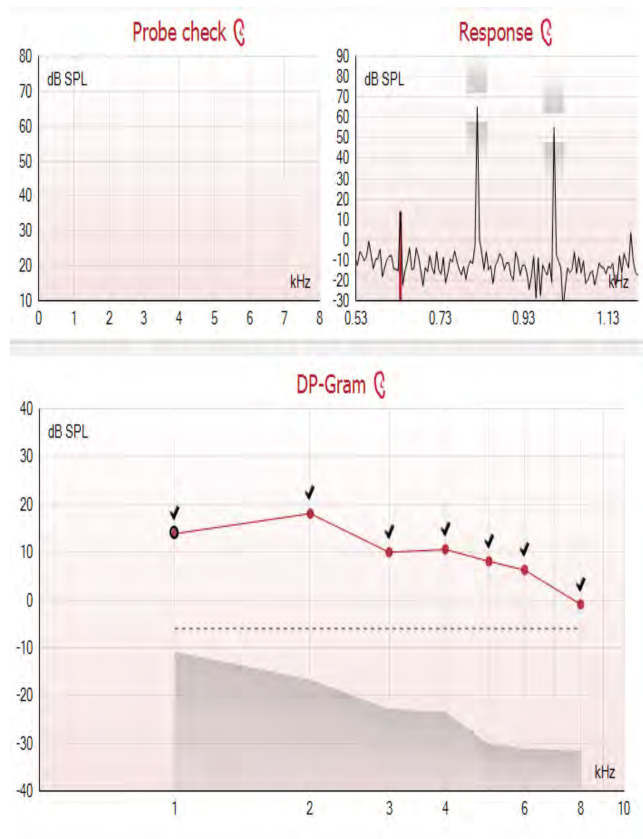
Test summary

Stimuli levels L1/L2	65/55 dB SPL
f2/f1 ratio	1.22
Min. DP reliability	98 %
No. of detected points	6

Point summary

f2 (Hz)	DP level (dB SPL)	Noise (dB SPL)	SNR	Reliab. (%)	Detected
1000	10.5	-6.5	17.0	100.0	✓
2000	16.2	-15.3	31.5	100.0	✓
3000	9.1	-17.8	26.9	100.0	✓
4000	9.1	-25.4	34.5	100.0	✓
5000	9.4	-31.0	40.4	100.0	✓
6000	6.2	-32.8	39.0	100.0	✓
8000	-6.2	-30.9	24.7	100.0	

DPOAE Left- at Peak



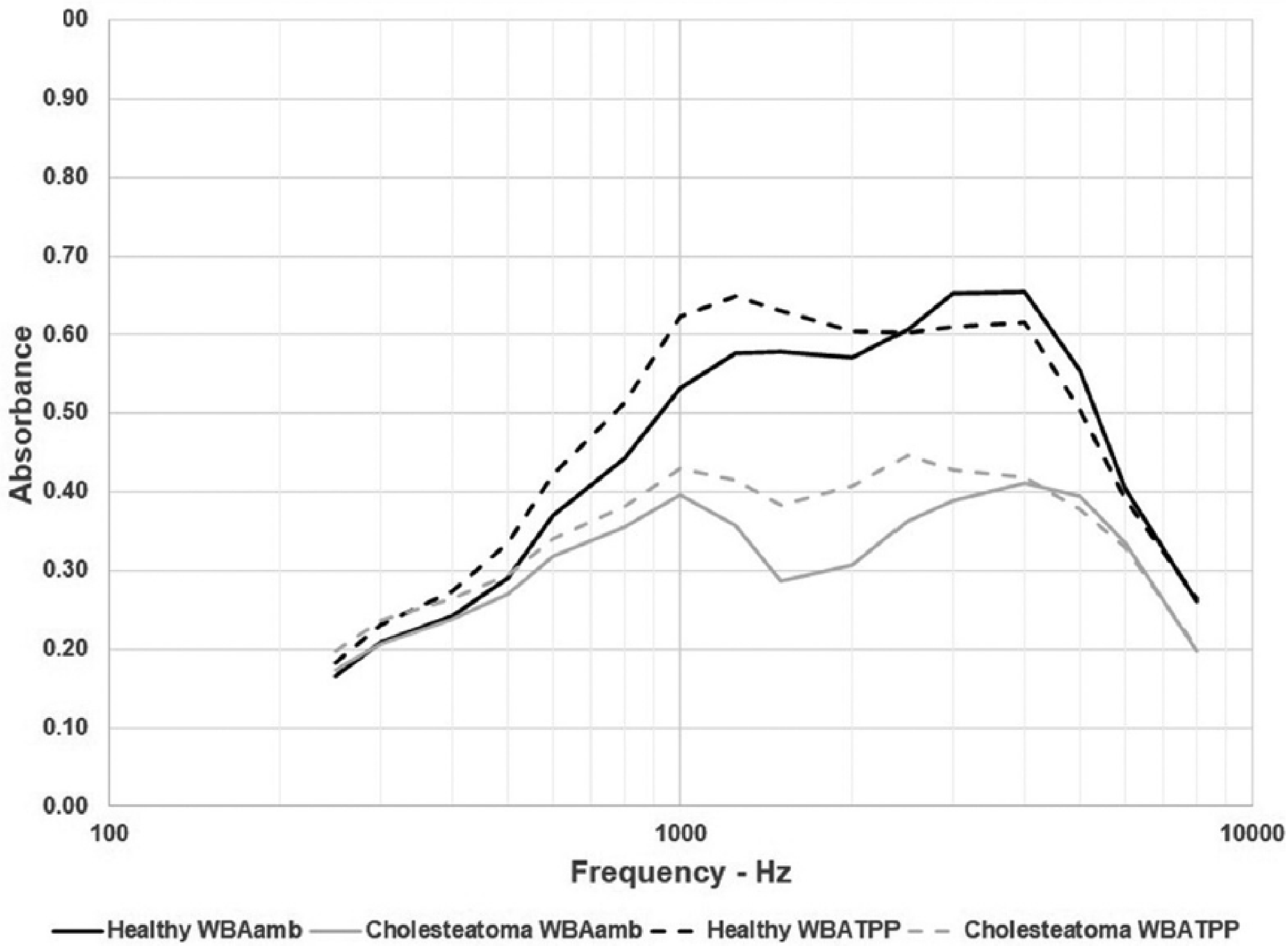
Test summary

Stimuli levels L1/L2	65/55 dB SPL
f2/f1 ratio	1.22
Min. DP reliability	98 %
No. of detected points	7

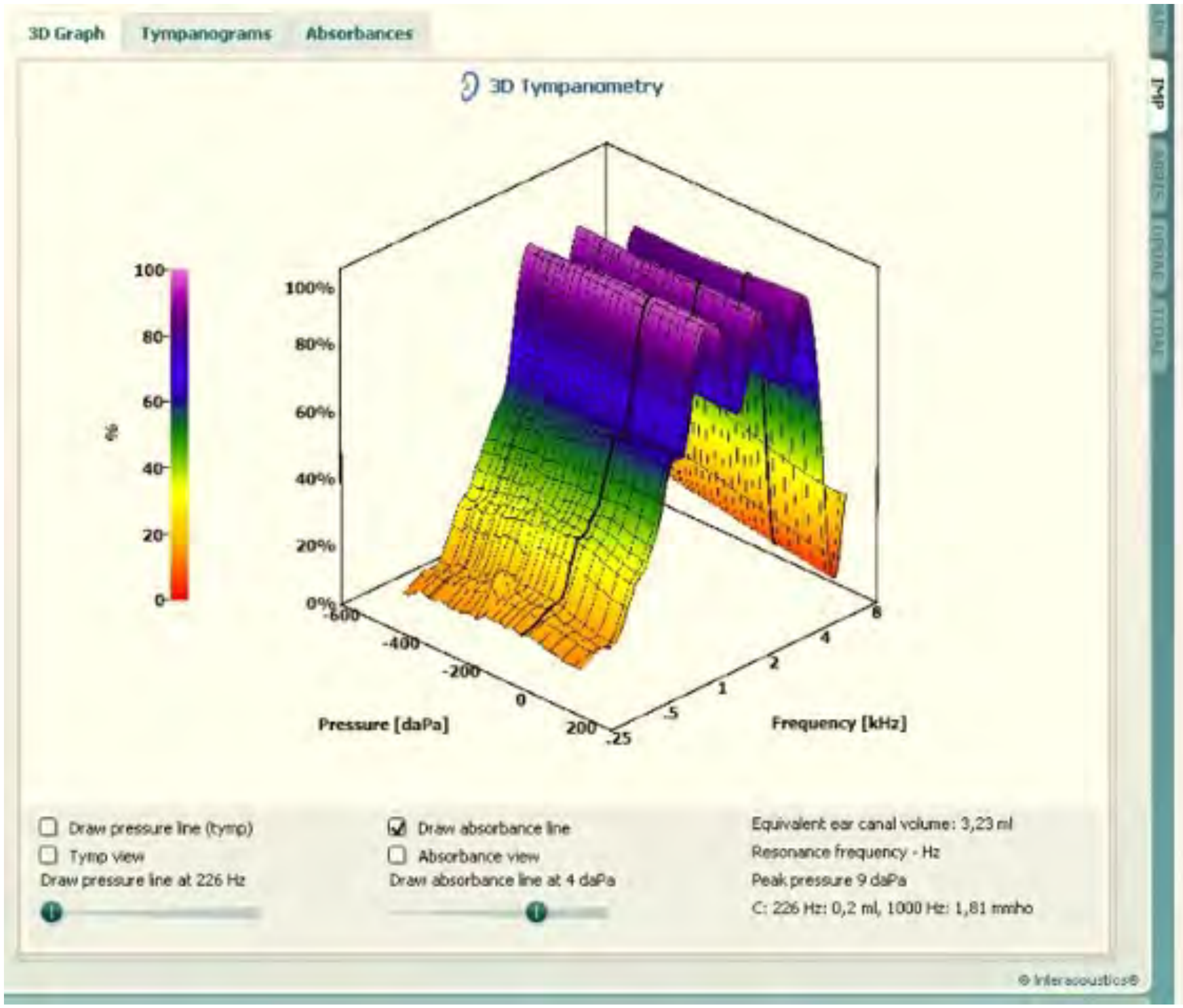
Point summary

f2 (Hz)	DP level (dB SPL)	Noise (dB SPL)	SNR	Reliab. (%)	Detected
1000	13.9	-10.8	24.7	100.0	✓
2000	18.1	-16.6	34.7	100.0	✓
3000	10.0	-22.8	32.8	100.0	✓
4000	10.6	-23.3	33.9	100.0	✓
5000	8.1	-30.2	38.3	100.0	✓
6000	6.3	-31.0	37.3	100.0	✓
8000	-0.9	-31.6	30.7	100.0	✓

Cholesteatoma- WIDEBAND ACOUSTIC IMMITTANCE IN CHILDREN/SHAHNAZ ET AL Semin Hear 2023; 44(01): 046-064



Case: Perforation



Courtesy:
Erik Hagerstrom, MD

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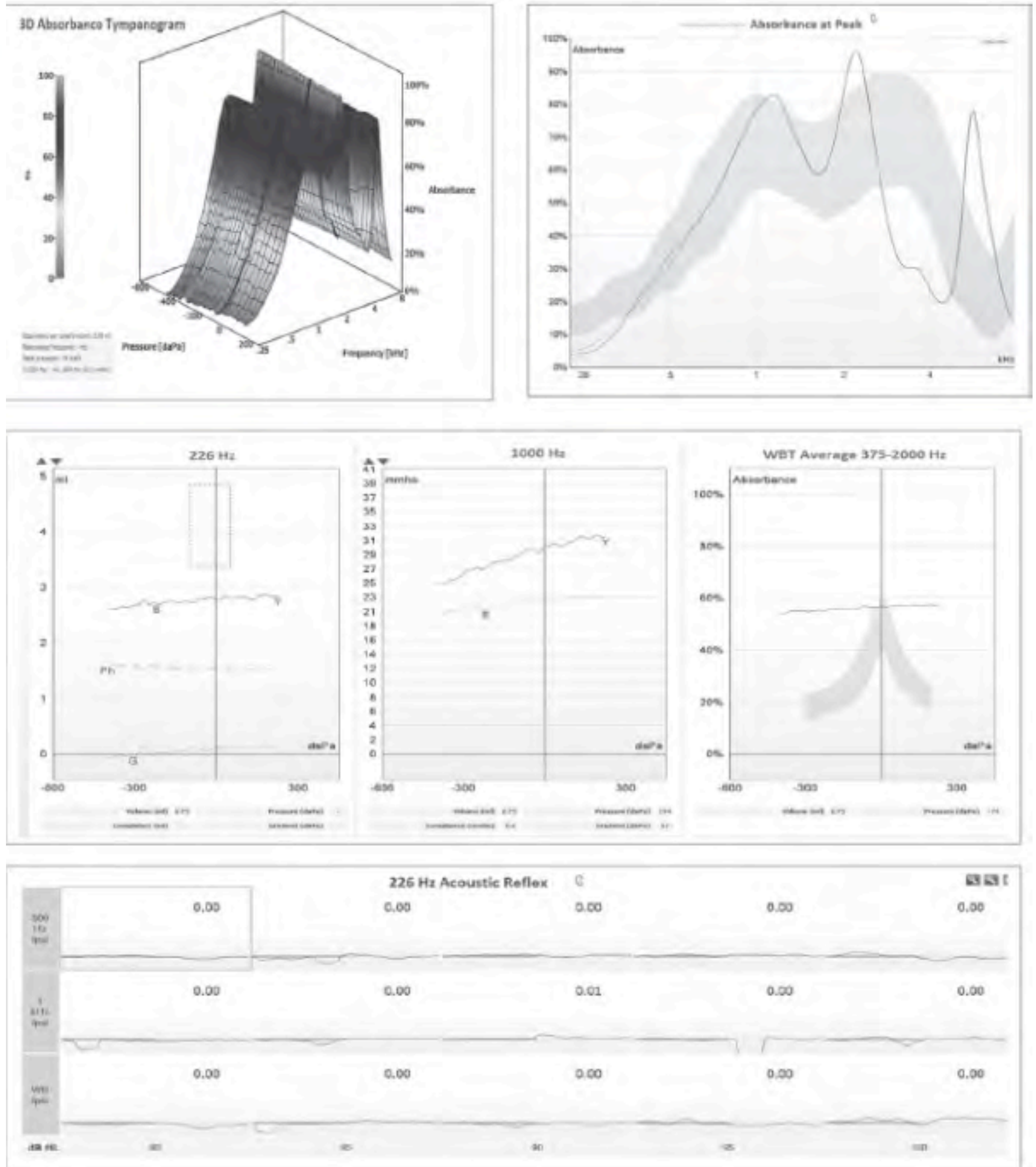
Perforation –
Shahnaz 2020



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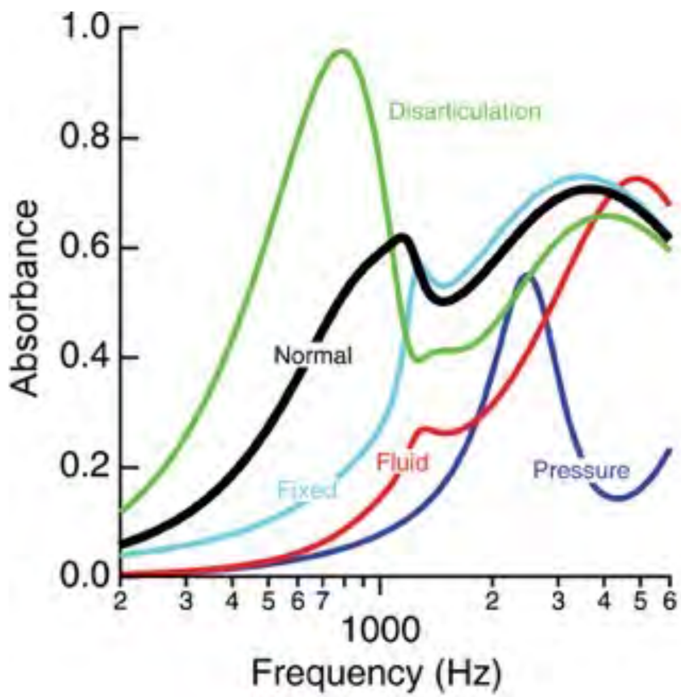
Despite inter-patient variation, the typical middle ear problems each show clear differentiating characteristics:

Model:



Benefit of air pressure:
Just as with Stapdius Reflex measurements, a negative (or positive) middle ear pressure will distort measurements… Measurements at Tympanometric Peak Pressure removes this issue!

Future Direction

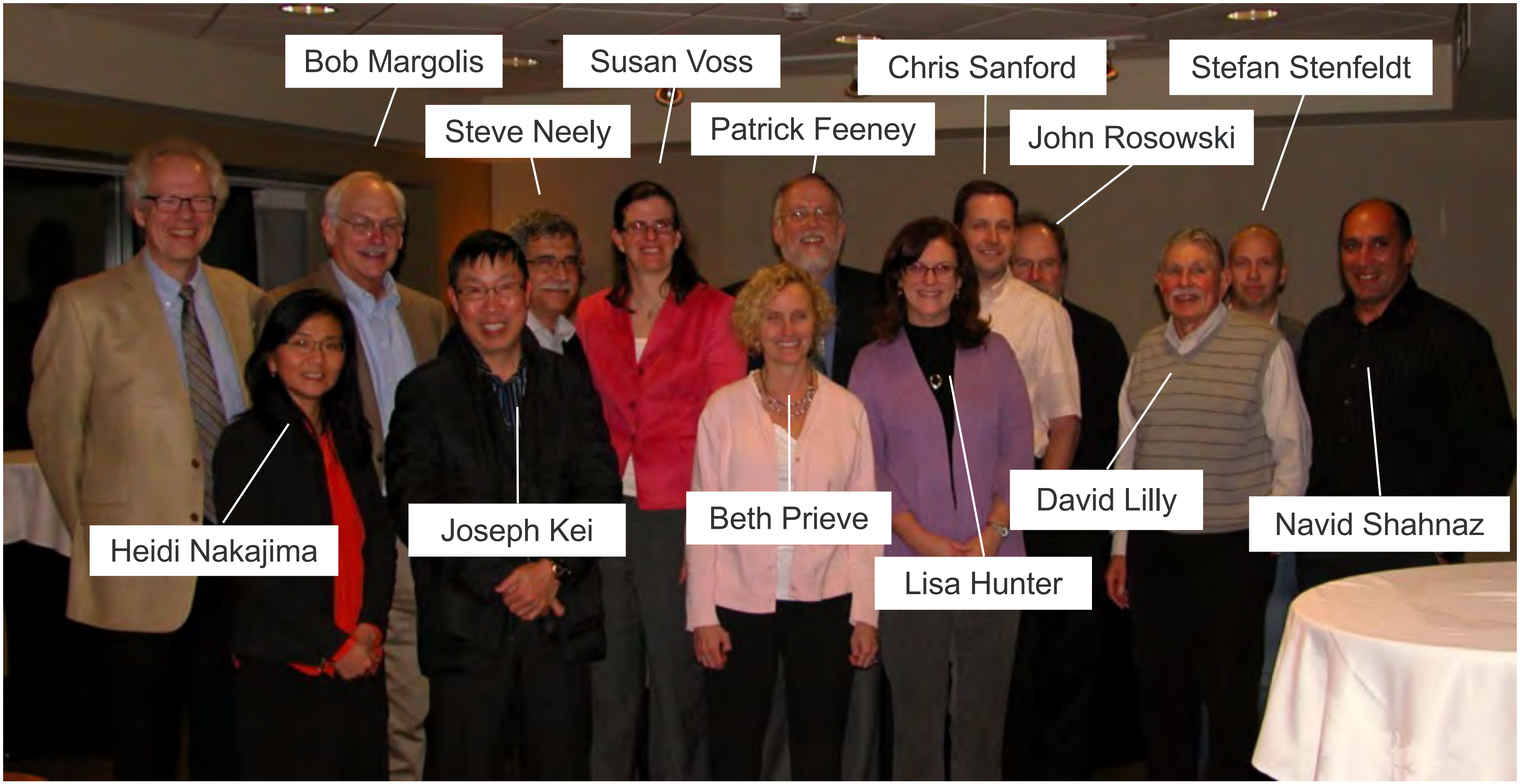
- Newborn hearing screening and diagnosis
- Detection of OME and conductive hearing loss
- Wideband acoustic stapedial reflex test
- Combined WBT, WBART, OAE test battery
- Adjusting OAE using pressure

Thank You – Middle ear Lab (MEL) Group Past and Present

Thank You – Middle ear Lab (MEL) Group Past and Present

Eriksholm Workshop Nov. 2012

- Supplementum in Ear & Hearing Early Summer 2013



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Journal of American Academy of Audiology

- 25, Number 5, 2014
  Special Issue

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Chapter 2: Application of wideband acoustic immittance (WAI) in assessment of the middle ear in newborns, children, and adults
N Shahnaz - Advances in Audiology and Hearing Science, 2020

Seminars in Hearing- Issue 01 · Volume 44 · February 2023

Assessment of Middle Ear Function Using Wideband Acoustic Immittance: Current Practices and Future Prospects
Guest Editor, Hammam AlMakadma, Ph.D., Au.D.

Seminars in Hearing Journal Special Issue on WAI

More live Webinars from this series on WAI:

- Dr. Jospeh Kei (Wed, Aug 23, 2023, at 6:00 pm EDT)
  Course: #38900
- Dr. Navid Shahnaz (Wed, Aug 30, 2023, at 12:00 pm EDT)
  Course: #38905

Thank You

Questions?